ESTABLISHING CRITICAL CONCEPTUAL AND PRAGMATIC PRINCIPLES FOR PHOTOINTERPRETATION METHODOLOGIES WHEN APPLIED AS FORENSIC EVIDENCE

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The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material, either in full or in part, for a degree at this or any other institution.

Robert Ebeyan

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Abstract:

The omnipresence of images within contemporary society has impacted on how visual evidence is perceived and presented within the criminal justice system. Currently there are no universally recognised methodological principles or practices established that allow robust and reliable forensic evaluation of images. The objective of this research was to elucidate critical conceptual and pragmatic principles for the development of a methodological framework aimed to support the forensic photointerpretation of photographic evidence. Using a mixed method research design, this project explored three methodological approaches, namely criteria, comparative and reconstructive based photointerpretation methods. Case studies, literary reflection, experimentation and evidence-based discussion were employed to unpack and investigate nuanced and complex concepts, values and principles required for consideration when using photographs as sources of evidence. Six key principles were derived from the values elucidated in response to each investigated approach. These principles consisted of methodology; objectivity; suitability; verifiability; specialised knowledge and error. The model developed by this research promotes transparency and clarity towards the process of photographic interpretation as forensic evidence presented within the criminal justice system.

Chapter 1

1.0 Introduction

...meaning and photographic truth are reliant on interpretation and contextualisation.

Glenn Porter & Michael Kennedy [Porter & Kennedy 2012, p. 187]

Since the invention of photography, the prevalence of images within our society has continued to increase exponentially as technology and its applications advance. This trend has significantly impacted the manner in which contemporary society communicates within a visual paradigm. Modernity now embodies the expression of ideas and complex concepts through the application of visual modalities as a standard method of communication. However, as such technology becomes engrained into our culture, our ability to comprehend images has not necessarily reached the same level of sophistication or visual literacy the technology may demand [Porter 2007]. This situation has significantly impacted on the justice system when its standard is moralistically and ethically based on accuracy, reliability, truth and fact. Technology has placed significant emphasis on the application of images within the process of criminal trials, especially within the domain of CCTV, yet there are significant gaps in understanding how evidence produced from images is processed, examined and presented.

The concept that forensic evidence may be derived from images rather than real life physical objects is an interesting notion. There is however, little understanding regarding what thinking and/or forensic analysis processes take place, or should take place, within this transitionary process from image to evidence. The court system has a significantly higher obligation for accuracy and truth than other applications of visual communication, like print and television media. What those obligations are exactly and what safeguards are necessary to be incorporated into the justice system and forensic examination methods are currently unknown. This is problematic because accused criminals are regularly convicted of serious crime based in part, or in some cases, exclusively on photographic evidence.

One of the most critical challenges faced by photographic evidence revolves around the common misconception regarding the ability for images to readily produce facts. The idea that the photograph may be considered a faultless reflection of reality stems from the flawed notion that the camera functions within a completely objective framework suggested by its apparently mechanistic operation. In other words, the broadly engrained belief that a simple click of the shutter button will result in the exact likeness of the world in front of the lens, in all its factuality, being captured and stored for future viewing, presents a dangerous level of understanding when concerning images presented in the legal environment.

The perception that photographs have the ability to faithfully depict reality has been challenged by the recognition of the inherent level of subjectivity affecting photographic processes. A multitude of technical photographic variables including framing, viewpoint, lighting, spectral sensitivity, colour fidelity, image resolution, depth of field, lens focal length and perspective, to list just a few, each have an impact on the depiction of the visible components within an image. Cameras cannot operate independently as unbiased witnesses because of this interference [Mnookin 1998; Porter 2007]. Further still, a viewer's comprehension of an image is influenced by their personal interpretation based on their knowledge, cultural and life experiences [Sontag 1978].

Images are examined as sources of forensic evidence in a multitude of contexts. Several of these contexts will be explored in detail within this thesis. An example of the use of photographs for evidential purposes can be typified by the fingerprint comparison (Figure 1.1). Fingerprints detected at crime scenes or on objects of forensic interest are often photographed to enable a comparison of the detected impression with other fingerprint images stored on police databases for purposes of identification [Hawthorne 2009].

Q1 **K1**

Key:

Minutiae Highlighted for Examination

Figure 1.1: Example of photographs as a source of evidence (fingerprints). Q1 represents an unknown fingerprint recovered from an evidence exhibit. K1 represents a known fingerprint impression. The two impressions can be compared by a fingerprint expert to determine if they are different or similar. Several minutiae (blue circles) are highlighted to illustrate some of the detail an analyst would consider during their examination.

Figure 1.2 illustrates another example of a scenario where evidence may be derived from photographs. In this example a hypothetical case is presented involving three images of a vehicle (Q1-Q3) captured at a fixed location via CCTV in both daylight and night-time conditions. Potential questions that might be asked of the photographs include:

- Are the vehicles differentiable or does each image depict the same vehicle?
- Do exhibits Q1 and Q2 depict the same vehicle at different times of day, or different vehicles during the same period?
- Is either vehicle Q1 or Q2 the vehicle depicted in Q3?

Q1 (Daylight)

Q2 (Daylight)

Q3 (Night Infrared)

Figure 1.2: Example of photographs as sources of evidence (vehicle).

How can such questions be approached, what knowledge and considerations are required and who could sufficiently address them? It is not safe to assume that anyone can address these queries by simply viewing an image for a given period. These difficulties extend to other contexts involving photographic evidence such as facial images or complex scenes and interactions.

The intricacies of forensic photographic comparisons are unpacked in detail within this thesis in Chapter 6, however, the example of the fingerprint comparison can be used to briefly highlight some of the central challenges faced by photographic evidence and its interpretation explored within this work.

In order to fairly and accurately conduct a fingerprint comparison, the fingerprint analyst needs the knowledge, experience and skill necessary to look beyond the abstract pattern of swirls typical of the romanticised fingerprint, and identify various details (e.g. minutiae – friction ridge pattern details that impart uniqueness) of importance to the comparison, while simultaneously ignoring differences in form between the two impressions including any spatial disparities and colour or tonal differences [Vanderkolk 2009]. Conclusions reached by the analyst are still within the realm of personal judgement (they have decided what details are in fact present and whether a link exists between the compared image pair), so procedures concerned with the minimisation of bias are also involved [SWGIT 2013]. Furthermore, the highly controlled photographic capturing process employed to recover and record fingerprint impressions greatly assists to minimise the number of variables that could adversely affect visual analysis. When specialised control of the photographic process is not possible, such as the case for images sourced from CCTV or personal cameras, the level of complexity involved with the image analysis process can increase dramatically [Porter 2011a].

Faced with an exhibit similar to Figure 1.1, would lay members of a jury be comfortable making their own decision regarding whether the two images depict the same fingerprint? Would they be more likely to depend on the opinion put forth by an expert? What if the exhibit consisted of much lower quality images? Perhaps several overlayed fingerprints where concerned? What if the exhibit only depicted partial fingerprint impressions? The body of expertise concerned with the examination of fingerprints has developed substantially over time and continues to be expanded and scrutinised [Dror & Cole 2010]. Consider the impact on evidence reliability that may occur if the knowledge base relevant to a particular scenario concerning photographic evidence was not well established or was ill-suited for answering the questions asked of the image. This is a danger currently facing some forms of photographic evidence.

Ultimately, an image can only be viewed as a form of representation, not a source of unassailable fact or faultless mirror of reality. How, then, should such considerations be applied to photographic evidence and within a forensic investigation model to serve the courts and provide the standard necessary for a fair trial?

1.1 Research Problem Statement

The omnipresence of images within contemporary society has impacted how visual evidence is perceived and presented within the criminal justice system. Currently, there are no universally recognised methodological principles or practices established that allow robust and reliable forensic evaluation of images or that allow objective and dependable evidence to be developed from the interpretation of photographic evidence.

Without a critical examination of the interpretive processes employed by experts, unsupported and dangerous evidence could result from the examination of images. This lack of understanding and absence of a well-informed systemised approach to forensic photointerpretation tasks can easily give rise to serious miscarriages of justice.

The establishment of comprehensive photointerpretation methodologies by first recognising critical principles essential for the provision of fair and accountable practice would greatly support the reliability of photographic evidence presented within the justice system. Furthermore, the recognition of critical principles would provide much stronger gatekeeping opportunities within our courts by assisting the identification and subsequent justification for the exclusion of unreliable image based evidence.

This knowledge would support forensic expert image analysis by providing the fundamental basis of understanding necessary for the effective construction and employment of photointerpretation methods that meet legal and forensic requirements and/or ethical standards when using images as sources of evidence.

1.2 Aim of Thesis

The aim of this work is to elucidate critical conceptual and pragmatic principles necessary for supporting robust forensic photointerpretation methodologies when applied as photographic evidence.

The aim of this thesis was achieved through the pursuit of the primary research question and fulfillment of the aims and objectives introduced in Chapter 2 and formally presented in Chapter 3. These accomplishments were achieved through the research activities undertaken within each of the presented chapters.

1.3 Thesis Chapter Overviews

This section provides an outline of the content of each chapter and their relationship towards addressing the central research question of this study.

Chapter 1 provides a brief introduction that assists to situate the study within the forensic science knowledge space together with a problem statement that explains the importance of the work undertaken in relation to current knowledge and practice. The chapter also presents the general aim of the work and an overview of the thesis structure.

Chapter 2 presents background knowledge relevant for understanding forensic photographic evidence and photointerpretation concepts. It also assists to frame the research in relation to the current body of work and further identifies significant gaps in the knowledge presented in the literature.

Chapter 3 defines the central research question and research design applied for addressing this question. The chapter further presents the overarching research methodology, aims and objectives. The justification of the research design and scope of work are also offered together with a research design map and identification of the knowledge sources drawn on during the study.

Chapter 4 introduces the notion of a 'criteria based' photointerpretation approach for assisting interpretive image examination. The theory and rational behind the process are presented within the chapter. A framework for governing the development of a set of photointerpretation related criteria is also presented and explored through its implementation in the following chapter.

Chapter 5 explores the practical application of a criteria based approach to photointerpretation through the implementation of an assessment criteria method to a real world forensic photointerpretation question. A novel assessment framework was developed for the detection of second-generation images (rephotographed images) captured by devices such as camera phones. The task is of particular relevance to areas such as insurance fraud investigation where an image's authenticity can have significance to an investigation. This chapter together with the previous are employed for the exploration of important values apparent when considering a criteria based interpretation methodology for supporting the development of critical photointerpretation methodological principles.

Chapter 6 introduces the notion of comparative image analysis and provides an overview of the major theoretical concepts necessary for understanding the application of the approach to photographic evidence. The chapter also highlights several key complexities associated with image comparisons.

Chapter 7 further investigates comparative image analysis through the application of several comparative image analysis techniques to a case study involving facial comparison. The case involved addressing the question of whether two individuals depicted in historical photographs were in fact Adolf Hitler and Eva Braun. The investigation together with the previous chapter enabled first-hand insight into the capabilities and difficulties associated with forensic image comparisons, facilitating the contemplation of values exemplified by the approach that were considered important for supporting the development of photointerpretation methodological principles.

Chapter 8 presents the concept of reconstruction based photointerpretation as an approach for interpretive image analysis and a platform for the exploration of values important for supporting the conceptualisation of methodological photointerpretation principles. The thinking presented in the chapter was supported through a reflection on several reconstruction examples presented in the literature.

Chapter 9 presents the thesis discussion which encapsulates and further develops the key findings of this research in relation to the primary research question.

Chapter 10 presents a final summary of findings relating to the primary research question, research aims and additional queries.

Chapter 2

2.0 Background

Images are plastic, malleable, and lend themselves to any and every argument. They can exacerbate as well as mollify.

Errol Morris [Morris 2011, p. 217].

Photographs play a major role in our society and criminal justice system. From a legal standpoint, the photograph's ability to naturalistically document and preserve evidence and crime scenes and capacity to facilitate evidence enhancement has made them valued sources of information. Photographs can also help recount past events, act as memory aids, corroborate witness testimony and assist in the explanation of complex or technical phenomena. Photographic evidence which encompasses photographs, images and video footage, produced mechanically, optically or digitally and recorded on any media including electronic, optical, magnetic or film, have been utilised by the criminal justice system since the early establishment of the photographic process in the mid-19th century [Edmond *et al.* 2009; Mnookin 1998; Porter 2007, 2011a, 2012; SWGIT 2012].

Current literature has indicated a growing trend in the use of images as sources of evidence [see: Bramble, Compton & Klasen 2001; Edmond *et al.* 2009; Feigenson 2010; Porter 2009a, 2011a; Porter & Kennedy 2012]. The ever-increasing presence of photographic recording devices within our society has contributed substantially to this trend. In today's technological age images can be obtained from a multitude of sources including personal cameras, closed-circuit television (CCTV) systems, security cameras, mobile camera phones, speed cameras, webcams, in-car dashboard cameras, personal wearable video recording devices (body cams) and other overt or covert image recording systems.

Digital technology has transformed the way in which society engages and interacts with images. The modern ability to digitally transmit images has greatly contributed to society's widespread engagement and involvement with visual content. Photographs and videos can be viewed and shared through a variety of information and communication channels including; social-media websites and image databases (e.g. Google Images™ search service, Facebook™, Instagram™ and YouTube™); e-mail and multimedia smart phone messages. The proliferation of portable screen devices such as smart phones, tablets and laptop computers has further contributed to contemporary society's ubiquitous and continuous engagement with the photograph.

In 2011[1] the social-media website Facebook™ reported that over 250 million photographs were being uploaded to their site each day. This figure shows a significant increase compared to an earlier report in 2007[2] which announced that 60 million photographs were being uploaded to their site per week. This is almost a 3000% increase in uploads over a period of only 4 years. The 2007 report also stated

[1] http://blog.facebook.com/blog.php?post=10150262684247131
[2] http://blog.facebook.com/blog.php?post=2406207130

that over 3 billion images were being served to users each and every day. Porter [2012] refers to similar data:

> *This is in excess of 93 billion photographs uploaded to Facebook™ per year and that is only images on this particular social network site [Porter 2012, p. 2].*

Porter draws attention to the fact that these statistics only reflect trends concerning one particular website. Never before in our history has this number of photographs been captured and this phenomenon appears to be continuing to increase.

As a society, we regularly consume visual content through television, newspapers, magazines, and websites and share images with colleagues, acquaintances, family and friends. Our social environment is progressively becoming more visually oriented and as a result we are constantly bombarded with images. However, we have adapted to this situation. Unlike when photography first emerged and was considered a precious and rare commodity [Newhall, Kamins & Kruzic 1982], we have grown all too familiar with images and comfortably apply them within many aspects of our daily lives. Reading images in the context of 'everyday' has become second nature [Barrett 2006; Porter 2011a, 2012].

This condition has resulted in the development of a culture where we trust images and prefer to validate facts through visual confirmation. This phenomenon is exemplified by the media who regularly link imagery with news reports in order to increase their apparent factualness [Mitchell 2002; Porter 2007, 2011a, 2012].

Society's relationship with photographs has had an impact on the visual culture (the way society uses and communicates through images) experienced within our courts. Our everyday familiarity with images has affected how they are understood and used within the criminal justice system. Essentially, it has resulted in an increased level of reliance being placed on photographs that are presented as evidence [Porter 2007, 2011a, 2012; Porter & Kennedy 2012].

Despite the increasing reliance on photographic evidence, the criminal justice system suffers from several challenges in relation to existing evidence laws, specifically the *Evidence Act* 1995 (Australia, NSW[3]).

A number of aspects of evidence law have been shown to require greater investigation involving concepts of photographic evidence admissibility and image based opinion evidence. These issues have been recently explored in the literature [see: Edmond 2008, 2013; Edmond *et al.* 2009; Edmond *et al.* 2010; Edmond & Roque 2012] with particular focus on current laws and their application to identification evidence derived from photographic sources. However, these same issues are applicable to all facets of photographic evidence and need to be considered in this broader context.

The underlying problem is that the Australian adversarial legal system does not currently have the capacity to reliably utilise photographs as sources of forensic evidence in the manner in which they are currently being presented in various cases. Gaps exist in the legal jurisprudence surrounding photographic evidence and inadequacies exist in current forensic and law enforcement practices [Edmond *et al.* 2009; Edmond *et al.* 2010; Edmond & Roque 2012; Porter 2011a, 2011b, 2012; Porter & Kennedy 2012].

While the criminal justice system has used photographic evidence since the early introduction of photography, the predominant issue is that the system lacks a foundational understanding of how visual material can be reliably transitioned into the evidential form. What exactly is photographic evidence and how does it fit within our current models of the criminal justice system? Evidence has traditionally been examined and presented in our courts by practitioners of forensic science (exceptions include medical professionals and ad-hoc experts from various non-scientific fields). Over the history of the discipline, various practices and principles have been developed in order to support evidence examination with the highest levels of integrity and proficiency [Crispino *et al.* 2011]. But the question of who

[3] NSW – New South Wales, Australia. A state of Australia located along the eastern coast.

should be responsible to examine and report on photographic evidence is not well defined. If photographic evidence should indeed reside within the domain of forensic science, as this researcher advocates, then are there any robust forensic science principles that can deal with this type of evidence? How then can and should the judicial system respond to this practice?

2.1 Photographic Evidence & The Law

Evidence presented within the criminal justice system is governed by a set of rules which concern various aspects of evidence presentation, permissibility and issues relating to evidential weight. In Australia, the exact set of legal rules governing evidence varies by jurisdiction, but most legislature reflect a comparable set of conditions and concepts as presented in the *Commonwealth Evidence Act,* the body of evidence law applied by the federal court [National Archives of Australia 2016]. In the Australian state of New South Wales, the *Evidence Act 1995* is the legislation that governs evidence submission.

Photographs are indeed referred to in the *Act 1995 (NSW)* under section 115, however, the section is chiefly concerned with governing the admissibility of photographs as sources of identification evidence in order to minimise unfair prejudice. Certain scenarios, such as where photographs can unfairly suggest a link between a person and an offence, e.g. photographs taken when a defendant was in police custody (not necessarily charged), have several restrictions surrounding their use and submission as evidence. Section 115 also limits the use of custody photographs for purposes such as photo-boards or photo-arrays (matrix of images presented to a witness for the purpose of identifying the alleged suspect) unless a live 'identification parade' is unfeasible.

Porter [2011b] identifies a significant gap in the *Evidence Act 1995* stipulations relating to photographic evidence:

> *What is missing in the legislation however, is the application of photographs used for other modes of evidence outside photo identification arrays and, in particular, photographs that require interpretation. No further requirements of photographic evidence, with the possible exception of 'relevance', are*

> *expressed in Evidence Act 1995 that provide a legal framework to ensure appropriate representation of photographic evidence [Porter 2011b, p. 34].*

Part of the current criteria for evidence admissibility falls under s 56 of the *Evidence Act 1995*, which expresses that 'relevancy' is a principle condition for evidence admission. Relevancy reflects the concept that evidence 'could rationally affect (directly or indirectly) the assessment of the probability of the existence of a fact in issue in the proceeding'; or in other words, whether the evidence has probative value.

This is an issue for photographic evidence because currently the potential for such evidence to be misleading is not taken into consideration as a factor for admissibility. This means that deceptive photographic evidence can still be admitted into court if it is believed that it can contribute in any capacity to the issue at hand. In these circumstances, the admittance of the evidence may cause more harm than provide useful information for the triers of fact (jury) to utilise in their decision-making. However, gauging or detecting the deceptiveness of an image is a very difficult task and is not something that can be readily quantified. Edmond *et al.* [2009] acknowledges this problem:

> *For, images can provide probative evidence but they can also mislead. Often they mislead in ways that are insidious, because they unwittingly deceive viewers: whether expert, lawyers, jurors or judges [Edmond et al. 2009, p. 370].*

Sections 135 and 137 of the *Evidence Act,* also known as the 'exclusionary discretions', stipulate rules for the exclusion of unfairly prejudicial evidence. Photographic evidence can be considered unfairly prejudicial if it is deemed to possess low probative value due to the heightened potential to misleadingly influence viewers. For example, imagery of an unidentifiable perpetrator violently harming a victim could be considered unfairly prejudicial towards the accused since the perpetrator cannot be identified, yet the graphic imagery can influence the jury to form an emotional bias towards the accused, even though it may well not be them [Edmond *et al.* 2009].

The phenomenon of highly influential image evidence has also been observed in other fields such as neuroscience. The study conducted by McCabe & Castel [2008] provides scientific support for the idea that images can be prejudicial. The study found a significant relationship between the inclusion of brain scan imagery in research publications with that of reader's positive opinions regarding the level of credibility to afford research outcomes. The influential nature of the brain images was theorised to be related to the idea that the images somehow offered a convincing reflection of a physical proof regarding findings concerning brain activity or cognition; something that is technically studied and examined indirectly. The images represented areas of brain oxygenation, while researchers extrapolated this information and examined notions of thought. Essentially, the images were theorised to be considered a form of physical truth despite the information they provided only being part of a broader and indirect interpretation.

Unfair prejudice is of particular concern in scenarios involving 'half-truths'; evidence that only shows one side of the story, so to speak. Porter [2007] explores the phenomenon and explains that in some circumstances an image may indeed show certain 'facts', but not all the facts pertaining to the issue at hand. In such situations, the result may be the unfair shifting of the onus of proof away from the prosecution and onto the defence who now have the difficulty of proving the evidence incorrect.

Porter explored an exemplary scenario involving unfairly prejudicial evidence. In summary, the case involved a road rage related driving incident that happened between a car and a truck driver. The car driver was the complainant who managed to obtained photographic evidence of the incident. The issue went to court with the central question asked being whether the incident was a result of road rage caused by the car or by the truck driver. The photographic evidence provided proof that the truck driver had conducted an offense, yet the truck driver claimed that his actions were a result of the actions of the complainant.

Porter [2007] provides the following insights about the case:

> *In reality, the dangerous driving could have been contributed to either driver (car or truck) or to some degree both drivers [2007, p.86].*
>
> *No photographic evidence could support the truck driver's claim. The photographic evidence was selective in its representation of facts which placed an unfair onus on the accused to prove the photographic evidence wrong [2007, p. 86].*
>
> *The question this case raises is to what level did the photographic evidence support one witness while not supporting the other. From a representation of facts perspective, the photographs indicate the offence was committed, while the visual narrative form produced some significant gaps in the complete narrative and raises significant doubt regarding the complete story [2007, p. 87].*

As Porter suggests, the problem with half-truths and unfair prejudice is something that needs serious consideration when dealing with visual evidence. The criminal justice system does not currently have mechanisms to deal with this situation.

Edmond *et al.* [2009] state that the 'exclusionary discretions' of the *Act* are rarely applied to photographic evidence because judge's are hesitant to determine the probative value of the evidence since this is the duty of the triers of fact. Additionally, the literature indicates that knowledge gaps exist regarding photographic evidence and its influence on juror's decision-making adding to the complexity of the issue [Edmond *et al.* 2009; Feigenson 2010; Kahan, Hoffman & Braman 2009; Porter 2012].

Contemporary scholars have forewarned that the criminal justice system is currently faced by the dangers posed by the lack of scientific research and understanding concerning photographic evidence. As it stands, there are no widely accepted methods or standardised practises available for evaluating, analysing, interpreting and presenting photographs as forensic evidence. Law enforcement has not developed any standard procedures for recognising and processing photographs as evidentiary items and individual experts employed by the courts currently apply their own methodology according to their personal judgement and understanding [Edmond 2013; Edmond *et al.* 2009; Edmond *et al.* 2010; Edmond & Roque 2012;

Evison 2014; Feigenson 2010; Porter 2007, 2011a, 2011b, 2012; Porter & Kennedy 2012].

Section 76 of the *Evidence Act* provides the 'opinion rule' which essentially specifies that opinions are not admissible as evidence. However, s 79 of the *Act* provides exceptions to the opinion rule, enabling expert witnesses to provide opinion based evidence if certain conditions are met. The criteria necessary for circumventing the opinion rule is that an expert must possess specialised knowledge regarding the evidence they are giving an opinion on and that their opinion must be based 'wholly or substantially' on their specialised knowledge, which can come from training, study or experience. What then are the requirements for supporting expert opinions about photographs and who could be considered qualified to do so?

The development of evidence from images can be a very complex process and this complexity is often not understood by lay members of the jury. Porter [2012] makes this point evident:

> *…the effortless retrieval of visual information is easily transposed into a comfortable perception of reality. This perception however, does not automatically result in accuracy despite familiarity and confidence of the viewer [Porter 2012, p. 3].*

Porter states that the ease in which an image appears to be understood by a person creates a false sense of reliability. The more easily an image appears to be understood, the more undue credibility it is given. The problem is that the ways in which images are read and understood in the context of 'everyday' does not necessarily apply to evidential images. Images can be deceptive, so a thorough knowledge of photographic concepts is necessary when interpreting them to maximise the factualness of derived evidence [Barrett 2006; Edmond *et al.* 2009; Edmond *et al.* 2010; Edmond & Roque 2012; Porter 2011a, 2011b, 2012; Porter & Kennedy 2012].

Edmond *et al.* [2010] makes a point about image interpretation conducted by the jury:

> *We cannot simply assume that fact-finders are capable of overcoming some of the illusions created by image distortion, particularly in the context of a criminal trial where photographic interpretations are likely to be influenced—consciously and unconsciously (and perhaps irrationally)—by supplementary information [Edmond et al. 2010, p. 165].*

Issues have also been uncovered with current practitioners who are giving expert opinion evidence based on images, particularly for the purpose of identification. These experts (primarily anatomists in Australia) appear to lack a thorough understanding of photographic evidence principles, which can have a strong impact on the notion of a fair trial if unsound evidence is presented (e.g. *R v Jung [2006]; Morgan v R [2011]; R v Tang [2007]; Honeysett v R [2013])*. Unreliable expert testimony can foster unfairly prejudicial evidence particularly because of the credibility given to experts due to their status, irrespective of the soundness of their applied methodology [Edmond *et al.* 2009; Edmond *et al.* 2010; Porter 2007, 2011b, 2012]. Conversely, experts in photographic practice may not have the requisite knowledge to deal with interpreting certain forms of specialised image content such as medical images, or to make comments on aspects like anatomical structure.

2.1.1 Photointerpretation & Forensic Science

The act of interpreting an image to derive facts constitutes a major form of evidence development. In fact, the general nature of photointerpretation could be considered an 'inverse problem'. Tarantola [2005] explains:

> *This problem of predicting the result of measurements is called the modelization problem, the simulation problem, or the forward problem. The inverse problem consists of using the actual result of some measurements to infer the values of the parameters that characterize the system.*
>
> *While the forward problem has (in deterministic physics) a unique solution, the inverse problem does not. As an example, consider measurements of the gravity field around a planet: given the distribution of mass inside the planet, we can uniquely predict the values of the gravity field around the planet (forward problem), but there are different distributions of mass that give*

> *exactly the same gravity field in the space outside the planet. Therefore, the inverse problem — of inferring the mass distribution from observations of the gravity field — has multiple solutions (in fact, an infinite number) [Tarantola 2005, p. xi].*

When developing evidence through the interpretation of photographic data, an attempt is made to look back through the final result (the image) in order to determine various factors that contributed to its production. This task however can be quiet complex and might not be able to be resolved in the form of a single ‘correct’ answer. Therefore, it is important that all critical information considered within the analysis, including how any examinations were conducted are communicated, as these can significantly influence outcomes.

The lack of any robust forensic photointerpretation (the cognitive process of interpreting photographs) processes for developing visual evidence presents significant dangers to the criminal justice system. One of the most poignant consequences of unreliable photointerpretation evidence is the heightened potential for miscarriages of justice to occur. Unreliable interpretive analysis and presentation of photographic evidence poses a threat to the notion of a fair trial if used to inadvertently or deliberately misrepresent facts or alter the true value of the evidence [Edmond *et al.* 2009; Porter 2011a, 2011b, 2012; Porter & Kennedy 2012].

Porter [2011b] makes the following statement regarding the current status of photointerpretation in the criminal justice system and forensic science domains:

> *The absence of photointerpretation methodologies, or an understanding of the relationship between photography and physical evidence, may result in evidence derived from CCTV or other photographic sources being misrepresented, exaggerated or erroneous. A lack of transparency in the forensic reports further exacerbates the problems of reliability when the results cannot be further tested by other forensic specialists. This is a significant problem with contemporary photographic evidence and questions its level of reliability to provide evidence that is accurate and not unfairly prejudicial [Porter 2011b, p. 6].*

Porter suggests that a thorough understanding of photointerpretation processes is required for the development of fair evidence. The simple application of various techniques to photographic material is not sufficient without clear knowledge of their workings, strengths and limitations. This knowledge needs to be presented transparently in the reporting of the evidence to minimise unfair prejudice.

What is desperately needed within the criminal justice system is insight into how a robust capacity can be developed to support photographic evidence. The practise of photointerpretation needs some level of applied forensic rigor, enabling the evidence and interpretation processes to be scrutinised, tested, repeated and subjected to validation; thinking supported by this research and all other scholarly works that critique and explore how images can be reliably used as evidence sources.

Therefore, the primary question that underpins this thesis is:

- What are central or critical principles for establishing robust forensic photointerpretation methodologies within forensic science practice and the criminal justice system?

2.2 Evolution of the Photointerpretation Paradigm

The history of the photograph's evidentiary power stems from early preconceptions held within the legal environment that the photograph was a perfect and objective reflection of reality. This notion was believed to have arisen from the idea that the photographic process was a flawless method of documenting nature due to the camera's seemingly autonomous mechanical operation and its naturalistic depictions [Biber 2006; Mnookin 1998; Porter 2007, 2012; Porter & Kennedy 2012].

Guilshan [1992] states that photographs were presented within French courts as early as the 1850's and admitted as evidence in the United States since the 1860's. Mnookin [1998] quotes from an early American photographic journal expressing how French lawyers were using photographs to persuade both judges and jury far more articulately than what they could achieve using words alone. However, was there any scientific basis behind their claims? Did the presented 'photographic evidence' support their account of fact or merely act as a tool of persuasion?

Since the dawn of photography, the prevalence of images within our society has continued to increase at what seems like an exponential rate. This growth has resulted in a spill-over effect into our legal system. The increased presence and our familiarity and trust of images have impacted on the visual culture currently experienced within our courts. What has resulted is an increased utilisation and reliance on images as sources of evidence [Bramble, Compton & Klasen 2001; Edmond *et al.* 2009; Feigenson 2010; Porter 2007, 2009a, 2011a; Porter & Kennedy 2012].

Images are an important form of evidence and have an expansive set of functions within the forensic science sphere. The literary works of Porter [2007, 2009a, 2011a, 2011b] and Porter & Kennedy [2012] have emphasised that photographs do not have a single homogenous application as evidence. This means that different images meet different criteria and function differently as evidence; essentially not all images are equivalent. The various functional roles played by visual evidence has been articulated in Porter's [2011a] work *'A new theoretical framework regarding the application and reliability of photographic evidence'*. The framework was established as a response to the complexity of photographic evidence and the lack of a framework for assessing its reliability and relationship to physical evidence.

Porter's classifications consist of analyse, document, describe and witness 'modes of inquiry'. Bramble, Compton and Klasen [2001] have also acknowledged similar photographic evidence categories. Images of these types can provide various forms of evidence including the ability to assist with identification, the establishment of certain conditions important to an investigation, clarify chain of events and development of useful intelligence [Porter 2011a].

Each of these image categories requires a set of strict photographic principles regarding how they are to be captured to ensure the maintenance of integrity through the minimisation of artefacts and distortion that could otherwise affect the usefulness or reliability of visual information, except for 'witness' mode images, as defined by Porter. Such images are not captured by someone trained in forensic photographic practice so the condition of their capture needs to be carefully considered during examination [Porter 2011a].

As stated earlier, the criminal justice system has used photographic evidence since the early establishment of the photographic process. The problem is that the system has minimal insight into how images can be relied on as sources of fact. How exactly does an image become evidence? Photointerpretation is one particular mechanism for transforming images to evidence. 'Witness' images as explored by Porter [2011a] regularly undergo photointerpretation as part of the evidence development process, however, there is little literature specifically exploring photointerpretation concepts.

Porter and Kennedy [2012] state:

> *Law enforcement and forensic institutions are reinforcing technique driven operations and creating a further divide between 'technique' and 'content' which is an inherent quality within photographic evidence. However, what is dangerously missing is the consideration of content or the contextualisation of the photographic evidence which is essential when the pursuit of truth and reliability of this form of evidence is paramount [Porter & Kennedy 2012, p. 3].*

An examination of current forensic photographic practices advocated by the Scientific Working Group on Imaging Technology (SWGIT), an American established international collective that aims to create standards for multimedia evidence, attests to this viewpoint. SWGIT provide useful information for forensic practice related to images such as best practice and guideline based documentation. In the document *'SWGIT guidelines for the forensic image practitioner: Section 12 - best practices for forensic image analysis',* the process of photointerpretation is acknowledged under the header of 'content analysis', which is defined as 'drawing a conclusion form an image'. The guide understandably provides a very broad definition of what content analysis or photointerpretation entails. The SWGIT document also provides a typical example of how to apply their recommendations regarding this practice [SWGIT 2012].

The SWGIT example involves an image depicting physical trauma which had been documented on the body of a child which had subsequently passed away and been cremated. The image contained evidence as to whether foul play was involved (the documented injury) and was later relied on in a coroner's inquiry.

The following hypothetical work flow is presented by SWGIT [2012, p.11]:

1. The agency reviews the request and:

a. determines that they perform this type of analysis,

b. determines that all necessary items to support the requested exam have been submitted,

c. determines that they have the necessary equipment, materials, and resources needed to conduct the requested analysis, and

d. assigns the analysis request to a medical examiner (ME).

2. The ME acquires the necessary imagery.

a. The ME calls the hospital and subpoenas the child's records.

b. The ME confirms that the imagery is a copy of the digital snapshots taken by the ER doctor.

c. The ME reviews the documents and imagery and selects several images for further analysis.

3. The ME makes working copies of the selected imagery, and safely stores the received data.

4. No image processing is required.

…

The fifth step involves interpretation by the medical examiner and the sixth involves a report addressing the reasoning behind the interpretation.

What is lacking from the SWGIT process is some level of interaction between the medical examiner and a photographic expert regarding the image's ability to be used for medical diagnosis. In the example, the colour and texture of the injury were important parts of the interpretation process. What if the colour wasn't recorded accurately by the camera or that the camera to subject distance employed could have distorted the appearance of the injury? There is no analysis of the image from this perspective and no communication with the medical examiner about these issues. A positive point to note however, is that the sixth step in the SWGIT workflow process involves documenting the basis of the interpretation. The lack of consideration for the photographic aspects of the evidence highlights the need for examinations to be expanded to encompass photointerpretation concepts.

Perini [2012] supports a similar viewpoint regarding visual evidence; '…an account of image interpretation is needed.' This same notion has been strongly advocated by Porter [2011b, 2012] who also poses important questions around topics such understanding the specifics involved in the interpretation process and how evidence based on photointerpretation can be made more transparent and provide a level of accountability.

Only recently has research started emerging relating to concepts of photointerpretation from a scientific perspective.

The philosophical issue of 'mechanically produced images' (not diagrams, drawings or graphs) being used as scientific evidence is explored by Perini [2012]. The claim is made that current scientific research has revealed significant gaps in our knowledge regarding how images can take on evidential roles. Porter [2011b] has also highlighted that the link between image and forensic evidence has not been clearly addressed by the literature.

Perini's work frames a debate around whether or not images hold purely rhetorical roles, or can function as rational sources of evidence. Their work concludes that images do have the potential to be used as evidence, although obtaining a comprehensive understanding of their capacity to act as reliable evidence is a seemingly multifaceted issue. Perini provides examples such as in medical imaging (e.g. x-rays) where interpretation is claimed to be able to be conducted more reliably due to the specific conditions and knowledge known about the sample and imaging technique used. These specifications include that the imaging technique is selectively sensitive to the item being studied, is applied to only a restricted sample range and that detailed knowledge is known about the sample, preparation and imaging process. Allamel-Raffin [2011] supports a similar view.

However, Perini's reasoning is centred on the study of scientific images; the type obtained under very specific and controlled parameters, e.g. micrographs, medical images and radiographs. Although these images undergo a photointerpretation process, in the domain of forensic science, images requiring interpretative analysis are often obtained under non-ideal conditions and from a variety of sources.

What is more, viewers also often have some level of familiarity with the types of images involved in forensic investigations. Supposedly understandable still images or video footage of scenes depicting people, actions and places, unlike seemingly ambiguous images that can be obtained from under a microscope, are often presented to the triers of fact (jury). This adds to the current challenges faced by forensic evidence derived through photointerpretation. Porter [2012] suggests:

> *...confidence associated with photographic viewing can inappropriately become the threshold of fact without a more suitable forensic evaluation of the evidence [Porter 2012, p. 45].*

Porter's work states that since we trust our sense of vision, essentially following the axiom 'seeing is believing', then it is easy for triers of fact to think they see truth in an image.

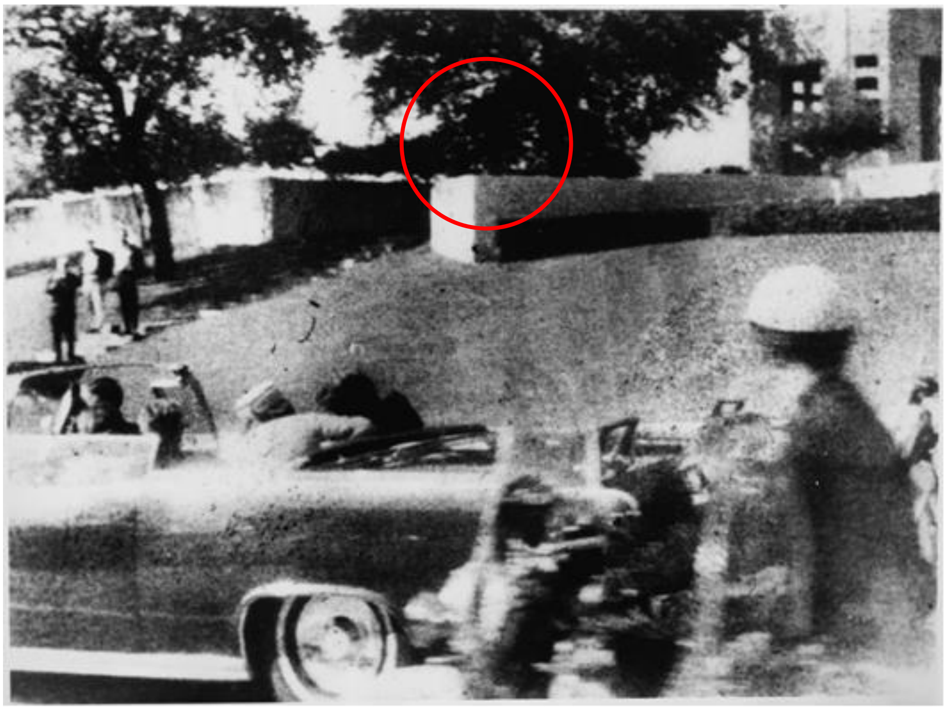


*Figure 2.1: Moorman's photograph of the 'Grassy Knoll' during the assassination of US President J.F. Kennedy. 'Badge Man' can allegedly be seen visible within the area highlighted (red circle). Photograph by Moorman [1963]. Public domain.*An example

of this phenomenon can be demonstrated by the conspiracy theory dubbed 'Badge Man' (Figure 2.1). The conspiracy was based on a suspicious figure supposedly located hidden behind a fence within Mary Moorman's famous photograph of the 'Grassy Knoll', an area directly adjacent to where United States President John F. Kennedy was assassinated in 1963. The famous image was captured mere moments after the time of the incident. The suspicious figure behind the conspiracy was believed to be a hidden assassin and apparently resembles a person wearing a police uniform with a badge visible, hence the name 'Badge Man' [Reitzes 2013]. Such conspiracy theories have been long since proven false, however, a period of time did exist when such beliefs were in part perpetuated by what people thought was clearly visible in a blurred, grainy, low resolution image.

Low resolution is not the only catalyst for obscuring the link between truth and photograph. Stedmon [2011] experienced firsthand the problems that can be introduced through the overconfident viewing of images. Stedmon describes a case involving the false charge of a driving offense in the United Kingdom based on a traffic camera system, despite the availability of clear and easily identifiable images. Stedmon expresses the need for greater understanding regarding the issue of error in these circumstances. The common perception held by society about the independence and objectivity of photographs is suggested to significantly enhance the apparent credibility and persuasive power of unreliable evidence. Understanding the 'truth' apparent in an image is a complex matter. According to the provisions presented in *Evidence Act 1995*, who then would qualify to make an opinion about photographs?

The concept of the truthful photograph, or 'photographic truth' as referred to in the literature, has been reflected upon and discussed in a number of papers [see: Barrett 2006; Lesy 2007; Milliet, Delémont & Margot 2014; Mnookin 1998; Porter 2007, 2011a, 2011b, 2012; Sontag 1978; Thompson 2008]. The overarching opinion is that the notion of photographic truth is misleading. The reasoning behind this stance is clarified by Porter [2007] who states that there will always be some level of subjectivity in the photographic process, explaining that technical variables such as framing, lighting, the selection of lens focal length, and so forth, will contribute to the distortion of the image in some way. Beyond this, the viewer's interpretation of the image will also be influenced by their own beliefs and experiences.

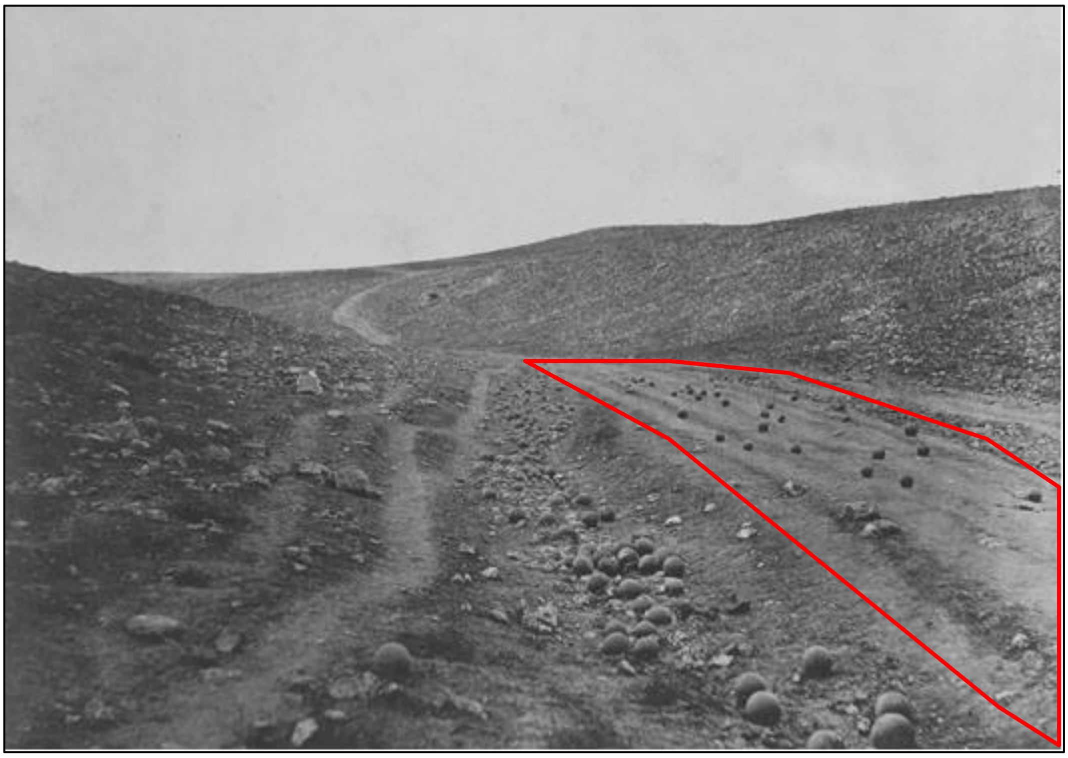
The latter point is highlighted by Kahan, Hoffman & Braman's [2009] work based on the case *Scott v. Harris* [2007]. Their investigation established that different people of different social backgrounds and ideologies can interpret the same visual evidence (in this case a video of a police car chase ending with the use of lethal force) as bearing widely different levels of significance. Porter and Kennedy [2012] also acknowledge that images undergo an interpretive process that is influenced by factors such as context, as well as experience and reasoning among viewers, resulting in potentially different interpretations of the same visual stimulus.

This phenomenon is something that needs further exploring in the forensic and legal contexts. Just how do our perceptions shape our interpretation and affect the significance we draw from visual evidence? Kahan, Hoffman & Braman's work shows that this poses a real danger. How can we approach this phenomenon from a scientific perspective? Porter [2012] acknowledges that there is little contention over the fact that some images can be interpreted in a straight forward manner but makes the point that not all images fall under this ideal.

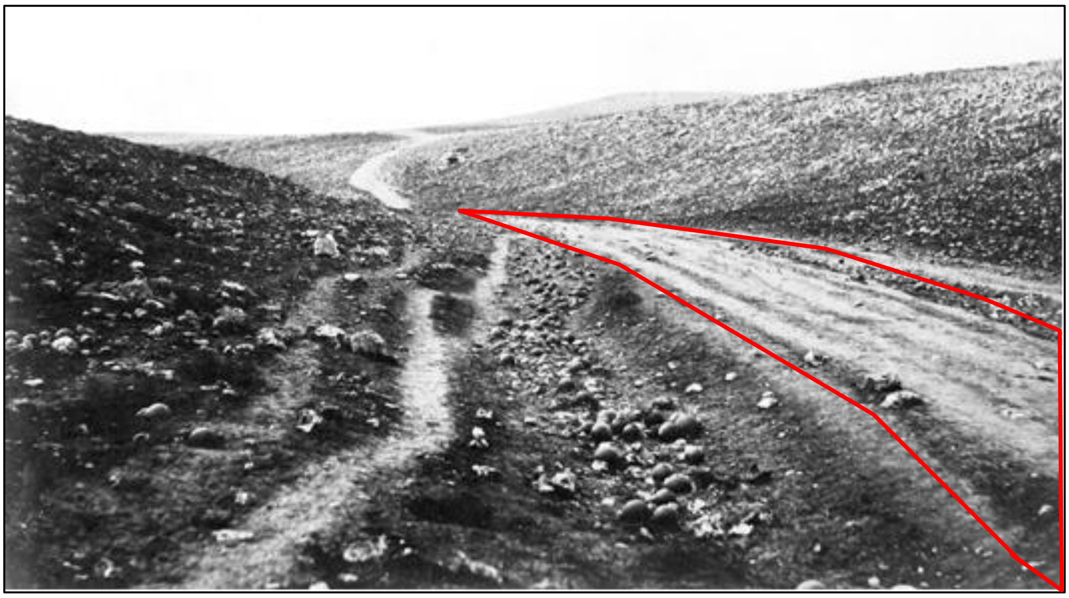
Due to the need for an understanding of photographic principles in order to reliably examine an image and develop forensic evidence to be used in a court of law, the opinion of this author is that forensic science should take the responsibility for developing evidence through images. The need for expert knowledge has been somewhat acknowledged by the legal system. Experts are employed in some instances to examine images; however, no substantial capacity has been developed for handling photographic evidence in the legal environment. A number of the experts employed to examine images are not aware of the more complex issues involved with photographic evidence beyond the 'obvious'.

Porter and Kennedy [2012] express the dangers of unreliable expert witness testimony compounding the hazard of unsubstantiated visual evidence. Porter and Kennedy explain that images can be used in the courts in a manner similar to media convention; to artificially increase the believability of the visual narrative or persuasive argument being offered about the evidence related to the image. Presenting opinion evidence as a matter of fact alongside an image can create a false sense of reliability. This is especially dangerous if the evidence presented is factually weak or misleading.

Careful consideration must be taken when examining an image and expressing findings. Without a critical examination of the interpretive processes undergone to determine ‘fact’ from ‘image’; opinion and speculation can easily replace the position of verifiable facts [Porter 2011b, 2012]. This phenomenon is explored by Errol Morris [2011] who through a series of essays in his book ‘Believing is seeing (observations on the mysteries of photography)’ questions the narrative presented about a number of famous images. Morris goes through a process of critical fact checking and examination of several images to explore the relationship between narrative and reality, providing excellent examples of the dangers introduced by simply accepting narratives without having an understanding of the facts the images actually support.



ON



OFF

Figure 2.2: Roger Fenton's 'Valley of the shadow of death', 1855 Crimean war photographs. ON [Fenton 1855b] and OFF [Fenton 1855a] represent images where cannonballs appear either present or absent on the dirt road (highlighted). Photographs studied by Errol Morris to determine which was captured first. Public domain.

One example of Morris' work is the analysis of a pair of photographs captured from the same tripod position by photographer Roger Fenton in 1855 as part of an effort to document the war in Crimea at the time (Figure 2.2). The photograph depicting a cannon ball laden road labelled 'ON' (a convention also used by Morris to differentiate the two images) is reportedly the most commonly reproduced [Morris 2011]. As a consequence of reading an essay by Susan Sontag titled 'regarding the pain of others' which suggested that the photograph 'ON' was captured after 'OFF' (cannon balls next to the road) and was therefore staged by the addition of cannon balls onto the road, Morris questions how it is that anyone could know which photograph was taken first let alone make the assumption that the 'ON' image was not entirely genuine.

Morris posits several hypotheses developed in consultation with various experts that could explain the ordering of the photographs including the possibility that the cannon balls were cleared from the road to assist access (ON first, OFF second) or that the cannon balls were moved onto the road to make the scene more dramatic (OFF first, ON second).

To find the truth behind the 'valley of the shadow of death' photographs, Morris consulted an array of experts who assisted to attempt various visual analysis tasks. These tasks included shadow analysis to gauge time of day and length of time between photographs, the counting of the number of cannon balls recorded between the two photographs to indicate whether any might have been removed for reuse by the opposing military force and lastly the examination of the positioning of various scene objects (specifically rocks) between photographs. The later examination proved the most definitive.

Morris finally concluded based on the results of objective image examination that the 'OFF' image was indeed photographed first, followed by the 'ON' image. This was based on the apparent movement of several rocks downhill (i.e. based on the laws of gravity) between images due to some disturbance. However, Morris makes the strong point that there is nothing that can indicate how or why the cannon balls were moved from to the side back onto the road.

Morris' initial efforts to investigate the nature of the photographs resulted in the presentation of various unsupported speculations, thoughts and opinions by different commentators regarding their beliefs about the images. The reasoning behind the commentator's opinions were largely based on their own apparent understanding of the personality of Fenton (the photographer) and what they thought a typical photographer would do in a similar situation. Not all opinions were in agreement either which certainly did not satisfy Morris who was alert to the dangers of blindly following a constructed narrative without any supportive objective information. The difficulties of establishing a reliable link between truth and photograph, not just based on opinion, are similarly reflected in the legal system.

The challenges faced by images and photointerpretation within the criminal justice system involve legal jurisprudence surrounding the gatekeeping role of the courts. The failure is that sections 56, 135 & 137 of the *Evidence Act 1995* are primarily the only methods available for the legal system to contest the presentation of photographic evidence. Edmond *et al.* [2009] suggest that the successful application of these laws seems to be rarely enacted. Supporting this observation, Porter [2011b] claims that at the time of their research, experts still continued to present unreliable photointerpretation evidence to the courts.

Porter's [2012] paper *'Zak coronial inquest and the interpretation of photographic evidence'* provides a clear illustration of the misleading and unreliable use of photographic evidence. In the examined case, several images were presented by expert witnesses who did not have sufficient knowledge about photographic concepts in an attempt to provide new evidence at an inquest into the death of Romuald Todd Zak. The new evidence was proven to be based on unreliable photointerpretation and was criticised heavily by the coroner. The work summarises several issues with the presented evidence including the lack of consideration regarding the limitations of the image evidence and the failure to utilise supportive contextual information that could have greatly assisted interpretation. The evidence presented was considered as unsubstantiated subjective opinion. What is important to note is that the same evidence that was highly criticised in the inquest was earlier presented and accepted by the Western Australia Supreme Court[4]. The unreliable evidence provided the legal basis for the establishment of the final inquest to take place under the ruling of the Supreme Court.

Another case examined within Porter's [2007] paper '*Visual culture in forensic science*' is the case of Rodney King. The case involved both the prosecution and the defence using the exact same video evidence to support both their claims. The same imagery was interpreted to support opposite narratives. This highlights the intricate role of context in the photointerpretation process. Porter and Kennedy [2012] explain that context is a key component of visual evidence reliability, but express that current gaps exist in both the forensic and legal domains regarding its consideration. Clearly, understanding reliable ways to integrate contextual information into the interpretation process would assist in developing useful evidence.

The methodological approach known as reconstruction based photointerpretation (Chapter 8), is one such method that can assist to provide greater contextual support when examining photographic evidence. The approach involves considering an image as if it were a crime scene and subsequently reconstructing the scene in order to better examine questions about the photograph through additional information provided by understanding the physical aspects of the scene. The approach can assist to answer questions related to topics such as confirmation of location, whether an observation in a photograph is a fair representation or illusionary, or details concerned with the dimensional and spatial relationships between different scene elements.

Comparative image analysis is another methodological approach that can be used to examine photographic evidence (Chapter 6). The method is employed when a comparison is required between two or more images. There are no widely recognised universal forensic standards for conducting image comparisons, but there are several generally adopted frameworks and approaches such as side-by-

[4] The Supreme Court is the state's highest court.

side comparisons and image overlays. All comparative photointerpretation techniques attempt to fundamentally determine whether any significant differences or similarities exist between features observable within examined images. Comparative image analysis is often used as a means of identification.

Edmond *et al.* [2009] explored issues with identification derived through image analysis. Currently, identification techniques are largely an interpretive process. Edmond *et al.* [2009, p. 338] explain that since the case *Smith v The Queen* [2001], the Australian legal system has required experts to conduct interpretations of 'incriminating photographs and videos', within the restricted scope of opinions about similarities between the unknown and the accused only. One such technique criticised by Edmond *et al.* is 'facial mapping', which involves the comparison of an unknown individual to a known suspect via a visual comparison of facial features present in a photograph. This technique was used in cases such as *R v Jung* [2006], *R v Tang* [2007] and *Morgan v R* [2011]. The technique is argued to not be based on any specialised knowledge, lacking in standards and has no consideration for error. This type of analysis has been mainly conducted by anatomists in Australian courts due to their specialised knowledge of the structure of the human body. Edmond *et al.* however explain that anatomists do not have relevant knowledge regarding photographic concepts to utilise images reliably when conducting this type of photographic comparison. This issue was also raised during the *Morgan v R* [2011] and recently, *Honeysett v R* [2013] appeals. Edmond *et al.* [2010] and Edmond [2013] also examine similar issues apparent with facial mapping and other image interpretation based facial identification methods.

The facial identification evidence given in these cases have been centred on body features which have been deemed significant, such as nose and lip shape and skin colour. Aside from distinctive identifying features such as scars, moles and tattoos, the comparison of body features does not provide any substantive proof for positive identification unless some sort of statistical significance can be attributed. Edmond *et al.* [2009] discuss the role of statistical databases that would assist with this sort of empirically based interpretation, but also express the difficulties that would be involved in developing one due to the complexities of the population data and genetic information required.

A final example of a photointerpretation approach that can assist the development of more transparent and reliable photographic evidence is that of criteria based image examination (Chapter 4). The criteria based examination framework is centred on the development and utilisation of a set of criterion developed specifically for assisting to address a particular forensic question asked of an image. Well defined criteria can assist to clearly articulate to all parties concerned with the analysis all observations detected during examination, their significance and the outcome their totality suggests. This form of communication can enable greater scrutiny of findings by other parties/experts and helps to substantiate any opinions developed by the examiner. Chapter 5 explores the development and implementation of a criteria based approach for the detection of second-generation (copies) images.

2.3 Chapter Summary

The question remains regarding who should be responsible for the examination and reporting of photographic evidence and how the judicial system can respond to such practice.

The literature has indicated that concepts and issues relating to forensic photointerpretation are multifaceted and complex. Currently, a number of difficulties plague the photograph's transition into the evidentiary form such as unfair prejudice, insufficient scientific and legal support, non-standardised practice and unsound expert testimony. Forensic science and the criminal justice system need further knowledge about photointerpretation concepts in order to develop more reliable practises that can help support the fair and accurate development and utilisation of visual evidence.

This work aims to provide a deeper understanding into the fundamental principles required for supporting a robust forensic capacity within the criminal justice system for the development of evidence derived through the interpretation of photographic material.

Chapter 3

3.0 Research Design

Understanding photographs is different from looking at them. ... Thought, research, and an occasional revision of initial impressions are necessary, and these take more time than a brief look.

Mary Warner Marien [Marien 2014, p. XIV]

This research project involved the application of case studies, experimentation and critical literary analysis to unpack and investigate various nuanced and complex principles when considering images as evidential sources for the derivation of fact through 'expert' interpretation. This was achieved through the use of a mixed methods research methodology which enabled the examination and integration of various data types for assisting investigation. Three distinct methodological approaches were selected for the exploration of concepts and principles important for supporting sound photointerpretation practice. Investigation of these approaches was conducted through several discreet research components which resulted in the extrapolation and contemplation of a number of values intimately associated with concepts of reliable and just forensic photointerpretation practice. A reflection on the sum total of the accumulated values enabled the elucidation of several key conceptual and pragmatic principles regarded essential for supporting photointerpretation methodologies; fulfilling the primary research question.

3.1 Research Questions

This project investigated the following **primary research question**:

- What are central or critical principles for establishing robust forensic photointerpretation methodologies within forensic science practice and the criminal justice system?

Further to the central question, this research also examined the following **secondary questions**:

- What values integral for conceptualising forensic photointerpretation methodological principles are exemplified or inspired by:
  - A criteria based approach for forensic image examination?
  - Comparative image analytical techniques?
  - A scene reconstruction approach to photointerpretation?

3.2 Research Aims & Objectives

The **aims** associated with this work were to:

- Provide new knowledge regarding the application of photointerpretation methodologies for developing evidence for use in a court of law;
- Determine critical concepts and principles integral to the development of a framework for supporting forensic photointerpretation practice and henceforth for supporting current and future expert image analysis;

- Recognise and clarify gaps in knowledge and practise regarding current forensic photointerpretation approaches;
- Improve the reliability of the application of forensic photographic evidence within the justice system through the development of critical photointerpretation principles;

This work achieved these aims through the realisation of the following **objectives:**

- Introduction of the notion of a criteria based methodological approach for forensic photointerpretation;
- Establishment of a method for the detection of second-generation digital photographic images through the novel application of a criteria based photointerpretation approach;
- Exploration of the application of comparative image analysis to forensic photointerpretation work;
- Investigation of a unique case involving comparative image analysis and the questioned identities of individuals depicted in historical photographs believed to be Adolf Hitler and Eva Braun;
- Consideration of the notion of reconstruction as a methodological approach to assist forensic photointerpretation practise through the examination of several theoretical examples of application;
- Elucidation of major conceptual and pragmatic principles associated with the methodological approaches investigated throughout the study.

3.2.1 Research Hypothesis

This work relied on the following hypothesis:

- The three methodological approaches (criteria based, comparative image analysis and reconstruction based interpretation) examined within this body of work are sources that can provide grounds for extracting values and constructing generalised concepts and principles pertaining to a broader photointerpretation methodological framework.

3.3 Research Method

Forensic photointerpretation encompasses a complex interplay of elements from various fields including photography, visual culture, forensic science and law that coalesce at the core of the discipline. Due to the interdisciplinary nature of the research topic together with the complexity demanded by the primary research question, a 'mixed methods' research approach was determined the most appropriate for undertaking this work. A design variant of the approach referred to as an 'embedded design' by Creswell & Clark [2011, p. 90] was implemented to facilitate the exploration of supplementary data types within the confines of larger investigation components undertaken in pursuit of the primary research question. The embedded design variant strongly supported the research strategy developed for the successful undertaking of the study.

3.3.1 Mixed Methods Research Overview

Mixed methods research is a relatively recent established approach that supports the utilisation and integration of both qualitative and quantitative data sources for a single research purpose. The approach has seen increasing popularity and evolution since its early academic foundations in the late 1950's due to the extended depth and comprehensiveness multiple data types can provide to a study. Mixed methods was established in response to the apparent limitations of research focused strictly on either quantitative or qualitative data which in comparison, result in a relatively reduced scope of understanding when applied to complex research topics that require consideration from multiple viewpoints [Creswell & Clark 2011; Greene, Caracelli & Graham 1989; Onwuegbuzie *et al.* 2009].

The application of mixed methods research has predominantly been within the social sciences but has seen successful application in a wide range of disciplines including education, nursing, health research and behavioural studies [Abowitz &

Toole 2010; Barg *et al.* 2006; Creswell & Clark 2011; Creswell, Fetters & Ivankova 2004; Greene, Caracelli & Graham 1989; Teddlie & Tashakkori 2006].

The 'embedded design' approach implemented in this study is a methodological variant of mixed methods research that enables the use of complimentary supportive investigative components nested within the context of a dominant investigation type. This approach is advantageous in studies such as this project, where secondary data of a different type can add further value to primary investigations and assist with answering research questions.

3.3.2 Research Approach

From a conceptual perspective, the research approach implemented in this thesis consisted of several embedded layers of differing foci (see Figure 3.1). Overall, the work adopted a predominantly qualitative emphasis or 'qualitative priority' with a secondary focus on supplementary quantitative data. The work also adopted both pragmatic and constructivist paradigms. The former takes a stance which focuses heavily on solving the research problem using all applicable data types and methodologies that can assist the process, while the latter is geared towards building generalisations from the collective examination of different perspectives and developed information [Creswell & Clark 2011].

An overarching theoretical outlook encompassed the development of core principles critical for the establishment of robust forensic photointerpretation methodologies, i.e. the primary research question. In order to pursue the overall goal of the study, the work entailed the exploration of three methodological approaches to photointerpretation; criteria based analysis, comparative image analysis and reconstruction based analysis. These methodological approaches were investigated through the aid of case study and literary reflection (the primary qualitative modes of inquiry) complimented by experimentation where appropriate (embedded supplementary quantitative component).

Each of the three methodological approaches were unpacked through research components presented as separate chapters that included specifically devised methods, research questions and aims for investigation. Research components that focussed on different methodology were regarded as independent which enabled simultaneous branches of exploration to occur concurrently throughout the course of the study. Critical concepts or values inspired or exemplified by each approach were largely established within chapter discussions. Data integration occurred within the final thesis discussion chapter where the isolated findings from the research components were presented together in the wider context of the primary research question through the discussion medium. Key principles were precipitated and crystallised as a result of the newly presented knowledge and perspectives. The synthesis and amalgamation of information developed throughout the study occurred within the major discussion chapter and resulted in the successful realisation of the primary research question.

3.3.3 Technical Considerations

All examinations undertaken as part of this research involving digital photographs, unless stated otherwise, were conducted on a calibrated LCD monitor (Dell U2312HM IPS) attached to a PC running a Windows® operating system with an AMD Radeon™ HD 6900 series graphics processor. Calibration of the display monitor was conducted using ‘ColorVision® Spyder2 Express’ sensor and calibration software by Datacolor. Adobe® Photoshop® and Bridge® CS6 software packages were also employed by default for supporting photographic examination.

3.4 Research Map

The following section diagrammatically illustrates the research design employed by this thesis.

Figure 3.1 depicts the conceptual structure of the embedded mixed method design adopted by this work. Each nested box represents a layer of research focus. Core research involved the exploration of photointerpretation methodological approaches through case study, literary reflection and experimental work.

Investigations concluded with chapter discussions that elucidated a number of values integral towards addressing the main goal of the thesis. The determined values informed the thesis discussion which, guided by the overarching theoretical outlook, addressed the primary research question.

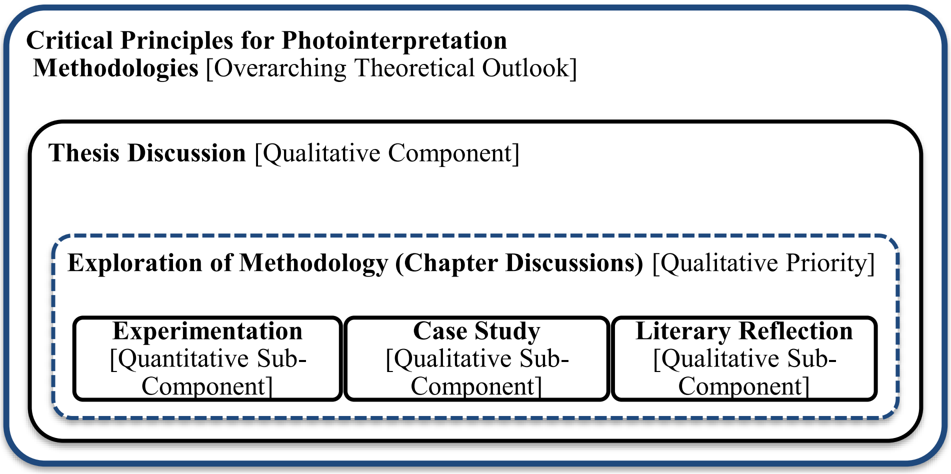


Figure 3.1: Conceptualisation of the embedded design approach adopted by this study.

Figure 3.2 offers a different style of representation concerning the overall design approach adopted by this study, but presented in a linear manner in order to assist further clarify the conveyance of the research strategy.

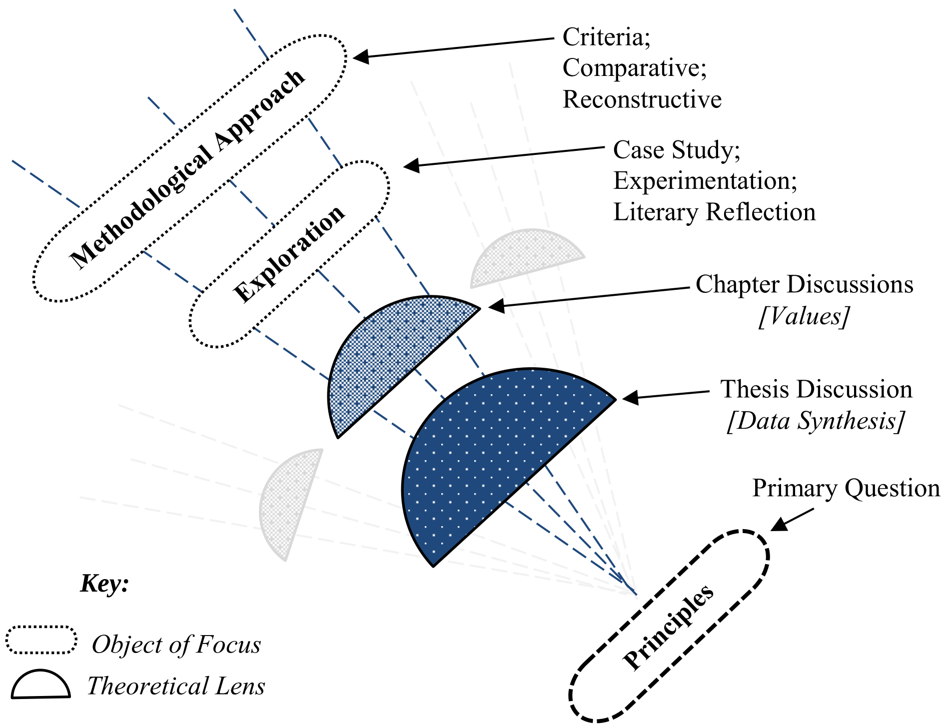


Figure 3.2: Representation of general research approach.

Figure 3.3 provides a map that summarises the research design employed by this study. Research was approached from a tiered bottom-up manner where each layer contributed upwards towards consecutively broader research components. The thesis discussion facilitated data synthesis, uniting interdisciplinary literary and practical knowledge sources together with information obtained throughout the course of the study. The ‘criteria based analysis’ methodological approach was explored through experimentation involving the detection of ‘second-generation images’. ‘Comparative image analysis’ was unpacked through a case study involving ‘facial analysis’ questions. Lastly, ‘reconstruction based interpretation’ was investigated through reflection concerning ‘conceptual applications’ of reconstruction based forensic photointerpretation techniques.

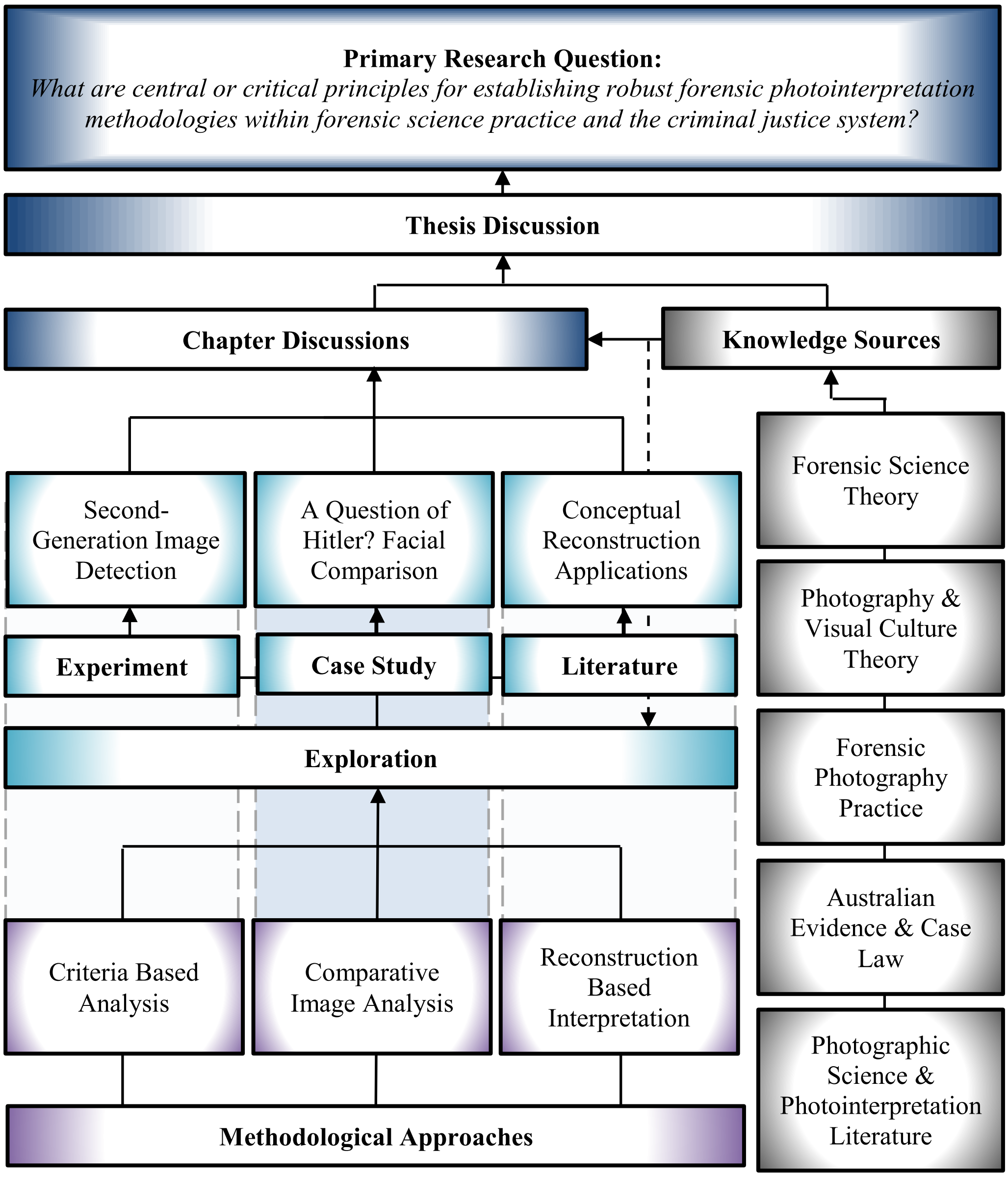


Figure 3.3: Research design map.

3.5 Research Design Justification

Photographic evidence is currently being used in courts world-wide; any new knowledge regarding concepts of evidence reliability which can contribute towards preventing potential miscarriages of justice warrants immediate attention by the forensic and legal community.

The underlying goal of this thesis reflected a quest for the elucidation of principles for supporting robust forensic photointerpretation methodologies. Why was such a broad goal devised and pursued? Why didn't this work focus simply and only on the technical development of methodological tools that could be applied to various questions or forensic scenarios involving photographic evidence?

The need for a better understanding of photointerpretation concepts extends well outside the currently small community of forensic researchers and photographic experts. Lawyers, lay members of the jury, judges, investigators or any persons concerned with or interested in photographic evidence would benefit from further education resulting from contemporary research.

The notion of 'principles', a set of guiding concepts founded in theory, supported by practice and presented in a common-sense manner, facilitate the accessible conveyance of complex ideas to a wide cross-section of society who might depend on or be involved/interested in photographic evidence. Principles are advantageous for several reasons. Firstly, they are important to establish and communicate to relevant experts because such knowledge can assist to inform the future development of more reliable photointerpretation methodologies. Equally, principles are important to convey to a broader non-technical audience because members of such a group might need to place a high degree of significance on photographic evidence that has been developed through interpretation. Knowledge that is broadly comprehensible has a greater potential to impart a positive impact within society and the legal environment than strictly esoteric findings.

The methodological approaches examined within this study were chosen for their applicability to a wide range of photointerpretation questions. Furthermore, the approaches were hypothesised to be foundations from which the extrapolation of generalised concepts could be achieved. The impact of this approach was that a greater contribution of knowledge could be attained from the finite number of investigations/research components unpacked within the scope of the study.

3.6 Research Scope & Limitations

The research components undertaken as part of this work were approached from a forensic science perspective. This study was not concerned with exploring or developing findings considered within other disciplines also relating to visual phenomena such as psychological, neuroscientific or semiotic research fields.

It was acknowledged that the work undertaken within this project may have been subject to the limitations imposed by human based analysis and interpretation such as bias or restrictions imposed by the degree of knowledge and understanding (or lack thereof) held by the researcher. Other limitations or biases critical to specific research components were detailed where relevant.

The ultimate ideal that this project contributed towards was the notion of a comprehensive universal photointerpretation framework that encompasses and supports all aspects of practice. This research project was constrained to the development of principles originating from the three methodological approaches examined. Although the approaches explored in this study were conducted based on their capacity to support the development of generalised principles, the results from this research endeavour still only span a moderately small segment of a much larger continuum (i.e. universal photointerpretation framework). Addressing all aspects of this continuum is far beyond the reach of a single project and will require a further sustained research effort for its realisation. The work undertaken as part of this thesis was a significant early step towards the achievement of the all-inclusive photointerpretation framework.

Chapter 4

4.0 Methodological Approach: Criteria Based Image Examination

An "inner process" stands in need of outward criteria.

Ludwig Wittgenstein [Wittgenstein 1953, remark 580]

This chapter puts forth the notion of a 'criteria based' photointerpretation approach for assisting interpretive image examination. The theory and rational behind the approach are presented herein.

Both this and the following chapter concerning related experimentation are utilised as gateways for the exploration of critical values important for supporting forensic photointerpretation principles that are apparent when considering criteria based interpretation methodology.

4.1 A Criteria Based Approach to Photointerpretation

Tversky & Kahneman [1975] suggest that humans depend on a limited set of experiential based principles and assumptions when dealing with uncertainties, probabilistic outcomes, likelihoods and predictions. The subconscious procedures employed for processing complex situations into more manageable cognitive operations, although generally useful, are reported to be fallible and subject to bias which can result in significant errors in judgement. The scholars provide several examples to communicate this notion. One example is related to the ability to visually judge object distance based on the perceived level of blur associated with said object. The subconscious principle employed for assisting decisions concerning distance is based on the experience that the further away an object is, the less clearly it appears to be defined. Yet, the scholars illustrate several situations where errors in distance judgement are made as a result of this rule being breached such as when a nearby object appears blurry, or when far away objects appear more clearly resolved than expected.

> *Here too, people are rarely aware of the basis of their impressions, and they have little deliberate control over the processes by which these impressions are formed. However, they can learn to identify the heuristic processes that determine their impressions, and to make appropriate allowances for the biases to which they are liable [Tversky & Kahneman 1975, p. 2].*

Tversky & Kahneman suggest that by understanding how individuals make their own decisions, systems can be implemented to assist minimise bias and error. McDaniels, Gregory & Fields [1999] echo Tversky & Kahneman's arguments through their proposal that humans, both expert and non-expert, often conduct poor decision-making when unassisted and faced with complex scenarios, particularly those involving uncertainties.

> *In short, there are many reasons to expect that, on their own, individuals (either lay or expert) will often not make informed, thoughtful choices about complex issues involving uncertainties and value tradeoffs [McDaniels, Gregory & Fields 1999, p. 498].*

Not only is poor complex decision making an important limitation that requires attention from a photointerpretation and legal standpoint, but also the danger presented by our certainty regarding the accuracy of our opinions. The study by Fischoff, Slovic & Lichtenstein [1977] examined the general issue of the frequency of overconfidence associated with opinions through a series of psychology experiments. Their findings can be best summarised by the following extract:

> *How often are people wrong when they are certain that they know the answer to a question? The studies reported here suggest that the answer is "too often."[Fischhoff, Slovic & Lichtenstein 1977, p. 552].*

The presented observations regarding human decision-making are important considerations for any pursuit that involves elements of human cognition, complexity and critical decision outcomes. Photointerpretation is a field of analysis that intricately involves these elements. From a forensic science and legal perspective, a real danger is posed by the human inadequacy to reliably make decisions concerning complex uncertainties together with the propensity to overstate the level of confidence associated with our opinions. A possible solution for minimising these dangers is the application of a criteria based methodological approach for supporting photointerpretation.

The notion of a criteria based photointerpretation approach can be described as:

- The utilisation of specifically devised set of criteria for guiding the image interpretation process.

A criteria based methodology for forensic photointerpretation can provide a framework that can support an analyst's complex decision-making while simultaneously providing greater detail to those who would benefit from an understanding of the decision-making processes involved, such as triers of fact, external experts and legal professionals.

4.1.1 Existing Applications of a Criteria Approach

The concept of employing a set of criteria to assist decision-making is certainly not novel and several literary examples exist that showcase the strengths and versatility of the method. Academic assessment marking often employs criteria to assist examiners with appropriately grading assessable work. Criteria guided academic assessment facilitates fair evaluation by providing a clear set of rules to assist the assessor's decision-making while concurrently clarifying to students the conditions required for success. 'Criteria based content analysis' is another technique that utilises criteria to assist with the task of complex decision-making. The method was developed by various psychologists and researchers to help facilitate the determination of the veracity of a child's verbal testimony; a form of potentially important legal evidence. The technique employs a criteria that has been developed from the premise that 'truthful and fabricated statements differ in content and quality…' [Ruby & Brigham 1997, p. 709]. A third and final example is 'multi-criteria decision analysis', a method primarily utilised to support managerial decision-making. The technique can be applied to a host of scenarios where decision-making needs to involve the evaluation of various multi-faceted issues. The approach facilitates decision-making based on clear and structured guidelines, incorporating mathematical and computational support for assisting the process of weighing the value of different criteria and decision outcomes based on pre-defined factors. For example, the technique can be applied to determine which series of actions would result in the greatest monetary savings for a company with minimal impact on staff employment [Linkov & Moberg 2011].

There is an obvious necessity to break complex situations down into manageable components and provide a logical process structure to help tackle the short fallings of human cognition when faced with difficult decision situations. The aforementioned examples, although varying in purpose and implementation, all employ criteria at their core to assist complex decision-making. Photointerpretation can be considered a multifaceted, intricate and subjective undertaking that would benefit from any mechanisms that can provide support and assistance to practitioners engaging in complex analysis and examination.

4.2 Conceptual Framework for a Criteria Based Photointerpretation Approach

This chapter presents a generalised framework for facilitating the construction of a criteria assessment method for supporting photointerpretation tasks. The following conceptual components are critical to establish when devising a criteria based approach:

- **Criteria Purpose:**
    - Clearly define the purpose or goal of the criteria.
- **Criteria Development:**
    - Develop relevant criteria based on knowledge, experience or understanding;
    - Criterion can be binary in nature (positive/negative; yes/no; present/absent) or have a set value (calculated by a formula or intrinsic to the criterion itself such as date and time);
    - Criteria can be updated through future developments in knowledge or as a result of testing or validation studies. The most supported and up-to-date criteria relevant to the task should always be considered.
- **Criteria Testing:**
    - Express the rationale behind the selection of each criterion;
    - Determine whether the set of criteria is effective at achieving its purpose or goals;
    - Criteria can be evaluated through experimentation, validation and/or a peer review processes.

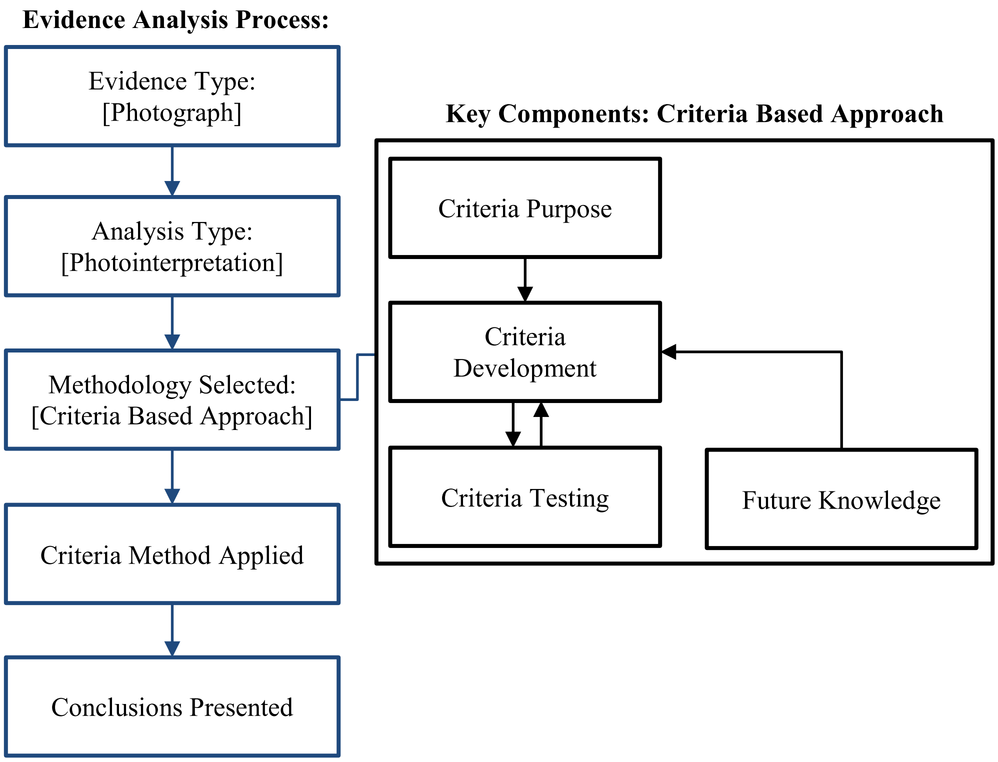


Figure 4.1: Overview of the conceptual framework for a criteria based photointerpretation approach. The key components of the framework are outlined and shown in relation to a conceptually generalised process of photographic evidence analysis.

The initial step of the criteria development framework requires the formation of a clear definition of the purpose of the criteria, followed by the development of a set of criterion that will achieve this purpose.

Criterion should reflect specific observations which when examined collectively indicate certain conditions, conclusions or facts. The absence, presence and/or intrinsic value of each criterion can equally provide vital information for supporting the interpretation process.

Developed criteria finally require a form of testing to ensure the fitness of the assessment method. A justification of each included criterion should be provided as part of the photointerpretation method's written documentation highlighting the rationale behind why each particular observation is helpful towards the overall purpose of the criteria/examination. Such justifications should be conveyed in an easy to understand manner due to the potential scope of readership/audience the documentation might be presented to, e.g. jury members (non-expert lay members of the public), legal practitioners and investigators. Experiments can be conducted to assess the real world practicality of any untested or theoretical criterion. Additionally, the transparent and clear articulation of criteria components can convey sufficient detail to relevant experts to enable a review and critique of the method which can provide further support for the evaluation of the appropriateness and reliability of the approach.

Any conclusions reached at the end of a criteria based photointerpretation process are still the result of subjective human decision-making, however, the interpretation process has now been guided by a documented and tested methodology, adding a level of objectivity to the process. A criteria based photointerpretation approach assists the elucidation of the thinking process involved during image examination to any triers of fact or other individuals concerned with the evidence. This level of transparency is critical for any forensic function offered within the legal justice system because of the significant impact evidence can have on personal freedom.

4.2.1 Hypothesised Strengths of Approach

The following views are theorised to be benefits that can be achieved through the application of a criteria based methodological approach to an appropriate photointerpretation problem.

A criteria based approach to photointerpretation could:

- Provide a structured and logical framework to assist image examiners with complex decision-making;
- Introduce objectivity to the interpretation process;
- Provide a transparent methodology that facilitates testing, peer review and cross-examination.

Whether these hypothesised views are valid and useful as part of a broad forensic photointerpretation framework will be discussed deeper within this thesis.

4.3 Questions

This chapter sets the stage for the exploration of the following questions:

- Can key conceptual and pragmatic principles for forensic photointerpretation methodologies be elucidated from examining a criteria based interpretation approach?
- If so (following from above), what values integral for developing photointerpretation principles are exemplified and/or inspired by a criteria based approach for forensic image examination?

4.4 Chapter Summary

This chapter introduced the notion of a criteria based methodological approach for interpretive image examination. The approach was based on the notion that people often conduct poor decision-making when faced with complex scenarios where no guidance is provided for the thinking process. Photointerpretation involves complex decision-making and therefore would benefit from a methodology such as criteria based assessment for guiding interpretation, in scenarios where such an approach is appropriate.

Criteria based photointerpretation involves the development of a specific criteria to assist interpretive image analysis. Each individual criterion is constructed based on specific observations which when examined collectively, help indicate certain conditions, conclusions or facts about the analysed photographic evidence.

The methodological framework for supporting the development of a criteria based photointerpretation approach involves several key conceptual components. The purpose of the criteria needs to be firmly established accompanied by a clear and relevant set of criteria, articulated justifications for each criterion and an exhibited level of criterion testing. The purpose of a criteria based assessment or methodological approach is for the development of clear, logical and transparent structure for assisting image examiners and triers of fact navigate the complexities involved throughout the photointerpretation process.

The pragmatic application of the criteria based photointerpretation approach is examined in more detail through the experimental investigation presented in the following chapter.

Chapter 5

5.0 Experiment: Detecting Second-Generation Digital Photographic Images

I mean Picasso had a saying he said good artists copy great artists steal.

Steve Jobs [Triumph of the nerds, 1996]

In the previous chapter the notion of a 'criteria based' approach for assisting forensic photointerpretation was presented. This chapter explores the practical application of the approach through the implementation of an assessment criteria method to a series of experiments modelled on a real world forensic scenario which further enables the exploration of critical values important for supporting forensic photointerpretation principles.

In this chapter, a novel criteria based assessment framework was developed to support the detection of second-generation images captured by devices with digital photographic capabilities such as digital cameras, camera phones and tablet computing devices.

The ability to distinguish between 'original' and 'copied' images has been a persistent forensic imaging difficulty. Such distinction can be of significant importance to certain criminal and civil investigations [Bestagini *et al.* 2013; Thongkamwitoon, Muammar & Dragotti 2015; Yin & Fang 2012]. In the context of this study, the ability to differentiate between first and second-generation digital images can be of particular relevance to areas such as insurance fraud investigation where an image's authenticity may hold legal significance or assist in shaping investigative efforts.

Currently, the task of authenticating first and second-generation images remains challenging. Standardised methods have yet to be formalised and adopted within the wider forensic imaging discipline. A limited number of methods are also presented in the literature for the detection of rephotographed imagery. The bulk of publications focus on the algorithmic-based detection of second-generation images from sources such as LCD screens [Bestagini *et al.* 2013; Cao & Kot 2010; Thongkamwitoon, Muammar & Dragotti 2015] and rephotographed hardcopy prints [Gao *et al.* 2010; Yin & Fang 2012; Yu, Ng & Sun 2008]. The underlying commonality among current second-generation image detection methods is their foundation in computational based image analysis.

This investigation aims to expand the knowledge and tools available for the detection of second-generation images through the introduction of an approach that, dissimilar to existing techniques, does not have a fundamental dependence on computational analysis for the detection of second-generation images.

The need to determine whether photographic evidence consists of original or second-generation images has been seen in insurance fraud investigation. Due to the importance of developing a practical solution for addressing this issue, the work presented in this chapter was focused through a generalised case scenario involving the examination of images captured specifically by camera phones. By extension, the results of the study can be equally applied to other similar sources of image acquisition such as digital cameras and camera equipped tablet devices. The camera phone was selected as the source device in this study because of their functionality and common trend as the ‘go to’ system employed by individuals for undertaking photographic documentation tasks [Kindberg *et al.* 2005]. Photographs examined throughout this investigation were considered part of the evidence pertaining to a generic insurance claim (see 5.1.1 Case Background).

The photointerpretation approach developed involved the interpretation of an image’s authenticity through the holistic examination of the pictorial and metadata elements of questioned digital photographs. The process was governed by specifically devised criteria. The criteria were founded on the premise that the creation of flawless photographic copies of hardcopy images is a technically difficult task which can lead to the production of artefacts as technical errors.

In this chapter a photointerpretation approach for detecting second-generation images was developed according to the framework for criteria based image examination outlined in Chapter 4. The developed criteria assessment method was subjected to an experiment based testing process. One experiment evaluated the presence and frequency of occurrence of several visual image artefacts theorised to assist in the detection of second-generation images. Further experimentation examined the role of embedded image (EXIF) metadata, including GPS coordinates and the use of image exposure value (EV) for supporting photointerpretation.

5.1 Critical Knowledge

5.1.1 Case Background

This experimental study was based directly on real world case scenarios. As part of the insurance claim process, companies often require proof of ownership of insured items. This can be satisfied in the form of photographs that can prove that insured items were in fact under the possession of the claimant (Figure 5.1).

Issues can arise when investigators examine the time and date of capture of digital images submitted alongside claims. When image metadata appears to conflict with details of a claim, e.g. information suggests photographs were taken at a date and time after their subject matter was reported to have been stolen or lost; suspicions of fraud can arise.

> **Proof of loss and ownership**
> When you make a claim, we may ask you to provide proof of ownership and value for an item — for example, a receipt, valuation or photograph. So, make sure you keep these documents safe.

Figure 5.1: Extract from an insurance policy information booklet. Source:[Home insurance buildings and contents: product disclosure statement and policy booklet NSW/ACT/TAS 2013, NRMA Insurance].

In such circumstances, the authentication of the questioned images can have legal significance. Whether an image is of first or second-generation is important. From the insurance company's viewpoint, circumstances where images appear to be captured after the claim date can suggest that the insured item(s) were still under the claimant's possession. The ensuing action of the insurance company is to contact the claimant regarding their suspicions.

A typical defence assertion put forth by claimants is that the submitted image was in fact a digitisation of a pre-existing hardcopy photograph that was rephotographed to email the image to the insurance company. This is conducted typically through the convenience of a smart phone camera.

This scenario is generally acceptable provided that the original hardcopy photograph is made available for verification. Problems arise when this condition cannot be met such as when claimants advise that the original hardcopy photograph has become unavailable.

Subsequently, from an investigative standpoint the reality of the situation can be regarded as either of the following:

1. The image sent by the claimant is indeed a digital copy of a pre-existing hardcopy photograph (second-generation digital photographic image).

2. The image sent by the claimant is an original capture (first-generation digital photographic image) taken at a date after the insured items were reported to have gone missing.

Confirming the image is a second-generation reproduction may support the defence allegation. However, several insurance cases have found that the supplied images were originals, which means items, reported stolen or missing, must have been available at the time of the photographs (i.e. after the date of the claim). If the images under investigation were made by photographing the object directly, it is understandable how an insurance company may have an issue with the claim.

The problem for forensic investigators or photographic experts is determining whether the supplied images are 'originals' or 'second-generation' (as claimed by the insured) in order to assist investigative efforts.

Please note that the case scenarios explored in this chapter rely on the underlying assumption that the time and date settings of the imaging device (e.g. camera phone) was accurate at the time of photographic capture. This assumption is also generally applied in real world investigations unless the device used for the capture of the questioned image is made available for inspection in order to verify time and date settings.

5.1.2 First & Second-Generation Digital Photographic Images

In this section, the notion of first and second-generation digital photographic images are elucidated.

First-generation photographic images are photographs captured physically at the location of a scene and include elements of that scene. First generation images are in essence the original products formed when light, reflected or emitted from the objects of the world around us is transformed into a two-dimensional photographic representation.

Second-generation photographic images are photographs of pre-existing images. Their capture can occur at a different location and under dissimilar photographic conditions than that of the original. Second-generation images include products of successive iterations of the photographic copying process. For example, the third, fourth, fifth, etc., photographic copies of an existing image are all considered second-generation images (Figure 5.2).

First and second-generation digital photographic images are the end products of the photographic capturing system utilised by digital camera devices. Typical digital camera systems comprise of a lens, shutter assembly, image sensor and electronic subsystem [Salvaggio 2009]. Results produced from other devices that facilitate photographic reproduction such as photocopying and scanning systems may be considered ‘second-generation digital images’ but not ‘second-generation digital *photographic* images’.

Second-generation digital photographic images (referred to as ‘second-generation images’ from this point), can include photographic reproductions (see 5.1.8 Copywork Practice), but not all photographic reproductions can be considered second-generation images. Such is the case where non-photographic artworks are photographically reproduced resulting in the production of a first-generation image.

The output of both first and second-generation images can be either hardcopy e.g. a physical photographic print or softcopy e.g. a digital display. This work focuses on second-generation images produced by re-capturing first generation images that are in hardcopy format.

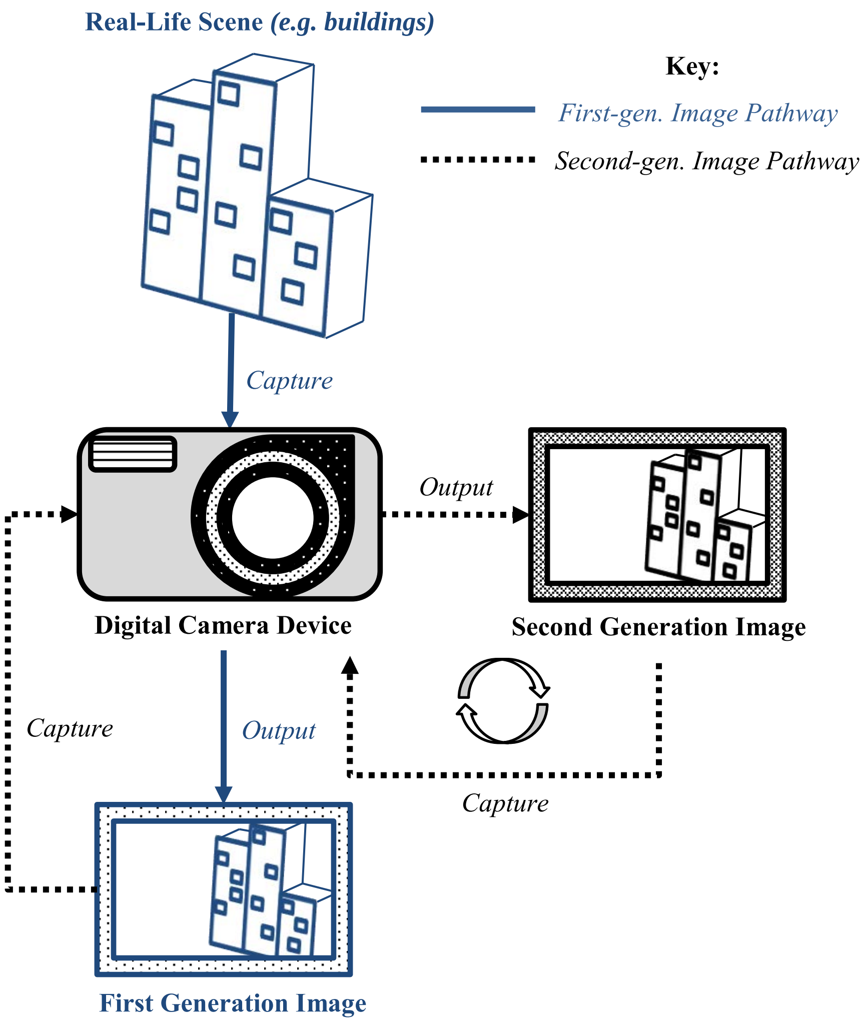


Figure 5.2: Diagram illustrating the concept of how first and second-generation digital photographic images are produced.

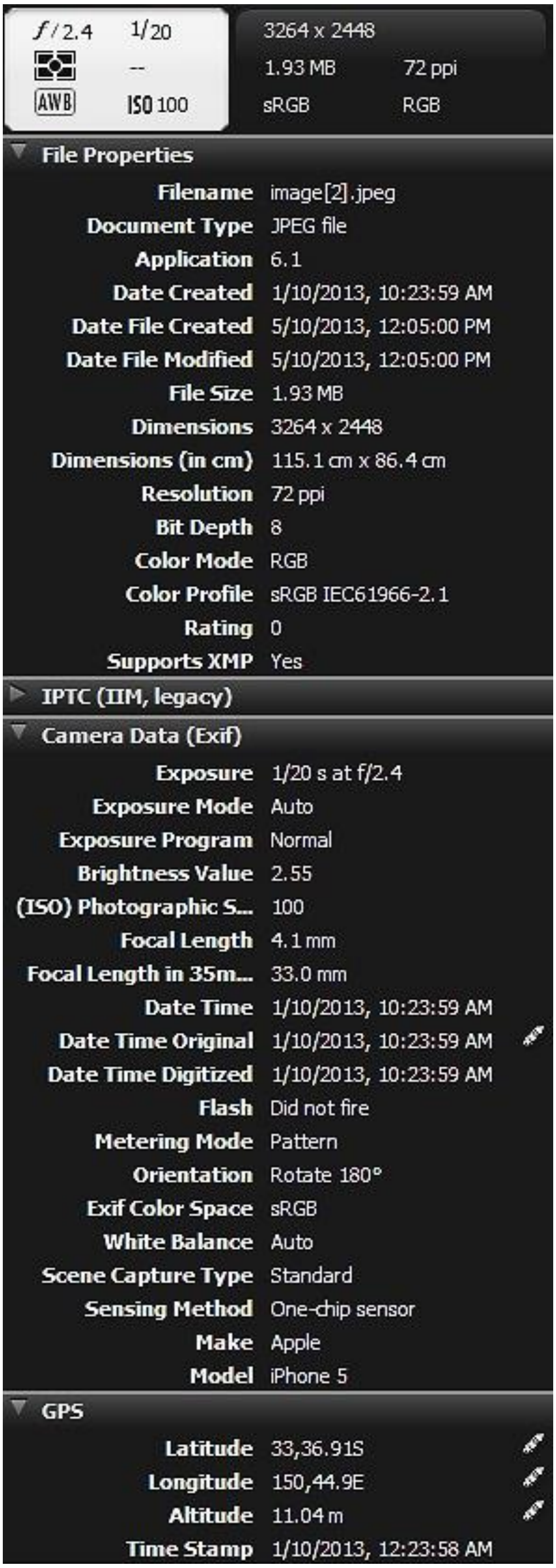
First generation images result from a real-life scene being captured and transformed into a 2D photographic representation. Second-generation images result from the photographic capture of an existing 2D photographic representation, regardless of whether the target is a first-generation image or existing copy.

5.1.3 Digital Image Metadata

Image metadata consists of information embedded into a digital image file. The modern digital image capturing process usually results in the automatic inclusion of a number of technical details regarding the parameters of capture incorporated into newly created image files. Details such as time and date of capture, lens focal length, flash status, white balance and so on, can be retrieved from an image file which can assist forensic analysis and image interpretation [Orozco *et al.* 2014].

Digital image files are available in a number of different formats such as JPEG/JPG, TIFF, PNG and RAW. Each image file format has a specification of how internal metadata storage is handled. The most common file type employed by digital photographic devices is JPEG. The metadata format employed by JPEG and TIFF file types is known as Exchangeable Image File Format (EXIF) [Orozco *et al.* 2014].

The embedded EXIF data within a JPEG or TIFF image contains the majority of the metadata information relating to an image's capture including global positioning system (GPS) coordinates. This information can be retrieved by examining the file through a compatible metadata reading program (Figure 5.3) [Orozco *et al.* 2014].



f/2.4	1/20
--	
AWB	ISO 100
3264 x 2448	
1.93 MB	72 ppi
sRGB	RGB
File Properties	
Filename	image[2].jpeg
Document Type	JPEG file
Application	6.1
Date Created	1/10/2013, 10:23:59 AM
Date File Created	5/10/2013, 12:05:00 PM
Date File Modified	5/10/2013, 12:05:00 PM
File Size	1.93 MB
Dimensions	3264 x 2448
Dimensions (in cm)	115.1 cm x 86.4 cm
Resolution	72 ppi
Bit Depth	8
Color Mode	RGB
Color Profile	sRGB IEC61966-2.1
Rating	0
Supports XMP	Yes
IPTC (IIM, legacy)	
Camera Data (Exif)	
Exposure	1/20 s at f/2.4
Exposure Mode	Auto
Exposure Program	Normal
Brightness Value	2.55
(ISO) Photographic S...	100
Focal Length	4.1 mm
Focal Length in 35m...	33.0 mm
Date Time	1/10/2013, 10:23:59 AM
Date Time Original	1/10/2013, 10:23:59 AM
Date Time Digitized	1/10/2013, 10:23:59 AM
Flash	Did not fire
Metering Mode	Pattern
Orientation	Rotate 180°
Exif Color Space	sRGB
White Balance	Auto
Scene Capture Type	Standard
Sensing Method	One-chip sensor
Make	Apple
Model	iPhone 5
GPS	
Latitude	33,36.91S
Longitude	150,44.9E
Altitude	11.04 m
Time Stamp	1/10/2013, 12:23:58 AM

Figure 5.3: Example of digital image metadata (EXIF data) extracted using Adobe® Bridge® CS6.

5.1.4 Image Artefacts

The 'pictorial' aspect of a photograph is a term that signifies the visual information present within a photographic representation. In this investigation, the pictorial aspect important for detecting second-generation images consisted of a series of image artefacts.

Image artefacts are manifestations that corrupt visual data or impair the quality of an image [Porter 2011a]. Artefacts include a broad spectrum of occurrences such as lens flare, distortion, noise, aliasing, pixel defects, data loss, compression artefacts and chromatic aberration [Salvaggio 2009].

In the context of second-generation images, the artefacts targeted for examination are occurrences that are directly bi-products resulting from photographing an already existing two-dimensional physical image. They include visual anomalies that cannot manifest under normal conditions when capturing a first-generation image. Image artefacts specific to second-generation digital photographic images were investigated during this work (see 5.4.1 Developing Second-Generation Image Detection Criteria).

5.1.5 Global Positioning System (GPS) Metadata

Any location on the surface of the earth can be referred to by a set of coordinates. The global positioning system (GPS) is jointly operated by the United States Air Force and Department of Defence. The system consists of a network of 32 satellites that orbit the earth and continually emit signals. A GPS device can use the satellite signals to triangulate its three-dimensional location which involves calculating latitude, longitude and altitude anywhere on the planet (see bottom of Figure 5.3 for an example of how this information is recorded in image metadata) [Daniel & Daniel 2012].

Recent advances in technology have resulted in most modern smart phones and tablet devices having the capability to access and embed GPS coordinates into the EXIF data of digital image files. This process is referred to as geospatial/geographic location tagging or geo-tagging [Sandnes 2010; Toyama *et al.* 2003].

Several methods exist for acquiring GPS data in mobile devices. The technology implemented in a given device can vary depending on manufacturing conditions or available resources. The most common GPS methods include standard GPS, Assisted GPS (A-GPS), Wi-Fi positioning and cellular positioning. Standard GPS relies on obtaining signals directly from satellites orbiting the earth and performing the required computations for acquiring coordinates locally. A-GPS involves using a remote GPS server to conduct many of the functions of a full GPS receiver to save power and speed up processing time. Wi-Fi positioning uses Wi-Fi access points to calculate location. Cellular positioning likewise uses cellular tower signals to determine locational data [Zandbergen 2009].

Information provided by embedded GPS data can be useful for image interpretation. Discrepancies between the depicted location in an image and the location indicated by GPS coordinates may suggest that an image is a second-generation reproduction. For example, a photograph depicting the Sydney Opera House which resides in the state of New South Wales, Australia that contains embedded GPS data indicating that the image was captured in a totally different location could indicate that the image is a photographic copy.

GPS data can vary in accuracy and this needs to be factored into the interpretation process. Studies have been conducted assessing the reliability and variability of data obtained from portable GPS devices with a specific focus on smart phones (Table 5-1). This investigation explored how GPS information can influence the photointerpretation process.

Table 5-1: Literature based median errors for mobile phones with built-in GPS

	GPS Coordinate Acquisition Method:		
Device:	**A-GPS**	**Wi-Fi**	**Cellular**
†3G iPhone®	~8 m	~74 m	~600 m
‡Motorola & Sanyo	~5-8.5 m	-	-

Sources: [†Zandbergen 2009; ‡Zandbergen & Barbeau 2011].

5.1.6 Exposure Values

Exposure value (EV) is a quantitative parameter that reflects the lighting environment of a captured scene. EV is dependent on the relationship between the sensor/film sensitivity (ISO), aperture (f/stop) and shutter speed of a camera system (Equation 5-1).

Equation 5-1: Calculating Exposure Value

$$\mathrm{EV} = \frac{\log\left(\frac{N^2}{t} \text{ x } \frac{S}{100}\right)}{\log_2}$$

Whereas:

N = Aperture or f/Stop
t = Shutter Speed
S = ISO

The exposure value calculated by the formula [expressed in Gimena 2004] provides an indication of scene luminance, considering the image was correctly exposed. Scenes that contain ample light available for photographic exposure generally result in photographs that exhibit a higher EV value than photographs captured under less available light requiring longer exposure times.

Each EV value represents a doubling or halving of exposure. For example, direct sunlight has an EV15 value and if compared with an indoor environment of EV8, is an exposure variation of 7 stops or 128 times (EV difference of 7EV), which is a significant difference.

The EV values for particular lighting conditions are documented in photographic literature (generally in the form of exposure value tables) and have been used historically in photographic practice to assist photographers determine the camera parameters that will result in a correct exposure for a given lighting environment (e.g. axes of EV table indicate which combination of *f*/stop and shutter speed result in the correct exposure for a given lighting condition when using a recording medium with a given ISO) [Bilissi, Triantaphillidou & Allen 2011; Prakel 2009].

The concept of using EV values to assist in determining the necessary camera parameters required for a correct photographic exposure can also be reversed in a manner helpful to the goals of this investigation. Image metadata (specifically *f*/stop, shutter speed and ISO) can be analysed in order to determine the type of lighting environment a photograph was captured under. Sandnes [2010] employed a similar approach as part of their research. Their work focused on utilising calculations based on data derived from EV values in conjunction with EXIF metadata to determine the geographical location of image capture through the relationship they established between location on earth and differing levels of sunlight.

Work conducted as part of this thesis utilised EV data to derive information about scene information. The relationship exhibited between EV and scene information was theorised to be helpful for assisting the detection of second-generation images. To illustrate this concept, take for example a hypothetical scenario involving a digital photograph depicting a sunny outdoor scene, e.g. EV15. Upon examination, the calculated EV for the image was EV5, reflecting a value typical of a photograph taken under indoor lighting conditions. Such an observation may suggest to an analyst that the image is a photographic reproduction. A feasible explanation for such an observation could be that the examined photograph was produced by the photographic copying of a pre-existing image depicting the original outdoor scene, with the re-photographing occurring at an indoors location. In other words, a pre-existing photograph of a brightly lit scene was captured again, but indoors where there was less available light.

5.1.7 Image Authentication

Forensic image authentication, the process of verifying the integrity and provenance of a given image is currently a growing field of research, particularly within the computer science domain. The aims of current forensic image authentication research are source camera identification and image forgery or manipulation detection. Current authentication methods largely depend on algorithms to detect tell-tale signs of unwarranted changes to pixel values or for the identification and scrutiny of artefacts caused by a camera's physical hardware configuration and applied image processing procedures. Factors such as the properties and direction of lighting and shadows, geometric inconsistencies, lens based aberrations, pixel array imperfections, image noise patterns, interpolation processes, compression artefacts, embedded manufacturer watermarks and even frame rate and encoding related anomalies specific to video authentication are engaged to support image authentication tasks [Bestagini *et al.* 2013; Birajdar & Mankar 2013; Bramble, Compton & Klasen 2001; Brugioni 1999; Redi, Taktak & Dugelay 2011; Rocha *et al.* 2011; Van Lanh *et al.* 2007].

The examination of the above mentioned features enable questions such as the following, surmised by Sencar & Memon [2007, p. 2], to be investigated:

- *Is this image an "original" image or was it created by cut and paste operations from different images?*
- *Does this image truly represent the original scene or was it digitally tampered to deceive the viewer?*
- *What is the processing history of the image?*
- *What parts of the image has undergone processing and up to what extent?*
- *Was the image acquired by a source manufactured by vendor X or vendor Y?*
- *Did this image originate from source X as claimed?*

Various techniques and processes ranging in creativity and sophistication continue to be developed that allow examiners to extract useful information from images that enables source determination and manipulation detection.

The work presented in this chapter does not focus on the detection of digitally manipulated images or the identification of the camera used for image capture. It does however address the issue of authenticity.

The second-generation images that are the focal point of this investigation have not undergone any post-capture editing. The images are essentially non-manipulated (i.e. not 'photoshopped') however, their subject matter is comprised of pre-existing imagery. Therefore, second-generation images contain no digital image manipulation artefacts, but may contain visual and metadata artefacts reminiscent of the practice of copywork.

5.1.8 Copywork Practice

Photographic reproduction or 'copywork' encompasses the art/task of photographically documenting a subject (e.g. a piece of artistic work) at a sufficiently high quality for reproduction and/or documentary purposes.

The article by Guild Sourcebooks [2004] presents an articulate summary of copywork practise, techniques and goals. The article suggests that an advanced level of technical photographic skill is required to create a successful photographic reproduction of a given subject. Technical competency and photographic understanding in areas including lighting, photographic perspective, camera positioning, lens utilisation, framing and depth of field concepts are part of the necessary photographic skills required.

The aim of the photographic reproduction process is to achieve a high quality photographic result with the absence of any destructive image artefacts that may arise if quality is compromised during the copying process.

The primary artefacts sought to be eliminated during good copywork practice, as suggested by the Guild Sourcebooks article include:

- Incorrect colour balance;
- Specular reflections;
- Uneven lighting;
- Image distortion;
- Incorrect exposure;
- Poor focus.

Due to the high level of technical skill required to achieve artefact free photographic reproductions, attempts to photograph an existing image by a lay person, especially using sub-optimal photographic equipment such as a camera phone, theoretically presents an increased chance of artefacts being included in the end product. Therefore, the developed approach presented in this chapter focuses on identifying the above artefacts among other clues that may aid in the indication of whether an image is a photographic reproduction.

5.2 Aims & Objectives

The primary **aims** of this chapter are to:

- Develop new knowledge regarding the application of a criteria to the detection of second-generation digital photographic images;
- Explore values stemming from a criteria based photointerpretation methodology that are integral towards establishing a robust forensic photointerpretation capacity.

This investigation achieves its aims through the realisation of the following **objectives**:

- Analysis of a sample of second-generation digital photographic images to determine the frequency of occurrence of a number of specific assessment criteria;
- Examination of digital image metadata including embedded GPS data and exposure related parameters from sourced image samples;
- Determination of exposure values for specific lighting environments and compare data to existing literary values.

The **scope** of this research was limited to the examination of photographs captured via camera phones only. Images produced by photocopying, scanning, fax systems or other imaging devices that operate without the typical optical lens and sensor system employed in digital cameras were not included for investigation.

5.3 Questions

Further to the aims, this chapter explores the following **questions**:

- Are second-generation digital photographic images detectable?
- What are the strongest indicators useful for the detection of second-generation digital photographic images?
- Can GPS metadata embedded in digital image file EXIF data play a role in the photointerpretation process?
- Can exposure values (EV) assist photointerpretation?
- Is the developed approach for detecting second-generation images dependable?

5.4 Experimental Design

5.4.1 Developing Second-Generation Image Detection Criteria

Criteria for the detection of second-generation digital photographic images were constructed following the framework outlined in Chapter 4. Criterion were initially constructed based on theoretical knowledge. Several criteria were subsequently validated through experimentation (Figure 5.4).

The theoretical knowledge foundations used in the development of the preliminary detection criteria stemmed from sources including photographic science, copywork practice and experience. Each criterion was developed with a focus on being helpful indicators or having a propensity to manifest solely in second-generation images.

Developed criteria fell under one of two overarching categories; 'pictorial' or 'metadata' elements. Criteria categorised under pictorial elements consisted of visual image artefacts. The metadata category contained criteria relating to EXIF data such as EV and GPS information.

Several theorised criteria were subsequently tested through an experimental approach which focussed on the determination of each criterion's real world effectiveness. Experimentation simultaneously provided an avenue for further criterion development and refinement.

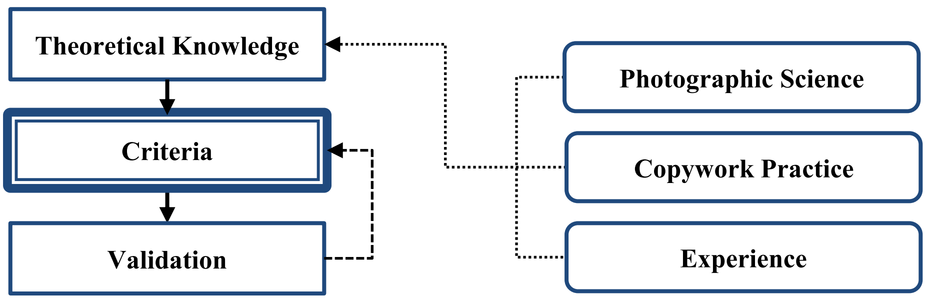


Figure 5.4: Diagram illustrating the process of criteria development for the task of detecting second-generation images. Theoretical knowledge was initially used to construct a set of criterion. Subsequent experimentation enabled criteria evaluation and validation.

5.4.2 Frequency of Occurrence of Second-Generation Image Artefacts

The effectiveness of developed pictorial based criteria for assisting the detection of second-generation images was evaluated through the experimental approach presented here.

The main question investigated by this experimental component was:

- How frequently do theorised second-generation visual artefact based criterion occur in a sample of photographically reproduced images?

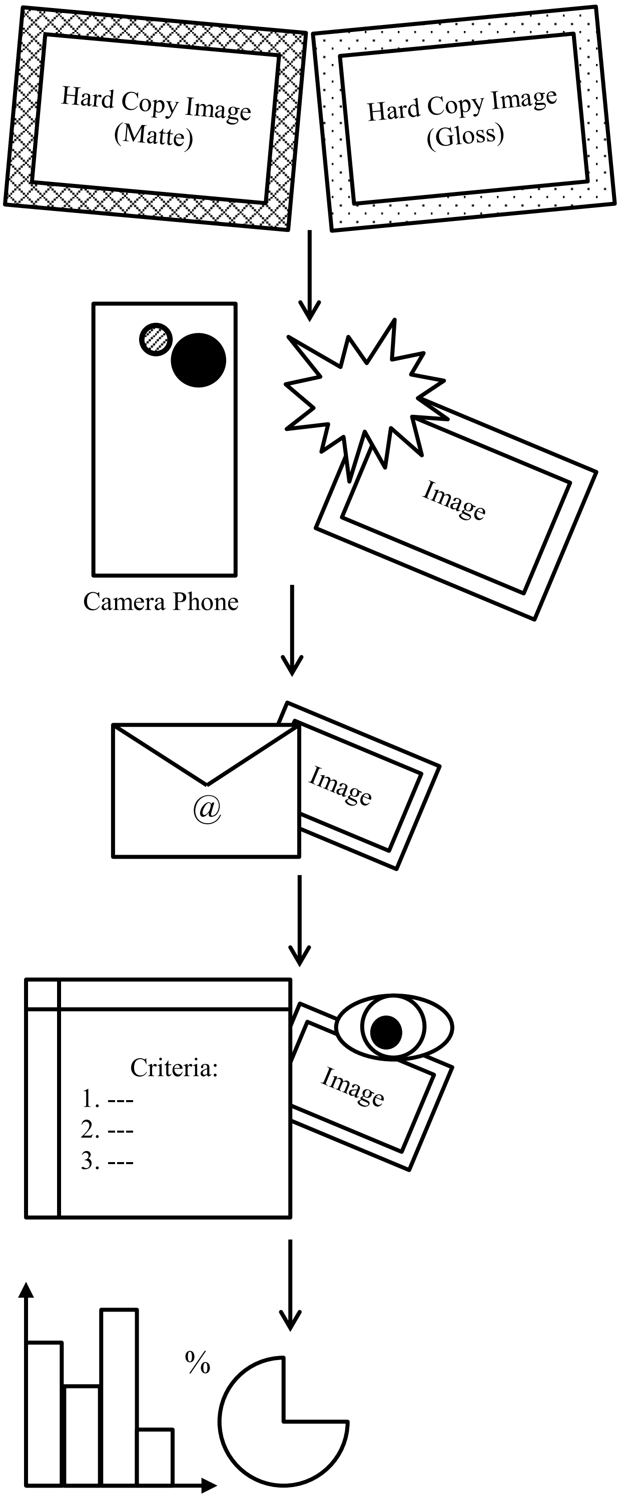
In order to address this question, a collection of second-generation image samples produced by a set of anonymous research volunteers was compiled and subjected to a visual analysis based on the developed detection criteria.

Several different matte and gloss finished prints (target images) were made available for photographing (see 5.4.3 Constructing Target Images). Volunteers were requested to use camera phones to photograph the target photographs. The images were then electronically collected for analysis. Volunteer instructions can be reviewed in Appendix B.

Variations produced by each volunteer's natural approach to rephotographing were considered important to preserve, therefore volunteers were encouraged to copy photographs to the best of their ability while not being aware that the second-generation images were destined to be analysed for artefacts arising from the copying process. This study's approach for test sample development contrasted with Cao & Kot's [2010] approach for testing their technique for identifying copied images originating from LCD screens. Dissimilar to this study, Cao and Kot favoured a highly controlled process for acquiring high quality second-generation images that avoided artefacts usually produced by 'casually recapturing' [Cao & Kot 2010] scenes. This study developed an approach involving a set of printed target images with a specific focus on the casual recapture process because this phenomenon most closely reflects real world practice in the context of the study.

Collected image samples were then analysed according to the developed criteria. A visual examination resulted in the recording of detected artefacts. Statistical analysis of the results provided insight into the frequency of occurrence of each visual artefact detected within the sample population. The metadata based artefact ‘exposure value and pictorial information conflict’ was also included as part of the visual analysis process conducted by the researcher.

An overview of the data collection and analysis process is depicted in Figure 5.5.



Test targets consisted of hard copy Australian standard 4 x 6" prints captured by a DSLR camera.

Targets were printed from a digital image kiosk in duplicate on standard matte and gloss finished photo-paper.

Volunteers photographed each image with their camera phones.

Volunteers submitted their second generation images to researcher via email attachment.

Images were examined according to the developed criteria.

Results were statistically analysed to determine artefact frequency in order to gain insight into the veracity of the criterion for the detection of second generation images.

Figure 5.5: Overview of the data collection and analysis process for the determination of the frequency of occurrence of second-generation image artefacts.

5.4.3 Constructing Target Images

Target images were used as photographic subjects by research volunteers for the production of second-generation digital image samples. The target images consisted of hardcopy 10 x 15 cm (4 x 6 inch) Australian standard photographic prints.

Target images were constructed from several different scenes that provided a varied scope for the examination of image artefact occurrence. These target scenes were captured using a digital single lens reflex (DSLR) camera and printed on both matte and gloss finished photographic paper from a retail digital imaging kiosk.

Target images consisted of the following scenes:

- Utility trailer;
    - Captured outdoors under direct sunlight.
- Night scene depicting sparkler;
    - Captured outdoors using available light.
- Textbooks;
    - Captured outdoors under direct sunlight.
- Brick wall;
    - Captured outdoors under open shade.
- Car wheel.
    - Captured outdoors under open shade.

Figure 5.6: Test target consisting of a utility trailer captured under direct sunlight.

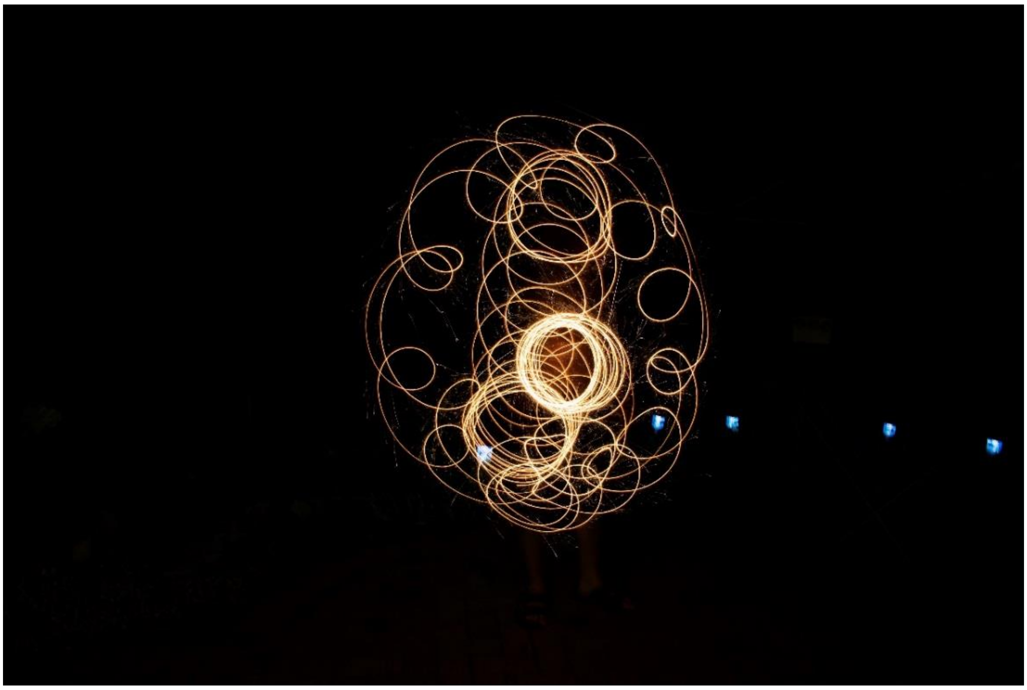


Figure 5.7: Test target consisting of an outdoor night-time scene. Scene depicts a person twirling a sparkler (a spark emitting decorative pyrotechnic) captured using available lighting through a long exposure. (Small blue-white inclusions in the background are garden lights).

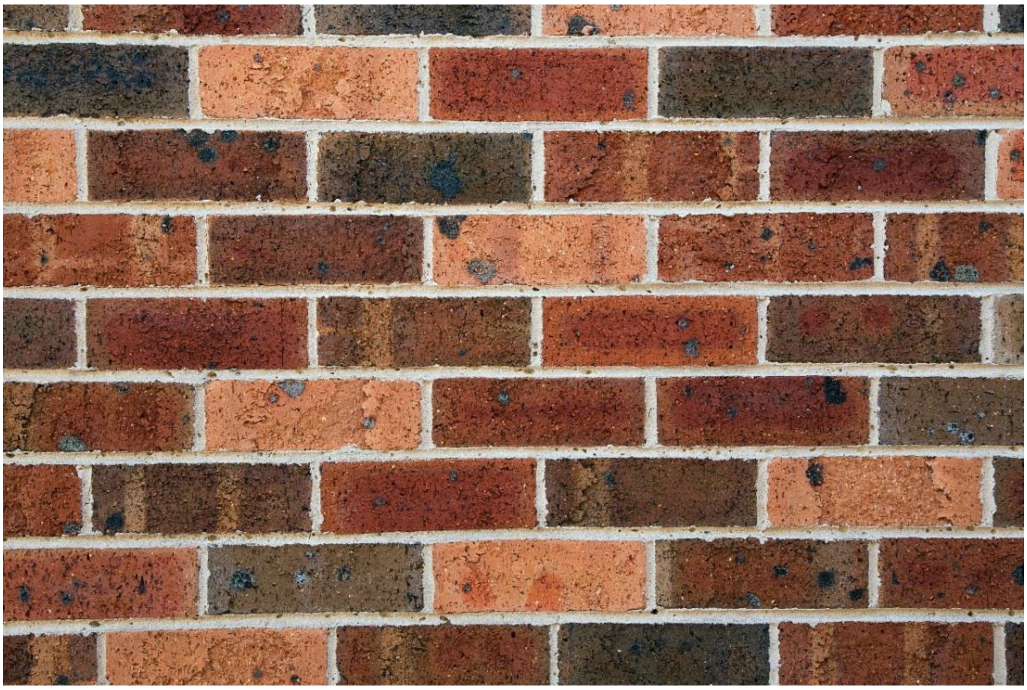


Figure 5.8: Test target consisting of a brick wall captured under open shade (slight barrel distortion evident in image and noted during image analysis).

Figure 5.9: Test target consisting of a car wheel captured under open shade.

Figure 5.10: Test target consisting of a set of tessellated textbooks captured under direct sunlight.

5.4.4 GPS Metadata for Supporting Photointerpretation

An examination into the usefulness of GPS information for supporting the detection of second-generation digital photographic images was conducted.

The following questions were examined:

- What percentage of the sample population (volunteers) have GPS geo-tagging capabilities active on their image capturing device?
- How variable is the accuracy of GPS coordinates under real world conditions?
- How useful is GPS information for supporting photointerpretation?

All sample images photographed by volunteers were undertaken at known locations.

Only devices with GPS capability and geo-tagging enabled during image capture would result in GPS metadata being embedded into the digital image file. Collected image samples were therefore examined to determine whether GPS information was embedded within EXIF data.

Recovered GPS coordinates were referenced via Google Maps™ to plot and mark location. Concentric circles representing approximately a 30 m and 60 m radius from the location of image capture were also superimposed on digital maps. The marked radial distances were estimated through use of the distance measuring tool available in Google Maps™. Observing the locations of recorded GPS coordinates recovered from digital image samples enabled an understanding of the accuracy of GPS data.

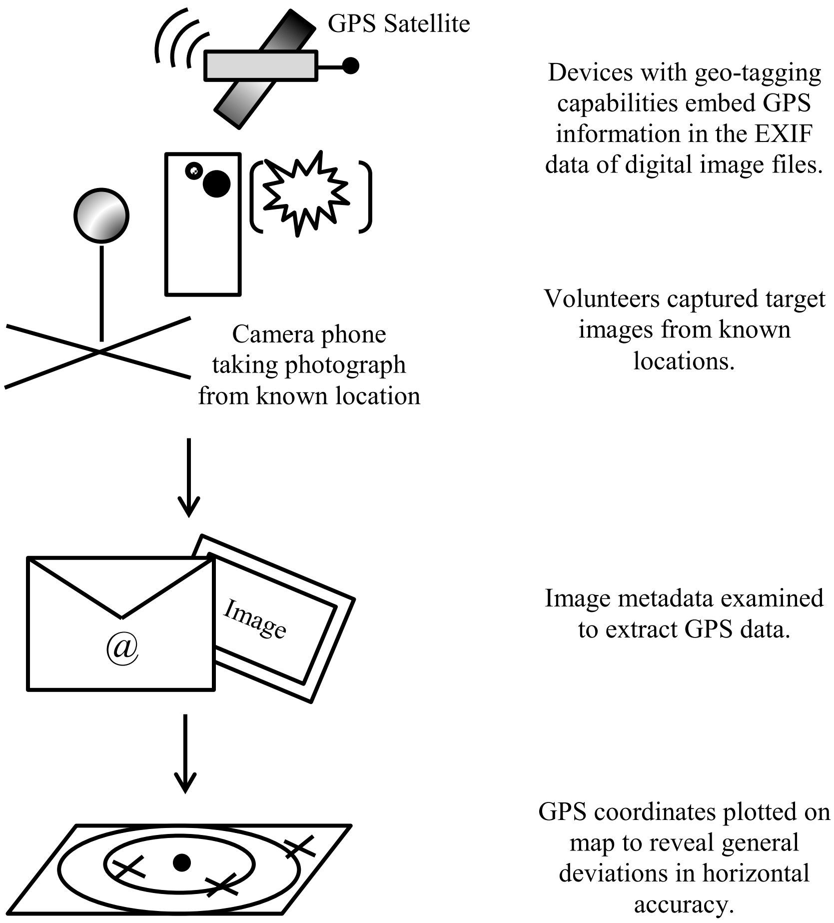


Figure 5.11: Overview of data collection and analysis process for exploring the role of embedded GPS metadata for assisting the photointerpretation of second-generation images.

5.4.5 Exposure Values for Supporting Photointerpretation

Exposure values for several lighting environments were examined in order to validate their relationship to published literary values. The lighting environments selected for investigation were those believed to be most relevant for producing second-generation images (Table 5-2 and Table 5-3).

Table 5-2: Lighting environments examined for EV determination

	Outdoors	**Indoors**
Natural	Direct Sunlight	
	Open Shade	
	Partially Cloudy	
	Overcast Days	
Artificial	Bright Street Scenes at Night	Domestic Interiors (Tungsten)
	Sports Arena	Industrial and Office Interiors (Fluorescent)

Each lighting environment was analysed using a Sekonic® L-478D Litemaster Pro light meter using ‘ambient mode’. Incident light readings were taken with the diffusion dome engaged. Each light reading was taken from roughly waist weight and aimed appropriately at the light source.

Shutter speed, *f*/stop and ISO details were recorded during each reading and computed using Equation 5-1 in order to derive EV values. Recorded *f*/stops were rounded to the nearest whole stop during the process. The EV for each lighting environment was calculated based on an average of 10 samples, with each sample based on data obtained on separate occasions. During each sampling occasion, x5 light readings were taken of the lighting environment from several different positions within the area of illumination. The calculated EVs for each environment were then averaged together to produce a representative EV for that particular lighting condition.

Table 5-3: Definitions of lighting environments investigated

Lighting Environment:	Definition:
Direct Sunlight	Bright, clear sky sunny day. Light meter pointed directly at unobstructed sun.
Open Shade	Standing under a shaded location open overhead to the sky. Light meter pointed directly at clear sky.
Partially Cloudy	Sky containing several clouds and patches of blue sky. Light meter pointed up at sky.
Overcast Days	Sky blanketed mostly or completely by cloud. Light meter pointed up at sky.
Bright Street Scenes at Night	Night-time environment. Light meter pointed up at street light from within a ~2 m radius of the physical light source.
Sports Arena	Night-time environment. Light meter pointed at flood light from several positions within a ~2 m radius of the physical light source.
Domestic Interiors	Indoor lighting environment isolated from external light sources. Light meter aimed at light source and taken from several positions within area illuminated by tungsten lighting.
Industrial and Office Interiors	Indoor lighting environment isolated from external light sources. Light meter readings aimed at light source taken from several positions within area illuminated by fluorescent lighting.

Table 5-4 provides an example of the data collection scheme used for the determination of the EVs for the different lighting environments examined.

Table 5-4: Example EV data collection approach

Lighting Environment:	EV Calculations (x10):	Light Readings (x5):				
Environment 1	EV 1 (calculated from x5 light readings)	1	2	3	4	5
	↓	…	…	…	…	…
	EV 10	…	…	…	…	…
	Average EV					
Environment 2	EV 1	1	2	3	4	5
	↓	…	…	…	…	…
	EV 10	…	…	…	…	…
	Average EV					

This table illustrates how EV data was recorded for each lighting environment.

5.4.6 Bias & Limitations:

Bias had the potential to manifest during the investigation into the detection of second-generation images. Visual and metadata analysis was performed by a sole researcher. During sample analysis, the fact that all image samples submitted for examination were second-generation images was not blind to the researcher, since the phenomenon being investigated (frequency of artefacts) was solely specific to second-generation images.

Confirmation bias could have affected the data obtained by producing results with an exaggerated frequency of artefact detection because the analyst may have subconsciously more likely erred towards the decision that a questionable artefact was indeed present/detectable due to the knowledge that the image being examined was indeed a second-generation image.

Furthermore, due to the involvement of human judgement during the process, error may have resulted in second-generation artefacts being missed, either systematically due to limitations concerning the knowledge or understanding of the analyst, or randomly due to natural variations in human performance (type II error). There was also the possibility that artefacts may have been falsely detected as being present (type I error).

Moreover, there was also the inherent design limitation imposed by the restricted scope of the test targets. The sample population consisted of depictions stemming from the limited number of target scenes. Although the target images were designed to accommodate a broad scope of visual features, they did not and could not comprehensively represent the almost infinite scope of photographic conditions that could be encountered in real life scenarios.

5.5 Results

5.5.1 Second-Generation Image Detection Criteria

The following tables present the criteria developed throughout this investigation for the detection of second-generation images. Definitions of criterion alongside explanations regarding their cause and a justification as to why each criterion is useful for their task of aiding the detection of second-generation images are presented below.

Table 5-5: Pictorial based second-generation image detection criteria

Criterion	Cause	Justification
Display Edge of Photograph	Camera framing includes some areas or all of the copied photograph's edge.	It is typically not possible to have a well-defined edge surrounding a first generation image unless an extraneous border or frame is purposefully incorporated into the scene during capture, a practice usually undertaken for artistic purposes.
Flare or Reflection of Light Source	The reflection of the light source appears visible on the surface of the copied print, apparent as specular reflection. This artefact is particularly evident when on-camera flash is used.	First generation images should not depict non-reflective scene elements appearing to reflect light. For example, open sky should not display any unwarranted specular reflections.
Reflection of Camera on Surface	The reflection of the camera itself may be evident in prints, particularly those with a gloss surface and if shadow areas are located towards the centre of the image.	The self-reflection of a camera in a first generation image is generally not possible under normal photographic conditions unless photographing a reflective surface such as a mirror. For example, open sky should not depict the reflection of a camera.

Unnatural Rectilinear Distortion	Caused by the camera not being parallel to the copied photograph. This artefact must be inconsistent with any normal rectilinear distortion encountered in standard photographic practice.	Unnatural rectilinear distortion can only occur in a second-generation image if the angle of the camera is opposed to the angle of the original image.
Unnatural Barrel Distortion	Images that display a flat perspective with unnatural barrel distortion indicate a mismatch of optical aberrations.	A first-generation image cannot simultaneously be affected by contradicting distortions. In regards to this criterion, a first-generation image cannot be affected by distortion due to short and long focal lengths or by wide angle and telephoto lenses, at the same time.
Issue with Light Coverage	Lighting falloff is caused by uneven lighting of the copied photograph. Falloff needs to be inconsistent with the variability in natural lighting displayed in the original image.	An evenly illuminated scene should not contain inconsistent and unnatural light coverage. For example, a clear blue sky should not have a shadow or an unnatural change in lighting occurring across it.
Conflict between EV and Pictorial Information *(Based on Metadata)*	The overall exposure value is not consistent with the pictorial elements and exposure standards displayed in the image.	Modern digital cameras typically produce an image correctly exposed for a given lighting environment. Camera settings should reflect parameters appropriate for the lighting environment. A bright/sunny scene can't be correctly exposed through camera settings required for the correct exposure of a scene with less available light, i.e. a darker scene. For example, a bright sunny scene should typically result in EV ~15. An image depicting a sunny scene but with an EV ~7 contains a conflict between the EV and pictorial information.

Other:	It is important to include an 'other' category as a criterion in the event that future cases provide new and/or case specific artefacts useful for analysis.	Below are x3 artefacts that were developed as a result of considering potential 'other' artefacts when examining the image samples pertaining to this study. These artefacts were not originally theorised to be criterion useful for the detection of second-generation images.
Print Surface Texture Visible	Textured hardcopy prints such as those with matte finishes may reveal the print medium's surface texture when photographed.	Real life scenes do not typically have a textured pattern overlaying captured scene elements. For example, a clear blue sky should not appear unnaturally textured.
Foreign Objects Visible on Surface	Objects such as dirt particles, hairs and fibres may be present on the surface of hardcopy photographs and remain visible in second-generation images particularly in shadow and highlight areas.	Foreign objects with unnatural scale and placement are atypical inclusions in first-generation images. The objects referred include material such as visible fibres and dust granules. An exception to this is when foreign objects are physically present on the sensor or the lens of the camera producing foreign object artefacts in first-generation images. These instances can potentially be detected as they tend to produce darker shadow-like artefacts due to the physical presence of the object preventing light from reaching the image sensor. Objects on the lens or sensor also tend to be less clearly resolved taking on a more diffuse appearance.
Fingerprints Visible on Surface	Latent fingerprint impressions may be visible on the surface of hardcopy images, particularly those with gloss finishes.	The presence of fingerprints in unexpected locations and with unnatural scale are atypical in real world scenes. For example, a visible fingerprint seemingly suspended in the sky is an unnatural occurrence in a real life scene. This occurrence can however be explained if the image is in fact second-generation.

Table 5-6: Metadata based second-generation image detection criteria

Criterion	Cause	Justification
Time & Date	The time recorded is inconsistent with the pictorial elements of the photograph. The metadata conflicts with visible elements such as natural lighting, shadow placement, etc.	Capturing an original scene at a given time and date should preserve any visible elements within the scene that are dependent on time including features such as shadow and sun light direction and seasonal occurrences such as snowfall and seasonal colour changes to foliage.
Exposure Value	The overall exposure value is not consistent with the pictorial elements and exposure standards displayed in the image.	A first-generation image should have consistency between the depicted lighting environment and the exposure settings used for capture due to a camera's inbuilt exposure metering.
GPS Coordinates	The GPS coordinates where the copy took place are inconsistent with the apparent location depicted within the photograph.	As an example, a digital photograph depicting the Sydney Opera House, Australia would present a conflict if it contained embedded GPS coordinates for a location in China. This conflict can be explained however if the image is second-generation.
Lens Focal Length	Focal length of lens not consistent with the depicted image perspective.	Focal length impacts camera 'u' distance (subject to lens distance) which ultimately governs photographic perspective. A conflict would occur if the lens focal length used for capture would not support the 'u' distance required for the capturing of the depicted perspective.
Shutter Speed	Moving scene elements captured in image display motion that contradicts the camera's shutter speed setting.	The pictorial elements in a first-generation image should be consistent with the camera shutter speed settings used for capture. For example, a moving object should appear clearly frozen in time if captured by a sufficiently fast shutter speed. Conversely, a sufficiently slow shutter speed should result in the motion caused blurring of a moving subject.
***f*/Stop and Depth of Field**	The *f*/stop used for image capture is inconsistent with depth of field apparent in the photograph.	An image with a visually shallow depth of field would present a conflict if camera settings were used that should result in the capture of a large depth of field and vice versa.

White Balance	Inconsistency between the indicated white balance setting and the colour temperature of the light source used, if known.	Typically, first-generation images should suffer from minimal colour cast due to the modern digital camera's built in white balance detection function, which adjusts the white balance of an image to account for the colour temperature of the dominant light source.

5.5.2 Pictorial Artefact Examples

The following section depicts a selection of visual examples of second-generation image artefacts detected during this investigation:

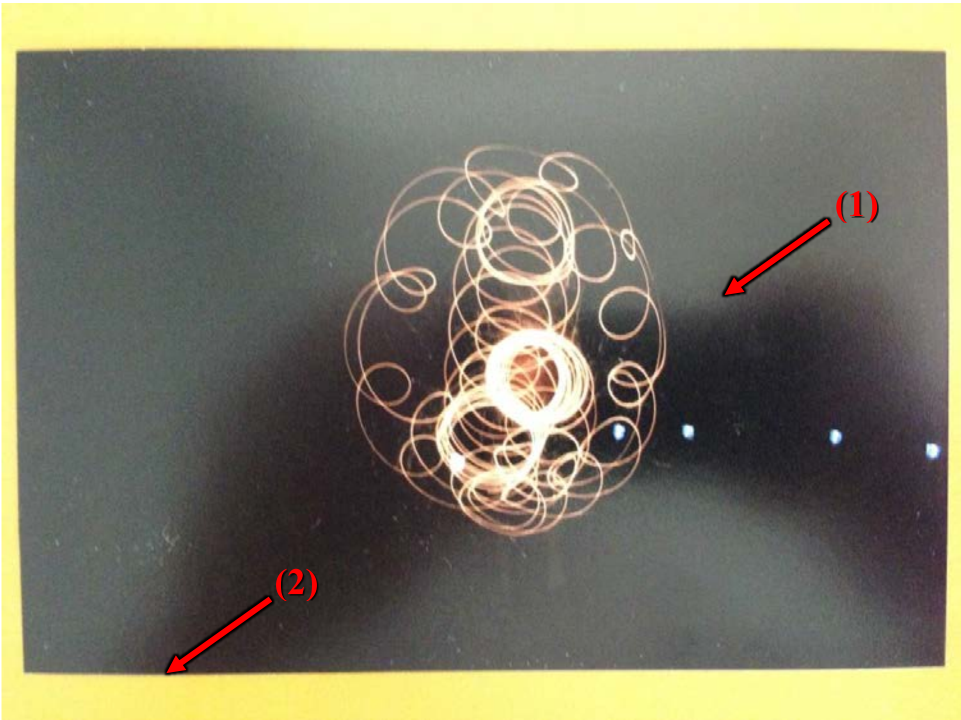


Figure 5.12: Night-time scene image sample exhibiting (1) 'reflection of camera on surface' and (2) 'display edge of photograph' artefacts. [Not to scale].

Figure 5.13: Brick wall image sample exhibiting 'unnatural rectilinear distortion' artefact. [Not to scale].

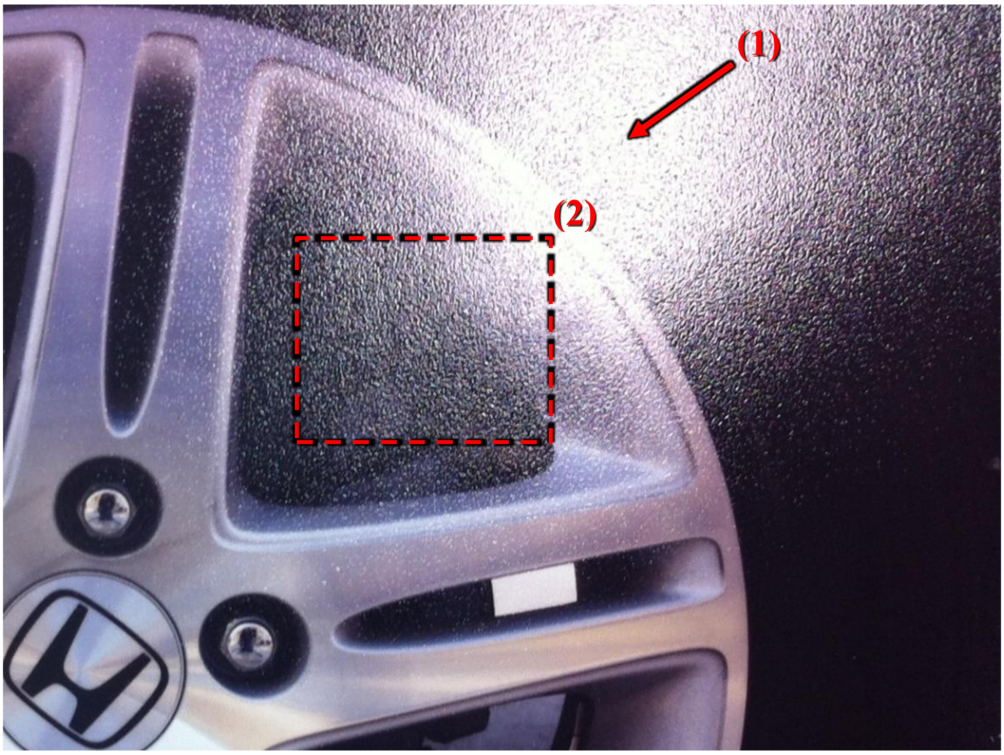
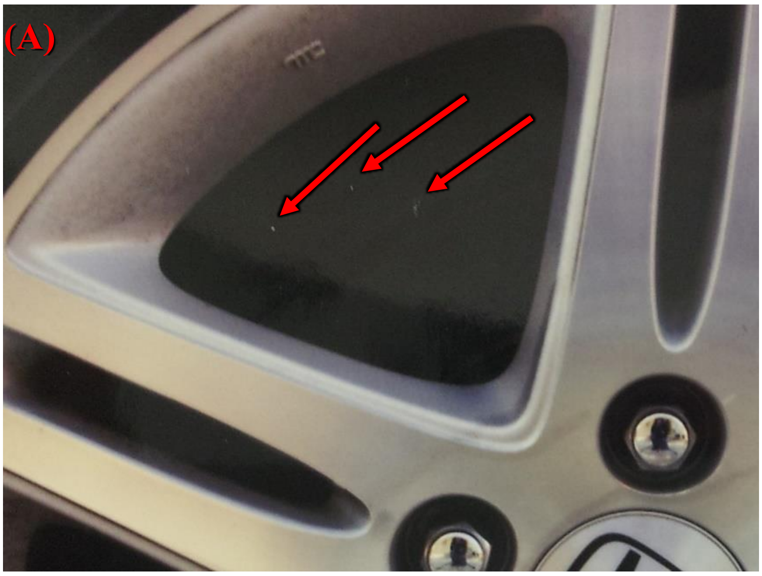
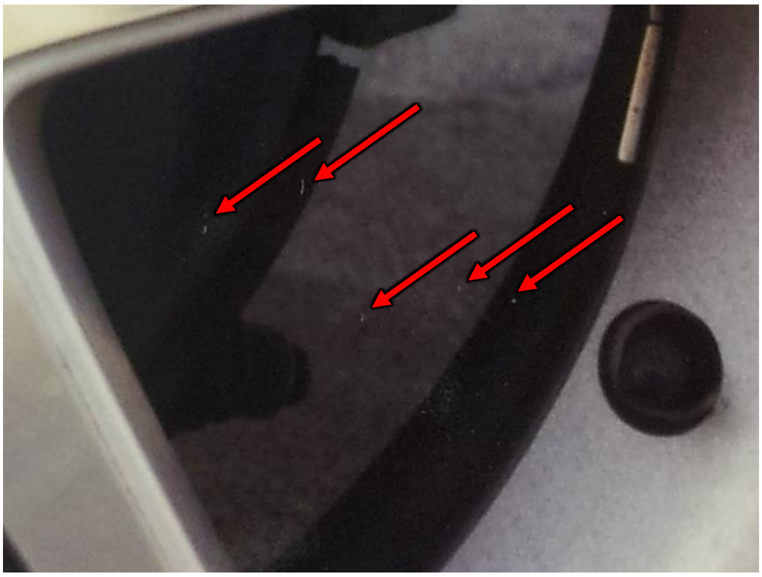


Figure 5.14: Car wheel image sample exhibiting (1) 'flare or reflection of light source' and (2) 'print surface texture visible' artefacts. [Not to scale].

Figure 5.15: Car wheel image sample exhibiting (1) ‘fingerprints visible on surface’ artefact. [Not to scale].



(B)



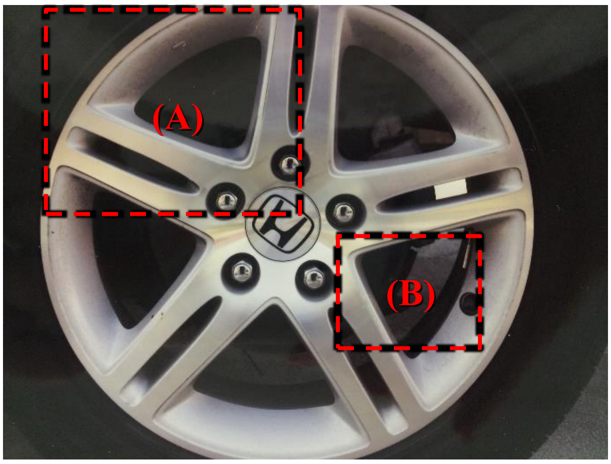


Figure 5.16: Car wheel image sample exhibiting 'foreign objects visible on surface' artefacts in the form of dust particles. Sections A & B enlarged. [Not to scale].

5.5.3 Frequency of Occurrence of Second-Generation Image Artefacts

The following section presents statistical information regarding the frequency of occurrence of second-generation image artefacts investigated throughout this chapter.

Overview of sample population characteristics:	
No. of second-generation image samples:	67
No. of unique image sources (volunteers):	19

Note: All percentages presented have been rounded to the nearest integer.

Out of the 67 second-generation image samples examined as part of this investigation, all samples were found to contain at least 1 or more second-generation artefacts.

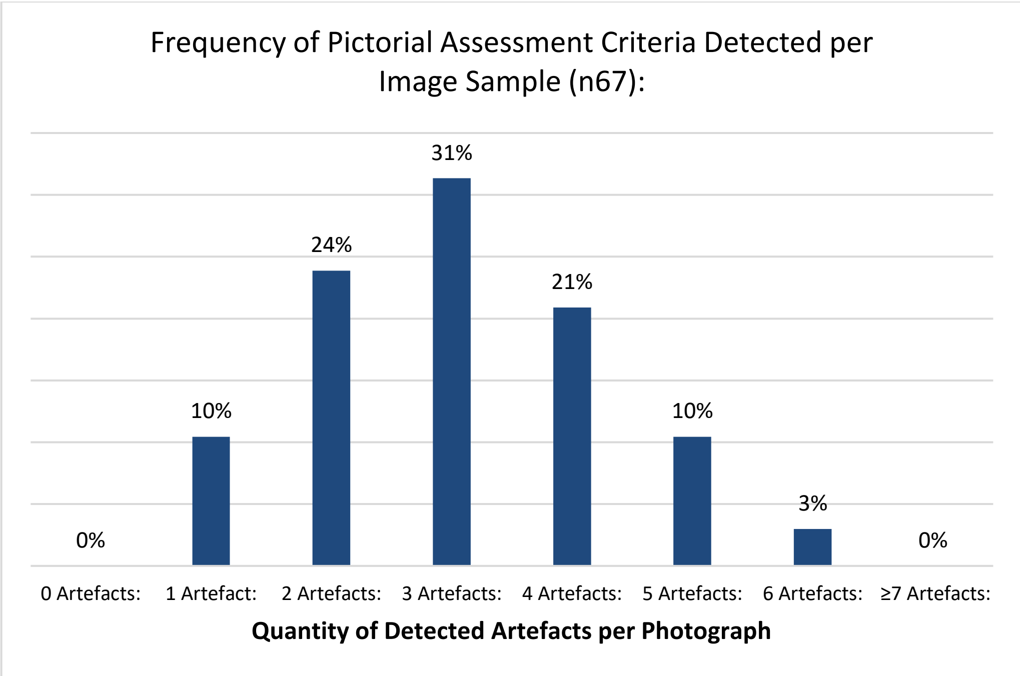


Figure 5.17: Frequency of the number of pictorial based second-generation artefacts detected per image sample (n67).

Figure 5.17 displays the percentage of pictorial based second-generation artefacts detected per image sample across the sample population. The majority of artefacts detected per sample ranged between 2 to 4 artefacts with 3 artefacts 31% (21 out of 67) being the most frequently encountered per image sample. 24% (16 out of 67) of samples contained only 2 artefacts and 21% (14 out of 67) contained 4 artefacts. No samples were found to contain 7 or greater artefacts.

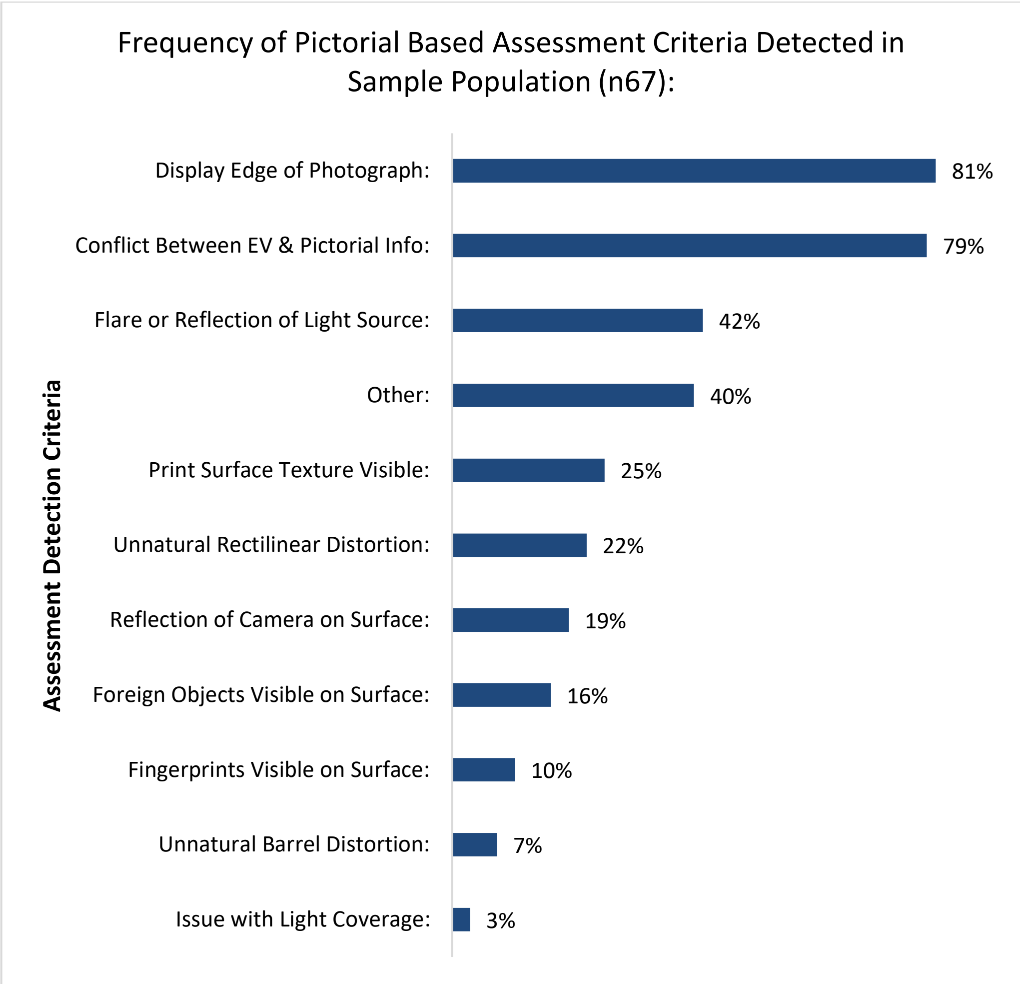


Figure 5.18: Frequency of second-generation image pictorial based artefacts detected within sample population.

Figure 5.18 depicts the frequency of occurrence of pictorial based second-generation image artefacts examined during this investigation within the sample population. The 'display edge of photograph' criterion was the most frequently encountered second-generation image artefact and was detected in 81% (54 out of 67) of image samples followed closely by the 'conflict between EV & pictorial information' criterion found in 79% (53 out of 67) of samples. The 'flare or reflection of light source' was the third most frequently detected artefact found in 42% (28 out of 67) of samples.

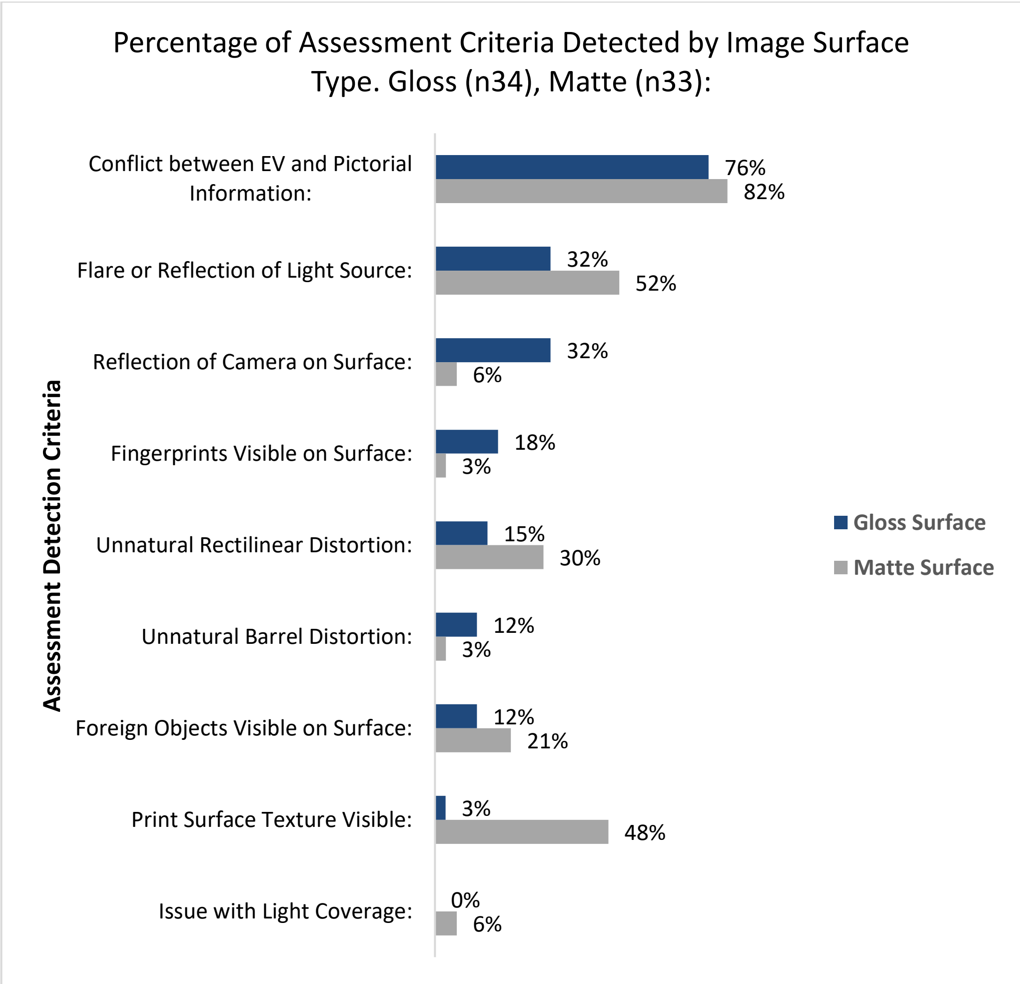


Figure 5.19: Percentage of detected second-generation assessment criteria based on sample image surface type (gloss and matte).

Figure 5.19 depicts the percentage of second-generation assessment criteria detected during image analysis based on the print media surface type (gloss or matte) of the target scene used for capturing samples. Out of the total of 67 second-generation images collected, 34 were based on gloss and 33 based on of matte finished hardcopy prints.

5.5.4 GPS Data for Supporting Photointerpretation

The following section contains information regarding GPS data collected during second-generation image sample analysis.

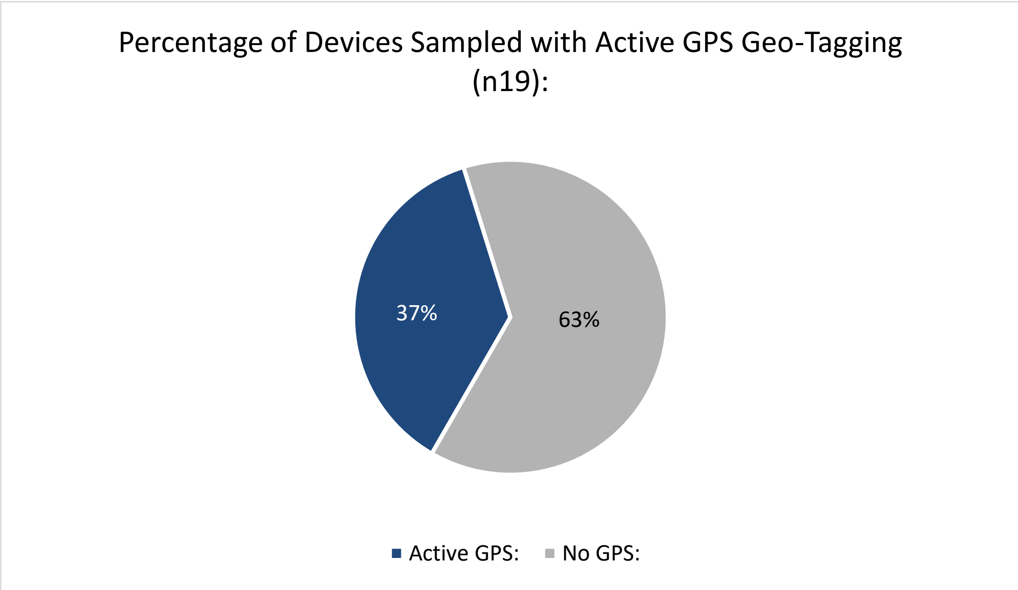
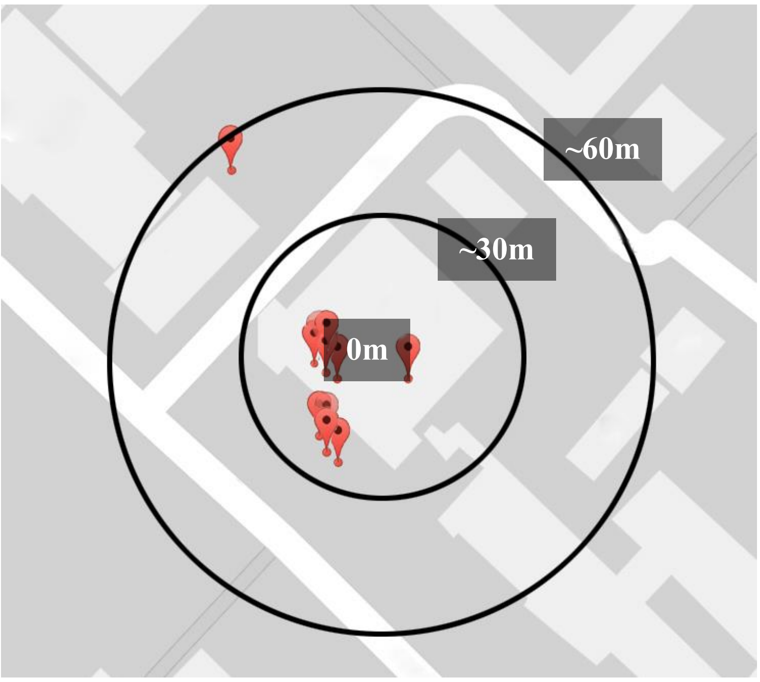


Figure 5.20: Percentage of devices that exhibited active GPS geo-tagging during sample collection.

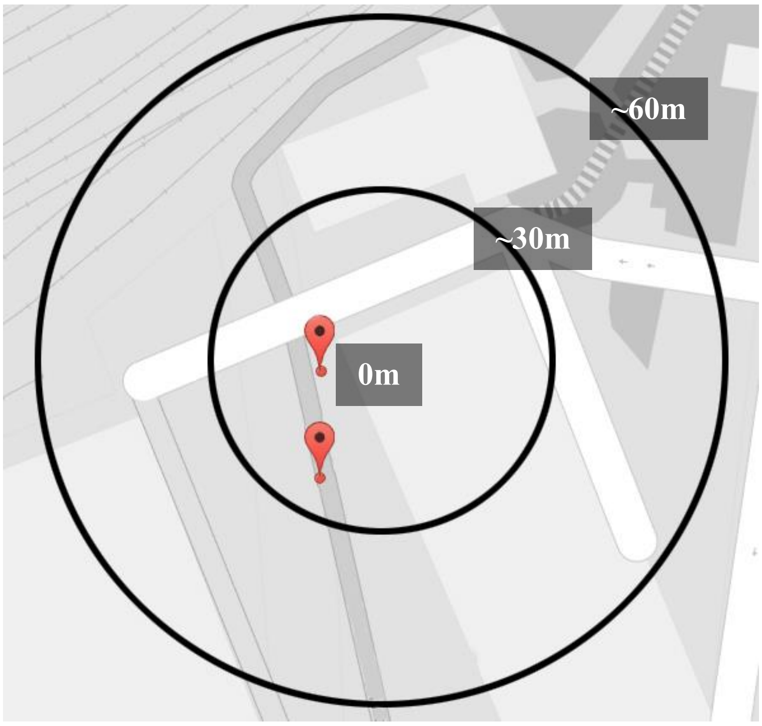
Figure 5.20 depicts the percentage of camera devices used in the study that displayed the capability to embed GPS data into the metadata of captured digital image files. Out of the 19 individual image capturing devices used for sample collection, 37% (7 out of 19) displayed active GPS geo-tagging capability while 63% (12 out of 19) did not exhibit such functionality as evidenced from metadata analysis.

During second-generation image sample collection, 15 image samples contained embedded GPS information. Figure 5.21 and Figure 5.22 depict visual representations of the locational information provided by the embedded GPS data within these image samples.



Map data ©2015 Google

Figure 5.21: GPS coordinates recovered from 13 second-generation image samples captured at location #1. Image modified to remove locational information.



Map data ©2015 Google

Figure 5.22: GPS coordinates recovered from 2 second-generation image samples captured at location #2. Image modified to remove locational information.

Figure 5.21 shows the recorded locations of 13 samples containing embedded GPS data captured at one particular location. The majority of the depicted geo-tagged image samples were found to contain coordinates relatively close to the area of capture. 12 of the 13 samples were recorded within a 30 m radius from the area of capture. A single sample was recorded to be within approximately 60 m radius from the area of capture.

Figure 5.22 shows the recorded locations of 2 samples containing embedded GPS data captured at a secondary location. In this instance, both samples were observed to have been recorded within a 30 m radius of the area of capture.

5.5.5 Exposure Values for Supporting Photointerpretation

The following section contains information regarding results from the exposure value (EV) data collected during the course of this investigation.

Figure 5.23 illustrates the mean, maximum and minimum EV values measured for the lighting environments investigated in the study. Refer to Appendix B for further data used to support EV determination.

Table 5-7 contains a comparison between EV values available in the literature to those experimentally determined in the study. The majority of lighting environments selected for investigation had an equivalent descriptor reflected in the literature. However, EV values for the ‘open shade’ and ‘partially cloudy’ lighting environments were not found in the literary sources used for comparison.

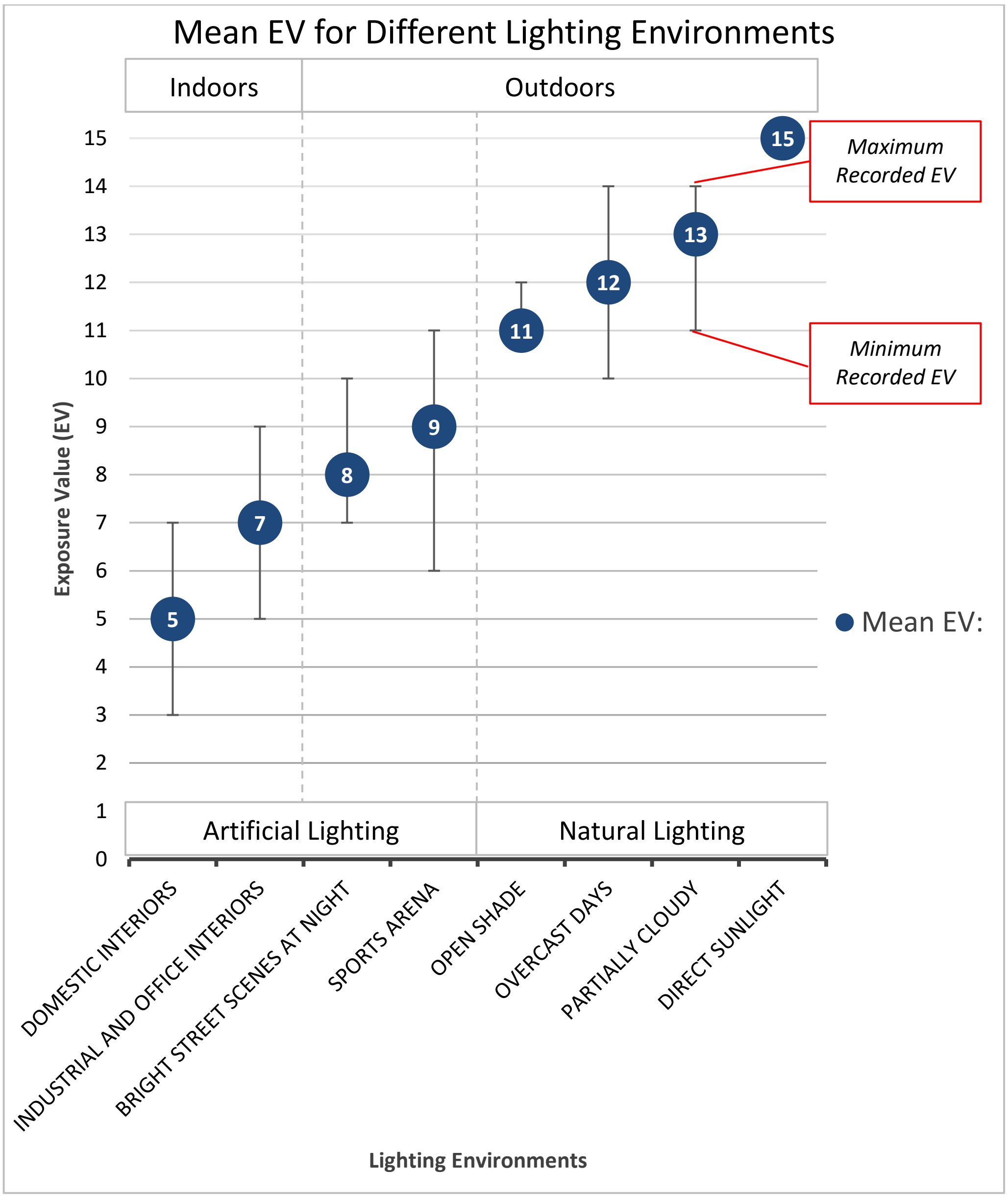


Figure 5.23: Diagram illustrating mean, maximum and minimum recorded exposure values for 8 different lighting environments. Environments are categorised under indoors/outdoors and artificial/natural lighting environments.

Table 5-7: Comparison between exposure values available from literature and experimentally determined results from investigation

Lighting Environment:	†EV from Literature Source:	Experimentally Determined Mean EV:
Domestic Interiors	5−7	5
Industrial and Office Interiors	7−8	7
Bright Street Scenes at Night	8	8
Sports Arena	8−9	9
***Open Shade**	−	11
Overcast Days	10−12	12
***Partially Cloudy**	−	13
Full Sun with Clear Shadows Cast	15−16	15

†Source: [Prakel 2009]

Figure 5.24 to Figure 5.28 are graphs that visualise data related to the 'conflict between EV and pictorial information' assessment criterion. The graphs depict EV information extracted from second-generation image samples that contained sufficient exposure related metadata to enable EV calculation. Each graph represents information pertaining to a specific target scene. Within the graphs each image sample instance represents EV data extracted from an individual sample image. Ground truth values represent the EV of the original scene that was used as the target subject for the production of second-generation image samples. Mean expected EV indicates the typical value representative of a given lighting environment based on literary and/or experimental data. Upper and lower EV limits represent a ±1 EV variance from the expected EV of a particular lighting environment, assisting photointerpretation. Ground truth values were observed to fall between the established EV thresholds supporting their validity as reliable indicators of lighting conditions.

During image sample analysis, when considering the 'conflict between EV and pictorial information' criterion, conflict was determined to exist if the EV value of a given sample fell significantly above or below the expected threshold for the given lighting environment (in this study, ≥ ±2 EV from the ground truth value). Each of the presented cases in the EV graphs demonstrate a conflict between EV and pictorial information with the exception of 'Figure 5.27, sample instance 8' which did not deviate from ground truth data significantly enough to be considered a conflict.

It must be noted that the results obtained in this study were highly dependent on the fact that the target images were all photographed under lighting conditions that did not reflect a typical indoor lighting environment. Had the ground truth target images involved indoor lighting conditions, the conclusions drawn from the results may have been significantly different.

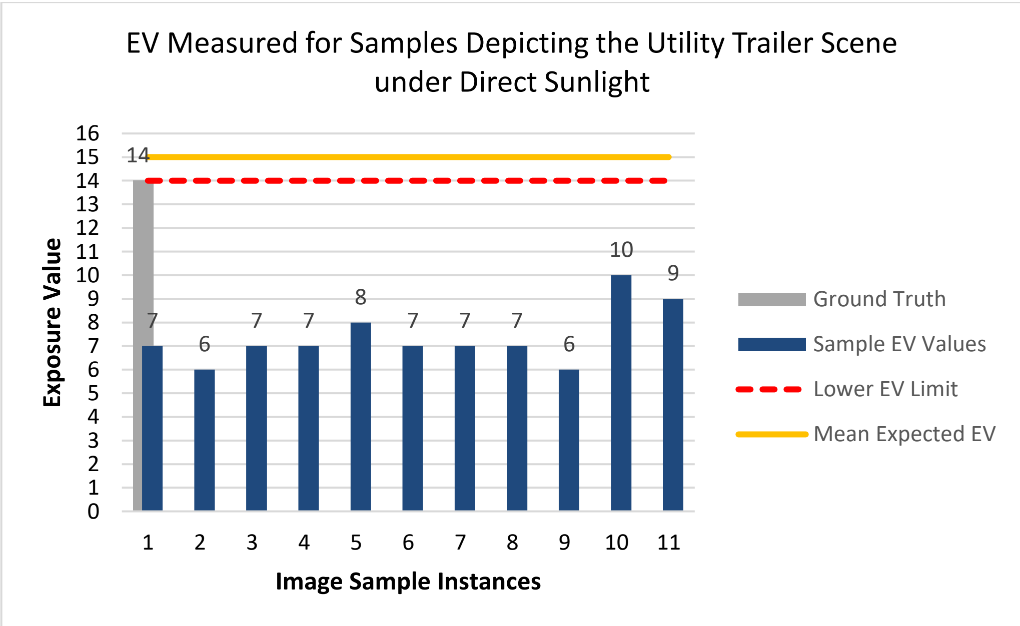


Figure 5.24: Diagram illustrating EV values for 11 second-generation image samples of the utility trailer scene which was photographed originally under direct sunlight.

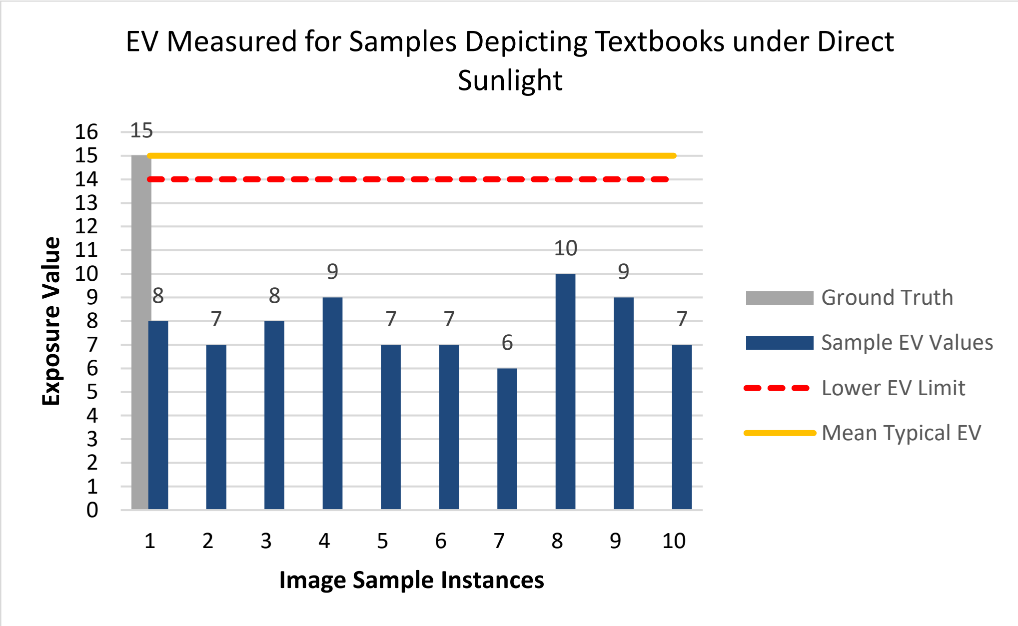


Figure 5.25: Diagram illustrating EV values for 10 second-generation image samples of the textbooks scene which was photographed originally under direct sunlight.

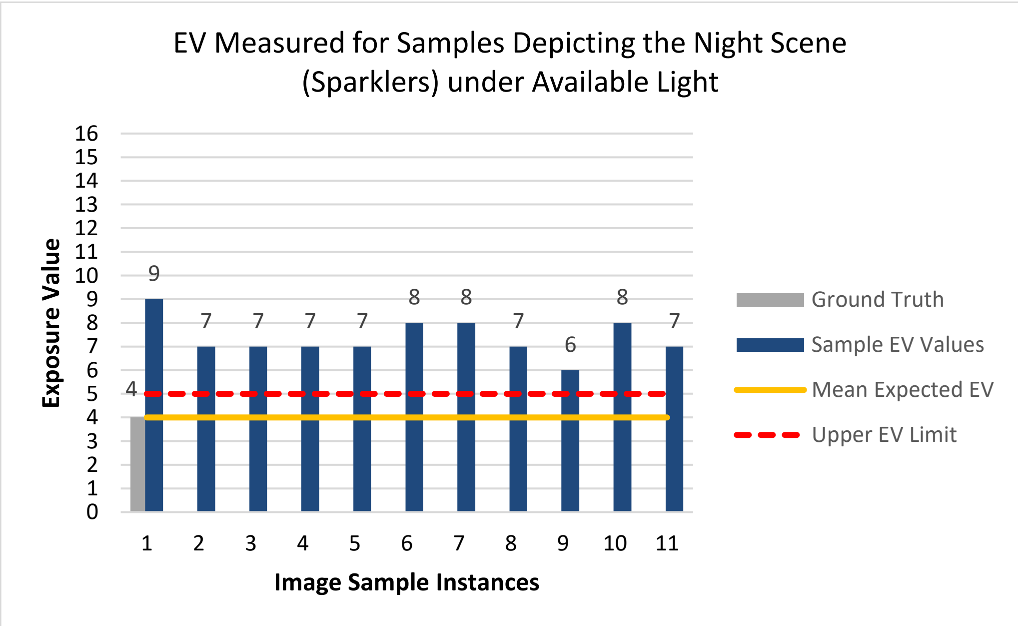


Figure 5.26: Diagram illustrating EV values for 11 second-generation image samples of the night scene which was photographed originally using available light.

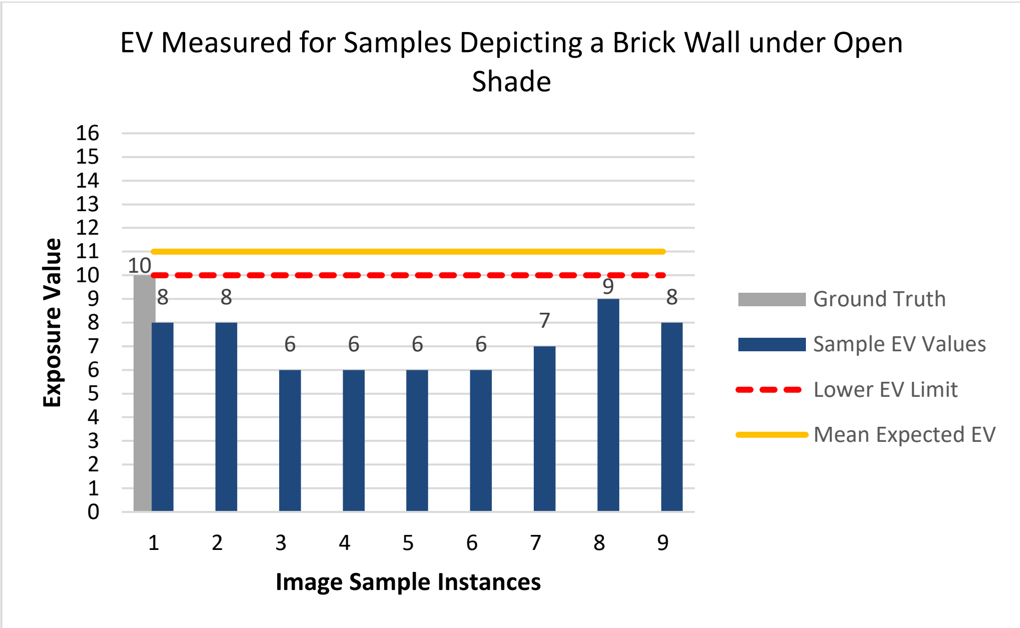


Figure 5.27: Diagram illustrating EV values for 9 second-generation image samples of the brick wall scene which was photographed originally under open shade.

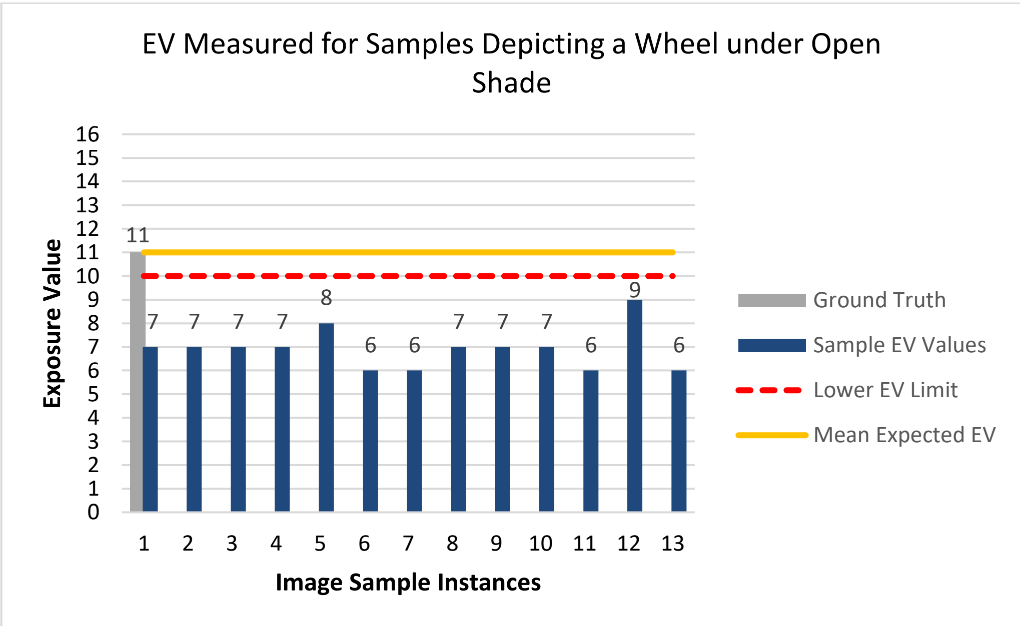


Figure 5.28: Diagram illustrating EV values for 13 second-generation image samples of the wheel scene which was photographed originally under open shade.

5.6 Chapter Discussion

This chapter introduced an innovative method for the detection of second-generation digital photographic images that does not have a requirement for computational analysis, through the implementation of a criteria based photointerpretation approach. This chapter's case based experimental focus enabled a reflection on the values a criteria based approach can offer interpretive image examinations, contributing towards addressing the central research question of this thesis concerned with the elucidation of principles for supporting robust forensic photointerpretation methodologies.

The discussion in this section commences with an initial focus on the experimental results obtained from the investigative component that examined the detection of second-generation digital photographic images. The discussion then progresses towards exploring deeper issues surrounding the criteria based photointerpretation approach and the values such an approach can inspire or exemplify that are important for supporting robust and reliable methodological practices for forensic photointerpretation tasks.

5.6.1 Detecting Second-Generation Digital Photographic Images

It is useful at the start of this discussion to briefly reiterate the defence and prosecution arguments regarding whether an image is of first or second-generation in the context of insurance fraud investigation.

Prosecution:

- The prosecution's argument in investigations that involve scenarios where images of insured items appear to be photographed at a time after the items were alleged to have gone missing is that insurance fraud was likely to have been attempted. Photographing an item after it has apparently gone missing suggests that the insured item(s) must still have been under the claimant's possession, contrary to their claim.

Defence:

- The typical defence positon would argue that the images in contention were in actuality digitisations of pre-existing hardcopy photographs that were rephotographed (through the convenience of a smart phone camera) at some time after the insured items were claimed to have gone missing to assist the transfer of the images to the insurance company via electronic means such as through email.

The truth of the situation can be regarded as either of the following:

- The image sent by the claimant is indeed a digital copy of a pre-existing hardcopy photograph (second-generation digital photographic image) - supporting the defence argument.

- The image sent by the claimant is an original capture (first-generation digital photographic image) taken at a date after the insured items were reported to have gone missing – supporting the prosecution argument.

To assist case scenarios involving questions of image authenticity and investigation into potential insurance fraud, a photointerpretation method was developed for the detection of second-generation digital photographic images using a novel criteria based assessment approach. The final assessment criteria consisted of 10 pictorial and 7 metadata artefacts that assist the forensic task of detecting photographic reproductions of hardcopy images.

A key finding of this investigation was that the majority of second-generation image samples examined did in fact contain image artefacts specific to second-generation images and that these artefacts were detected during analysis. In fact, artefacts hinting at the photographic reproduction process were detected in all samples examined.

The conclusion reached by an analyst regarding the authenticity of a questioned photograph is fundamentally a subjective judgement. This facet of the photointerpretation process strongly reflects the nature of the inherent difficulties experienced by examiners when pursuing such inquiries. The evidential weighing of observations and the determination of the degree of confidence such observations can provide for supporting a particular hypothesis is largely determined by human cognition. Henceforth, a method to focus, simplify and objectivise interpretations based on communicable observations, such as a criteria based assessment approach, can be significantly advantageous to the performance of photointerpretation tasks.

The most common number of second-generation artefacts detected within each second-generation image sample ranged from 2 to 4 artefacts with 3 artefacts being the most frequently observed (Figure 5.17). Can the quantity of detected artefacts influence the confidence an examiner places in the results of their analysis? The detection of several corroborating artefacts within a questioned image could be reasoned to increase the confidence an examiner places in their decision that an image is in fact second-generation. The detection of several second-generation criteria would suggest that the artefacts were much less likely to have arisen from unknown or unaccounted phenomenon not resulting from the rephotographing process (i.e. the detection of several artefacts could be seen to suggest that their existence was not just a random occurrence that simply manifested by chance alone). Contrarily, the presence of just a single artefact could also provide sufficient evidence to support the conclusion that an image is a reproduction, if the examiner is confident that the detected artefact is genuine and truly specific to the production of second-generation images.

Can the confidence of the forensic examiner in making their decision on an image's authenticity be influenced by the type of artefacts they detect? The three most commonly encountered assessment criteria were 'display edge of photograph', 'conflict between EV and pictorial information' and 'flare or reflection of light source' (Figure 5.18). Therefore, are these artefacts the strongest indicators of second-generation images? In other words, can more confidence be placed on a decision if these particular artefacts were detected in a questioned image?

The presence of any artefact prescribed in the criteria could be theoretically sufficient to conclude that an image is of second-generation. At the most, artefacts that were found to have a high frequency of occurrence in the sample population strongly support their inclusion as useful detection criteria. To elaborate, consider that although the artefact ‘flare or reflection of light source’ was encountered more frequently than ‘reflection of camera on surface’, if a clear reflection of a camera was seen in a questioned photograph, this finding would carry the same evidential weight as would the detection of specular reflection/flare or even the outside border of the original hardcopy image being rephotographed.

Figure 5.19 illustrated how the frequency of occurrence of various second-generation image assessment criterion were influenced by the properties of the original hardcopy print media used as the subject for rephotographing. While the majority of artefacts examined were technically independent of surface texture, several criteria could be theorised to be affected by photographic print surface. This notion was reflected in the results. Criterion including the ‘reflection of camera on surface’ and ‘fingerprints visible on surface’ artefacts were more frequently encountered in gloss prints than those with matte finishes. This is consistent with the properties of the highly reflective and smooth surface texture of gloss print media as opposed to the more textured and diffuse matte finishes. The artefact ‘print surface texture visible’ was more frequently encountered in matte than gloss prints. Again, this remains consistent with the diffuse and granulated texture characteristic of matte prints in contrast to smooth and flat gloss finishes. The majority of the remaining criteria appear to show a polarity towards one of the two types of print texture however, print media surface properties could not be theorised to actively affect the occurrence of these artefacts. Instead, the polarisation can be simply attributed to the randomness of the occurrence of the artefacts.

The statistical results of this study indicate that the assessment method developed was highly successful at detecting second-generation images in the samples examined. The 100% detection rate observed from the results however, does not indicate that the technique has no associated error.

The limitations imposed by the investigation’s experimental design (samples restricted to x5 different scenes), potential experimental biases (systematic and random errors) and the nature of the phenomenon being investigated (i.e. the technically unconstrained variability in captured scene information that can be encountered in real world cases), suggests that the results of this study should not be considered as an absolute representation for all cases concerned with the detection of second-generation images. The unique circumstances and nuances of individual cases combined with the limitations imposed by human knowledge will result in variations in the applicability and error rate of the assessment criteria method in differing circumstances. In other words, each second-generation image examination needs to be considered on a case-by-case basis since each questioned image will contain different degrees of contextual information and exhibit variations in the manner that they were photographed. In some instances, the assessment criteria approach would prove effective for assisting interpretive evidence analysis and in others cases the approach might prove less useful. The practicality of the criteria is essentially dependent on the pictorial and metadata content of an image. However, regardless of image quality or composition, approaching photointerpretation tasks through a structured methodology such as a criteria based assessment enables transparent communication of the suitability, limitations and application of the criteria in assisting analysis. Communicating such details effectively is an integral forensic science principle. Nevertheless, the results of this study support the view that the probability of a rephotographed image captured using a mobile camera phone, not containing any second-generation artefacts is doubtful.

The statistical results concerning the frequency of occurrence of second-generation artefacts could be seen to provide subtle insight into the practices and thinking of lay people engaging in copywork. Artefacts such as the edges of hardcopy prints, reflections, lighting anomalies and distortions were frequently encountered in rephotographed images despite volunteers being prompted to capture the best quality copies they could. This observation might suggest that the photographers believed second-generation images did not need to avoid the inclusion of artefacts because the fact that they were rephotographed images was not something necessary to conceal. Additionally, or alternatively, results may suggest that lay photographers did not have an awareness or understanding of image artefacts, hence their frequent inclusion.

Contextual information inherent in image samples provided the data necessary for evaluating and exploring EV and GPS related second-generation artefacts. The real world practical application of the 'conflict between EV and pictorial information' assessment criterion relies on the requirement to be able to identify the lighting environment used for capturing the image being examined. In this study, if ground truth information was not available, the only scenes that would qualify for the EV based assessment were the outdoor direct sunlight and night-time scenes where enough visual context was captured for the identification of the predominant source of lighting. The thresholds used for assessing whether an EV conflict existed would also need to be based solely on literary/experimental data. A benefit of the 'conflict between EV and pictorial information' artefact resides in its difficulty to be eliminated unless the same lighting environment is used during the rephotographing process. Even if good copywork practise is undertaken to remove various reflections and distortions, a conflict between the pictorial elements of the image and EV may still exist.

The exploration of EV data within this study not only validated existing literary values but shed light on the requirement to consider the potential EV latitude for a given lighting environment during the photointerpretation process. Mean EV values calculated for each examined environment strongly reflected literary data, however instances existed where deviations were recorded from typical EV values. For example, as depicted in Figure 5.23, the 'overcast days' lighting environment (typical EV12) experienced EV values that ranged between EV10 to EV14. Artificial light sources were observed to be affected by variation in EV more so than natural light. Deviations in recorded EV can be attributed to factors specific to the data collection process. The subjective identification of different lighting environments, changes in weather, variations in date and time of light measurement, positioning of light sources and locations used for light meter readings could have all impacted EV data collection. Nonetheless, these conditions can also affect real life instances of image capture. Therefore, maintaining an understanding that EV values can vary from their typical expected or representative value is useful for photointerpretation purposes. This understanding illustrates that the strength of EV values for assisting examination resides in the ability to detect conflicts between broad light source groups (indoor v. outdoor) as opposed to close differences such as the various descriptors of natural lighting (direct sunlight v. open shade).

The results of this investigation found that the accuracy of embedded GPS metadata contained in examined image samples supported the figures reported by Zandbergen [2009] and Zandbergen & Barbeau [2011] (Table 5-1). The majority of GPS coordinates obtained from samples were accurate within approximately 30 m of their real world positions. The findings from this study regarding real world GPS accuracy support the validity of GPS data as a second-generation image assessment criterion. The usefulness of GPS coordinates for assisting second-generation image detection may vary depending on the extent of the geographical information available in an image.

GPS can assist with the detection of second-generation images if there is a recognised conflict between the reported location of image capture, location depicted in the image and recorded GPS metadata. Large discrepancies between the supposed location of image capture and GPS coordinates, such as deviations spanning cities or geographical regions, are more obvious signs of second-generation images as such anomalies can be attributed to the rephotographing process occurring at a different location to that of the original image.

The examination of visible clues such as buildings, architectural style, vegetation, key landmarks and objects within a questioned image can also be useful for determining if the location of image capture is different from the location indicated by GPS data. Comparisons of this nature can be conducted using map services that display satellite imagery such as Google Maps™. Care has to be taken during such comparisons to consider potential errors that might affect analysis. Daniel & Daniel [2012] explain several errors that affect GPS evidence interpretation. One source of error is deviation of GPS accuracy due to weak signal reception and noise. The results from this investigation suggest that locational GPS accuracy, as reflected by current consumer smart phone technologies, appears to be somewhat accurate with the greatest deviation in reported position observed to be within a 60 m radius from the origin. Still, the potential error radius of GPS data points need to be factored into the photointerpretation process. Additionally, Daniel & Daniel state that imagery used by different map services, used when investigating real world positions of GPS coordinates, is often non-unified and managed independently. Therefore, attention has to be cast to the date of satellite imagery used by various providers if performing an examination that assesses visible geographic features. Changes in landscape and structures over time may or may not be accurately reflected in satellite imagery and this may impact examinations.

The fact that not all second-generation images may be captured at a location different from the original scene location is also required for consideration when examining GPS based artefacts. Some rephotographed images may actually be captured at the same location as the original. This scenario can be expected if, for example, home contents are the focus of an insurance claim. If an original hardcopy image is digitised via photographic reproduction at the same location, then any associated GPS coordinates will reflect this location.

The underlying practicality of GPS related artefacts for detecting second-generation images relies on obvious and discernible differences in geographical position between reported location of capture, GPS coordinates and visible geographical information that can only be explained by the relocation of a hardcopy photograph during capture.

Finally, the developed image criteria assessment detection method, although useful for detecting second-generation images, cannot prove whether an attempt at fraud had occurred or not. If copy artefacts are apparent, the method can determine that a questioned image is second-generation. However, in situations where no artefacts are detected, consideration needs to be given to the potential risk that the absence of artefacts may not only be indicative of originality but as a result of a photographic copy that has in some way negated the inclusion of artefacts. The results of this study do however provide insights into the likelihood of image originality when captured by a camera phone.

Ultimately, the limitations of the second-generation image detection technique mean that the process is excellent for exculpating potentially innocent claims via the detection of second-generation images, but not as effective at attributing guilt via the determination that a questioned image is an original. There is also the possibility that a second-generation image has been purposefully incorporated into a more sophisticated insurance fraud scheme.

This investigation focused on the detection of second-generation images sourced from camera phone devices for the underlying purpose of assisting insurance fraud cases. The technique can be equally applicable to images sourced from other photographic devices with a typical lens and sensor system including compact or DSLR cameras and tablet computing devices with built in cameras. The developed method could also see potential application and adaptation beyond the scope of insurance fraud to areas such as art fraud and copyright infringement.

The case scenario involving the detection of second-generation images for supporting insurance fraud investigations provided an excellent stage for the exploration of the strengths and values demonstrated by a criteria based approach for photointerpretation. Firstly, the implementation of a criteria based approach can add necessary structure and systemisation to photointerpretation tasks that in essence can be pursued arbitrarily by an examiner. By developing a set of criteria, a large complex problem or question can be broken down into smaller and more manageable components. This process can reduce error and maximise the repeatability of examination. In this example, the task of determining whether an image was second-generation was pursued through the detection of particular assessment criterion.

The process of defining and explaining the function of criterion and establishing whether said criterion can accomplish the purpose for which they were formulated instils a level of objectivity and assists the accessible communication of important aspects of the photointerpretation process.

As demonstrated by this investigation, the conclusion regarding whether an image is second-generation is ultimately subjective and reliant on individual judgement. Hence, maintaining transparency in the decision-making process, which is facilitated by a criteria based approach in this instance, is of upmost significance.

The communication of the interpretation process also needs to occur between further experts, legal professionals and jury members whose opinions of the process employed may be of legal importance. The transparency of the analysis process further imparts accountability to the examiner, which should on principle, be integral to all photointerpretation methodologies.

5.7 Chapter Conclusions

This chapter introduced a novel approach for the detection of second-generation digital photographic images captured by photographic devices, particularly camera phones, through the implementation of a criteria based analysis process.

The developed approach involved the interpretation of an image's authenticity through the holistic examination of the pictorial and metadata elements of a questioned digital photograph. This method was governed by a specifically devised criteria tailored towards the detection of specific artefacts that assisted analysis.

This work showed strong evidence to support the following hypotheses:

- A criteria based approach can provide a structured and logical framework for assisting image examiners with complex decision-making;
- A criteria based approach can assist to objectivise the photointerpretation process;
- A criteria based approach can provide a transparent methodology which can facilitate communication, testability, cross-examination and peer review of an otherwise subjective and internally inaccessible approach to evidence development.

The work also addressed the following questions:

- Are second-generation digital photographic images detectable?

  - Yes. This investigation found evidence to support that second-generation images can contain artefacts indicative of the rephotographing process.

  - Out of the 67 second-generation image samples examined as part of this study, all were found to contain at least 1 or more artefacts indicative of rephotographing.

- What are the strongest indicators useful for the detection of second-generation digital photographic images?

  - Although various artefacts were observed more frequently than others, each criterion developed as a result of this investigation holds equal weight for indicating whether an image is of second-generation.

  - The final set of criteria consisted of 10 pictorial and 7 metadata artefacts that can assist the forensic task of detecting photographic reproductions of hardcopy images.

- Can GPS metadata embedded in digital image file EXIF data play a role in the photointerpretation process?

  - Yes. GPS metadata has the potential to assist the detection of second-generation images. The usefulness of the data may depend on geographic information visible in the image. Image detection can be achieved through noticeable differences in geographical position between reported location of capture, GPS coordinates and visible geographical information. The results from this investigation showed recorded GPS coordinate accuracy remained within a mostly narrow range with the majority of data points located within 30 m and all recorded locations within 60 m of their location while operating under real world conditions.

- Can exposure values (EV) assist photointerpretation?

    - Yes, exposure values have been shown to be useful for assisting with the detection of second-generation images. Any conflict between an image's EV value, determined through an examination of image metadata and depicted lighting environment within the image can be indicative of a photographically reproduced image. Examining this artefact outside of controlled experimental conditions however, requires a questioned image to contain sufficient contextual information to identify the predominant source of lighting.

- Is the developed approach for detecting second-generation images dependable?

    - This investigation demonstrated the success of the assessment criteria method as a highly suitable approach for this type of forensic image analysis. The results of this study suggest that the probability of a rephotographed image captured with a camera phone not containing any second-generation artefacts is unlikely. This would suggest that the absence of artefacts indicates that an image is likely an original. However, the developed method cannot definitively prove such a position. Due consideration needs to be given to the potential risk that the absence of artefacts may not only be a consequence of originality but as a result of a high-quality copy that has negated the inclusion of artefacts. The findings of this study does provide insight into the likelihood of originality when examining suspected images captured by a camera phone device.

Finally, this investigation enabled the elucidation of the following values important for supporting the development of methodological based photointerpretation principles that were strongly demonstrated by the criteria based assessment approach:

- **Systemisation:**
    - A systemised approach to complex photointerpretation tasks can reduce chances of procedural error and maximise the repeatability of examination, greatly enhancing the reliability of developed evidence.
- **Transparency:**
    - Photointerpretation methodologies need to remain transparent to maintain the accountability of the analyst and to facilitate the clear and accessible communication of the interpretation process to interested individuals who might include triers of fact, legal professionals, experts or others concerned with photographic evidence. Transparency can further assist peer review and testing of any newly developed photointerpretation methodologies.
- **Justification:**
    - Clarifying the rationale behind why particular observations are helpful towards the overall purpose of the criteria/examination is useful for bolstering reliability.
- **Testability:**
    - Establishing whether photointerpretation methodologies can accomplish the purpose for which they were formulated is of significant importance. Being able to test the interpretation

process, or components of the process, instils a level of objectivity to an otherwise subjective endeavour.

The following chapters continue the development of key methodological and conceptual photointerpretation values and principles through the introduction and exploration of comparative image analysis.

Chapter 6

6.0 Methodological Approach: Comparative Image Analysis

Direct visual comparison is subjective and individual, and commonly places too much responsibility on lay jurors who cannot be expected to become forensic experts in the time allowed them in court.

Glenn Porter & Greg Doran [Porter & Doran 2000, p. 99]

In the preceding chapters, values relating to forensic photointerpretation stemming from a 'criteria based' approach for image analysis were explored and developed. This theme is continued throughout the following chapters through the elucidation and exploration of critical values inspired by a 'comparative image analysis' approach that are important for supporting forensic photointerpretation principles.

Forensic image comparison introduces a series of unique complexities to the photointerpretation process that require consideration if a comprehensive framework is to be established for supporting robust photointerpretation practice.

This chapter introduces the notion of comparative image analysis and provides an overview of the major theoretical concepts necessary for understanding the application of the approach to photographic evidence. This chapter also highlights several key challenges associated with the approach. Image comparison is further explored and unpacked through the following chapter's related case study investigation.

6.1 Image Comparisons & Forensic Science

The 'scientific working group on imaging technology' (SWGIT) defines forensic comparative image analysis as the systematic assessment of the similarities and differences between characteristics observed within photographic evidence or between a photograph and physical subject [SWGIT 2013].

The fundamental function of comparative image analysis involves identifying both agreeing and/or differing characteristics between subjects including the assessment of class and individualising features, for the overarching goal of developing an expert opinion regarding the establishment or exclusion of identity or case relevant information [Edmond *et al.* 2009; Porter 2011a; SWGIT 2012; SWGIT 2013; Vorder Bruegge 1999].

The comparison of photographic evidence is an important examination component for several forensic physical evidence fields including fingerprint, shoe mark, tire, tool mark and questioned document analysis. Photographic comparison is likewise a key methodological component of the forensic image analysis discipline and is employed for tasks including facial and body comparisons, comparisons involving subjects such as vehicles, clothing and weapons and for the authentication and identification of source cameras used for image capture [Porter 2011a; SWGIT 2013].

Comparative analysis is typically conducted through an examination between a primary item of photographic evidence, which usually consists of an unidentified subject, and a secondary item of photographic (or physical) source material where the identity/information about the subject has been established. Photographic evidence depicting unidentified subjects are referred to as questioned or unknown images. Evidence where identity (or fact) has been established are referred to as ground truth, known or exemplary material [Porter 2011a; Vorder Bruegge 1999].

For the express task of identification, ground truth is essential for the comparison process. Exemplary material (where truth has been established) is required to enable the potential exculpation or identification of an unknown individual or object depicted in questioned photographic evidence [Porter 2011a]. Comparisons between evidential sources depicting only unidentified subjects can also take place but the information obtained is not conducive to identification purposes. Rather, a comparative examination consisting of only unknown images may be valuable for intelligence development [Porter 2011a].

In a situation where an unknown serial offender has committed multiple offenses that have each been recorded on separate CCTV systems, comparative analysis could be used for criminal intelligence development. Comparative examination of photographic evidence sourced from various CCTV systems could be undertaken in an attempt to establish links between the repeated documented instances of the same unidentified person of interest alongside details concerning modus operandi, time, date and locational information. In other words, even if the offender cannot be identified, a clear relationship could be established between their person and alleged activities or offences. Such information could be useful for assisting future policing and investigatory work. This example reflects some aspects of the underlying concept behind the forensic intelligence model (application of forensic science techniques for the development of intelligence to assist law enforcement and defence functions outside of the typical court room environment) presented by the works of Ribaux *et al.* [2010], which demonstrates a similar process of intelligence development through examples involving information linkage derived from physical and trace evidence sources.

6.1.1 Issues Impacting Comparative Analysis

The overarching goal of comparative image analysis is the establishment or rejection of a relationship between two or more photographic subjects (or photograph to physical object). The technical nuances that govern the manner in which a valid relationship can be determined is a current focus of contemporary academic research.

Despite a unified understanding regarding the general approach to photographic comparison, several scholarly sources call for caution when comparative evidence is presented within the legal environment, especially as facial identification evidence. Scholars contend that facial based photographic evidence can be considered unreliable due to the lack of validation studies or standards governing the forensic comparison techniques currently demonstrated in the courts. This lack of scientific rigor coupled with unsound expert testimony is strongly purported to result in the presentation of unfairly prejudicial evidence to triers of fact; a dangerous scenario that has the potential to impinge on the fundamental principles of justice and equality that underpin a fair trial [Edmond 2013; Edmond & San Roque 2013; Evans 2014; Porter & Kennedy 2012; PCAST Report 2016].

Researchers examining the field of forensic image comparison have called for further advances regarding the methodological approaches employed for comparative image analysis in order to bolster objectivity and ascertain standards in practice. The literature suggests that more research is needed to enhance our understanding of photographic comparison techniques and the parameters that define characteristics useful for comparative purposes, as well as the enhancement of the fair recognition, valuation and communication of their associated significance, particularly in regards to facial identification evidence [Edmond 2013; Edmond *et al.* 2009; Edmond & San Roque 2013; Evans 2014; Mallett & Evison 2013].

6.1.2 Complexity of Comparative Image Examinations

The level of complex detail involved in real world cases requiring comparative image analysis can vary significantly. Cases can range from relatively straight forward queries that involve a low level of complexity, where ordinary visual literacy (i.e. our ability to read and understand imagery developed through our exposure to the visual norms associated with everyday life) could be considered sufficient to enable a fair evaluation of evidence; to complex scenarios where technical knowledge of photographic and imaging science are required for in-depth expert consideration [Edmond & San Roque 2013; Porter 2007].

A hypothetical example involving a less complex or more straightforward requirement for interpretation could be a simple vehicle identification case. Such a scenario could involve the comparison of two sharply resolved high resolution images depicting registration plates on two similar appearing vehicles. A visual examination of the images would yield whether the alphanumeric characters displayed on the registration plates are one and the same, therefore confirming or rejecting the identification or linkage of the vehicle.

An example of a more complex comparative image based photointerpretation scenario is the case of the bank robbery described by Vorder Bruegge [1999]. Image comparison was employed to compare footage of a bank robber wearing denim trousers at the time of the incident to that of a suspected seized denim garment. Vorder Bruegge explains that numerous technical considerations were required when undertaking the comparison including the development of an understanding regarding how denim garments develop class and individualising characteristics and consideration of the photographic systems used for image capture, both at the bank and in the laboratory studio (for the production of exemplar material). Vorder Bruegge stated the necessity to ensure that the image capturing systems used for the original bank footage and the in-studio reconstruction did not introduce any degrading artefacts that could impact analysis. Vorder Bruegge further stressed the necessity for the imaging systems involved in the comparative process to be comparable in all aspects including lighting conditions, resolution, focal length, perspective and recording medium to ensure that a one-to-one comparison, a process that facilitates the fair assessment of compared photographs by replicating similar conditions in both images, could be closely approximated. Vorder Bruegge concluded that the questioned and suspected garments were one and the same based on the examination of the photographic evidence and their developed knowledge regarding denim garments and feature development.

A widely echoed maxim within the literature concerning forensic image analysis is that the level of expertise and knowledge of the analyst conducting an examination is considered integral for ensuring sound practice and evidence development [Edmond *et al.* 2009; Porter 2007, 2011a; SWGIT 2012; SWGIT 2013].

The SWGIT [2013] guide states the following requirement concerning specialised knowledge for image analysis purposes. The condition is presented within the section of the guide concerned specifically with comparative image analysis:

> *Before conducting forensic photographic examinations, individuals should have expertise in a number of areas. The most critical of these are image science, subject matter expertise, and the science of individualization [SWGIT 2013, p. 4].*

Certainly, considering the above examples, the call for analysts with specialised knowledge for performing comparative analysis tasks can be appreciated. Vorder Bruegge [1999] appears to support such a notion through their allusion to the importance of photographic and task specific knowledge:

> *As a final caution, the importance of experience and training in the conduct of examinations such as this cannot be underestimated. Without a good working knowledge of the photographic process, an inexperienced individual might misinterpret a simple difference in perspective or a defect in the film as true differences in the shape, size, or characteristics of a photographed object when compared with an item of evidence. Similarly, without an understanding of the means by which clothing is manufactured and the means by which class and individual identifying characteristics are generated, an individual could misinterpret the significance of a given characteristic or set of characteristics and reach an incorrect conclusion. To avoid these problems, individuals should receive extensive training prior to conducting examinations on actual casework [Vorder Bruegge 1999, p. 621].*

Despite the recognised requirement for expertise with specialised knowledge within the literature, Edmond & San Roque [2013] highlight the fact that this condition is not always recognised by the courts (who continue to rely on the capability of the lay person) when considering photographic evidence requiring comparison:

> *Notwithstanding the increasing reliance on 'experts', courts continue to assume that lay people are conversant with the visual medium, and both judges and fact-finders tend to believe that they are able to attach meaning or significance to images far more reliably than experimental studies suggest [Edmond & San Roque 2013, p. 258].*

On the other hand, a number of legal cases involving photographic comparisons and 'experts' have been observed that have highlighted significant gaps or an under appreciation of the critical requisite knowledge important for conducting sound forensic comparative image examinations; i.e. lack of a technical photography and photographic science understanding.

Porter [2007] conveyed the following caution when describing the application of photographic evidence within the legal environment at the time of their publication:

> *Extrapolating concepts of interpretation, identification, intelligence and physical evidence requires a more complex application of visual cultural concepts than that is currently employed in forensic science [Porter 2007, p. 88].*

The recent legal cases of *Morgan v R* [2011] and *Honeysett v R* [2014], each concerned with whether the defendant was the suspect robber depicted in related CCTV footage, attest to the warning purported by Porter. These cases provide marked examples of the dangers of expert witness evidence that does not adequately consider or utilise an appropriate level of photographic knowledge obligatory for the photographic comparison tasks undertaken. The expertise in both cases were recognised by the courts as being unreliable. The expertise consisted of anatomists providing identification evidence concerning anatomical similarities based on information available in the photographic evidence without consideration of a number of important image interpretation concepts [Edmond *et al.* 2014; Edmond & San Roque 2013; Edmond & San Roque 2014].

Scholars continue to push for the stronger recognition of the need for relevant and appropriate expertise when presenting photointerpretation evidence in courts or legal contexts [Edmond 2013; Edmond *et al.* 2009; Edmond & San Roque 2013;

Edmond & San Roque 2014; Evans 2014; Mnookin 1998; Porter 2007, 2012, 2013; Porter & Kennedy 2012].

The aforementioned challenges highlight several key complexities in the field of forensic comparative image analysis. Careful consideration is needed of the varied intricacies that impact image comparisons in order to bolster the development of future comparative evidence techniques.

6.2 Current Frameworks for Conducting Comparative Image Analysis

There are no universal standards that presently preside over forensic comparative image analysis techniques or practices. However, several prominent theoretical and pragmatic approaches currently exist that underpin the majority of comparative tasks. These approaches have been adopted broadly throughout industry.

6.2.1 Theoretical Frameworks

All comparative image analysis procedures attempt to address the following fundamental questions regarding questioned and exemplar photographic evidence items compared during examination:

- Are there any differences or inconsistencies between comparable characteristics or features exhibited by each of the subjects depicted in the examined items of photographic evidence?

- Are there any corresponding, identical or similar features between the subjects depicted within the examined items of photographic evidence?

- What is the evidential significance of any such observations?

Despite the lack of any universal comparative image analysis standards, according to the SWGIT [2013] guideline document:

> *A commonly accepted protocol applied to photographic comparisons is ACE-V (Analysis, Comparison, Evaluation – Verification). Not all photographic comparisons invoke this protocol. It is commonly invoked in footwear impression and fingerprint examinations, but it is uncommon in medical*

> *image evaluation and in photogeology. Some practitioners use a formalism referred to as "ACE-VR", which adds a "Report" phase. Other practitioners, such as physicians, do not use ACE-V but instead use conceptually similar approaches appropriate for their discipline [SWGIT 2013, p. 2].*

The 'ACE-V' protocol is typically employed for comparative forensic examinations involving pattern matching; the process of examining often complex visual formations in order to differentiate or identify objects/subjects such as fingerprint analysis which is the most common application [Dror & Cole 2010].

Within the ACE-V framework the 'analysis' phase of the protocol involves an overall assessment of the photographic evidence. The assessment includes the identification of characteristics helpful for analysis (i.e. class and individual features) and an evaluation of the properties of the photograph including quality, resolution, framing and lighting to identify any factors that may have an impact on examination.

The 'comparison' phase involves a cognitive analysis that investigates the degree of agreement or disagreement between observed corresponding features between evidence items.

The 'evaluation' phase is concerned with the development of a final conclusion regarding the photographic evidence based on the findings of the 'comparison' phase. Factors such as the degree of correspondence or differentiation between examined features and possible explanations for such observations are considered during the development of the conclusion.

The final 'verification' phase involves the validation of the comparison through an external examination of the results obtained from the investigation by an independent analyst in order to determine the validity and reproducibility of the examination [SWGIT 2012; Vanderkolk 2009].

The ACE-V framework was established to assist the detection of important visual characteristics and support the understanding of the significance of detected image details when used for comparative purposes, based on the skills and understanding of the examiner and wider community of external experts [Vanderkolk 2009]. ACE-

V appears to provide some level of reliability and objectivity to an otherwise completely subjective comparison process. However, the approach in-itself is not an entirely adequate solution to the challenges faced when comparing subjects depicted in photographs.

Edmond *et al.* [2014, p. 189] highlight the critical limitations of the ACE-V framework by drawing attention to comments made in the National Research Council of the National Academy of Sciences Report (NAS Report) 2009 titled *'Strengthening Forensic Science in the United States: A Path Forward'*; a report compiled by the NAS, as directed by the United States Congress, to assist the recognition of improvements required by the U.S. forensic science community. The NAS Report [2009] concludes the following regarding the ACE-V protocol, albeit in the context of fingerprint analysis:

> *ACE-V does not guard against bias; is too broad to ensure repeatability and transparency; and does not guarantee that two analysts following it will obtain the same results [National Research Council 2009, p. 142].*

Further investigation into frameworks for comparative image analysis revealed Porter's [2011a] *'A new theoretical framework regarding the application and reliability of photographic evidence'*. The work explains that the physical evidence examination process of comparative analysis can be extended and applied to photographic evidence through the application of physical evidence comparison processes to images that fall under their definition of the 'analyse' and 'witness' photographic evidence 'modes of inquiry' categories.

Porter describes the 'analyse' category as encompassing photographic evidence that can be considered as legitimate substitutes for physical evidence. 'Analyse' forms of photographic evidence are those that can be examined to extract spatial details (dimensional measurements) and visual features significant to comparative examinations, as is equivalently possible with physical evidence items. In fact, photographic evidence might be considered more advantageous to examine due to the potential to enhance the visibility of details through photographic and image processing and adjustment techniques. One particular caveat of the 'analyse' mode is the requirement for image capture to be undertaken in a strictly controlled manner in order to ensure evidence integrity and assist the maximisation of detail. This notion is expanded further within this chapter in the section 'Controlled & Uncontrolled Acquisition of Photographic Evidence'.

'Witness' mode images are described by Porter as evidence sourced from media providing an eye-witness style account of events such as CCTV, camera enabled mobile phones and personal cameras. Such evidence can be subjected to an array of physical evidence examination methods including comparative analysis, however Porter urges great caution when analysing this type of evidence because of the uncertainty introduced by the uncontrolled image capturing process.

6.2.2 Practical Frameworks

Two key practical methodological approaches underpin several image comparison techniques. One of the primary techniques that underpins numerous comparative image analysis processes is the 'side-by-side' comparative method.

The SWGIT guidelines [2012] state:

> *Photographic comparisons are frequently referred to as "side-by-side" comparisons since they usually involve a comparison of class and individualizing characteristics in imagery [SWGIT 2012, p. 3].*

The information communicated by the SWGIT [2012] guideline is referring to a particular technical aspect of photographic comparison methodology where two images are examined visibly adjacent to one another in order to assist the visual assessment of corresponding features. Jayaprakash [2013] explains that the 'side-by-side' approach is often adopted for the examination of pattern evidence stemming from flexible three-dimensional sources such as fingerprints which do not benefit from an 'overlay' type examination (the 'overlay' method being the other key technique underpinning comparative analytical methods).

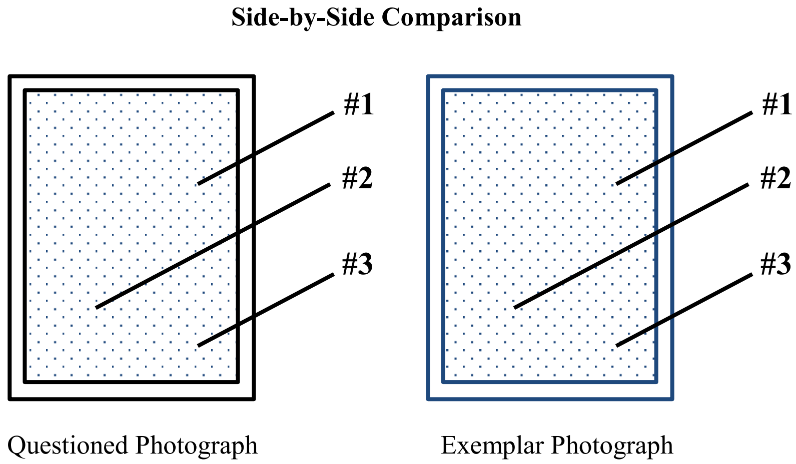


Figure 6.1: Diagram illustrating the concept of 'side-by-side' comparative image analysis. Photographic evidence undergoing examination are simultaneously displayed next to each other to aid the visual examination of dissimilar or corresponding features.

A 'side-by-side' comparison is valuable for highlighting corresponding features between exhibits (Figure 6.1) particularly when the relative relationships between characteristics (e.g. position, orientation) are of greater importance to the analysis than spatial relationships. This concept is of particular relevance to fields such as fingerprint analysis because of the inherent plasticity exhibited by friction ridge skin which is responsible for fingerprint pattern deposition. Each print impression deposited from the same friction ridge skin (i.e. fingerprint) will result in an impression whose characteristics appear somewhat spatially different due to distortions introduced to the skin itself from the various physical variables that affect fingerprint deposition such as changes in pressure and the physical properties of the deposition substrate receiving the print [Dror & Cole 2010]. Hence, the evidential value of the analysis resides in the establishment of corresponding relationships exhibited between characteristics observed within the questioned and exemplar evidence items. Similarly, side-by-side comparative methods are useful when comparing other forms of evidence whose evidential value is affected by the relationships observed between corresponding or dissimilar characteristics, such as facial morphological analysis.

The 'overlay' or 'superimposition' technique involves placing one image on top of the other while aligning the images based on points of correspondence (Figure 6.2).

The two images can then be revealed in various proportions either statically or through the use of wipe, swipe or blink modes which affect the opacity of the overlaying image in various ways, assisting the comparison process. A wipe or swipe reduces the opacity of the overlaying image along one side of a defined boundary. Wipes can be static or consist of a gradual transition between images along a moving boundary, the latter mode being dubbed a swipe or video fade. Blinking involves cyclically rendering the overlaying image visible or invisible [Edmond *et al.* 2009; Evans 2014; Jayaprakash 2013; Strathie & McNeill 2016].

Aulsebrook *et al.* [1995] provides the following insight into the evolution of the technical instrumentation necessary for the implementation of the superimposition method:

> *In retrospect, superimposition can be seen to have passed through three phases. The first made use of viewing boxes, slide projectors and overhead projectors. The next phase introduced video technology and its capacity for a variety of electronic superimpositions and comparisons. The third incorporated the analytical potentials of computer graphics [Aulsebrook et al. 1995, p. 102].*

Contemporary superimposition techniques typically take advantage of digital imaging, modern computer systems and off the shelf image and video editing software such as Adobe® Photoshop® and Final Cut Pro® [De Angelis, Cattaneo & Grandi 2007; Silva *et al.* 2015; Strathie & McNeill 2016].

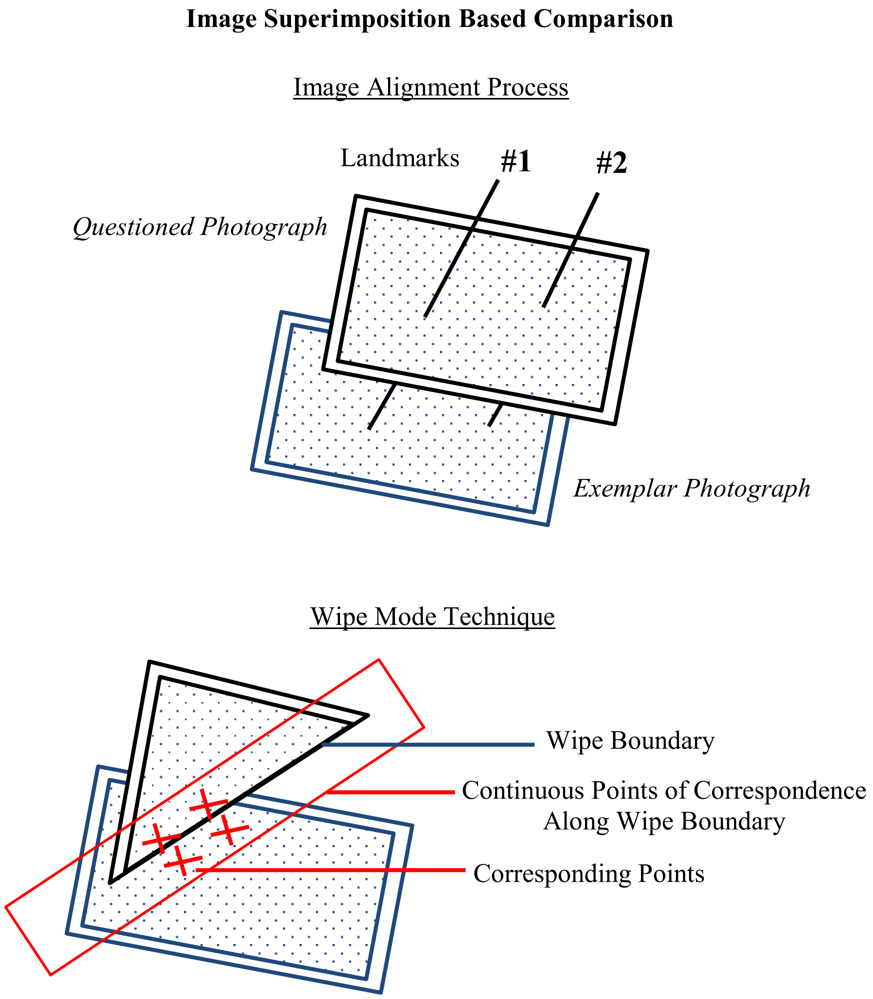


Figure 6.2: Diagram illustrating the 'overlay' or 'superimposition' comparative image analysis technique. Images are overlayed and aligned based on landmark locations. The opacity of the topmost image is adjusted to reveal details of the image underneath. Points of correspondence are revealed along the wipe boundary.

The superimposition technique has seen application in a number of forensic areas. The technique originated as an anatomical method for assisting the identification of unknown skulls. Superimposition was intended to provide a way to enable a link between an unidentified skull to a facial image of a known individual (cranio-facial superimposition) through the detection of a sufficient number of corresponding anatomical features. The method extended to the consideration of specific anatomical features such as dentition. Superimposition has also been used in an attempt to identify unknown individuals depicted in images or footage through a similar approach, but instead using two facial images as the sources of comparison.

Lastly, the superimposition technique has been employed to assist the examination of footwear impression evidence. In footwear analysis cases, a questioned or exemplar shoe impression can be physically overlayed over another impression through the use of a transparency, facilitating the visual identification of any corresponding or dissimilar characteristics [Aulsebrook *et al.* 1995; Bodziak 2000; De Angelis, Cattaneo & Grandi 2007; Evans 2014; Gordon & Steyn 2016; McKenna, Jablonski & Fearnhead 1984; Miranda *et al.* 2016; Silva *et al.* 2015].

Jayaprakash [2013] argues that the strength of a comparative approach such as superimposition stems from its ability to reveal continuous points of correspondence along the entire axis of the boundary made evident by a wipe, providing evidence with far greater significance than what could be communicated through the process of counting individual instances of correspondence, which is the typical mode of evidence development encountered in other comparison methods. However, the study by Strathie, McNeill & White [2012] has cautioned against the use of static 'chimeric' superimposition composites (combination of two source images) for facial identifications as it was found that the process reduced the accuracy of identification. Strathie & McNeill [2016] also warn that not only can static superimposition images be misleading, presenting gradually transitioning video wipes to triers of fact has also been shown to increase the rate of false positive identifications. A similar notion is suggested by Evans [2014] who claims that animated superimposition techniques 'can create an 'illusion' of similarity' [Evans 2014, p. 227].

6.2.3 Controlled & Uncontrolled Acquisition of Photographic Evidence

A distinction lies between the manner in which an image is captured and the level of reliable information that can be extracted from the image during a comparative visual examination. Photographic evidence can either be captured in a controlled or uncontrolled manner.

A controlled photograph is an image captured under strict photographic conditions that can be directly influenced by the photographer. Several important photographic parameters should be controlled by the photographer in order to optimise image detail and minimise detractors of quality such as distortion and artefacts. This is of particular importance to pattern matching fields such as fingerprint, shoe print and tool mark analysis which rely heavily on the quality of the information provided by the photograph during analysis [Edmond *et al.* 2009; Porter 2009b, 2011a].

Porter [2009b] and Porter [2011a] explain that the following parameters require careful consideration when photographing a subject to ensure high quality evidential images:

- Image contrast, sharpness and resolution;
    - Photographs must be resolved sufficiently to enable the visualisation of individual characteristics useful for identification purposes.
    - Utilisation of high quality optics, correct camera focus and consideration of appropriate aperture, shutter speed and ISO settings for maximised detail, depth of field and minimal distortion from camera shake and image noise.
    - Use of appropriate lighting techniques including external flash, reflectors, diffusers and specialised lighting tools such as monochromatic collimated light sources, to ensure correct exposure, maximisation of feature visibility and control of shadow and highlight regions that may impact contrast and tonal range.
- Dimensional integrity;
    - Photographs must be captured in a manner which minimises errors in dimensional representation.
    - Utilisation of a lens that minimises the effects of distortion such as a macro lens.

  - Appropriate use of linear scales to accurately represent size and assist with the detection of distortion.

  - Photographic capture must be undertaken with the camera positioned with the film/sensor plane parallel to the subject in order to minimise rectilinear distortion due to changes in perspective.

- Colour accuracy;

  - Photographs must be captured and displayed in a manner which most accurately represents the original colours of the scene/subject.

  - Use of correct camera white balance settings, appropriate digital image file colour space selection and consideration of file type, compression rate (preferred lossless or no compression formats) and bit depth to record accurate colour information.

  - Utilisation of a calibrated display, appropriate gamma settings and colour management software when viewing and displaying images in a digital format.

- Further Considerations.

  - Camera metadata settings (e.g. date/time) should be appropriately set to assist analysis and the maintenance of evidence integrity.

  - All enhancement procedures including digital image adjustments must be transparent and recorded in a format that assists reproducibility, such as through contemporaneous note taking.

An uncontrolled photographic capture is one where such parameters are not taken into consideration or controlled by the photographer at the time of image recording. Again, examples of sources of uncontrolled images relevant to forensic investigations include CCTV systems, camera phones and personal compact cameras.

Differences between controlled and uncontrolled photographic capture are necessary to understand because of the impact various photographic parameters can have on analysis and interpretation.

When examining controlled images, any observed differences or similarities regarding features or characteristics are less likely a result of an artefact and more likely a genuine visual phenomenon. If a photographer has the requisite knowledge and ability to control the variables that influence the capture process, important evidential details can be targeted for enhanced visualisation which can improve evidence recovery and aid analysis. Furthermore, a controlled photographic capture is more receptive to the implementation of standard practice and systematic improvements to photographic evidence recovery techniques that may be developed or enhanced through further research and experience.

Images obtained in an uncontrolled manner have comparably lower quality and cannot be subject to the same stringencies and advantages as controlled forensic photographs. Controlled images often provide less sources of error and are more likely to support valid interpretations. Uncontrolled images are highly variable in quality and require caution and vigilance when examining.

6.3 Questions

This chapter presented relevant background knowledge and highlighted key gaps in understanding necessary for the exploration of the following research questions:

- Can key conceptual and pragmatic principles for forensic photointerpretation methodologies be elucidated from examining the comparative image analysis process?

- If so, what values integral for developing photointerpretation principles are exemplified and/or inspired by comparative image analysis for supporting forensic image examination methodologies?

6.4 Chapter Summary

This chapter introduced the notion of comparative image analysis and provided an overview of key theoretical concepts necessary for understanding the application of comparative methods to photographic evidence. The chapter further explored difficulties associated with image comparisons highlighting the complexities and intricacies that effect this particular area of photointerpretation.

At present, there are no universally recognised standards for forensic comparative image analysis tasks but several prominent frameworks and methodological approaches are repeatedly encountered within the literature, namely the ACE-V framework, side-by-side and superimposition comparison techniques. Comparative image analysis processes are subjected to further complexities when applied to photographic evidence obtained in an uncontrolled manner, which is often typically the nature of evidence involved in forensic investigations. Comparative image concepts are further explored and unpacked through the following chapter's related case study investigation.

Chapter 7

7.0 Case Study: A Question of Hitler?

It seems that a singular and universally accepted method of facial comparison is still a long way off. There is still debate whether facial comparison will continue to be used in its present form, disappear altogether or emerge as a combination of technology and agreed scientific terminology.

Ray Evans [Evans 2014, p. 230]

The previous chapter introduced comparative image analysis as a forensic photointerpretation approach. This chapter further investigates image comparisons through the application of comparative image analysis techniques to a unique case study. The case demanded a focus on the comparison of facial information. The study enabled first-hand insight into the capabilities and difficulties associated with forensic image comparisons, facilitating the contemplation of values exemplified by the process of comparative image analysis for supporting the development of photointerpretation principles.

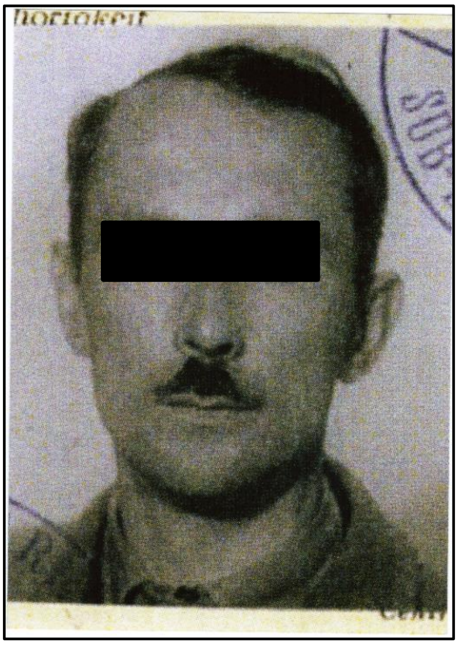
7.1 Case Background

A member of the public (who shall remain anonymous) requested an expert opinion regarding the identity of two individuals depicted in 'passport-size ID photographs' they had obtained as part of documentation relating to their personal research endeavours. The 'enquirer' believed the photographs depicted Adolf Hitler and Eva Braun [Anonymous Enquirer, Personal Communication, October 7, 2012].

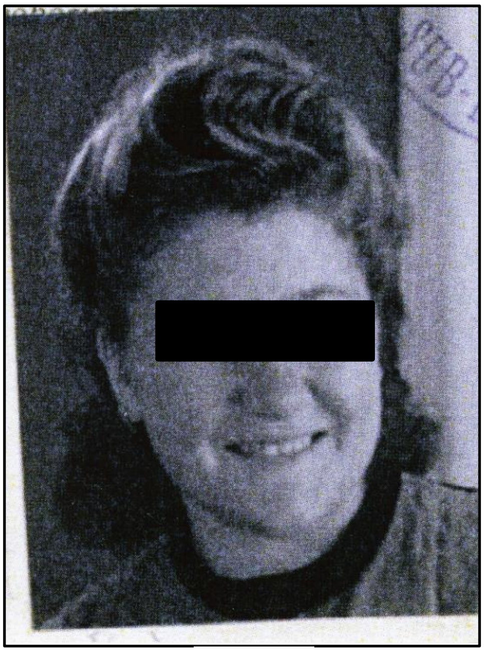
Upon agreement to examine the questioned images, the following documentation was provided for analysis by the enquirer:

- 1x A4 sized white sleeveless cardboard pocketed folder (labelled "AH & EB") containing the following items:
    - 1x A4 typed and signed letter of correspondence;
    - 1x questioned 5 x 7-inch photographic print of unknown individual (suspected to be Adolf Hitler);
    - 1x questioned 6 x 8-inch photographic print of unknown individual (suspected to be Adolf Hitler);
    - 1x questioned 5 x 7-inch photographic print of unknown individual (suspected to be Eva Braun);
    - 1x questioned 6 x 8-inch photographic print of unknown individual (suspected to be Eva Braun);
    - 6x printed images (on standard A4 printer paper) allegedly depicting Adolf Hitler from unknown internet sources;
    - 3x printed images (on standard A4 printer paper) allegedly depicting Eva Braun from unknown internet sources.

All questioned photographic prints were reported to be enlargements made from 3.5 x 4.5 cm ID photographs.



QA



QB

Figure 7.1: Questioned images provided for examination. Photograph 'QA' depicts an individual believed to be Adolf Hitler and photograph 'QB' depicts an individual believed to be Eva Braun by the inquirer. [Not to scale].

Please Note: The questioned images presented within the published version of this thesis have been censored to maintain the privacy of the individuals depicted.

Who were Hitler and Braun? Adolf Hitler (1889-1945) was the infamous German Chancellor and Fuehrer who lead Nazi Germany into World War II (1939-1945). Eva Braun (1912-1945) was his love interest who later became his wife shortly before their alleged double suicide nearing the conclusion of the war [Görtemaker 2011].

Facial recognition research suggests that a level of familiarity with a face increases the likelihood of successful identification even when involving low quality images, whereas unfamiliarity tends to result in significantly inaccurate recognition and identification performance [Bruce *et al.* 2001; Burton *et al.* 1999; White *et al.* 2014]. What makes this case interesting is despite widespread familiarity with the historical figure of Hitler, it is difficult to readily dismiss the questioned image. This highlights the importance of employing a photointerpretation approach when examining questions of recognition, even when involving identities that are well known.

7.2 Aims & Objectives

The primary **aims** of this chapter are to:

- Unpack photointerpretation concepts involved in forensic comparative image analysis;

- Explore photointerpretation values stemming from a comparative image analysis methodological approach integral for the establishment of a critical forensic photointerpretation principles.

This chapter achieves its aims through the realisation of the following **objectives**:

- Examination of a case involving historical photographs believed to depict Adolf Hitler and Eva Braun with a focus on photointerpretation concepts linked to facial image comparison techniques;

- Exploration of morphological analysis as a tool for assisting the comparison of facial information;

- Exploration of image superimposition as a tool for assisting the comparison of facial information;

- Investigation of a comparison approach based on facial symmetry to assist with suspect exclusion.

7.2.1 Note Concerning Photographic Evidence Examination and Presentation

Exemplar and questioned images examined during the course of this investigation were analysed at their original sizes and not at the down sampled sizes presented in this thesis. As a consequence of fitting diagrams to the page space available, a degradation in image quality may be evident.

7.3 Questions

The primary inquiry driving this case study is:

- Do the two questioned evidential photographs depict the identities of Adolf Hitler and Eva Braun?

The following **questions** were also investigated. Can the following techniques be considered useful for assisting photointerpretation?

- Morphological analysis;
- Photographic superimposition;
- Facial symmetry comparison;

7.4 Forensic Photointerpretation Methods for Facial Comparisons

Several major comparative image analysis techniques are presented within the literature for examining facial images for the purposes of identification or exclusion [Edmond 2013; Edmond *et al.* 2009; Edmond *et al.* 2010; Evans 2014; Mallett & Evison 2013; Porter & Doran 2000; Prince 2012].

These techniques include:

- Facial morphological analysis;
    - Analysis based on the examination and comparison of individual facial features one at a time.
- Photographic superimposition;
    - The aligning and overlaying of facial images with various adjustments to the opacity of the uppermost image to assist comparison.

- Facial symmetry;
    - Comparison of faces based on a split along the sagittal plane or left-side/right-side of the face.
- Photo-anthropometry or facial measurement.
    - The measurement, quantification and comparison of distances, angles and ratios between various facial landmarks.

The above image based facial comparison techniques were explored in this thesis excluding photo-anthropometric measurement. The underlying goal of each of the listed techniques is to assist an analyst making a comparison between exemplar and questioned photographic evidence when facial information is the primary focus or source of information.

7.5 Obtaining Exemplar Material for Comparative Image Analysis

Suitable exemplar material is necessary to enable effective comparative image analysis, therefore, exemplar material was required to be sourced preceding examination.

Despite the absence of mainstream protocols or standards for comparative photographic examination, the literature suggests a key axiom concerning the properties and suitability of ground truth material for comparison; the requirement for a ‘one-to-one’, ‘like-for-like’ or comparable series of photographs to be utilised as exemplar evidence during comparative examination [Denny 2015; Edmond 2013; Porter 2009a, 2011b; SWGIT 2013; Vorder Bruegge 1999].

This axiom translates to the need to have ground truth material with photographic properties that closely mirror those of the questioned photograph under investigation. These include obtaining an exemplar image with matching framing, perspective, lighting, ‘u’ distance, camera focal length and spectral sensitivity. This is necessary because such factors have a significantly noticeable influence over the appearance of visual information within an image. A further requirement for exemplar material is to obtain images that are free from image artefacts that may detract from analysis such as noise, flare, incorrect exposure, distortion, and compression artefacts [Edmond *et al.* 2009; Porter 2011a]. Due to these requirements needed to provide best evidence, the comparison material submitted alongside the questioned images by the inquirer was not considered of a quality suitable for analysis. It was necessary to independently source exemplar material to enable the various comparative techniques undertaken as part of this study.

Without being able to control the photographic process for obtaining ground truth material, exemplar images were sourced via image search databases (e.g. Google Images™) primarily based on subjects featuring a similar forward facing (*norma frontalis*) pose as the subjects depicted in the questioned evidence. All exemplar images were adjusted to remove associated colour casts which might have distracted from examination, resulting in each image being presented in grey scale. Exemplar images were also cropped to focus on the facial area in order to assist examination and presentation of results. Each image was examined at original size during the analysis process.

The following images were selected as exemplar material for the comparative examination of the alleged ‘Adolf Hitler’ questioned image:

H1

H2

H3

H4

H5

H6

H7

H8

Figure 7.2: Exemplar photographic material (H1-8) for ‘Adolf Hitler’. [Not to scale]. For image sources see Appendix C.

The following images were selected as exemplar material for the comparative examination of the alleged 'Eva Braun' questioned image:

Figure 7.3: Exemplar photographic material (B1-8) for 'Eva Braun'. [Not to scale]. For image sources see Appendix C.

7.6 Limitations Imposed by Examined Photographic Evidence

The properties of the exemplar and questioned material involved in this case impose several limitations that affect the scope and significance of the forensic photographic techniques that can be applied to examine evidence and address questions regarding identity. These limitations are highlighted below.

The following limitations are a consequence of the notion that the **questioned material** submitted for examination **supposedly** depicted **historical figures**:

- It is impossible to obtain any new questioned photographic material to assist examination;
  - Assuming that the questioned photographs are genuinely from the time period suggested (e.g. circa 1939-1945 or around the time of WWII), the people depicted in the questioned photographs would probably be no longer present in our current time period to enable the capturing of new exemplar facial photographs. If the subjects do happen to still remain, they would have significantly aged and therefore greatly different in appearance, rendering the process of obtaining new comparable exemplar material ineffective.
- No metadata is associated with the evidence that can be retrieved to assist examination.
  - The questioned images are not of a digital format and were suggested to have been captured with a film medium. Therefore, no image metadata is associated with the evidence that can be retrieved to assist examination.
  - Parameters that can impact photointerpretation remain unknown such as subject to camera ‘u’ distance and lens focal length.

The following limitations are attributed to the fact that sourced **exemplar material** depicted **historical figures** for comparison:

- It is impossible to obtain any new exemplar photographic material to assist examination;
  - The historical subjects required for the exemplar material are affected by limitations similar to those of the questioned material; the subjects are no longer present in this current time period or if they happen to still remain (despite historical documentation), they would have significantly aged and therefore greatly different in appearance.
- No metadata is associated with exemplar material that can be retrieved to assist examination;
  - Exemplar images of the historical figures are film based and therefore no digital metadata associated with the evidence can be retrieved to assist examination.
- The identities of the subjects depicted in exemplar material supposedly portraying the historical figures of interest cannot be verified.
  - Due to the nature of the source used to obtain exemplar material and the potential for said historical figures to have employed security measures, the identities of the individuals supposedly depicted in exemplar material cannot be conclusively verified.
  - The primary source used for obtaining exemplar material was through internet image search engines. Although online sources are not typically considered reliable repertoires of forensic evidence, they provided the most convenient access to photographs relevant to this investigation. Furthermore, the relative notoriety of the historical figures under examination added another level (albeit a somewhat weak one) to the

recognition of potentially relevant source material compared to an examination of person(s) completely unknown to the examiner, as is the case with typical forensic examinations.

- The previously mentioned notion of potential security measures employed by historical figures was alluding to the service of body doubles. It is not inconceivable to imagine that a high profile political figure, such as Hitler or Eva could have then utilised body doubles or 'doppelgangers' at various times throughout their time in power. Due to this possibility, it is difficult to authenticate photographs, even supposedly official photographs depicting Hitler or Braun.

- For the purposes of this investigation, exemplar images supposedly depicting Hitler and Braun are assumed to faithfully depict said individuals.

This investigation focused primarily on the exploration of principles stemming from the methodological approach of comparative image analysis rather than a sole focus on the end results of the comparative techniques employed throughout the investigation. If the authenticity of ground truth material was paramount to this thesis, as it should be in real world forensic case work, authentic source material useful for comparison could be obtained through official channels such as from photographic archives of reputable historical museums.

The following section provides a summary of the unknown properties related to the questioned and exemplar photographic evidence that could have an impact on analysis.

The following photographic properties remain **unknown** regarding the **questioned images**:

- Lens focal length;
- Shutter speed;
- Aperture;
- Camera type;
- Film type;
- Subject to camera distance (‘u’ distance);
- Lighting conditions;
- Time and date of capture;
- Location of capture;
- Application of image editing/retouching.

The following photographic properties remain **unknown** regarding the **exemplar images** sourced for comparison:

- Lens focal length;
- Shutter speed;
- Aperture;
- Camera type;
- Film type;
- Subject to camera distance (‘u’ distance);

- Lighting conditions;
- Time and date of capture;
- Location of capture;
- Application of image retouching;
- Verified identity of depicted subjects (assumed Hitler & Braun for the purposes of this investigation).

7.7 Morphological Analysis

Photographic based facial morphological analysis is a technique that attempts to identify an individual depicted in an image through the qualitative evaluation of facial information. Morphological analysis focuses on the determination of identity through the independent and systematic comparison of differing or corresponding facial features detected in analogous photographs.

Characteristics such as the size, shape, orientation, position and colour of observed facial features are utilised to assist assessment. Additional features such as skin blemishes, scarring, ear morphology or wrinkle patterns can further support examination [Edmond *et al.* 2009; Evans 2014; Mallett & Evison 2013].

7.7.1 Method

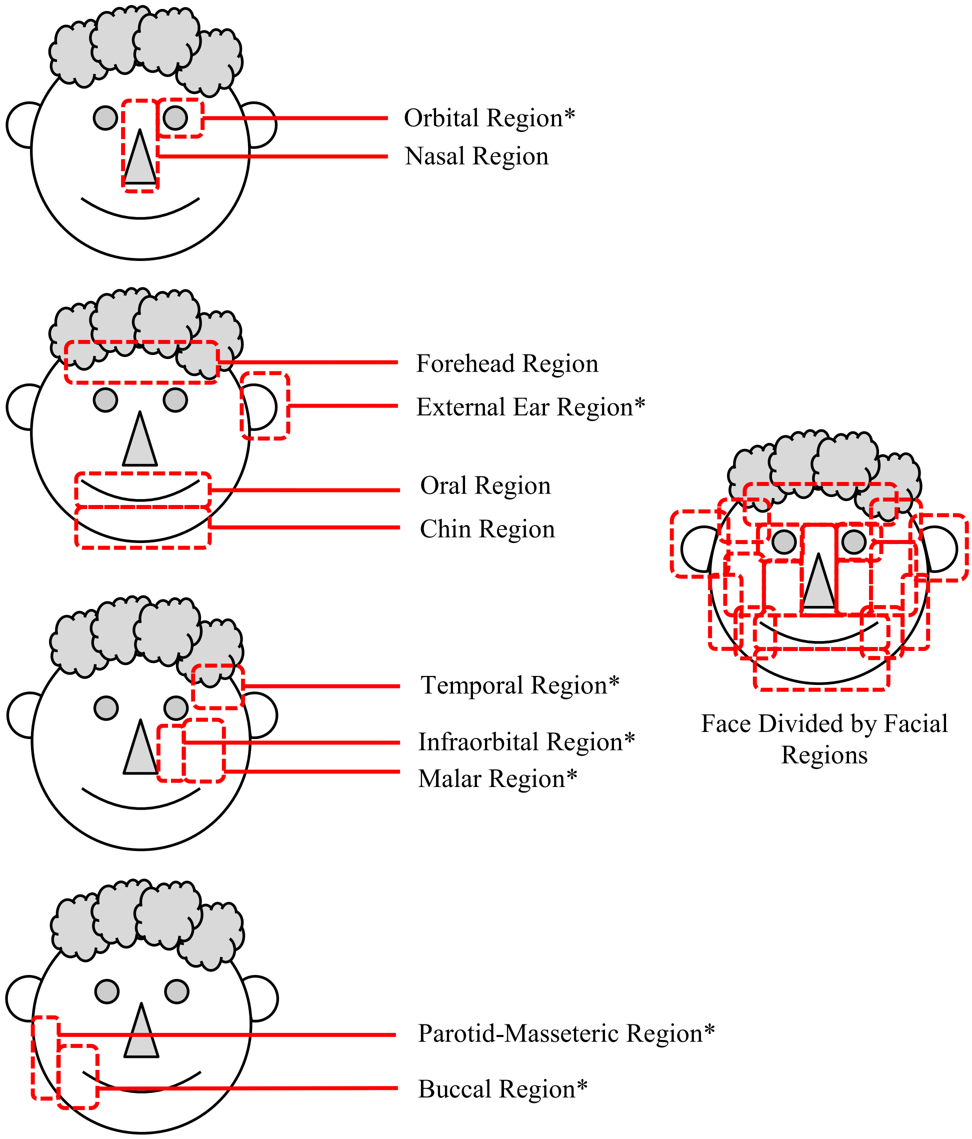
The morphological analysis approach was employed to assist the determination of whether the questioned images investigated within this case depicted the identities of Hitler and Braun.

The first aim of any comparative analysis should be to determine if an elimination or exclusion can be made [Mallett & Evison 2013; Porter 2011b]. Thus, all images were first examined with the aim of finding dissimilarities with enough significance to warrant an exclusion.

Before comparing the questioned images to exemplar material, each exemplar image was examined and compared to the other exemplar photographs in order to identify any significant distinctions that might exist between them. This was done due to the unverified nature of the exemplar material. Questioned images were subsequently examined and compared to the exemplar material.

During examination and results reporting, identified facial features were categorised under broad facial regions similar to those described by Meneghini & Bondi's [2012] publication *'Clinical facial analysis: elements, principles, and techniques'* (see Figure.7.4), except for the 'hair' category which was additionally described. The anatomical terminology used as identifiers for facial features were based on the descriptors adopted by Evans [2014] who argued for the incorporation of terminology used in disciplines such as plastic surgery, such as from the works of Dunn & Harrison [1997], as such expressions were more accessible to non-medically trained lay people. Instances where no appropriate anatomical descriptor was found to express a particular observation, common language was employed instead in an attempt to unambiguously communicate the feature.

Facial Regions Examined during Morphological Analysis



**Applicable to both left and right sides of the face*

Figure.7.4: Diagram illustrating approximations of the major facial regions examined during morphological analysis. Facial regions based on definitions presented by Meneghini & Biondi [2012, p. 42].

7.7.2 Results (Hitler Related)

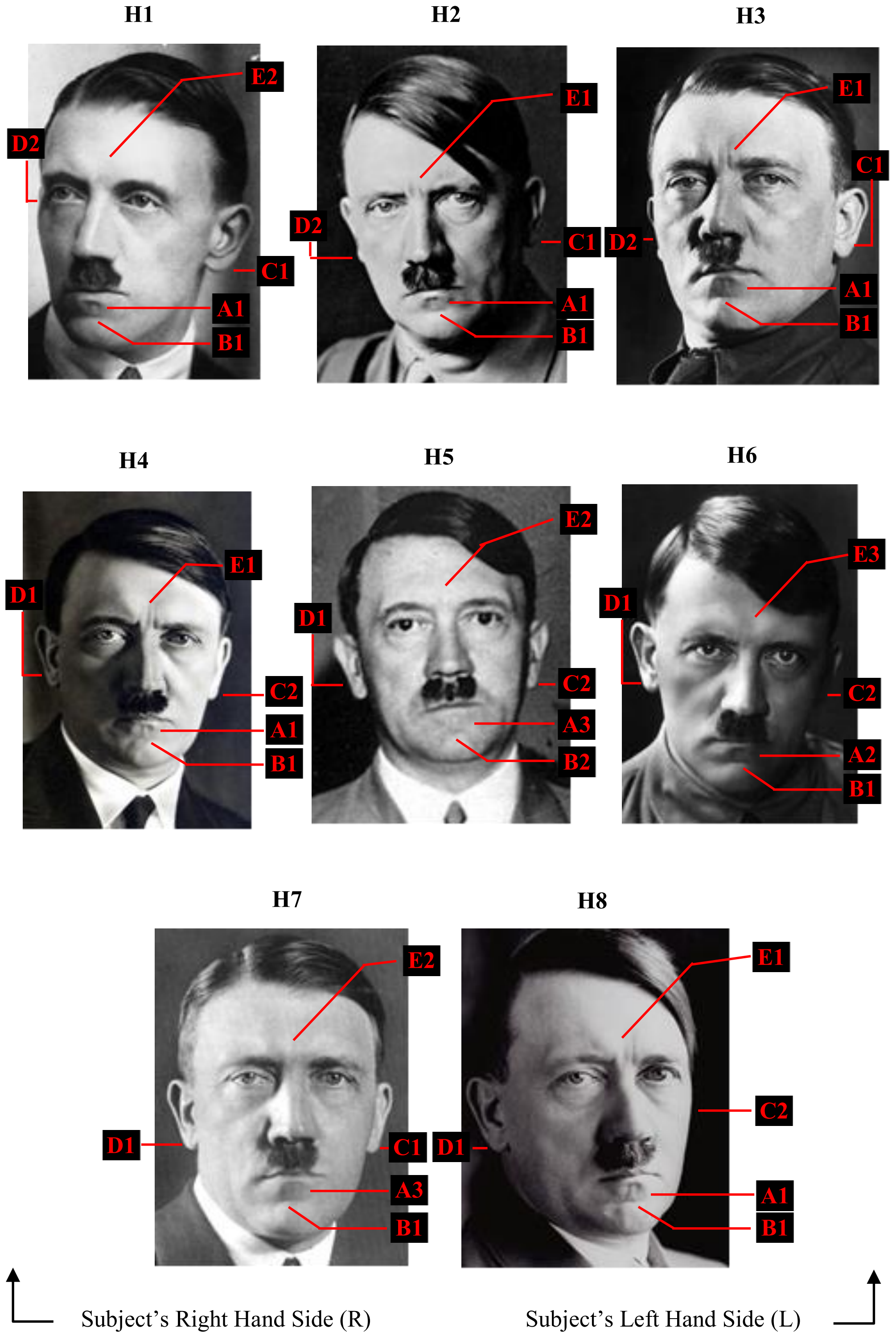


Figure 7.5: Morphological features detected during examination of Hitler exemplar material. [Not to scale]. See Table 7-1 for legend.

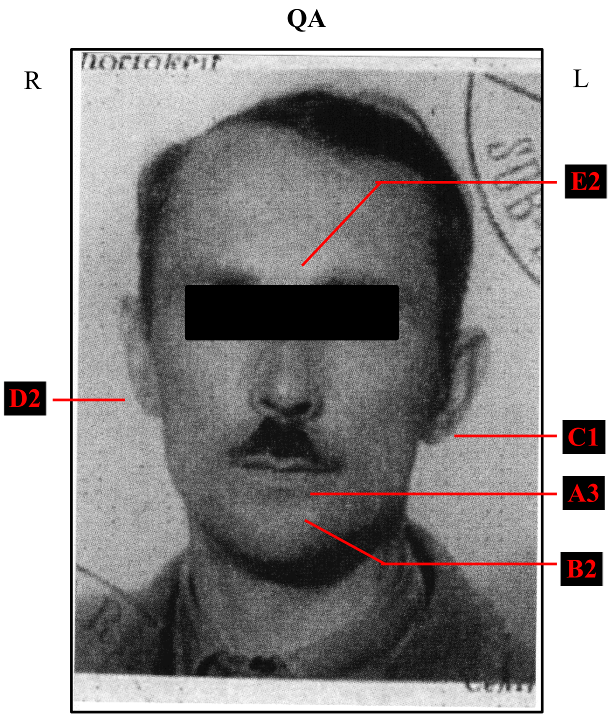


Figure 7.6: Morphological features detected during examination of the questioned image QA supposedly depicting Hitler. [Not to scale]. See Table 7-1 for legend.

Figure 7.5 and Figure 7.6 visually demonstrate the various facial morphological features identified during the examination of the subjects related to the Hitler inquiry. Each feature is indicated by a label whose description can be referenced in Table 7-1.

Features were selected based solely on the examiner's observation and understanding of clearly recognisable and definable facial characteristics, or lack thereof. All features were selected that were believed to potentially assist to differentiate one identity from another.

Table 7-1 highlights morphological facial features detected during the examination of exemplar and questioned photographic evidence concerning the supposed identity of 'Hitler'. The significance of these findings is highlighted in section 7.7.4 Significance of Findings presented after the following results sections.

Table 7-1: Summary of morphological features detected during comparison between questioned image QA and 'Hitler' exemplar photographic evidence

Legend		**Exemplar Images:**								
	Facial Features:	QA	H1	H2	H3	H4	H5	H6	H7	H8
	Oral & Chin Region									
A1	*Double dimple under lower lip*	○	●	●	●	●	○	○	○	●
A2	*Single dimple under lower lip*	○	○	○	○	○	○	●	○	○
A3	*No dimples discernible under lower lip*	●	○	○	○	○	●	○	●	○
B1	*Mental (chin) crease discernible*	○	●	●	●	●	○	●	●	●
B2	*No mental crease discernible*	●	○	○	○	○	●	○	○	○
	External Ear Region									
C1	**Left ear lobule unattached*	●	●	●	●	○	○	○	●	○
C2	*No left ear lobule discernible*	○	○	○	○	●	●	●	○	●
C3	*Left ear lobule attached*	○	○	○	○	○	○	○	○	○
D1	*†Right ear lobule unattached*	○	●	○	○	●	●	●	●	●
D2	*No right ear lobule discernible*	●	○	●	●	○	○	○	○	○
D3	*Right ear lobule attached*	○	○	○	○	○	○	○	○	○
	Nasal Region									
E1	*Vertical glabellar lines (furrows between eyebrows) discernible*	○	○	●	●	●	○	○	○	●
E2	*Vertical glabellar lines not discernible*	●	●	○	○	○	●	○	●	○
E3	*Vertical glabellar lines not present*	○	○	○	○	○	○	●	○	○
–	*Similar nose appearance*	○	●	●	●	●	●	●	●	●
	Hair									
–	*†Hair partitioned on right hand side*	●	○	●	●	●	●	●	●	●
–	*Facial hair (moustache)*	●	●	●	●	●	●	●	●	●

**Subject's left side, i.e. right side of image.*
†Subject's right side, i.e. left side of image.

Table Key:

● = Feature Detected

○ = Feature Not Detected

Five distinct types of anatomical facial features were detected that could assist comparison (dimple, chin crease & eyebrow furrow manifestation; left & right ear morphology).

Regarding features detected within the 'oral and chin region', a 'double dimple under lower lip' was detected in the majority (5 out of 8 | 63%) of exemplar images.

A ‘single dimple under lower lip’ was detected in a single exemplar image. No dimples underneath the lower lip were detected or discernible on the subjects depicted in the questioned image and two exemplar images.

A ‘mental (chin) crease’ was detected in the majority (7 out of 8 | 88%) of exemplar images. No mental creases were detected in the questioned image and a single exemplar image.

Regarding the ‘external ear region’, half of the subjects (4 out of 8 | 50%) exhibited an ‘unattached left ear lobule’ in several exemplars as well as the questioned image. The left ear lobule was not discernible in the remaining half of the exemplar material (4 out of 8 | 50%). No photographs depicted an individual displaying an attached left ear lobule.

Subjects with an ‘unattached right ear lobule’ were detected in several exemplar images (6 out of 8 | 75%). The right ear lobule was not discernible in the questioned image and exemplars two exemplars. No photographs depicted a subject displaying an attached right ear lobule.

Regarding the ‘nasal region’, ‘vertical glabellar lines’ were observed in half (4 out of 8 | 50%) the exemplar images. The presence of the feature was not discernible in the questioned image and a few exemplar images (3 out of 8 | 38%). One exemplar image depicted an individual that did not exhibit the feature.

The general morphology of the subject’s ‘nose’ appeared somewhat similar between all exemplar images. The nose of the subject depicted in the questioned image, when compared to the exemplar material, appeared somewhat dissimilar.

Regarding the assessment of the subject’s ‘hair’, the questioned image and the majority of the exemplar material (7 out of 8 | 88%) depicted individuals with similar appearing and styled head hair that was partitioned towards the subject’s right. The hair appeared visually similar in all subjects with dark, rather uniformly straight hair fibres (not noticeably wavy or curly). One exemplar image (H1) depicted an individual who was photographed facing towards an angle and slightly away from the forward facing pose exhibited by the other images examined. The angled face prevented an evaluation of the subject's hair style due to head positioning occluding detail.

7.7.3 Results (Braun Related)

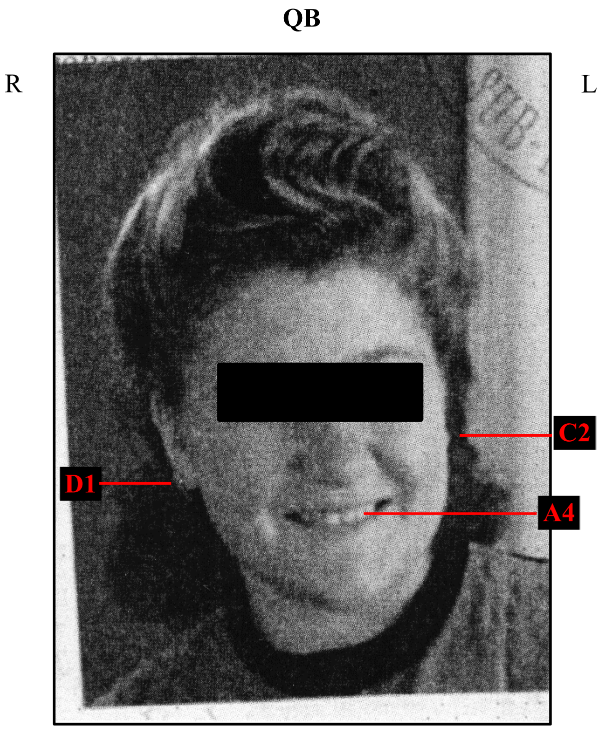


Figure 7.7: Morphological features detected during examination of the questioned image QB supposedly depicting Braun. [Not to scale]. See Table 7-2, p.160 for legend.

Figure 7.7 & Figure 7.8 visually demonstrate the facial morphological features identified during the examination of the subjects related to the Braun inquiry. Each feature is indicated by a label whose description can be referenced in Table 7-2.

Again, features were selected based solely on the examiner's observation and understanding of clearly recognisable and definable facial characteristics, or lack thereof. All features were selected that were believed to potentially assist to differentiate one identity from another.

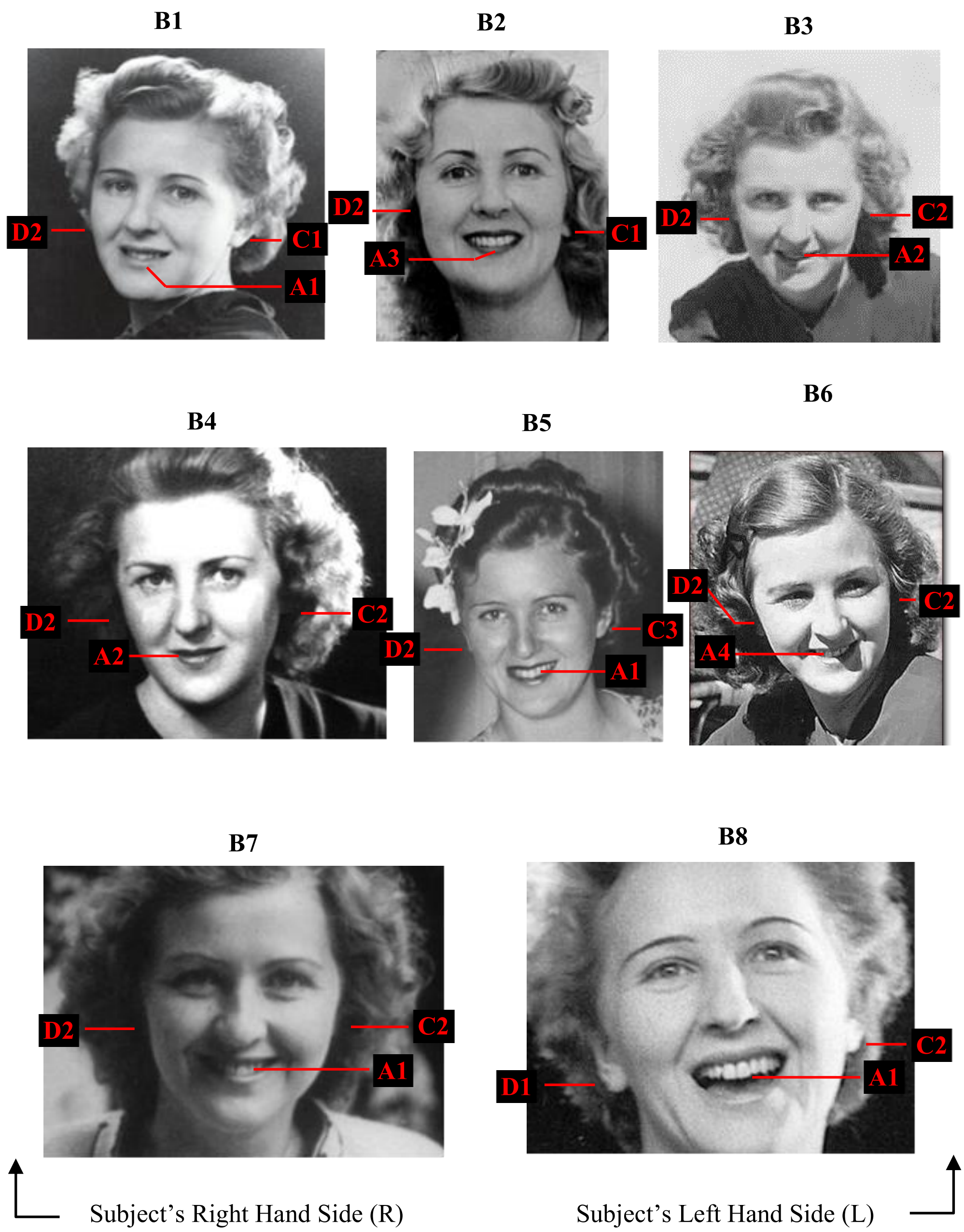


Figure 7.8: Morphological features detected during examination of Braun exemplar material. [Not to scale]. See Table 7-2, p.160 for legend.

Table 7-2: Summary of morphological features detected during comparison between questioned image QB and Braun' exemplar photographic evidence

Legend		Exemplar Images:								
	Facial Features:	QB	B1	B2	B3	B4	B5	B6	B7	B8
	Oral Region									
A1	**Left central incisor (front teeth) larger than right central incisor*	○	●	○	○	○	●	○	●	●
A2	*No central incisor size ratio determinable*	○	○	○	●	●	○	○	○	○
A3	*†Right central incisor (front teeth) larger than left central incisor*	○	○	●	○	○	○	○	○	○
A4	*Left and right central incisors appear similar in size*	●	○	○	○	○	○	●	○	○
	External Ear Region									
C1	**Left ear lobule unattached*	○	●	●	○	○	○	○	○	○
C2	*No left ear lobule discernible*	●	○	○	●	●	○	●	●	●
C3	*Left ear lobule attached*	○	○	○	○	○	●	○	○	○
D1	*†Right ear lobule unattached*	●	○	○	○	○	○	○	○	●
D2	*No right ear lobule discernible*	○	●	●	●	●	●	●	●	○
D3	*Right ear lobule attached*	○	○	○	○	○	○	○	○	○
	Nasal Region									
	Similar nose appearance	●	●	●	●	●	●	●	●	●
	Hair									
	Wavy/curly head hair fibres	●	●	●	●	●	●	●	●	●

**Subject's left side, i.e. right side of image.*
†Subject's right side, i.e. left side of image.

Table Key:

● = Feature Detected
○ = Feature Not Detected

Three distinct types of anatomical facial features were detected that could assist comparison (incisor size relationship; left & right ear morphology).

Table 7-2 highlights morphological facial features detected during examination of the exemplar and questioned photographic evidence concerning the supposed identity of ‘Braun’. The significance of these findings are highlighted in section 7.7.4 Significance of Findings.

Regarding facial features detected within the ‘oral region’, the ‘left central incisor’ was observed to be ‘larger than the right central incisor’ in half (4 out of 8 | 50%) of the exemplar images. No observations could be made regarding the central incisors in two exemplar images. The ‘right central incisor’ was observed to be ‘larger than the left central incisor’ in a single exemplar image (B2). The ‘left and right central incisors appear similar in size’ in the questioned (QB) and a single exemplar (B6) image.

Regarding facial features detected within the ‘external ear region’, an ‘unattached left ear lobule’ was exhibited by the subjects in two exemplar images (2 out of 8 | 25%). The left ear lobule was not discernible in the questioned image and the majority of exemplars (5 out of 8 | 63%). An ‘attached’ left ear lobule was observed in a single exemplar image (B5). An ‘unattached right ear lobule’ was detected in the questioned image and a single exemplar (B8) image. The right ear lobule was not discernible in the majority (7 out of 8 | 88%) of exemplar images. No item of photographic evidence depicted an individual who appeared to have an ‘attached right ear lobule’.

Regarding the ‘nasal region’, the general morphology of the subject’s nose appeared similar between all exemplar photographs. The nose of the subject depicted in the questioned image, when compared to the exemplar material, also appeared to have a similar morphology.

Regarding the assessment of the subject’s hair, all exemplars and the questioned image appeared to exhibit an individual who displayed wavy/curly head hair. Hair tone was difficult to assess because of the colour cast affecting the original appearance of several exemplar and questioned image requiring images to be viewed in greyscale.

7.7.4 Significance of Findings

Exemplar and questioned photographs concerning the alleged identity of Hitler (Part A) and Braun (Part B) were subjected to a morphological comparison process. The significance of the findings from the analysis are examined in this section.

(Part A) 'Hitler' Focused Morphological Analysis

Morphological analysis of the exemplar and questioned photographs concerning the alleged identity of Hitler focussed on the detection of facial characteristics that could assist analysis and identification. These features were determined from the examination of the 'oral & chin', 'external ear' and 'nasal' regions of the face.

Features detected for comparison included the visibility of dimples under the lower lip, chin creases, the presence of glabellar lines (furrows) between the eyebrows, the attached/unattached appearance of ear lobules, nasal form and hair appearance.

The results from the morphological analysis indicate that a number of facial characteristics were observed largely across several exemplar images and in some instances also within the questioned image. Other characteristics appeared less frequently between exemplar and questioned photographs. The significance of these results are explored in this section.

The majority of examined photographs depicted individuals sporting similar appearing head and facial hair. Observations concerning hair offered little evidential value for assisting with the determination of identity or for the exclusion of the questioned subject.

Hair can easily change in appearance as a result of natural (e.g. aging) or artificial influences (e.g. styling, colouring) which restricts the feature from being considered an indicator of individuality. This is true regarding both head and facial hair. Essentially, there is an inability to determine exclusively from a visual representation whether recorded hair detail accurately reflects the natural unaltered expression of an individual's phenotype (manifestation of physical traits encoded by an individual's genetic makeup [Campbell 2006]) or if the hair has been subject to some form of treatment altering its appearance.

The subject's nose appeared similar across all exemplar images but somewhat different to the questioned image. However, observations concerning the appearance of the nose also offered little value for assisting identification or in this instance, the exclusion of the questioned subject.

In order to examine and evaluate the apparent morphology of a feature, such as the nose, the image being examined needs to depict a fair and accurate representation of the subject's facial features. This condition enables said features to be equally comparable to other images and to the real life subject. If an image can be guaranteed to be an accurate reflection of the subject, then detectable differences in facial feature morphology could provide information with enough significance to assist with the exclusion of the subject.

The results from the analysis indicated that the nose appeared different between the exemplar and questioned image. A genuine difference in nose morphology could suggest different people, if morphological variances cannot be explained for by any other phenomenon. In our case, there are several factors that could explain the deviation in nasal appearance other than the potential that the occurrence was a consequence of different individuals.

Experimentation conducted by Porter [Edmond *et al.* 2009, p. 354] demonstrated that the size and appearance of morphological features can vary significantly when a subject is documented from different image perspectives. Perspective (change in the 2D representation of object size for 3D objects photographed at different distances) is directly affected by the subject to camera distance or 'u' distance. Since the 'u' distance properties of the questioned and exemplar photographic evidence items were unknown, the extraction of reliable information from scrutinising the morphological appearance of features, such as the nose, was not possible. Edmond *et al.* [2009] explained further that since the size relationships of morphological features change as a result of different image perspectives, any photo-anthropomorphic facial measurements conducted on the image would also be unlikely to provide any useful information. Furthermore, observations concerning nasal morphology in the Hitler analysis could have also been affected by several of the conditions discussed further below.

The double dimple, chin crease, unattached ear lobule and glabellar line characteristics were observed frequently among exemplar images. The repeated instances of detection of these features could suggest that these characteristics were genuine morphological features exhibited by Hitler. However, no double dimple, chin crease, glabellar line or unattached right ear lobule features were detected in the questioned image. The only clearly corresponding feature observed between the questioned image and exemplar material was an unattached left ear lobule. The significance of the single corresponding feature and the failure of detection of the remaining characteristics between examined images requires the consideration of several factors, particularly conditions that could possibly explain reasons for feature non-detection, aside from the absence of said features.

Due to the uncontrolled capture of the questioned and exemplar images (see 6.2.3 Controlled & Uncontrolled Acquisition of Photographic Evidence) several of the following factors could independently or accumulatively be responsible for the failure to detect, or the visualisation of a similar yet discernibly different facial characteristic in the examined photographs:

- Light quality and direction;
    - The directionality, hardness, softness and colour temperature of light sources could alter feature appearance or mask detail.
- Head positioning;
    - The positioning of the head could alter perspective, changing the dimensional representation of features or conceal detail.
- Facial expression;

  - The expression of an individual's face could distort, minimise or accentuate feature visualisation (e.g. scowling and presence of glabellar lines) or change the dimensional relationship exhibited between features.

- Angle of image capture;

  - Image capture angle could potentially occlude detail or alter image perspective, changing the appearance of features.

- Image perspective;

  - Image perspective is expressed as the size relationship exhibited between objects photographed at varying distances from the camera. Image perspective is a result of the two-dimensional photographic representation of a three-dimensional scene. Closer objects appear larger than objects further away invoking an impression of depth.

  - Photographing a subject from different image perspectives can cause same objects to appear visually different.

- Depth of field;

  - Insufficient depth of field may leave areas of the face out of focus, impacting detail recovery.

- Focus;

  - Focus on the incorrect focal plane may result in low level or poor recording of detail.

- Resolution of the capturing system;
    - Combination of lens type, quality and recording medium (e.g. film) properties may impact the ability to resolve and record fine detail.
- Genuine non-existence of a feature.
    - The non-existence of a feature could explain the inability to visually detect said characteristic.

A single or combination of the above parameters could plausibly explain:

- An exemplar image portraying a single dimple feature under the lower lip as opposed to a double dimple;
- The apparent non-detection of the double dimple feature in the remaining evidential photographs;
- The lack of any apparent mental crease in the questioned and an exemplar image;
- The failure to discern details concerning ear lobules in the questioned and several exemplar images;
- The failure to detect vertical glabellar lines in the questioned and several exemplar images;
- The difference in nasal appearance between the questioned and exemplar images.

Despite the limited number of corresponding facial features observed between questioned and exemplar images; the evidential value offered by the facial features detected in this investigation were significantly limited because of the inherent lack of individuality attributed to each characteristic. This would be true even if several of the detected facial features were found to correspond between examined photographs.

Features detected during the morphological analysis concerning Hitler were all considered class characteristics, which offer very little value for establishing identity. Nevertheless, class features can still be useful for exclusionary purposes if they are a true and accurate representation of morphology. The reason why detected features are not useful for identification is related to our current lack of understanding concerning the real world significance of observing similar facial morphologies within individuals, let alone facial images.

Edmond *et al.* [2009] and Edmond *et al.* [2010] draw attention to an important issue concerning contemporary facial analysis research, namely, the inexistence of a means to gauge the value class level facial features offer towards assisting identification. One particular line of thinking that could be entertained from a conceptual standpoint is that if several correspondingly 'similar' facial features were detected between a pair of images, this occurrence would lend support to the hypothesis that the images in fact depict the same person, with the detection of greater numbers of corresponding features offering increasingly stronger levels of support. However, this notion is fallacious and certainly dangerous when considered from a moral and legal perspective.

How many people have we witnessed over our lifetimes that look convincingly similar to other people we recognise? Without an understanding of the relative commonality or frequency of occurrence of facial features within a given population, detected similarities between facial photographs offers negligible evidential value. For example, if two individuals depicted in a pair of photographs appear to share a similar ear and chin features, what are the chances that this observation is just a random occurrence (i.e. simply similar appearing people) and not because the same individual is depicted in both images? Scholars also ask, how can we know that the presence of one particular feature does not have any correlation with the presence of another feature [Edmond *et al.* 2009; Edmond *et al.* 2010]? Could the expression of a particular nose morphology be associated with an increased propensity for the occurrence of a particular eye colour or different feature?

It is imperative that any form of inquiry presenting itself as 'forensic' has examination grounded in some form of scientific process or approach and can adequately address such critical questions and considerations and can further still, communicate clearly such limitations to the relevant audience.

Without some form of a comprehensive facial image database or related method for determining and understanding concepts of probability associated with facial feature occurrence, the conclusions that can be drawn regarding identity from similarities alone are extremely limited. This is why non-class facial features that impart some level of individuality such as a combination of tattoos, scars, blemishes and other distinctive landmarks are integral for assisting the facial comparison process [Edmond *et al.* 2009; Edmond *et al.* 2010]. Such distinctive features were not detected in the photographic evidence examined during this investigation.

A morphological analysis concept that is currently well understood is that if a single conflicting class level feature is observed to exist between questioned and exemplar material and no other explanation can be offered to explain the occurrence of such a discrepancy other than the fact that the conflicting features must genuinely exist; this would warrant an exclusion of identity. Such an occurrence would suggest that the examined photographs depict different individuals. No such conflicts were detected during the morphological analysis performed as part of this investigation.

Conclusion

The conclusion regarding whether or not the individual depicted in the questioned image (QA) was Adolf Hitler based on the results of the morphological analysis was found to be ***inconclusive***. This conclusion was based on the following key points:

- No distinct differences in facial feature morphology were observed that would warrant exclusion;

- An extremely limited number of clearly defined characteristics (x1, unattached left ear lobule, similar hair appearance) were found to correspond between the questioned and exemplar photographs;

- Detected facial features were all considered class characteristics.

(Part B) 'Braun' Focused Morphological Analysis

Morphological analysis of the exemplar and questioned photographs concerning the alleged identity of Braun focussed on the detection of facial characteristics that could assist analysis and identification. These features were determined from the examination of the 'oral', 'external ear' and 'nasal' regions of the face.

Features detected for comparison included the size relationship between the two front teeth (central incisors), the attached/unattached appearance of ear lobules, nasal morphology and hair appearance.

The results of the morphological analysis indicated that the appearance of the subject's hair and nose were similar across all exemplar material and the questioned photograph. As explained in the section above concerning the results from the examination focusing on Hitler, observations concerning the appearance of class characteristics such as hair and nose morphology offer little value for identification. The ability for hair to so easily change in appearance also makes it a characteristic that it is not useful for exclusionary purposes.

No differences in nose morphology were observed. However, even if there were differences detected, the examined images needed to have been proven to have been fair and accurate representations of their subjects with no other explainable factors that could have contributed to the appearance of visual distinctions. Given the uncontrolled nature of photographic capture for all of images examined in this investigation, proving that an observed difference was not a result of an artefact would have been difficult.

Examination of the attached or unattached appearance of ear lobules revealed an instance where the questioned and one exemplar image shared what appeared to be an unattached right ear lobule. Two exemplar images similarly displayed unattached left ear lobules. One exemplar image depicted an individual which appeared to display a conflicting attached left ear lobule. The remainder of analysis targeting the external ear region resulted in the inability to discern any lobule detail mainly due to factors such as the low resolution of some images and the ears being occluded by hair, camera angle and head positioning.

The exemplar image that displayed a conflicting attached left ear lobule compared to two other exemplar images which depicted corresponding unattached ear lobules, did not offer any significant evidentiary value. This occurrence could have been the result of an imaging artefact caused by the particular head position, or camera angle used for capture. The individual depicted might also genuinely have attached ear lobules. Since detail concerning ear lobules within the majority of exemplar images could not be assessed, it is difficult to evaluate whether the true identity of Braun did or did not possess unattached ear lobules. Therefore, this information could not useful for exclusionary purposes.

The final facial characteristic targeted for examination was the size relationship exhibited between the two central incisors or front teeth. Out of the photographic material that supported an examination of teeth, several exemplar images exhibited a larger left incisor compared to the right. One exemplar image depicted an opposite trend with the right central incisor larger than the left. The questioned and one exemplar image depicted an individual with comparable central incisors. No evidential value was determined from examining this characteristic due to the uncontrolled nature of photographic capture of the examined images. A slight change in image perspective either resulting from head positioning or camera angle could credibly alter the relative appearance of the incisors or other facial features.

Lastly, all detected features in the investigation focussing on Braun were considered class characteristics. No features exhibited enough discriminatory power to assist with identification.

Conclusion

The conclusion regarding whether the individual depicted in the questioned image (QB) was Eva Braun based on the results of the morphological analysis was found to be *inconclusive*. This conclusion was based on the following key points:

- No major differences in facial feature morphology were observed that would warrant an exclusion;

- An extremely limited number of clearly defined characteristics (x1, unattached right ear lobule, similar nose and hair) were found to correspond between the questioned and exemplar photographs;

- Detected facial features were all considered class characteristics.

7.8 Photographic Superimposition

Photographic superimposition is a technique that attempts to identify a depicted individual through comparative analysis that involves an image overlaying process as described in section 6.2 Current Frameworks for Conducting Comparative Image Analysis.

7.8.1 Method

Photographic evidence concerning the identities of Hitler and Braun were subjected to the superimposition analysis technique.

Exemplar material was screened in order to select the most suitable images for the comparison process. Suitable images included material which most closely reflected the properties of the questioned photograph. For analysis concerning Hitler, exemplar images were selected that exhibited individuals facing directly towards the camera in a manner similar to the questioned image. For analysis concerning Braun, exemplar material was required that depicted the subject facing at a slight angle towards their left shoulder. Images were subsequently scaled, overlayed, aligned and then subjected to different wipe modes to reveal underlying detail.

Scaling was implemented through the use of Equation 2 which was based to some extent on the equation used by Roelofse, Steyn & Becker [2008] for determining facial index values used for facial image measurement and comparison. The distance between the lateral canthus (*pl.* canthi) of each eye; the junction point of the upper and lower eye lids furthest away from the nose; was used as a reference (Figure 7.9) [Meneghini & Biondi 2012]. The scaling process was initiated by first measuring the distance between the lateral canthi of the eye in pixels (to the nearest whole pixel) on both the exemplar and questioned image (Figure 7.10). The larger of the two images was then downscaled using the calculated ratio between the two sets of measurements so that the distance between the two sets of landmarks became comparable. The largest image was selected for resizing in order to maintain image integrity by preventing the introduction of added pixel data via digital image interpolation.

All scaling, overlaying, alignment and opacity adjustments were conducted through the use of Adobe® Photoshop® CS6 software. Image proportions were constrained when using the image resizing function to maintain dimensional integrity. For an example of the scaling process, the first line in Table 7-3 communicates that in order to superimpose exemplar H2 with the questioned image QA, the questioned image, which had the greatest lateral canthus measurement of the pair, was required to be reduced to 6.5% of its original size based on the calculated value.

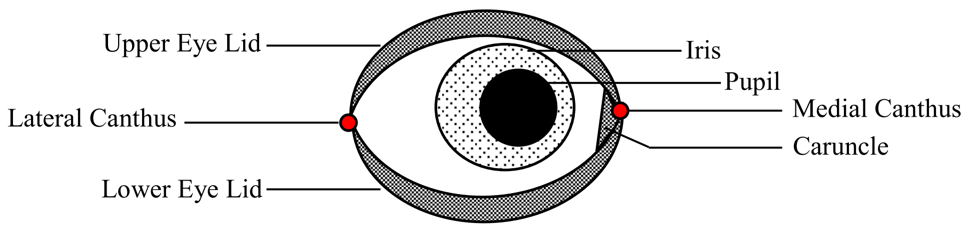


Figure 7.9: Diagram illustrating the lateral and medial canthus facial landmarks used for image scaling and alignment. Diagram based on information sourced from Meneghini & Biondi [2012].

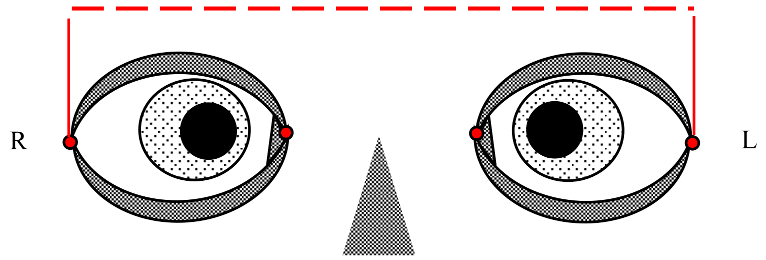


Figure 7.10: Diagram illustrating the measurement of the distance between the lateral canthi of the eyes used during the superimposition technique for image scaling.

Scaled images were subsequently aligned according to the locations of the left and right eye lateral canthi landmarks via image translation and rotation. The alignment process was supported by the implementation of highly visible digital markers at landmark locations (Figure 7.11).

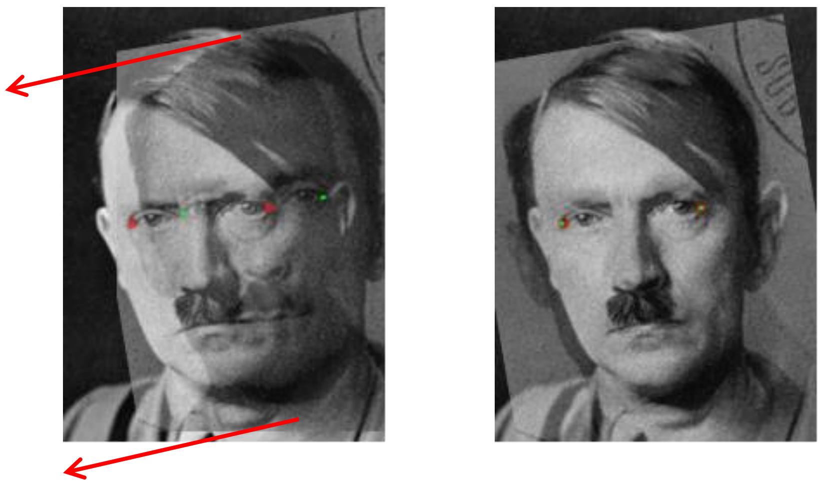


Figure 7.11: Image alignment for superimposition aided by digital markers. [Not to scale].

Finally, the opacity of the overlaying image was adjusted via various modalities to reveal underlying detail and assist comparison.

Equation 2: Image Scaling based on Inter Lateral Canthus Distance

$$Photoanthropometric\ Index = \frac{Inter\ Lateral\ Canthus\ Distance\ (Small)}{Inter\ Lateral\ Canthus\ Distance\ (Large)} \times 100$$

Whereas:

Inter Lateral Canthus Distance (Small) =	*Smallest inter lateral canthus distance measurement.*
Inter Lateral Canthus Distance (Large) =	*Largest inter lateral canthus distance measurement.*
Photoanthropometric Index =	*Image with largest inter lateral canthus distance scaled to the calculated index value in order to make the inter lateral canthus distance comparable in both images.*

7.8.2 Results

The results of the superimposition analysis are presented below. The significance of the results obtained from the superimposition process are discussed in the following section.

Table 7-3: Image superimposition scale adjustment calculations

	Distance between Left & Right Eye Lateral Canthi (pixels):		
Exemplar Image:	**Exemplar Measurement:**	**Questioned Measurement:**	**Photoanthropometric Index:**
Hitler		QA	
H2	80	1494	5.4
H4	442	“	29.6
H5	83	“	5.6
H7	100	“	6.7
H4 & H7	442 (*H4*)	100 (*H7*)	22.6
Braun		QB	
B6	93	1095	8.5
B3 & B7	59 (*B3*)	102 (*B7*)	57.8

Table 7-3 presents the photoanthropometric index data used to assist image scaling during the photographic overlaying process.

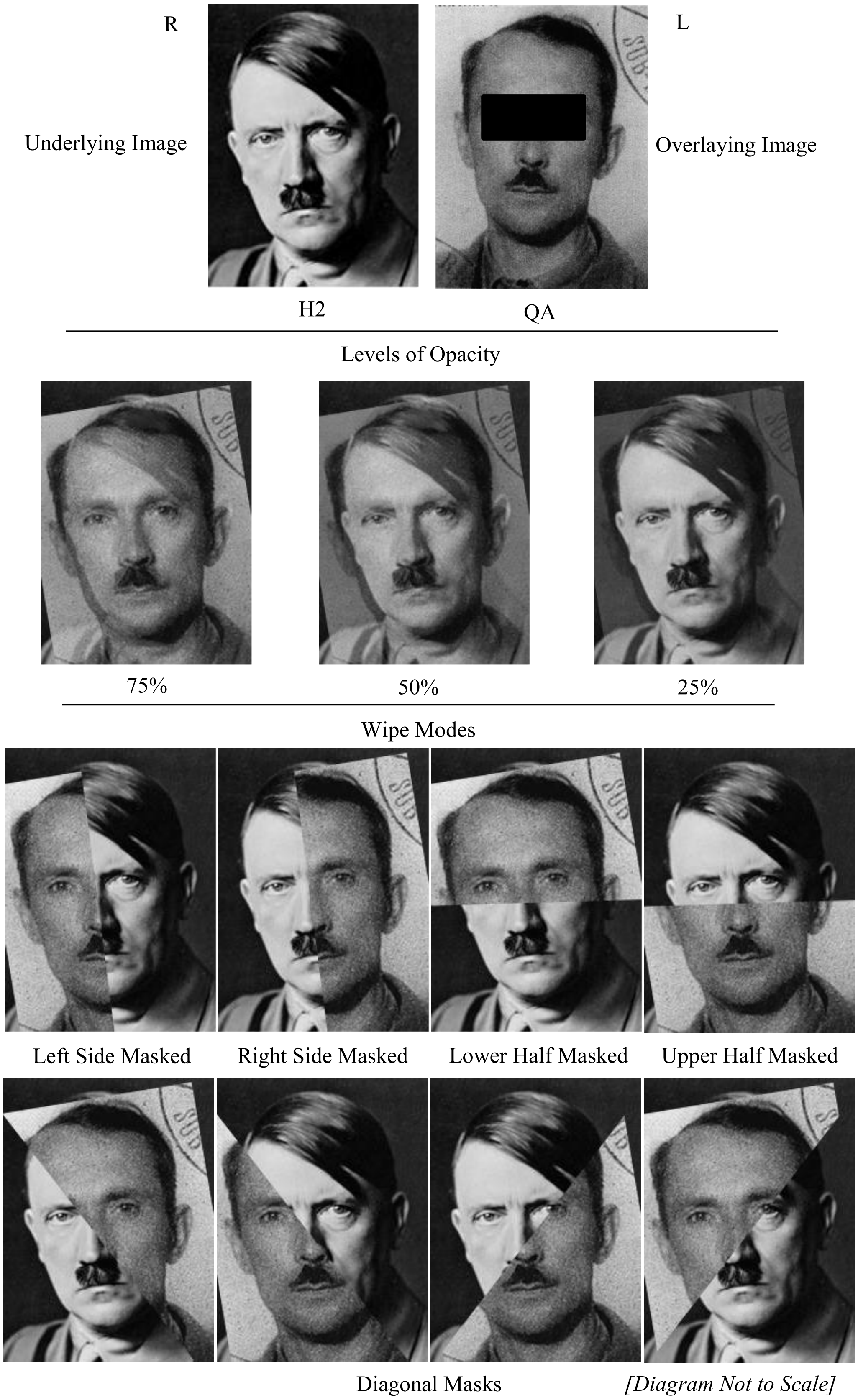


Figure 7.12: Superimposition results for exemplar H2 and questioned Hitler image QA.

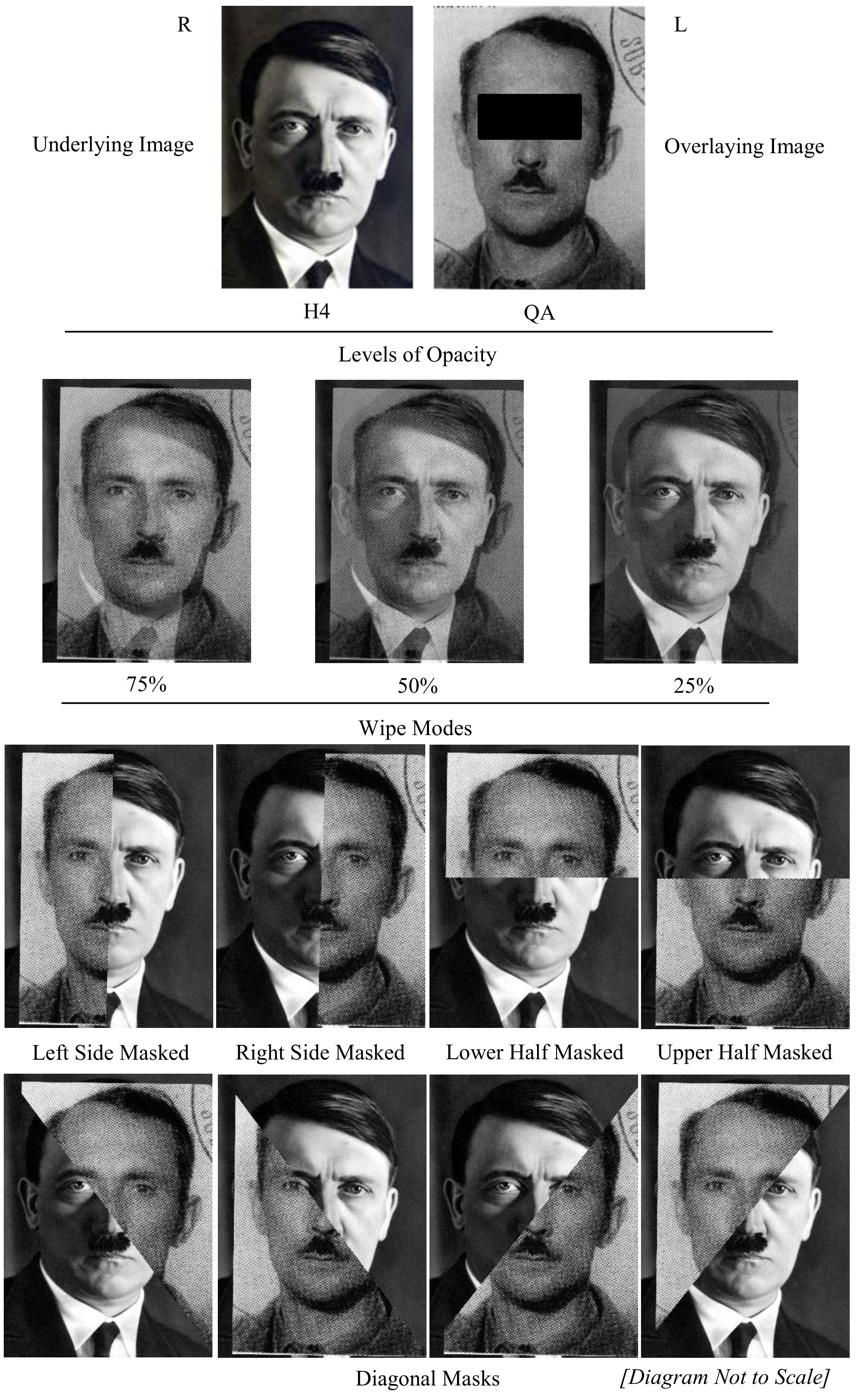


Figure 7.13: Superimposition results for exemplar H4 and questioned Hitler image QA.

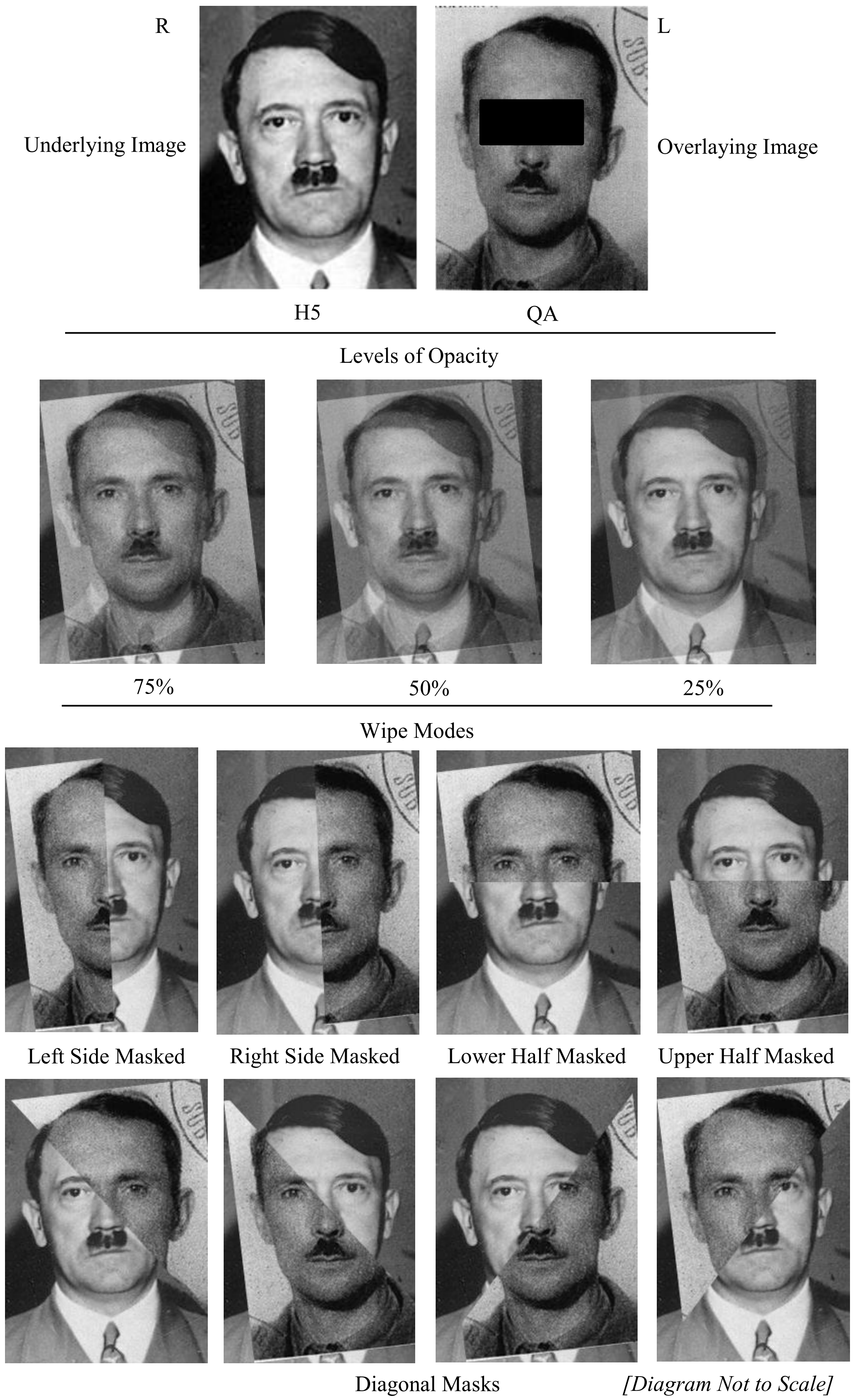


Figure 7.14: Superimposition results for exemplar H5 and questioned Hitler image QA.

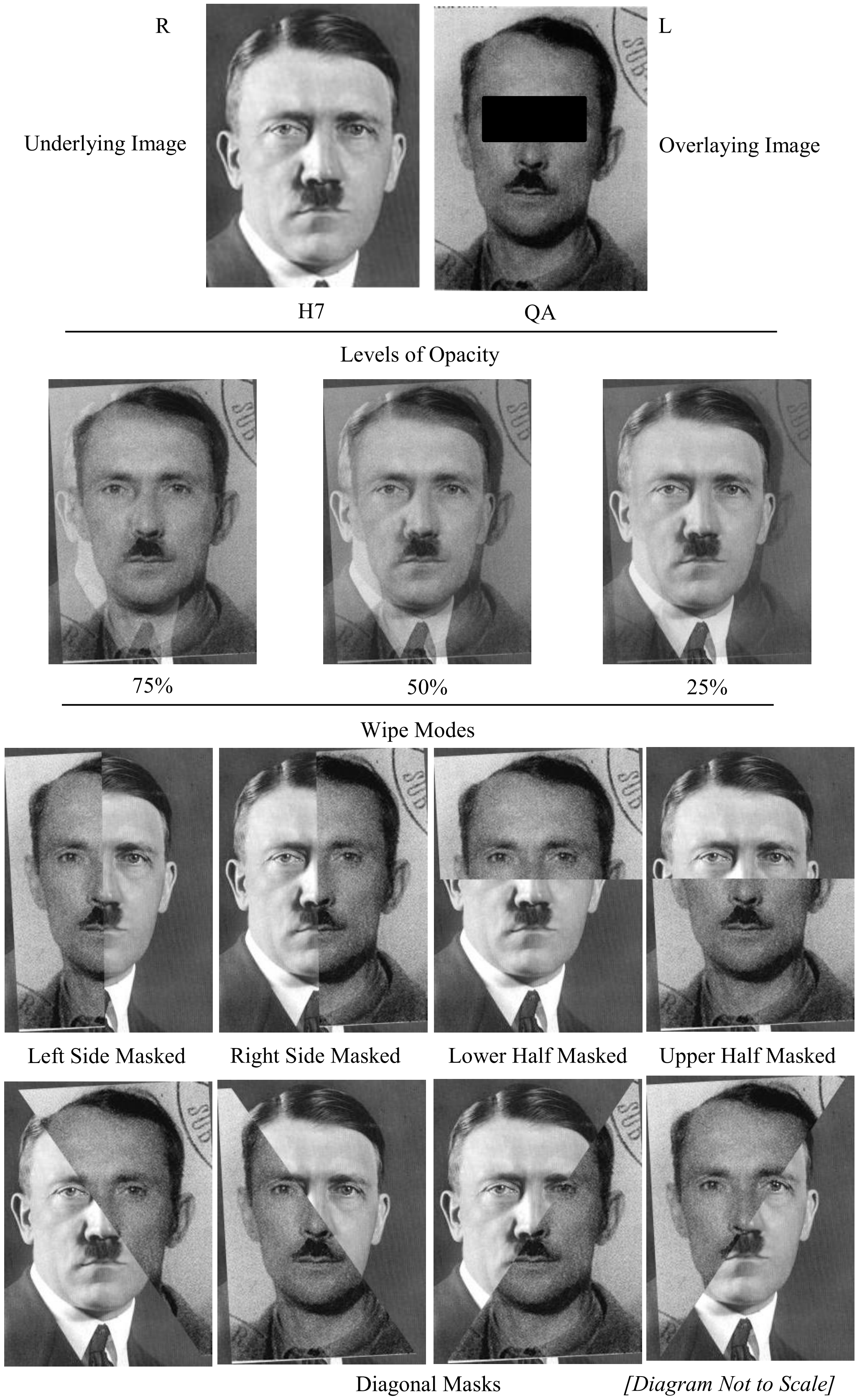


Figure 7.15: Superimposition results for exemplar H7 and questioned Hitler image QA.

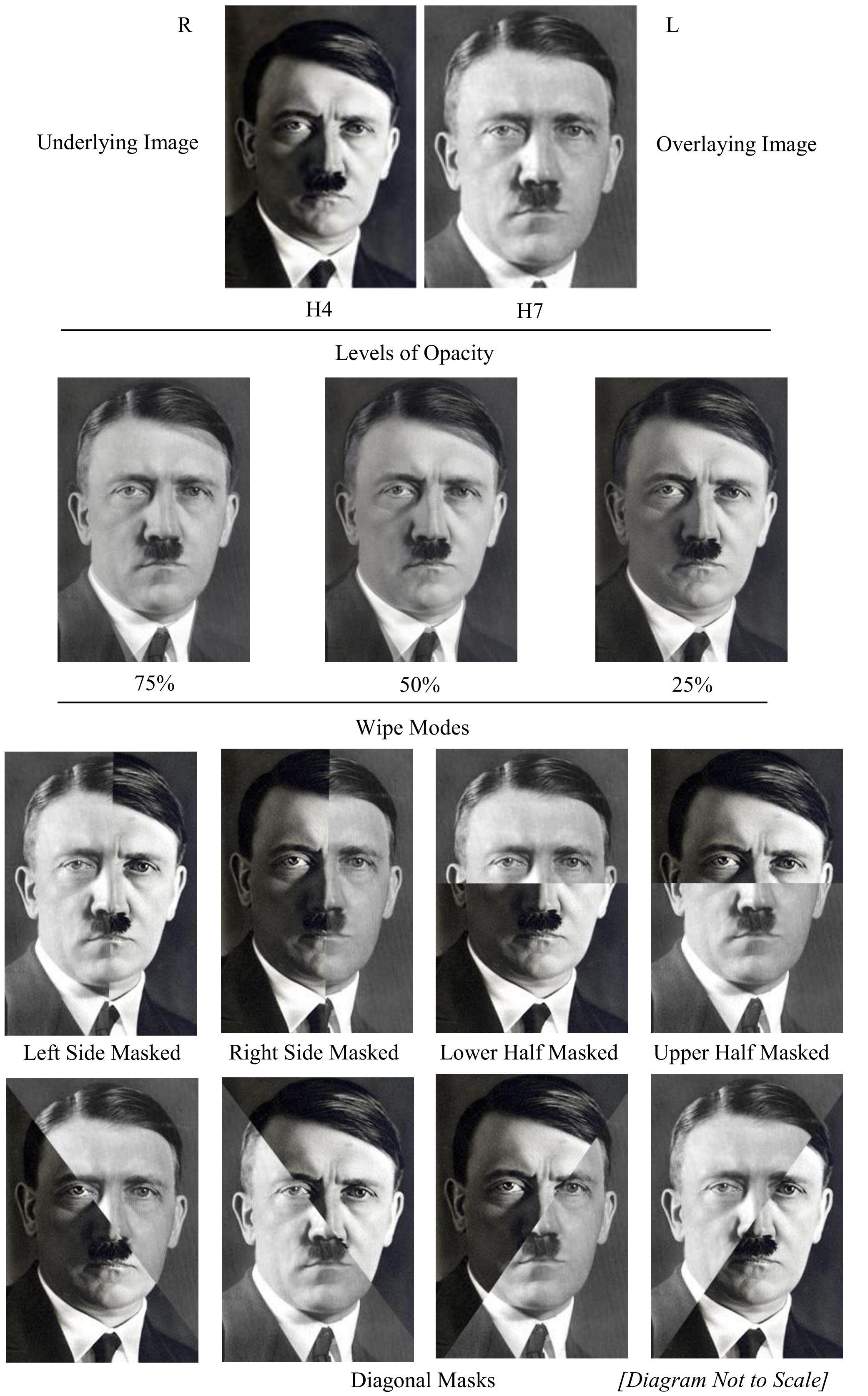


Figure 7.16: Superimposition results for Hitler exemplars H4 and H7.

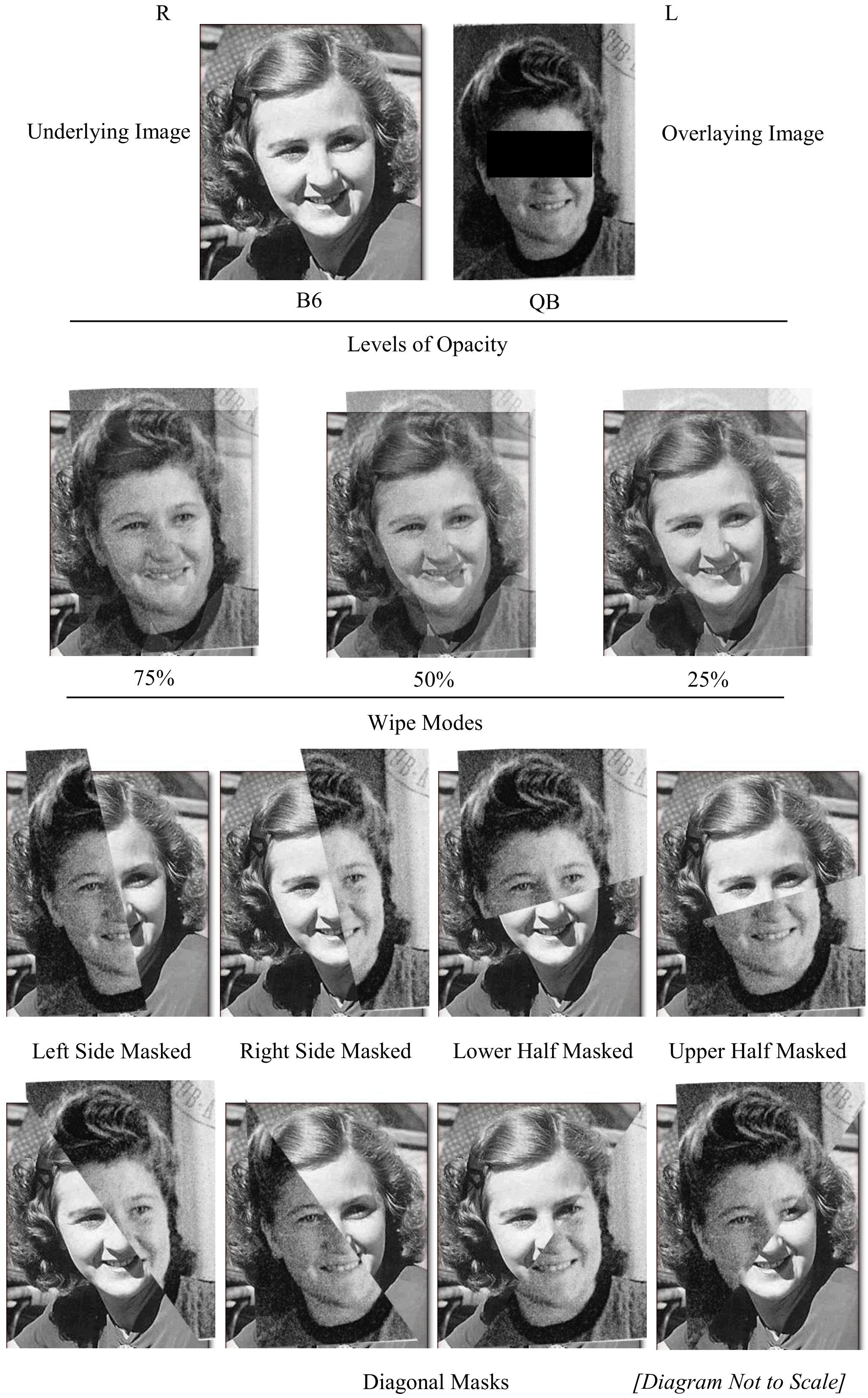


Figure 7.17: Superimposition results for exemplar B6 and questioned Braun image QB.

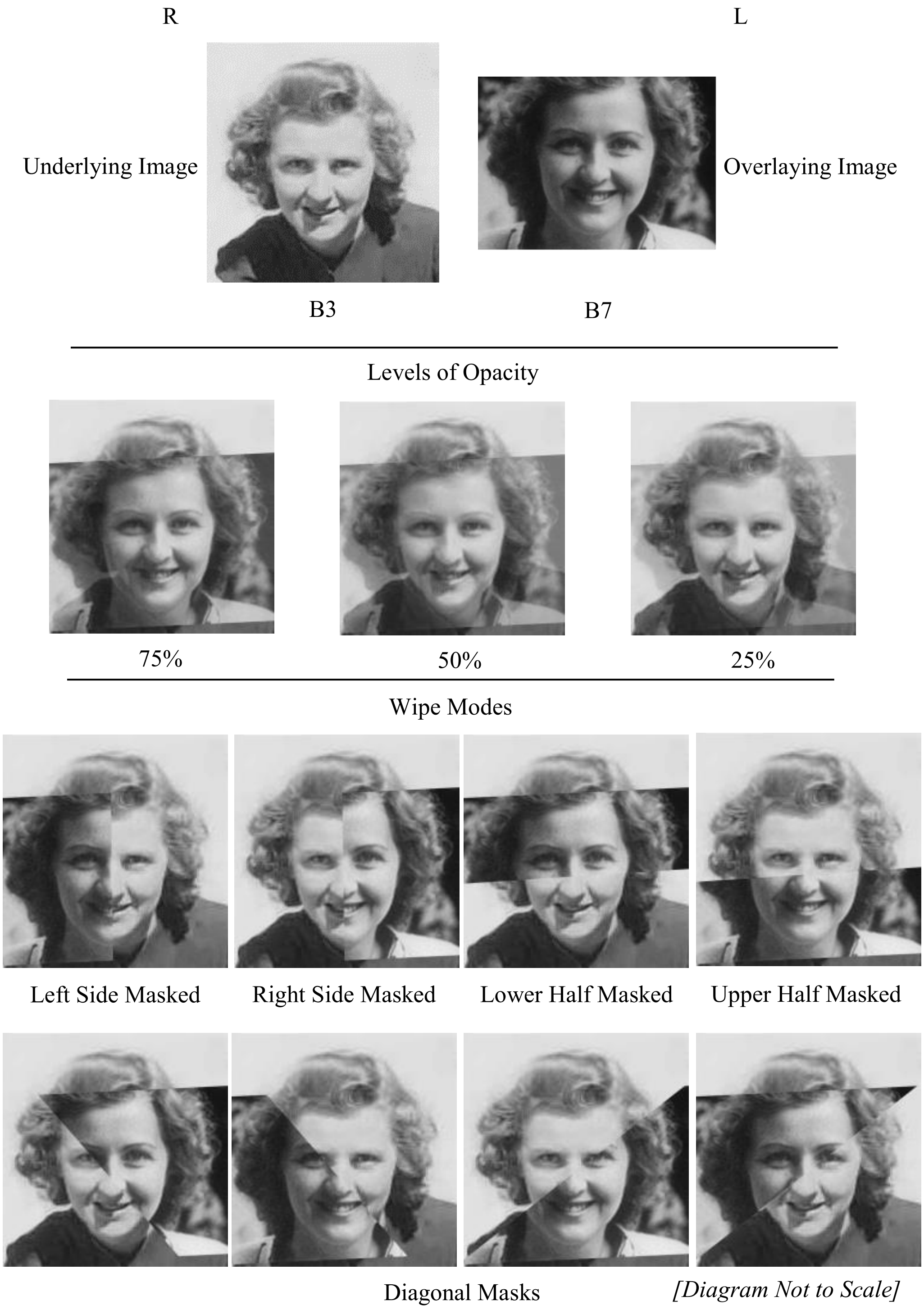


Figure 7.18: Superimposition results for Braun exemplars B3 and B7.

7.8.3 *Significance of Findings*

The results obtained from the implementation of the superimposition technique, although visually dynamic, offered no substantive evidential value. From a technical perspective, several limitations affected the successful implementation of the superimposition method in the context of this investigation.

Firstly, the process of locating landmarks introduced a potential source of error. The quality of the examined images often prevented the location of the lateral canthus landmarks in absolute confidence, resulting in examiner determined approximations being used. If a superimposition technique was to be implemented to assist a real world case in earnest, a statistically grounded process for landmark location could be implemented to increase accuracy and minimise the level of error that might affect photoanthropometric index determination. Such an approach may well entail the obtainment of several sets of landmark measurements, removal of statistical outliers and use of the mean measurement as the basis for calculations.

The alignment process of overlayed images introduced a further source of error. The determination of whether the lateral canthi landmarks were correctly aligned was an arbitrary decision. The alignment process was a visually difficult task despite the ability to control the opacity of the overlaying image. The implementation of digital markers assisted the process but their placement and alignment was also largely subject to the examiner's discretion.

Secondly, differing image perspectives prevented like-for-like comparisons from being possible even when images were comparably scaled. Any slight deviations in head positioning or camera angle between images prevented accurate image alignment, a phenomenon also demonstrated by Burton *et al.* [2015]. Image pairs with equivalent inter lateral canthus distances did not exhibit equivalent scaling for other facial regions, impacting the efficacy of the superimposition technique. This limitation was observed to have affected all examinations conducted between exemplar and questioned photographs undertaken as part of the research component examining superimposition.

The critical issue of working with precisely matching image perspectives has been recognised by researchers working with superimposition techniques such as De Angelis, Cattaneo & Grandi [2007] who have in response, developed a systemised approach for assisting the replication of perspective in live skeletal models used for comparisons by measuring the flexion, extension and torsion of the photographic subject. However, the replication of image perspective cannot be controlled in situations where there is no physical access to exemplar subject material, such as when dealing with historical photographic items, similar to this investigation.

Lastly, the examination of the boundary regions between superimposed images offered no value. There were no series of complementary details observable along the wipe borders that would assist identification or exclusion. This was mainly attributable to the poor resolution of the examined images. The only details observed along the borders were bisected macro facial features such as the nose, eyes, ears, hairline and lips. The alignment of the lateral canthi landmarks did not result in any significant observations regarding the alignment of other facial features. This observation did however, appear to be largely due to mismatches in image perspective.

Notably, both the Hitler and Braun superimpositions involving the comparison of two exemplar images appeared to produce the most visually coherent results. Understanding that a superficial similarity in facial features does not translate to a forensic identification, an important question needs to be contemplated; were the observed high degrees of facial coherence a result of the examination of images with sufficiently similar photographic properties, or a result of the examination of photographs depicting the identities of the same individuals? A comparable level of facial coherence was not observed in the superimposition instances that involved the questioned images, but this could be a result of the selected exemplar images not being captured under sufficiently comparable photographic conditions, instead of a suggestion of differing identities.

Wipe boundaries were also designated arbitrarily since no guides or processes currently exist to assist with their placement. The designation of these boundaries were based largely on the observed practices in the literature [see Austin-Smith &

Maples 1994; Jayaprakash 2013; Strathie & McNeill 2016]. Perhaps the simplified split style (vertical/horizontal/diagonal) wipe mode is not the most effective or useful boundary pattern to convey complex facial feature relationships?

The reduction of the opacity of the top most image to reveal information concerning the level of facial feature correspondence also offered minimal evidential value. The simultaneous visibility of photographic details from both sets of images obfuscated visual information required to communicate the degree of feature correspondence or disagreement.

Several levels of image opacity were presented as part of the examination. A major query that arose from the scrutiny of image opacity was; what degree of opacity, if any, offers the most optimum conditions for observing the level of facial feature correspondence? Is a range of opacities, in a manner similar to what was presented necessary, when conducting superimposition examinations that involve whole facial overlays?

The levels of opacity applied to the top most image in this investigation were 25%, 50% and 75%. Miranda *et al.* [2016] presented superimposed images with varying levels of opacity in their work, employing instead a 25%, 75% and 100% opacity regime. The opacity levels selected in this investigation were arbitrary. It is difficult to contemplate whether a completely objective, mathematically determined optimum level of opacity can potentially be formulated that would enable the clear visualisation of details important for the comparative examination of both superimposed images simultaneously. This view is based on the experience gained from undertaking the experimentation conducted as part of this research component. Three levels of opacity were observed that communicated distinct information. A 50% opacity depicted an equal blend of facial features from both images. This opacity level confused the most facial detail but enabled large discrepancies in alignment to be observed, made evident by the visible misalignment of the periphery of the face. The other opacity level extremes (25% & 75%) simply aided the dominant visibility of either the top or underlying image.

Conclusion

The conclusions regarding whether the individuals depicted in the questioned images QA & QB were Hitler and Braun based on the results of the superimposition comparative image analysis were found to be *inconclusive*.

However, the 'inconclusive' decision was not a reflection of the failure of the technique to provide sufficient evidence for identification or exclusionary purposes, similar to the previous morphological analysis method, but rather because the technique failed to provide any useful information for assisting the task of facial identification from pre-existing photographs.

7.9 Facial Symmetry Comparison

Facial symmetry comparison is a technique inspired by the naturally occurring variation in facial symmetry exhibited by individuals.

The examination of facial symmetry is typically conducted as part of the initial qualitative assessment procedure involved with clinical facial analysis; an important process that supports various specialist medical practices and procedures such as facial surgery. Clinical facial analysis involves a detailed and comprehensive qualitative and quantitative three-dimensional examination of the face, including an examination of facial symmetry [Meneghini & Biondi 2012].

The facial symmetry comparison technique developed through this investigation is more simplistic in application compared to the detailed assessment process expected during a clinical analysis. The developed symmetry comparison technique is purely concerned with the two-dimensional representation of the face and was designed to assist an image examiner to visualise the dominant symmetries/asymmetries concerning the left and right sides of a facial image. The asymmetry of a face can sometimes be clearly apparent in an individual but most often presents as a subtle manifestation. Henceforth, the developed technique was used to assist the visualisation of facial symmetry.

Porter & Doran [2000] also explore the use of facial symmetry as a method to assist with forensic facial photographic identification. The examination of the relative asymmetry of the face provides an avenue for facial image comparison because it stands to reason that any photographs suspected to depict the same individual, captured in a comparable manner, should exhibit the same division of facial symmetry unless some form of trauma or facial contortion has affected the individual. Any observed contradictions between facial symmetries of comparable images may indicate that the images may in fact depict different identities.

Lastly, the facial symmetry comparison technique was developed as a tool to support the process of suspect elimination and not intended as a means towards identification.

7.9.1 Method

Photographic evidence concerning the identities of Hitler and Braun were examined and compared based on observed facial symmetry.

Initially, exemplar material was screened in order to select the most suitable images for the comparison process. Selected images exhibited subjects facing directly forward towards the camera. Image screening was important because the technique is vulnerable to changes in perspective and camera angle, as these properties can greatly alter the apparent symmetry of the face. This was shown by the investigation conducted into the impact head positioning had on the representation of facial symmetry prior to the examination of the Hitler and Braun images.

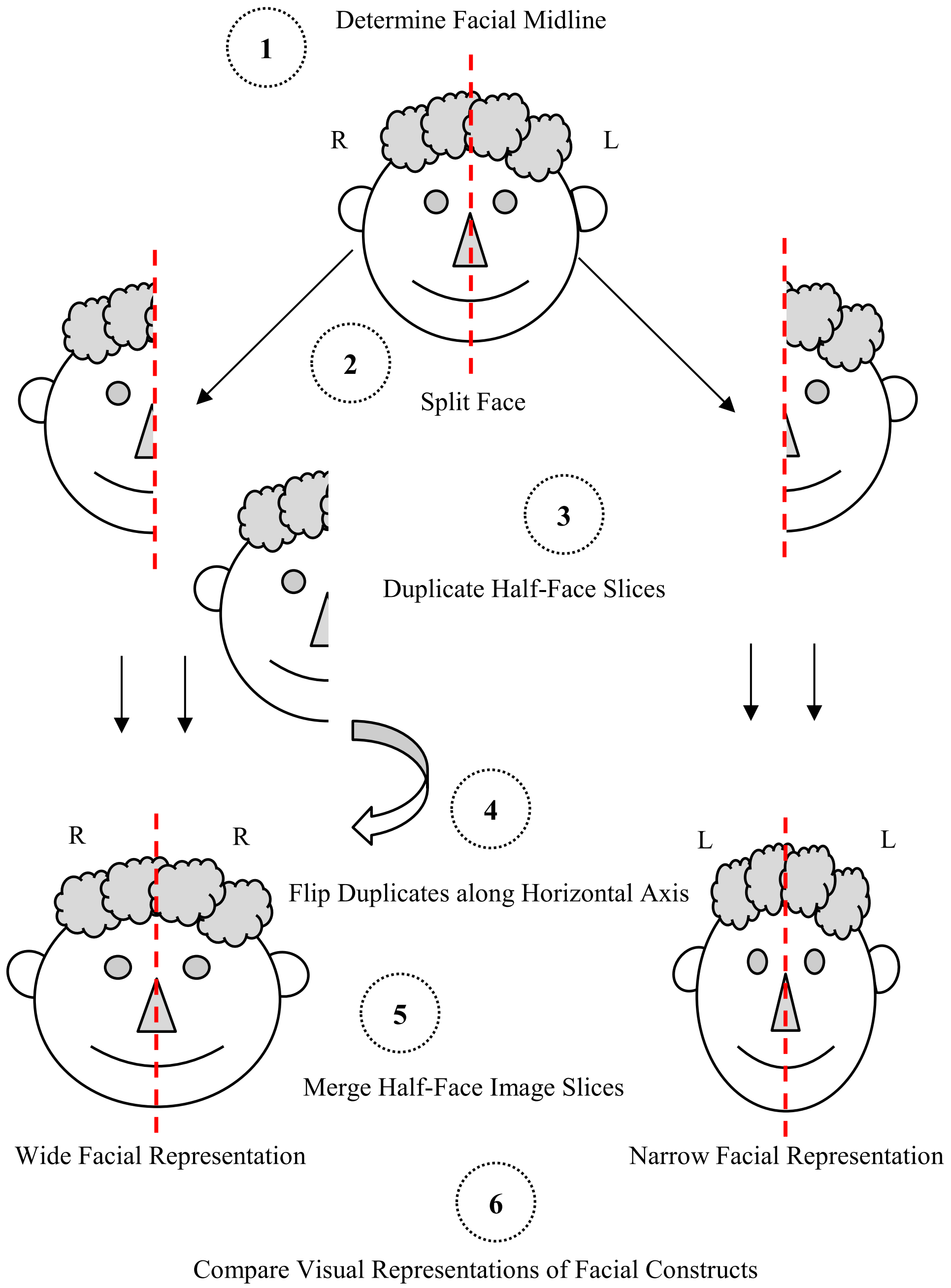


Figure 7.19: Diagram illustrating the process employed to examine facial symmetry through the use of facial constructs.

The Braun questioned image (QB) was deemed unsuitable for undergoing symmetry based comparison because the depicted subject was captured facing at an angle away from the camera, hindering the fair assessment of symmetry due to the distorting effect of perspective. However, two suitably comparable exemplar images were selected for comparison in order to gain some insight into the relationship between the identities depicted.

Meneghini & Biondi [2012, p. 43], authors of the text *'Clinical facial analysis: elements, principles, and techniques'*, state that during clinical practice they inspect symmetry by a process of physically marking the midline of a patient's face. This procedure assists with the assessment and documentation of facial asymmetry and further aids the demonstration of findings to patients.

Figure 7.19 provides an overview of the key steps involved in the developed facial symmetry comparison method. The first step in the facial symmetry comparison method involved determining the midline of examined facial photographs. However, unlike the method employed by Meneghini & Biondi during clinical analysis, midline determination was based closely on the anatomical concept of the sagittal plane (hypothetical plane dividing the body into right and left halves) and not through the faithful division of the face based on 'midline skin points' which considers contours and distortions about the facial midline such as a misshapen nose. This approach was similar to Porter & Doran's [2000] technique which also relied on a single line dividing the face.

The right and left sides of the face were subsequently split based on the determined sagittal boundary. Each half-face was then duplicated to form a pair, resulting in each facial image being deconstructed into x2 right and x2 left half-face image slices. One of each duplicated half-face image slice was next reoriented by flipping along the horizontal axis then aligned and merged with their corresponding same side counterpart to form a new 'face' construct. These processes were conducted through the use of Adobe® Photoshop® CS6 software.

The end result of the splitting, facial-half duplication and merging process was a pair of images derived from the right and left sides of each examined facial image. The derived images comprised of photographic facial constructs that exhibited either a wider or narrower facial representation when compared to one another, unless the examined face displayed perfect balance. The process essentially visualised which side of the face exhibited the dominant symmetry. Nevertheless, the visual determination of the symmetry of the face was largely a subjective process.

In order to assist the process of determining which construct presented the dominant facial symmetry (i.e. wide v. narrow), measurements were also conducted between the lateral canthus of the right and left eye of each of the two facial constructs, to the nearest pixel. It was hypothesised that the facial construct with the larger inter lateral canthus distance indicated a wider facial symmetry representation and inversely, the shorter distance signified a narrower facial symmetry.

Prior to examining photographic evidence pertaining to the Hitler & Braun investigation, an initial exploratory experiment was conducted to examine the impact head positioning or camera angle had on the manifestation of apparent facial symmetry. The outcomes of the experiment informed the exemplar image selection process applied for the examination of the Hitler and Braun images.

To examine the impact of head positioning on facial symmetry, a subject was photographed (Table 7-4) with their head in several orientations including facing directly forward towards the camera, head tilted upwards, head tilted downwards, head facing forward and rotated towards the left and towards the right. The head pose images were then processed using the developed symmetry method.

The facial symmetry determined from the examination of the forward facing neutral orientation were considered the ground truth. Facial constructs from each head orientation image were compared with the ground truth in order to identify the range of conditions which may affect the reliability of the symmetry based comparison technique.

Table 7-4: Parameters employed for the photographic capture of subject used for testing impact of head pose on symmetry

Camera Properties:	
Camera Model:	Canon 6D
Lens:	24-105 mm
Lens Focal Length:	75 mm
ISO	2000
Aperture:	*f*/4.0
Shutter Speed:	1/60th sec
'*u*' Distance:	~2.5 m
Elevation:	Subject Eye Level

7.9.2 Results (Impact of Head Positioning on Facial Symmetry)

The results of the facial symmetry comparison technique, comprising a series of tables and visual diagrams, are presented below in two parts. First presented are results from the investigation into the relationship between head orientation and symmetry, followed by the results of the facial symmetry comparison of images concerned with Hitler and Braun.

Table 7-5: Empirical based symmetry determination for head orientation images

	Distance between Left & Right Eye Lateral Canthi (pixels):		Face Construct Symmetry Representation:		Conflict Detected:
Image:	**Right Side:**	**Left Side:**	**Right Side:**	**Left Side:**	**(Y/N):**
Forward Neutral	594	563	Wide	Narrow	-
Head Upwards	560	550	Wide	Narrow	N
Head Downwards	602	561	Wide	Narrow	N
Right Tilt	550	613	Narrow	Wide	Y
Left Tilt	634	540	Wide	Narrow	N

Table 7-5 summarises the data obtained from the empirical examination of facial image constructs produced from the application of the symmetry comparison technique to the series of photographs exploring the impact of head pose on facial symmetry representation (Figure 7.20 & Figure 7.21). The table indicates the dominant symmetry of the right and left sides of the face based on inter lateral canthus facial measurements. In order to gauge the impact head positioning had on the ability to faithfully examine facial symmetry; the results from each pose were compared to the ground truth. The table indicates that the 'right tilt' head position conflicted with the ground truth representation of symmetry.

Exemplar: Symmetry Representation:

R L R L

Forward Facing Neutral | Forward Facing | R | Wide | Forward Facing | L | Narrow

Figure 7.20: Facial symmetry representations of forward facing head orientation. Symmetry was visually determined and considered ground truth for this investigation. [Not to scale].

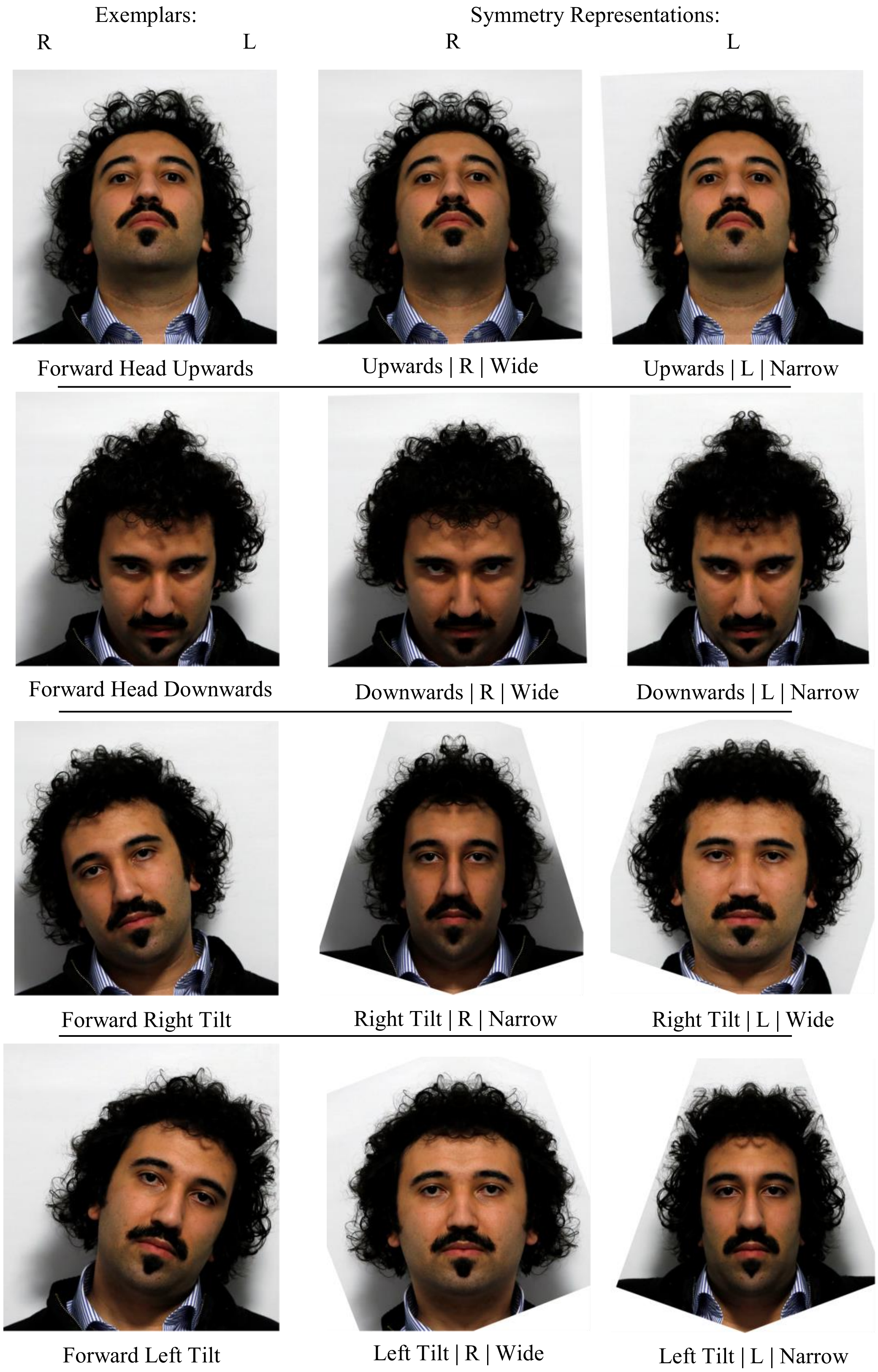


Figure 7.21: Facial symmetry representations of exemplar images depicting various head positions. Labelled face construct symmetries were determined visually. [Not to scale].

Table 7-6: Summary of facial symmetry results determined by visual analysis for head orientation images

	Visually Determined Symmetry:		Conflict Detected:
Image:	**Right Side:**	**Left Side:**	**(Y/N):**
Forward Neutral	Wide	Narrow	-
Head Upwards	Wide	Narrow	N
Head Downwards	Wide	Narrow	N
Right Tilt	Narrow	Wide	Y
Left Tilt	Wide	Narrow	N

Figure 7.20 & Figure 7.21 depict facial constructs produced from the application of the symmetry comparison technique to photographs used for the assessment of the impact head positioning can impart on the ability to faithfully determine the symmetry of the face. The dominant symmetries of each side of the face were visually determined and reported underneath each image. These visual based results are summarised in Table 7-6. Comparison of the visually determined results with the ground truth revealed that the 'right tilt' head position depicted a conflicting symmetry.

Table 7-7: Comparison between visually and empirically determined symmetry for head orientation images

	Visually Determined Symmetry:		Empirically Determined Symmetry:		Conflict Detected:
Image:	**Right Side:**	**Left Side:**	**Right Side:**	**Left Side:**	**(Y/N):**
Forward Neutral	Wide	Narrow	Wide	Narrow	N
Head Upwards	Wide	Narrow	Wide	Narrow	N
Head Downwards	Wide	Narrow	Wide	Narrow	N
Right Tilt	Narrow	Wide	Narrow	Wide	N
Left Tilt	Wide	Narrow	Wide	Narrow	N

Table 7-7 provides a comparison between the visual examination and empirical measurement modes of symmetry determination conducted during the investigation. No conflicts were detected between these modes of examination. Both modes acted in concordance and concluded the same results concerning symmetry for each head orientation image.

7.9.3 Results (Facial Symmetry Comparison of Hitler & Braun Images)

Table 7-8: Empirical based symmetry determination for Hitler & Braun related photographic evidence

	Distance between Left & Right Eye Lateral Canthi (pixels):		Face Construct Symmetry Representation:		Conflict Detected:
Image:	**Right Side:**	**Left Side:**	**Right Side:**	**Left Side:**	**(Y/N):**
QA	1606	1426	Wide	Narrow	-
H4	476	410	Wide	Narrow	N
H5	71	71	Balanced	Balanced	Y
H7	105	95	Wide	Narrow	N
B3	57	59	Narrow	Wide	-
B7	103	95	Wide	Narrow	Y

Table 7-8 contains data obtained from the empirical examination of Hitler and Braun related facial symmetry images (Figure 7.22 & Figure 7.23). The table communicates the conclusions reached regarding the dominant symmetry of the right and left sides of the face supported by inter lateral canthus distance measurements. Conflicts between the apparent symmetries of questioned images (QA and hypothetically exemplar B3) and exemplar images are flagged. Exemplar H5 appeared to conflict with the questioned image (QA) since neither facial construct derived from H5 was measured to have a longer or shorter lateral canthus distance. The balance of symmetry exhibited by exemplar B7 also appeared to conflict with exemplar B3.

Table 7-9: Summary of facial symmetry results determined by visual analysis for Hitler & Braun related photographic evidence

	Visually Determined Symmetry:		Conflict Detected:
Image:	**Right Side:**	**Left Side:**	**(Y/N):**
QA	Narrow	Wide	-
H4	Wide	Narrow	Y
H5	Wide	Narrow	Y
H7	Wide	Narrow	Y
B3	Narrow	Wide	-
B7	Narrow	Wide	N

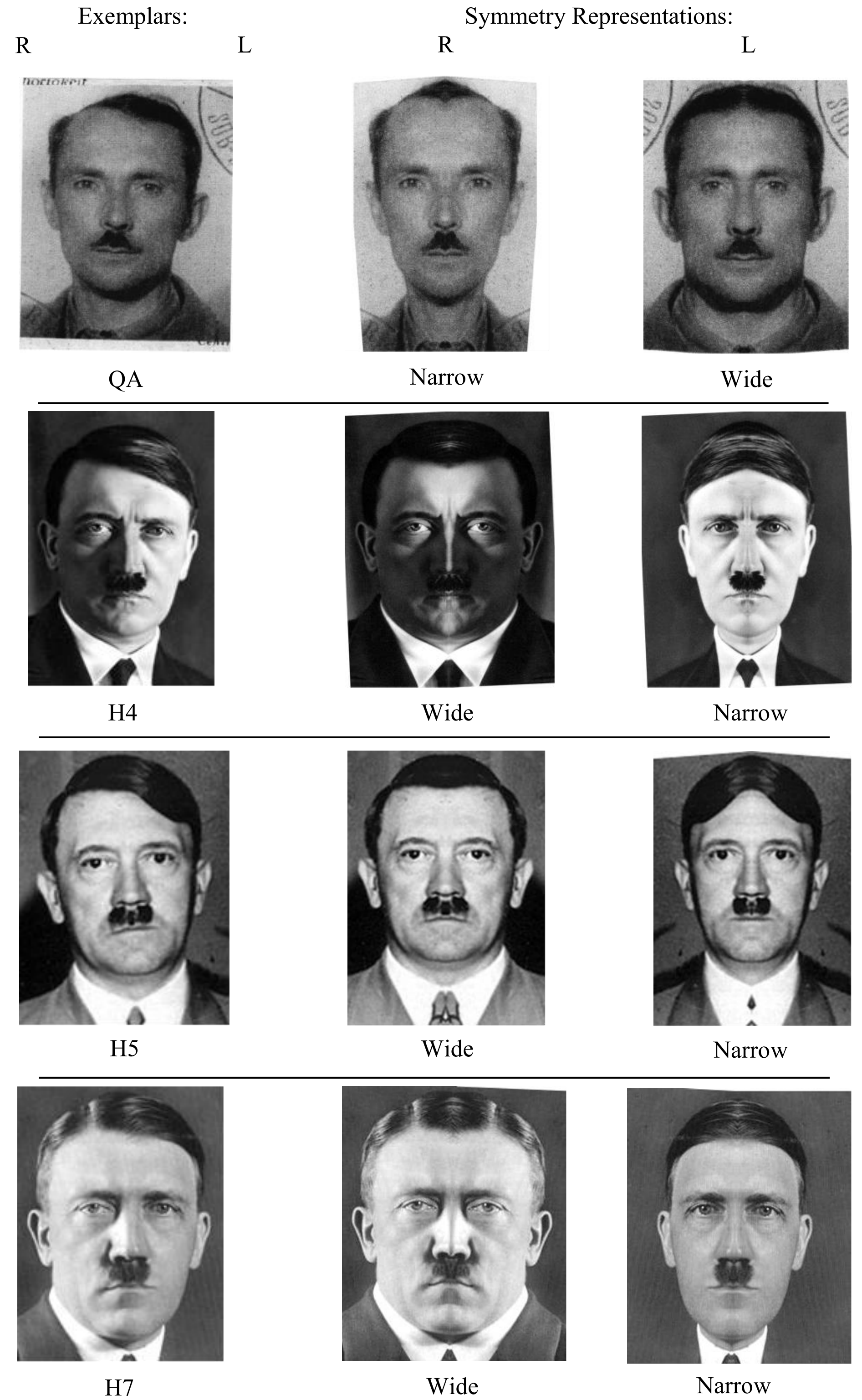


Figure 7.22: Facial symmetry representations of questioned image QA and related Hitler exemplar images. Labelled face construct symmetries were determined visually. [Not to scale].

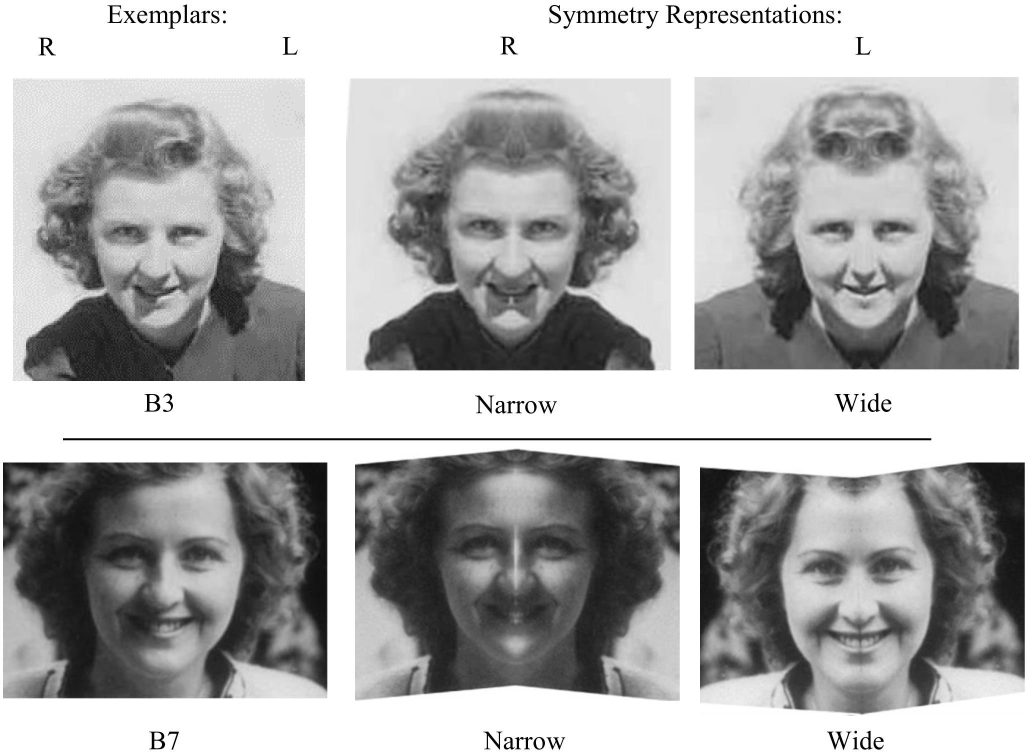


Figure 7.23: Facial symmetry representations of Braun related exemplar images. Labelled face construct symmetries were determined visually. [Not to scale].

Figure 7.22 & Figure 7.23 depict facial constructs resultant from the application of the symmetry comparison technique to Hitler and Braun related photographs. The dominant symmetries of each side of the face were determined visually and are presented underneath each image. These visual based results are summarised in Table 7-9. Comparison of Hitler related exemplar images to the questioned image (QA) reveals that each exemplar exhibited conflicting facial symmetries with the questioned image. Comparison of the Braun related exemplar images indicated an inter-exemplar agreement in facial symmetries.

Table 7-10: Comparison between visually and empirically determined symmetry for Hitler & Braun related photographic evidence

	Visually Determined Symmetry:		Empirically Determined Symmetry:		Conflict Detected:
Image:	**Right Side:**	**Left Side:**	**Right Side:**	**Left Side:**	**(Y/N):**
QA	Narrow	Wide	Wide	Narrow	Y
H4	Wide	Narrow	Wide	Narrow	N
H5	Wide	Narrow	Balanced	Balanced	Y
H7	Wide	Narrow	Wide	Narrow	N
B3	Narrow	Wide	Narrow	Wide	N
B7	Narrow	Wide	Wide	Narrow	Y

Table 7-10 provides a comparison between the visual examination and empirical measurement modes of symmetry determination conducted during the investigation of the Hitler and Braun related images. The questioned image QA, exemplar image H5 and exemplar image B7 were found to exhibit conflicting information regarding the facial symmetry of their subjects determined by the two modes investigated.

7.9.4 Significance of Findings

(Part A) Impact of Head Positioning on Facial Symmetry

The results from the examination into the relationship between head orientation and facial symmetry assisted to illuminate the conditions which may affect the reliability of the developed symmetry based comparison technique.

The main finding of interest was that the faithful representation of facial symmetry was disrupted when applying the technique to the ‘forward right tilt’ photograph. The ground truth data indicated that the symmetry of the right side of the face of the subject in each of the investigated images, based on agreeing visual and empirical modalities, exhibited a ‘wide’ symmetry and the left side a ‘narrow’ symmetry. The opposite result was found when examining the tilted head image.

Drawing from photographic science knowledge, it was previously understood that head rotations about the y-axis, resulting in the subject not facing perpendicularly towards the camera, would introduce perspective distortion that would affect the perceived proportions of the face because one side would be closer or further away from the camera than the other. This is why the effects of shoulder facing head orientations were not examined and automatically excluded from images selected for analysis. The rotation of a subject's head about the *z*-axis (head tilt left/right, ear towards shoulder) were not theorised to be affected by perspective distortion, contrary to the observed results. On the other hand, rotations of the subject's head about the *x*-axis (head pivoted upwards/downwards) were expected to produce conflicting symmetry results, but this too was not observed in this experiment.

Contemplation of these findings, which initially appeared inconsistent with theory, revealed to be in agreement.

Firstly, considering the images depicting upwards/downwards head orientations. The tilting of the head about the *x*-axis does indeed introduce perspective distortion. Either the top or bottom half of the head would be closer or further away from the camera in these instances. However, since the defining axis of symmetry was dictated by the sagittal plane, perspective distortion has minimal impact on the location of the midline facial border. Orienting the head upwards or downwards while still facing perpendicularly towards the lens will not alter the location of the axis of symmetry which is the mechanism that determines the side of the face that exhibits greater or lesser dominance. Perhaps from an anatomical perspective, tilting or angling the head causes movement along multiple axes, whereas an upwards or downwards motion is more tightly confined to a single plane?

The result obtained from the left/right head tilt orientations can be explained if the influence of torsion is considered. Defined by De Angelis, Cattaneo & Grandi [2007] as 'left-right rotation'; understanding the degree of torsion experienced by a photographic subject was considered important by these researchers for their work concerned with the superimposition of dentition.

The impact of torsion can similarly affect the comparison of facial symmetry by introducing destructive perspective distortion. De Angelis, Cattaneo & Grandi constructed a ratio based system for measuring the degree of torsion affecting their subjects in order to enable exact pose replication with exemplar dental models. Perhaps a similar approach can be developed for the determination of the degree of head rotation that affects facial images? Such a system could be used to assist the screening of suitable imagery for undergoing the symmetry technique.

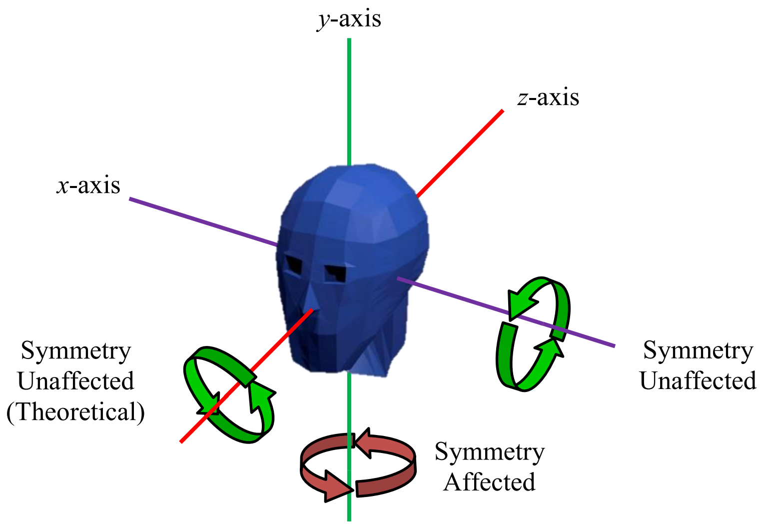


Figure 7.24: Diagram depicting the axes of rotation that can influence the appearance of facial symmetry. Rotations about the x and z-axis are considered to not affect symmetry unless accompanied by rotation along the y-axis.

The findings from this experiment resulted in the exclusion of several exemplar images from undergoing facial symmetry comparison including exemplars photographs H2, H6, B5 and B8. These images appeared to exhibit some degree of noticeable torsion about the *y*-axis.

Future research may aspire to determine the threshold for the degree of torsion that can affect head position before the examination of facial symmetry is rendered ineffective.

(Part B) Facial Symmetry Comparison of Hitler & Braun Images

The results from the examination of facial symmetry of Hitler and Braun related photographic evidence revealed a number of interesting insights into this form of evidence examination.

The examination of facial symmetry employed two modes of inquiry; visual and empirical. The visual examination of facial symmetry exposed an underlying level of subjectivity inherent in the process.

When considering the visual examination of the facial constructs that represented symmetry, what visual cues were utilised by the analyst to understand the distribution of symmetry? What indicators supported the conclusion that a construct depicted either a 'wide' or 'narrow' representation? Was it the placement of the eyes, chin broadness or pointedness, size of forehead relative to the jaw line or relative facial size?

When pairs of facial constructs were compared, one image tended to appear to represent one particular category of symmetry more strongly than the other. However, this division was not always straight forward. For example, the facial constructs derived from exemplar B7 (Figure 7.23) produced two distinct representations. The right side of the face which appeared 'pointier' than the left side and was ultimately designated 'narrow', appeared relatively larger than the other facial construct that was determined to represent the 'wide' symmetry. This observation contradicted the overarching trend of a wider facial symmetry being related to a relatively larger facial construct.

A series of rudimentary 3D computer generated head models were constructed to examine how facial symmetry could be divided in a manner that would produce a result other than a wide/narrow distribution. The model assisted to understand that an angled axis of symmetry could result in representations resembling those reflected by images QA and B7.

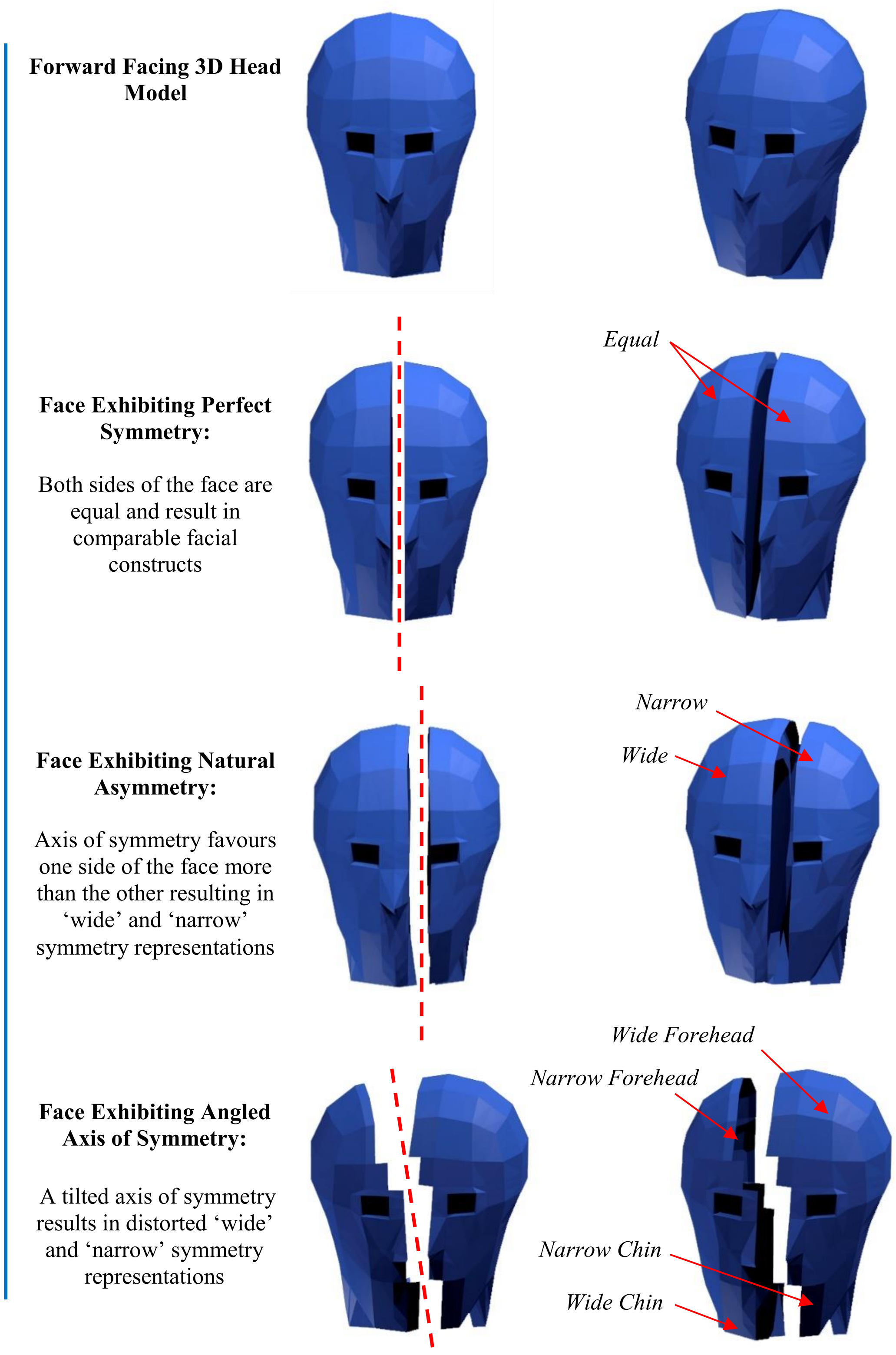


Figure 7.25: Diagram illustrating how the location of the axis of symmetry can produce different facial constructs that exhibit different distributions of symmetry.

After understanding that an angled axis of symmetry could produce facial constructs with different than expected size relationships, it is still not apparent whether an angled axis of symmetry is a natural manifestation of the face or an artefact caused by perspective distortion.

Henceforth, an attempt was made to assist the objectification of the examination process via the use of inter lateral canthus distance as an indicator of symmetry. This process too, shed interesting insight into the nature of symmetry based comparison, raising more questions than the answers it could provide. The idea that a larger inter canthus distance would reflect the concept of a wider facial symmetry seemed sound. This preconception was challenged however, by the findings from this experiment.

Facial symmetry examination of question imaged (QA) and exemplar B7 produced results where the ‘narrow’ symmetry representation exhibited a greater distance between the lateral canthus landmarks than the corresponding ‘wide’ facial symmetry representation. Similarly, exemplar image H5 presented two visually distinct symmetry representations which harboured equivalent distances between measured facial landmarks.

What is the significance of these observed conflicts between facial dimension and visual representation?

On first consideration, the two modes for determining symmetry could be seen as complimentary. If a facial image produces constructs that exhibit a particular visual symmetry coupled with a particular empirical dimension, then rather than being considered an error when these modes conflict; the phenomenon could be considered a true reflection the symmetry of the face. This would mean that when conducting a comparison of symmetry, the same combination of visual and empirical representations need to be observed in order to conclude a non-exclusion.

However, when considering the results obtained from the H5 and B7 exemplar images in relation to the results from the other examined exemplars, the observed conflict between visual and empirical symmetry indicators (i.e. the narrow symmetry representation exhibiting a greater inter canthus distance than the wider symmetry which depicted a shorter inter canthus distance), which were not observed in the other images, could be viewed as a reflection of the potential incompatibility of the empirical approach to symmetry determination or as an indication of error in the symmetry technique.

Perhaps the QA, B7 and H5 images were all affected by perspective distortion introduced by subtle torsion, which differentially distorted the apparent dimensions exhibited between measured facial landmarks?

The conflict between the empirical and visual modes of symmetry determination also appeared to be related to the phenomenon described earlier concerning the size relationship of facial constructs and apparent wide/narrow symmetry representation caused by an angled axis of symmetry.

Therefore, should a combined visual and empirical approach to symmetry determination be considered a valid examination method? It is difficult to draw conclusions regarding this question without further research. From the results obtained from this investigation, it is challenging to determine whether the use of empirical measurement, in the manner undertaken, could be considered:

- Useful for assisting the understanding of the distribution of facial symmetry;
- A potential indicator of perspective distortion when results conflict with visual based symmetry representations;
- An ineffective metric incompatible with the goals of the facial symmetry comparison technique.

The visual based comparison of facial symmetry between the Hitler images revealed a conflict between the questioned image (QA) and each exemplar image analysed. The visual based comparison of facial symmetry between the Braun exemplar images revealed an agreement between the observed distributions of symmetry.

Do the visual based symmetry results indicate that questioned image QA is not in fact Hitler? Before reaching a conclusion, one last consideration needs to be taken into account, the potential for image flipping or reversal to be a factor affecting facial representation within the questioned photograph.

Sorensen [2000] explains that early photographs exhibited a reversed left and right side (termed 'flops') as a result of early photographic processes. This was later rectified through the introduction of an additional mirror component in the camera body, but this corrective measure was reported to be slowly adopted by portrait photographers because of the increase in exposure time consequent of the additional mirror. Sorensen also commented on the potential that the subjects of the portraiture may have actually preferred the mirrored photographs due to their familiarity with that form of self-image (from being accustomed to viewing their reflection). The Sorensen paper alludes to the Victorian era (1837-1901) when discussing this phenomenon.

An investigation into the progression of photographic technology provided by Marien's [2014] text *'Photography: a cultural history'* suggests that around the time frame of 1930-1940's and throughout the period of World War II, significant technological advancements had occurred to photographic processes since the Victorian era. Additionally, many wartime images of Hitler and Nazi Germany depict the iconic swastika with the correct clockwise orientation, indicating that the image reversal problem had likely been rectified during that period.

Regardless of the apparent status of camera equipment during various time periods, it is impossible to conclude with any certainty that image QA, or the exemplar images had not been affected by image flipping or reversal, particularly since image scanning processes can also potentially introduced a mirrored reproduction depending on the parameters associated with the scanning device.

Conclusion

The result of the facial symmetry comparison between the individual depicted in the questioned image (QA) and Adolf Hitler was found to be *inconclusive*. This conclusion was based on the following key points:

- Conflict was detected between the apparent facial symmetry of questioned image QA and examined exemplar images. This would suggest that QA is not Hitler;

- Visually and empirically determined representations of facial symmetry were found to be conflicting. It was not clear if the conflicting results are an accurate reflection of symmetry or an indication that some form of error has affected the ability of the image to undergo this form of analysis;

- The potential for image flipping to have impacted the examined photographs could not be ruled out;

- Further research is required before this technique can be considered a reliable indicator useful for supporting photointerpretation tasks concerning facial images.

7.10 Chapter Discussion

This chapter explored forensic comparative image analysis as a methodological approach to photointerpretation. This was achieved through the application of several image comparison techniques to a case scenario requiring the examination of facial information. This chapter's pragmatic exploration of image comparisons provided first-hand insight into the limitations, challenges and capabilities associated with the methodological approach. The understanding acquired through the work undertaken facilitated the contemplation of photointerpretation values inspired by comparative image analysis processes for supporting the development of photointerpretation principles, thus, contributing towards addressing the central research question.

The image comparison techniques investigated throughout this chapter were guided by the overarching question of whether the two unknown questioned photographs depicted the identities of Adolf Hitler and Eva Braun. What made the 'Hitler' case interesting were the various limitations imposed by the nature of the case itself. Essentially, no ground truth information was available to support any conclusions concerned with identity. The absence of ground truth information did not however, impact the examination of the methodological aspects of the image comparison techniques explored. As presented earlier in section 7.6 Limitations Imposed by Examined Photographic Evidence, the aim of this chapter was to extrapolate principles stemming from the methodological approach of comparative image analysis without a critical focus on the final conclusions that may have resulted from such exploration. It ultimately did not matter whether the identities of the examined images could be confirmed or refuted, but instead how such a question could or should be approached.

The Hitler case was interesting to explore despite the absence of ground truth information because the situation reflected aspects of a typical real world case involving image comparisons in the criminal justice system. Such cases are usually centred on a question about an unknown individual depicted in a photograph and the strength of the proposed relationship between said photograph and a suspect believed to be the identity. The ground truth is never known in real world cases so approaching the Hitler case from this perspective added a level of realism to the limitations encountered by each of the techniques examined. Unlike typical image comparison cases though, the Hitler case was limited by the availability of pre-existing comparative material. Real world cases involving living suspects may enable the collection of controlled comparative material that can greatly assist examination.

Secondly, the Hitler case was also intriguing to explore because despite the widespread familiarity with the historical figure of Hitler (and Braun), it was difficult to dismiss or determine based on human facial recognition skill alone, whether the questioned images did or did not belong to such well recognised figures, highlighting the important role photointerpretation methods can play for assisting answer questions concerned with recognition, even when well-known identities are involved.

The comparative image techniques explored included morphological analysis, photographic superimposition and facial symmetry comparison. An important issue identified when considering the scope of techniques available for assisting comparative image analysis tasks was the issue of responsibility. Who determines the purpose or need for photointerpretation in the first place? Who decides which particular method is the most appropriate for the photointerpretation task or goal at hand? What is the knowledge, skill set and understanding necessary to enable this determination? Undoubtedly, a comprehensive understanding of the various limitations and critical issues pertinent to reliable photographic comparison techniques is required.

Unlike other forms of photointerpretation based examinations that have the potential to develop evidence solely from the examination of the photograph itself; the visual information considered significant to the aims of a comparative analysis are identified and developed dynamically throughout the process of comparison. The quality, content and context of each immediate set of compared questioned and exemplar photographs has a direct influence on the visual phenomena considered significant to the examination.

Resolution plays an important role in any image analysis technique that relies on visual cues for the development of information. When exploring concepts associated with the comparison of photographic content, one particular principle holds true; features relied on during an analysis need to adequately distinguish between different photographic subjects, or exhibit an appropriate level of sensitivity or resolution that permits such differentiation. The level of sensitivity required depends on the goal of the examination and the nature of the photographic subject. Exclusion tasks may require a comparatively lower level than the sensitivity necessary for supporting identification. Generally, the more similar in appearance objects of comparison appear, the greater the sensitivity required to distinguish them.

Vanderkolk [2009] presents a theoretical framework describing the 3 levels of detail that may be discernible within an image and how these levels may impact the ability to perform various comparison tasks. Level 1 detail reflects basic distinctive differences, equivalent to the concept of class characteristics. Level 1 detail is described to only enable exclusions based on crude differences. Level 2 detail is concerned with features that impart uniqueness and is considered the threshold required for identification tasks, analogous to the concept of individualising features. Level 3 detail is related to the availability of even greater detail concerning the features reflected by level 2. Hawthorne [2009] describes a similar level system for describing the sensitivity of distinguishing features within fingerprint impressions. Level 1 is associated with the ability to determine the overall pattern of the print, level 2 is associated with the characterisation of minutiae (the individuating characteristics of a print) and level 3 is associated with poroscopy and friction ridge edge detail, the highest resolution information attainable from fingerprint impressions. Similar to Vanderkolk's framework, a comparison with only level 1 detail resolvable permits only exclusions. Level 2 detail and above is necessary for fingerprint identification.

When considering the facial comparison techniques examined, varying levels of distinguishing feature sensitivity were demanded by each method. For morphological analysis, sample differentiation for exclusion purposes required the ability to resolve different class facial features. Identification was linked to the ability to resolve distinctive facial characteristics. Image superimposition demanded the same feature resolution as morphological analysis. Facial symmetry comparison was only concerned with exclusion and required a clearly resolved head shape with determinable axis of symmetry.

When considering the photographic comparison of objects such as vehicles, an exclusion can easily be made if conflict is detected concerning class level features such as the general shape, colour or make of the vehicle body. For identification purposes, the registration plate needs to be resolved. For faces, identification can be greatly assisted by the visibility of a combination distinctive features such as scars, skin blemishes or tattoos as suggested by Edmond [2009]. Both the vehicle registration plate and distinctive facial characteristics reflect the level of sensitivity required for supporting identification. However, the photographic resolution required to clearly visualise such detail is different between the two subjects. It is therefore critical that an examiner not only understands concepts relating to the level of detail necessary to support the goals of the comparative analysis, but likewise maintains an understanding regarding the capacity for the examined photographic material to resolve such features. This critical value is well supported by several scholars [see Edmond 2013; Edmond *et al.* 2009; Porter 2011a, 2013]. The same level of photographic resolution adequate for recording vehicle identification details may be grossly insufficient for the quality demanded for the successful resolution of useful individualising facial characteristics.

Furthermore, the non-detection of a particular feature does not necessarily equate to the notion that the feature is non-existent [Porter 2012]. Care has to be taken during comparative examinations not to erroneously attribute the inability to observe a feature as the basis for the determination that an agreement or conflict exists concerning said feature. Limitations such as poor photographic resolution may be the reason why discrepancies in detail visualisation exist.

When considering comparative image analysis techniques that involve facial information, Evans [2014] expresses that examiners should have specialised knowledge in facial anatomy, particularly to assist with the communication of findings:

> *The facial comparison expert must have a sound knowledge of anatomical and common descriptions of the surface anatomy of the face in order to report the results of their comparison [Evans 2014, p. 218].*

This researcher believes there is merit in the thinking espoused by Evans. During the facial examination processes undertaken as part of this case study, the lack of a detailed background in facial anatomy presented concern regarding the following points:

- The anatomical expression of detected features;

- Whether or not an observation was in fact a valid facial characteristic and not an artefact of the photographic process.

To illustrate these concerns, consider the detection of the ‘double dimple’ facial feature located ‘under the lower lip’ of the subject depicted within several Hitler related exemplar images during the investigation into morphological analysis, see section 7.7.2 Results (Hitler Related).

The concern is whether the dimple observation was either a true anatomical facial feature; a manifestation due to facial expression; or an artefact consequential of lighting or photographic conditions. The feature was labelled a ‘double dimple’ because the examiner believed this description most easily communicated the observation. However, this belief is not necessarily true. Perhaps the selected label does not clearly express the feature trying to be communicated to all potential audiences?

The benefit of linking anatomical descriptors to facial characteristic observations is the potential for unambiguous communication to people possessing relevant knowledge. Further benefits of anatomical knowledge relate to an increased likelihood regarding the detection of features of value. To illustrate this argument, consider the examination of the ‘ear lobules’ conducted during the morphological analysis research component of this chapter. If the examiner was not aware of the potential for the dimorphic appearance of the earlobe, i.e. whether earlobe morphology could present as attached or unattached [Saladin 2007, p. 145], then the feature could have been overlooked. In fact, the observation of earlobe variation may be falsely attributed to photographic distortion instead. Therefore, when considering facial comparisons, an understanding of anatomical features is advantageous and has the capacity to support analysis.

Similarly, an understanding of photographic concepts is equally, if not more so, integral to examinations concerning not just facial image comparison, but all forms of photointerpretation. The call for specialised photographic knowledge considerations was presented earlier in section 6.1.2 Complexity of Comparative Image Examinations. In the case of image comparisons, specialised knowledge in photographic principles is critical to ensure that any artefacts or distortions that may be introduced by the photographic process are not mistaken as genuine features for which the examination relies upon. This level of understanding needs to be recognised by the legal system and reflected through legislative mechanisms such as s 79 of the *Evidence Act 1995* which controls the admissibility of opinion evidence through the requirement to be based substantially on specialised knowledge.

Regardless of the textual descriptors selected for signifying facial characteristics, the manner in which these results were presented ensured that all features considered important to the examination were visually indicated. This style of pictorial communication assisted to circumvent limitations imposed by potential insufficiencies in technical anatomical knowledge held by both the examiner and/or receiving audience. The employment of expressions accessible to non-anatomically trained persons was a conscious communication strategy (7.7 Morphological Analysis). The use of diagrammatic representations can be seen as a measure to further support transparent and accessible communication regarding observations relied on during comparative analysis. Any system that facilitates the communication of qualitative information central to a subjective mode of examination is tremendously important. One particular complexity that must also be considered is; does the communication effort employed introduce bias that negates the benefits of any transparency offered?

This research has demonstrated that varying degrees of subjectivity are intrinsic to photointerpretation methodologies regardless of whether a systemised approach for guiding examination has been implemented. The reliance on personal discretion during examinations is a marked difficulty inherent to all interpretive forms of forensic analysis. Facial image comparison techniques such as morphological analysis, superimposition or symmetry comparison depend strongly on the examiner's judgement concerning the significance of various visual phenomenon including the supposed presence or absence of facial characteristics, alignment and location of landmarks and representations of proportion.

The demonstration of the rationale employed by the analyst, no matter the complexity, can greatly enhance the quality and reliability of photointerpretation evidence by enabling the scrutiny of any points of contention by triers of fact or through cross-examination by other experts. Similar notions were introduced in Chapter 5. Nevertheless, could the process of conducting an image examination through a seemingly transparent approach such as a side-by-side comparison minimise bias?

It is important to consider whether the simultaneous presentation and examination of a pair of adjacent images, where points of interest are clearly highlighted to facilitate viewer evaluation, provides an impartial medium for evidence development. This consideration is important because side-by-side examination is the dominant framework applied for undertaking comparative analysis tasks including facial image [Prince 2012] and fingerprint comparison and comparative analysis results presentations [Houck 2015; Saferstein 2007]. In addition to the requirement for the transparent communication of processes; it is also integral that the results of a photointerpretation examination are presented in a fair manner.

Reflection on the notions of fairness and evidence presentation gives rise to a host of questions. What would be considered the optimal method of expressing comparative image analysis results? Should a visual strategy be used that simultaneously indicates all features/sites of interest, similar to the style employed in this work? Alternatively, should only conflicting details be highlighted? Should a separate representation be introduced that indicates only corresponding features? Is there a danger that by employing a certain strategy, attention may be drawn to particular information considered important by only the examiner? What if the examiner was inadvertently in error? Could the use of diagrams that illustrate comparative results appear artificially or unfairly authoritative? Should a visual approach be even employed to communicate results? These questions require consideration.

Kuchler & O'Toole [2008] and O'Toole [2008] deliberate the potential dangers new technologies, specifically those based on visual representations, could introduce to the justice system. These scholars acknowledge the increase in prevalence and growing requirement for vigilance concerning electronic display based evidence representations including digital images, animations and computer simulations due to their highly persuasive and prejudicial nature in the United States Courts.

Kuchler & O'Toole allude to new legal considerations arising from the increasing integration of visual evidence into contemporary cases including the requirement for the legal counsel to contemplate whether selected members of the jury will 'be savvy enough' to understand the technical nature of presented evidence. The scholars also make the suggestion that factors such as the visual acuity of jury members, including medical conditions such as colour-blindness, may impact their ability to perceive and therefore conduct a fair assessment of the evidence that might be presented to them in various formats such as screen projections [Kuchler & O'Toole 2008, p. 214]. A real danger exists concerning visual evidence representation, presentation and manifestations of bias.

Langenburg, Champod & Wertheim [2009] describe contextual and confirmation bias as:

> *Context bias can be described as a bias due to exposure to extraneous information. Confirmation bias is related to the expectations of the observer. The observer tends to see what they want or what they have come to expect, rather than evaluate what is present [Langenburg, Champod & Wertheim 2009, p. 2].*

Could the implementation of a side-by-side comparative method introduce contextual bias to the analysis process through the suggestion of visual complementarity?

When comparing photographic evidence side-by-side, it can be argued that naturally weak correlations can become artificially strengthened as a result of subconscious persuasion. A feature that might normally be considered non-existent or insufficiently resolved for the provision of reliable information when examined in isolation, could transpire to being considered a genuine and significant feature of correspondence when examined in the format of a side-by-side comparison as a result of the existence of a supposedly complimentary and sufficiently resolved feature observable in the other image at a relatable location [Edmond *et al.* 2009].

In other words, a side-by-side approach to comparison might influence the perception of the presence of a characteristic when it is not really there. For example, when comparing two seemingly similar facial photographs, the detection of a clearly resolved ‘chin crease’ in one image might influence the determination that the ‘blurry shadow’ located above the chin in the other image is in fact a chin crease as well. The phenomenon would have an increased propensity to manifest in examinations involving lesser resolved images since there would be a reduction in the level of visual information available to assist with the distinction of differences.

Similarly, the presentation of two images to triers of fact in a side-by-side manner could introduce confirmation bias through the subtle visual suggestion of a relationship communicated by proximity. This situation would be particularly dangerous when an expert cannot determine a clear outcome of a comparison themselves, so instead present evidence with the view of enabling the jury to make their own determination. Any arguments put forward suggesting a possible relationship between the pair of images combined with the highly persuasive and prejudicial nature of the photographic exhibit could unfairly mislead triers of fact and result in serious injustices [Edmond *et al.* 2009; Porter & Kennedy 2012].

Further questions arise regarding whether the consideration of the order of the procedural steps involved in the comparison process could assist to minimise contextual bias from affecting examinations. If questioned and exemplar photographic material were to be initially assessed independently before a formal comparison stage, would such an approach negate the potential for context to influence feature detection? If such a process was employed, would the examination of the questioned image need to precede that of the exemplar material or vice versa? Would the order of examination even have an impact?

If a blind and independent examination was conducted for determining the presence or absence of important comparative features, how many characteristics would be needed to be identified before the examiner could feel confident to move on to examining the next image? What would happen if an examiner missed a point of significance? Would such a process place a heavier burden on the examiner and require greater time and resource allocation?

Langenburg, Champod & Wertheim [2009] explore the potential for the implementation of a blind testing approach for assisting the minimisation of contextual bias effects during fingerprint comparisons. However, the information the scholars are concerned with is the opinion of a secondary expert which is sought as part of the verification phase of the ACE-V framework. The scholars also propose that the implementation of such a system would indeed significantly increase the amount of resources required for its execution, something viewed as inhibitive or burdensome from an operational perspective.

The axiom of employing like-for-like exemplar material for comparative examinations was presented in section 7.5 Obtaining Exemplar Material for Comparative Image Analysis. This maxim can be viewed as another strategy important for assisting the minimisation of bias from affecting examination. The exploration of the various facial image comparison techniques conducted in this thesis confirmed that the involvement of like-for-like material is an exceedingly important requirement because of the influence variations in visual representation can have on findings. Subtle differences in properties such as perspective can significantly impact morphological, superimposition and symmetry based comparisons, as can lighting quality, direction and image framing. A comparative examination needs to take place between two comparable images in order for the evaluation to be considered fair.

Deeper contemplation regarding concepts of comparable exemplar images raises the following question; does the concept of like-for-like exemplar material equate to the requirement for all questioned image photographic properties to be faithfully reflected in the exemplar? If the questioned image has a lower resolution, can it be compared to an exemplar image that has a higher resolution? Do both images need to be displayed through the same medium, e.g. hardcopy to hardcopy or screen to screen? Can a comparison take place between a real life object and a photograph?

When considering the concept of exemplar equivalence, the maxim is concerned with the comparable representation of subject form. As such, the physical photographic properties of the questioned image including perspective, framing, camera angle and lighting conditions are important for replication in the exemplar image in order to document the subject with a similar representation. However, resolution need not be lowered to equate images. The higher the resolution of the exemplar material, the more beneficial to the process. As discussed earlier, the comparison of lower resolution images has greater potential for being influenced by bias because of the reduction in the information available to visualise differences.

A replication of display medium might not be as directly important for comparative examinations as the analysis of images under equal viewing conditions, which might very well dictate the nature of the display medium required. If comparing a questioned image to a real life object, it is advisable to capture a comparable exemplar image of the physical object to ultimately demonstrate the photographic equivalence, or lack thereof, between subjects. This is of particular importance when dealing with questioned photographs captured under alternate light sources such as infra-red radiation.

Another potential strategy that could be foreseen to reduce the degree of bias affecting comparative analysis is the use of multiple exemplar images. Instead of presenting a single side-by-side image pair to an examiner, a matrix of exemplar material including a genuinely suspected exemplar image together with other 'distractor' images, could be introduced into the process. The motivation for this approach is that by removing the binary relationship between the traditional side-by-side presentation of questioned and exemplar material, where the outcome is known to the examiner to be either a match or an exclusion; the rephrasing of the question to, 'which if any images correspond with the questioned' could theoretically minimise bias.

The comparison of a questioned image to multiple exemplars could prevent the analyst from being influenced by the occurrence of any happenstance correlations that might suggest a stronger connection between a pair of images than what is really warranted. If an analyst detects corresponding features between multiple unrelated exemplar images, this occurrence might prompt the recognition of the limitations of the approach being used, such as the realisation that class characteristics might be being targeted instead of more selective or individualistic discriminatory features.

Currently, there is a scarce amount of research in the literature that explores the application of a multiple exemplar approach to comparative analysis. The study conducted by Langenburg, Champod & Wertheim [2009] investigated the effects of contextual bias on fingerprint comparisons that follow the ACE-V framework, employing a multi-exemplar system as part of their research approach. However, the multiple exemplar system contained a mixture of both related and differing fingerprint image pairs and was implemented with the intent of gauging the degree of contextual bias that could be invoked through suggestions conveyed by 'other experts'. If one pair of images (questioned and exemplar) was deemed to represent a match and another pair containing the same exemplar material was concluded differently, the association between these findings assisted to measure bias effects.

The work undertaken as part of this thesis concerned with the examination of facial comparison techniques employed the use of multiple exemplar images, but with the intended purpose to maximise the amount of information available for analysis due to the uncontrolled quality of the exemplar material. The multiple exemplar comparison approach could prove useful for minimising bias but a danger also exists that it could equally detract from the reliability of the comparison process through the possibility of making obvious to the examiner the distractor images. Therefore, the level of similarity between comparative material needs to be sufficient enough to provide an environment that supports fair evaluation. This requirement could prove to be difficult in itself as finding very similar appearing photographic material might not even be possible for certain subjects. Basak, Bhattacharya & Chaudhury [2006] designed an image database search and retrieval system for the purpose of being able to recover an array of images similar to a given set of target image(s) with the intention that this could be applied within a forensic context among other fields. Such a system could prove invaluable for supporting a multi-exemplar comparison approach to examination.

Lastly, consideration would need to be given to the number of images that would be required for an effective multi-exemplar matrix. Would a 2 x 2 (4 image); 3 x 2

(6 image); 3 x 3 (9 image); 4 x 4 (16 image) and so forth; configuration of images be required? How would these configurations be displayed; a grid pattern, single row or multi-row display arrangements? Would the position of distractor images relative to the genuine exemplar image prove important? Scope exists for future research efforts to investigate further into the potential for the implementation of a multi-exemplar approach for supporting comparative analysis.

7.10.1 Viability of Examined Facial Comparison Techniques

Morphological Analysis

When reflecting on the issues faced by comparative image analysis techniques introduced earlier in Chapter 6 and within this discussion; morphological analysis can be viewed as a method that can easily give rise to highly subjective and unfairly prejudicial evidence if used outside of its limitations.

The notion that humans exhibit a reduced ability to identify unfamiliar faces, even when offered high quality images, was presented earlier in this chapter. Morphological analysis appeals as a potential solution to this problem. At a theoretical level, the technique can assist to exclude unrelated individuals, differentiate between similar appearing faces such as identical twins, and identify suspects all through the detection and comparison of discreet observable facial features; an approach similar to fingerprint analysis. The main caveat is that the conditions required to enable these outcomes are extremely limited and not what is reflected in the quality of material typical of current legal cases (e.g. high angle low resolution CCTV footage).

The nature of the evidence that can be determined through morphological analysis under ideal circumstances is limited to the detection of obvious visual differences or similarities concerning distinctive individualising features between subjects. This realisation could be seen to somewhat negate the need for expertise, but specialised knowledge is still required to assess the quality of examined images in order to conclude whether observations can be reliably compared. A detailed photographic background also enables the deliberation of alternate explanations for any agreeing and/or contrary observations.

Poor quality, distorted or uncontrolled photographs that cannot be replicated present a great challenge to the technique. The method should not be attempted in these circumstances. The ideal photographic conditions for supporting a comparison of photographs through morphological analysis involves high quality, minimised distortion front facing facial images that are captured and illuminated in the exact same manner. The comparison of identification photographs in airport or licence check scenarios present the closest conditions to this requirement. However, even under ideal circumstances, a significant degree of subjective judgement is involved in each step of the analysis, from the identification of facial features to the determination of the significance of said observations and the communication of findings, as was observed within this work.

In the context of the Hitler & Braun case, the morphological analysis technique failed to provide any useful information for assisting to answer questions of identity.

Photographic Superimposition

A reflection on the image superimposition technique reveals a method that can be considered ineffective and potentially dangerous. The entire outcome of the examination is based purely on an opinion about the apparent facial 'normality' of a given pair of superimposed images. No indicators of individualisation are explicitly involved throughout the process, only implied. The opinion is driven primarily by strong gestalt psychology principles which reflect the inclination of the human mind to see and link separate parts as a coherent whole, even if perceived similarities are only illusionary, and therefore provides an unreliable form of analysis [Trumbo 2006; Wagemans *et al.* 2012]. In other words, the mind has a propensity to consider two separate halves of a face as a unified whole when presented closely together. This association can artificially increase the likelihood of deciding that the superimposed construct 'makes sense' and therefore is 'normal' or that the separate components do in fact belong together, while ignoring any subtle yet important differences in light of the more obvious similarities shared by the human population.

Ultimately, the results of the superimposition technique present the same information that can be ascertained from a side-by-side examination. The superimposition technique can be viewed as an unfairly prejudicial and misleadingly authoritative process in the context of facial image comparisons.

In regards to the Hitler & Braun case, the superimposition technique failed to provide a useful avenue for obtaining information that could meaningfully contribute towards addressing questions of identity. The technique may have more credibility when applied to scenarios requiring the examination of rigid 2D patterns such as shoe mark analysis.

Facial Symmetry Comparison

When considering the capacity for facial symmetry comparison to support the analysis of facial photographs, the underlying premise of the technique appears promising however, the approach still requires further research and development before it can see dependable application.

The main areas requiring further research include the development of a reliable, repeatable and accurate method for locating the midline of the face and a method for reliably evaluating images to determine whether they are suitable to undergo analysis. By reducing the level of detail involved in the examination from the intricate analysis of facial features to a comparatively simpler judgement concerning the distribution of asymmetry, the complexity of the interpretation is somewhat reduced, although there is still a level of personal judgement required concerning the determination of symmetrical balance.

There is significant merit to any comparative technique that attempts to minimise the level of subjectivity involved during analysis. Facial symmetry comparison is one such effort and morphological analysis can be viewed as another. Other techniques have also been established by researchers that transform how photographic representation is normally presented in an attempt to minimise the subjectivity involved during comparison. One such technique was developed by Porter & Doran [2000]. The method reduces the complex facial image into a more straightforward representation formed by edge line tracings, enabling a direct comparison of separate photographs. The technique is beneficial because it mitigates distractions invoked by features such as facial and head hair that can subjectively influence the recognition of similarity. Also unlike image superimposition which obfuscates detail, the technique can be readily overlayed without compromising the level of information available for supporting comparison. A similar technique was developed by Miranda *et al.* [2016] for dentition based superimposition comparison using a line tracing or 'smile line' of the outer edge boundary of the teeth.

7.11 Chapter Conclusions

This chapter investigated the methodological approach of comparative image analysis through the application of various techniques to a case study requiring the comparison of facial information. The study enabled first-hand insight into the capabilities and difficulties associated with forensic image comparisons, facilitating the contemplation of values exemplified by the process of comparative image analysis for supporting the development of photointerpretation principles, thus, contributing towards addressing the central research question.

The work undertaken addressed the following questions:

- Do the two questioned evidential photographs depict the identities of Adolf Hitler and Eva Braun?
    - No determination could be made regarding the identities depicted in the questioned evidential photographs.
    - The comparative image analysis techniques applied to the questioned images each provided inconclusive results.
    - The case study provided an excellent platform for the exploration of values that can be considered integral for

supporting methodological principles necessary for a robust forensic photointerpretation capacity.

- Can morphological analysis be considered a useful image comparison technique for assisting photointerpretation?
  - Morphological analysis does have the capacity to be employed in a transparent manner. If used within its limitations and under the strict photographic conditions that ensures the maximum reliability of detected features, the method can be used for exclusions and potentially identification.
  - The technique did not aid in addressing the question of identity investigated in the case study.
- Can photographic superimposition be considered a useful image comparison technique for assisting photointerpretation?
  - The superimposition technique appears to be an unfairly prejudicial and misleadingly authoritative process when applied to the comparison of facial images. The application of image superimposition in the context of this investigation appeared to provide an avenue for purely subjective assessment.
  - The technique was not useful in addressing the question of identity investigated in the case study.
- Can facial symmetry comparison be considered a useful image examination technique for assisting photointerpretation?
  - Facial symmetry comparison has the potential to support the comparative analysis of facial photographs.
  - The underlying premise of the technique appears sound however, more research is required before the variation of the

technique presented in this thesis can see reliable practical application.

- Facial symmetry comparison did offer some insight towards addressing the question of identity investigated in the case study. There was conflict detected between the apparent facial symmetry of questioned image QA and exemplar imagery which suggest that QA is not Hitler. However, due to the infancy of the technique, conclusions were held with low confidence.

This investigation enabled the elucidation of the following values important for supporting the development of methodological based photointerpretation principles that were strongly demonstrated by the comparative image analysis approach:

- **Sensitivity:**
    - The resolution of the characteristics targeted within an image needs to be sufficient to distinguish between different samples for the purposes of the examination.
    - For example, two similar appearing vehicles can be distinguished based on the serial numbers depicted on their registration plates, whereas two similar appearing faces may require distinctive, minute facial characteristics to assist differentiation. Two distinctly different faces could be excluded based on more macro level feature differences such as between the nose or the ears.
- **Quality:**
    - The capacity of any photographic material undergoing analysis needs to be sufficient to resolve distinctive features relied on during analysis.

- **Specialised Knowledge:**
    - There needs to be the recognition of the requirement for specialised knowledge relevant to photointerpretation (e.g. photography and photographic science principles) necessary for supporting image based interpretive analysis for developing evidence.
- **Exemplar:**
    - All exemplar material used for comparisons should be obtained and compared in a like-for-like manner to ensure a fair evaluation and that any detected differences or similarities are indeed true manifestation and not a result of distortion or artefact.
- **Bias:**
    - The issue of bias must be a consideration when undertaking photointerpretation tasks. The format, order of process and selection of material during examination and presentation of findings may have an influence on examination findings and perception of evidence significance.

The following chapter continues the investigation into the establishment of key methodological and conceptual photointerpretation values through the introduction and exploration of reconstruction based image interpretation applications.

Chapter 8

8.0 Methodological Approach: Reconstruction Based Photointerpretation

Photographic and video images continue to play important roles in criminal justice systems, particularly in the investigation and prosecution of crime. Indeed, in recent decades the forensic use of images has been proliferating. Yet, photographic and video evidence is fraught with dangers. Images do not speak for themselves: they require interpretation.

Gary Edmond [Edmond *et al.* 2009, p. 1]

The previous chapters explored and elucidated critical photointerpretation values inspired by the process of comparative image analysis. This chapter presents the concept of reconstruction based photointerpretation as a technical approach for interpretive image analysis and a platform for the conceptualisation of values integral to supporting photointerpretation principles. A number of applied examples of reconstructive photointerpretation were investigated which enabled the exploration of a wide range of facets and nuances associated with the methodological approach that would otherwise be inaccessible through a single case study investigation.

8.1 Forensic Science & Reconstructive Approaches to Evidence Examination

The term 'reconstruction' within the forensic science domain is generally associated with the notion of crime scene reconstruction which is defined by Saferstein [2007] as:

> *The method used to support a likely sequence of events by observing and evaluating physical evidence and statements made by those involved with the incident [Saferstein 2007, p. 83].*

The purpose of an event or scene reconstruction is for the development of a narrative that can assist to uncover a number of details about an incident including the nature, time frame and order of the event(s) that had occurred. The goals of the reconstruction are achieved through the integration of several sources of information including physical evidence, crime scene photographs, video, diagrams, sketches, witness statements, computer modelling and simulations [Chisum 2011; Ogle 2004; Robinson 2007; Saferstein 2007].

Even though crime scene reconstruction is not the focal topic of this chapter, a brief background highlighting key concepts associated with the technique and its application to forensic science questions would benefit the exploration of reconstruction based photointerpretation due to the number of parallels the techniques share.

The reconstruction of an incident or crime scene is highly dependent on interpretation. Multiple types of evidence and input from multiple disciplinary experts may be required for the formulation of the overall reconstruction hypothesis (the proposed narrative that best fits the evidence). Despite being centred around evidence, reconstructions are subjective and depend substantially on the skill, experience and knowledge of the experts involved. Although any form of evidence can contribute to the reconstruction effort, several evidence fields and examination techniques share a clear resonance with the goals of crime scene reconstruction. Blood spatter analysis, ballistic examination, glass fragment examination, fire burn pattern analysis, medical examination, forensic engineering, 3D modelling and physics based simulations; in addition to providing factual evidence; augment the level of contextual information available for supporting the development of hypotheses that can plausibly explain the nature of the critical events that took place [Buck *et al.* 2007; Buck *et al.* 2013; Chisum 2011; Hueske 2016; Klasén 2001; Kolmogorov & Zabih 2002; Robinson 2007; Saferstein 2007; Sauter 2011; Schuh *et al.* 2013; Se & Jasiobedzki 2006; Yen *et al.* 2003; Young & Reina 2009].

Examples of incident types where forensic reconstruction can offer value include homicides, shooting incidents, assaults, fire related cases and traffic accidents. Reconstruction in these cases can provide insight regarding a number of questions. For example, when considering a shooting incident, reconstruction can assist to answer inquiries regarding the potential number of weapons involved, number of shots fired and bullet trajectories. For homicide investigations, reconstruction can assist in determining whether a murder or suicide may have taken place. Traffic incident reconstructions can assist in revealing whether an accident might have been caused by driver error or mechanical failure. Blood spatter analysis can reveal a host of contextual information including the potential nature of weapons used to cause bloody trauma, location of points of impact, movement of people around the scene and disturbances of object placement after spatter deposition. Fracture patterns found on panes of glass can reveal the order damage has occurred caused by a sequence of bullet holes or the direction of breakage, i.e. whether a glass pane has been broken from inside out, or outside in. Fire incident reconstruction can reveal the possible use of accelerants or origin of the fire. Physical crime scene reconstruction principles have even been extended to the domain of computer forensics where the process of digital event reconstruction can be used to develop and test hypotheses relating to digital system use [Carrier & Spafford 2004; Chisum 2011; Hueske 2016; Ogle 2004; Saferstein 2007; Yen *et al.* 2003].

8.1.1 Photographic Evidence and Reconstructive Based Analysis

The photointerpretation approach central to this chapter is concerned with the application of forensic reconstruction concepts to image analysis goals.

Reconstruction based photointerpretation can be defined as:

- The reconstruction of the photographic scene in order to develop a more contextualised understanding about the image and therefore, enable questions about the photograph to be answered that could not otherwise be done so without the additional information or insight provided by the reconstruction.

The photointerpretation approach shares similarities with crime scene reconstruction methodology. Reconstructive image interpretation considers the photograph as somewhat the equivalent of a crime scene. The photograph and the wider context of the physical scene become the primary sources of information. Questions that are investigated are explicitly concerned with or related to the contents of the image.

In a manner similar to the crime scene reconstruction process where different questions can be answered through various adaptations of the technique; reconstruction based photointerpretation can provide answers to various inquiries or provide further insights regarding a photograph and its visual content.

Reconstruction based photointerpretation should not be confused with the term 'image reconstruction' which is presented in some sources of literature. Image reconstruction is linked exclusively to the development of 3D computer generated models from a collection of digital images which can be of help towards crime scene reconstruction purposes [Bramble, Compton & Klasen 2001]. Reconstructive image analysis, unlike 'image reconstruction', is instead concerned with the exploration of forensic questions about an image that can only be addressed through the appropriate contextualisation and combined examination of real world and photographic scenes. Reconstructive image analysis can still involve aspects of computer modelling as demonstrated later in this chapter.

8.2 Questions

This chapter sets the stage for the exploration of the following questions:

- Can key conceptual and pragmatic principles for forensic photointerpretation methodologies be elucidated from a reconstruction based approach to image analysis?

- If so (following from above), what values integral for developing photointerpretation principles are exemplified and/or inspired by reconstructive image examination?

8.3 Aims & Objectives

The primary **aims** of this chapter are to:

- Investigate photointerpretation concepts involved in reconstruction based image analysis;

- Explore photointerpretation values stemming from a reconstruction based image analysis methodological approach important for the establishment of critical forensic photointerpretation principles.

This chapter achieves its aims through the realisation of the following **objectives**:

- Exploration and contemplation of the application of reconstructive image interpretation processes through a reflection on several literary examples.

8.4 Differentiating Contextual Bias and Contextual Support

When considering reconstruction based photointerpretation, context undoubtedly provides crucial information for supporting analysis. The subject of context, or more so, contextual bias has seen growing attention in its application to forensic science [Budowle *et al.* 2009; Dror, Charlton & Péron 2006; Dror & Cole 2010; Edmond *et al.* 2014; Langenburg, Champod & Wertheim 2009]. Champod [2014] highlights the fact that the issue of bias was designated a priority research area (recommendation 5 out of 13) by the NAS Report [2009, p. 24].

The notion of contextual bias was introduced previously in Chapter 7, specifically, with regards to dangers associated with comparative image analysis. Contextual bias problems extend beyond comparative analysis. For further elaboration, Edmond [2014] offers the following insight regarding the issue:

> *The perception and interpretation of evidence is a subjective process that can be influenced by a range of cognitive, contextual and experiential factors. This is particularly so where the evidence to be evaluated is of low quality or ambiguous. In such circumstances a common response is for the decision-maker to bring any and all information to bear on the task in the hope of reaching an informed decision. While this is a useful strategy in many day-to-day situations, it has the potential to introduce undesirable forms of bias into the work of forensic analysts. That is, where an analyst is exposed to extraneous (ie, domain irrelevant) information about the investigation, such as the suspect's prior criminal history, they may be more likely to perceive or interpret evidence in ways that are consistent with this domain irrelevant information [Edmond et al. 2014, p. 184].*

Research into the effects of contextual bias have predominantly focussed on visual based pattern analysis fields, particularly fingerprint examination. Findings have indicated that failures in objectivity can result as a consequence of exposure to extraneous information considered unrelated to the examination. The solution suggested for minimising the potentially damaging effects of context involve the implementation of systems and procedures that prevent examiner exposure to such information [Budowle *et al.* 2009; Champod 2014; Dror, Charlton & Péron 2006; Dror & Cole 2010; Langenburg, Champod & Wertheim 2009].

A few scholars, while acknowledging and conveying their support regarding the potential harm that can result from biasing contextual information; argue that context can also be important for forensic examinations.

Budowle *et al.* [2009] contends:

> *Complete ignorance to case specific information exhibits poor judgment and should not be considered. The difficulty is in determining what relevant information to request and what is superfluous [Budowle et al. 2009, p. 803].*

Champod [2014] also supports this thinking, expressing the following key points:

> *I can foresee the following risks of being focused on bias only:*
>
> *(a) The risk of enforcing the view that the forensic scientists should be detached, blind and immune from any external influences (especially from the inquiry).*
>
> *(b) The risk of enforcing the view that forensic experts can continue to operate as "black boxes" provided they work according to regulated standard operating procedures, designed to cure for bias and that estimates of the error rates associated with their decisions are disclosed. A corollary is the risk to ignore the needed requirement to develop fundamental research in areas dominated by decision-making processes based largely on human perception and skilled judgement [Champod 2014, p. 107].*

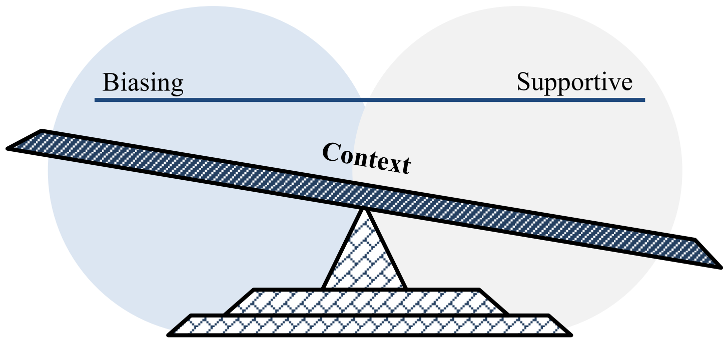


Figure 8.1: Diagram depicting the conceptual balance between the biasing and supportive potentials of contextual information. How exactly context can be assessed and weighed according to its ability to provide support is not yet understood.

Context can indeed offer important information, particularly when interpretative tasks are involved and should not be completely isolated from all forensic examinations. The differentiation between context that is negatively biasing, and context that is helpful and supportive to forensic examinations needs to be recognised.

Briefly introduced earlier in Chapter 2 of this thesis was a case study conducted by Porter [2012] titled *'Zak coronial inquest and the interpretation of photographic evidence'*. Porter unpacked the dangers of unsound photointerpretation examination through the exemplification of expert witnesses related to the *Zak* case who presented misleading and unreliable photographic evidence. The study is noteworthy because a key concern reflected by Porter was the failure of the experts in question to utilise supportive contextual information available to them through the post-mortem report compiled by the investigating pathologist that could have greatly assisted their interpretations.

In brevity, the key contentions examined in the study revolved around previously unconsidered evidence supposedly suggested by photographs that unjustifiably contradicted the findings of the investigating pathologist. These inconsistencies included the apparent identification of trauma not previously accounted for, unsound entomological evidence based on supposedly depicted insect mass and the inappropriate identification of evidential items at the scene that were somehow previously unaccounted for. The 'new' evidence supposedly conveyed through the photographs was concluded by the Coroner to having an unsubstantiated factual basis.

The following excerpts from Porter's [2012] study communicate a fundamentally important consideration that reconstruction based photointerpretation has the capacity to address:

> *Henneberg's[5] findings, as indicated in the Coroner's report, appear to be in contrast to the forensic pathologists, including Cadden[6] who witnessed the scene and body first-hand [Porter 2012, p. 44].*
>
> *The interpretation was also considered without proper contextual information that the forensic pathologist's report may have provided (Hope 2007)[7]. Sourcing facts directly from photographs may also suggest that evidence and the information captured in the photographs is implicit. This thinking is aligned with a misunderstanding of the concepts associated with photographic truth, and confidence associated with photographic viewing can inappropriately become the threshold of facts without a suitable forensic evaluation of the evidence [Porter 2012, p. 45].*

Porter alludes to the importance of a connection between real life and life's reflection (the photograph) that can prove essential for the development of reliable

[5] Henneberg was one of the experts in the case who practiced unsound photointerpretation.
[6] Cadden was a forensic pathologist who worked on the Zak case.
[7] Alastair Hope was the investigating Coroner. Reference: Hope AN (2007) Inquest into the Death of Romuald Todd Zak, Western Australian Coroners Court, Ref no 11/07.

evidence. In the *Zak* case, there was a disconnect between the information offered by the witness who physically attended and examined the scene/evidence (pathologist) compared to the information extracted solely from non-contextualised photographs. The idea of situating an image within the appropriate context in order to assist understanding and evidence development is at the heart of reconstructive based photointerpretation practice.

8.5 Reconstructive Image Interpretation Procedure

The exact methodological process required for photographic reconstruction depends on the goal of the analysis. Generally, the scene depicted in the questioned photograph is required to be physically attended. After confirming scene location, the photographic conditions that governed how the questioned image was captured at the scene may need to be established including camera angle, perspective and lighting conditions. This aspect is less challenging for systems that are fixed in place such as CCTV or surveillance cameras. Such fixed systems can possibly be commandeered to support reconstruction, eliminating the difficulty involved with the manual replication of photographic parameters.

Scene elements such as objects and people (or equivalent substitutes) depicted in the original questioned image may need to be re-introduced to recreate the scene as it was at the time of capture. External material may also be incorporated into the reconstruction such as measuring tools or reference indicators that might be helpful for the determination of physical scene dimensions or other photogrammetric functions. The scene may then be required to be recaptured to validate the integrity of the reconstruction and/or provide photographic evidence useful for further analysis.

Figure 8.2 provides a diagrammatic representation that outlines the key methodological components and considerations required for conducting photographic reconstruction.

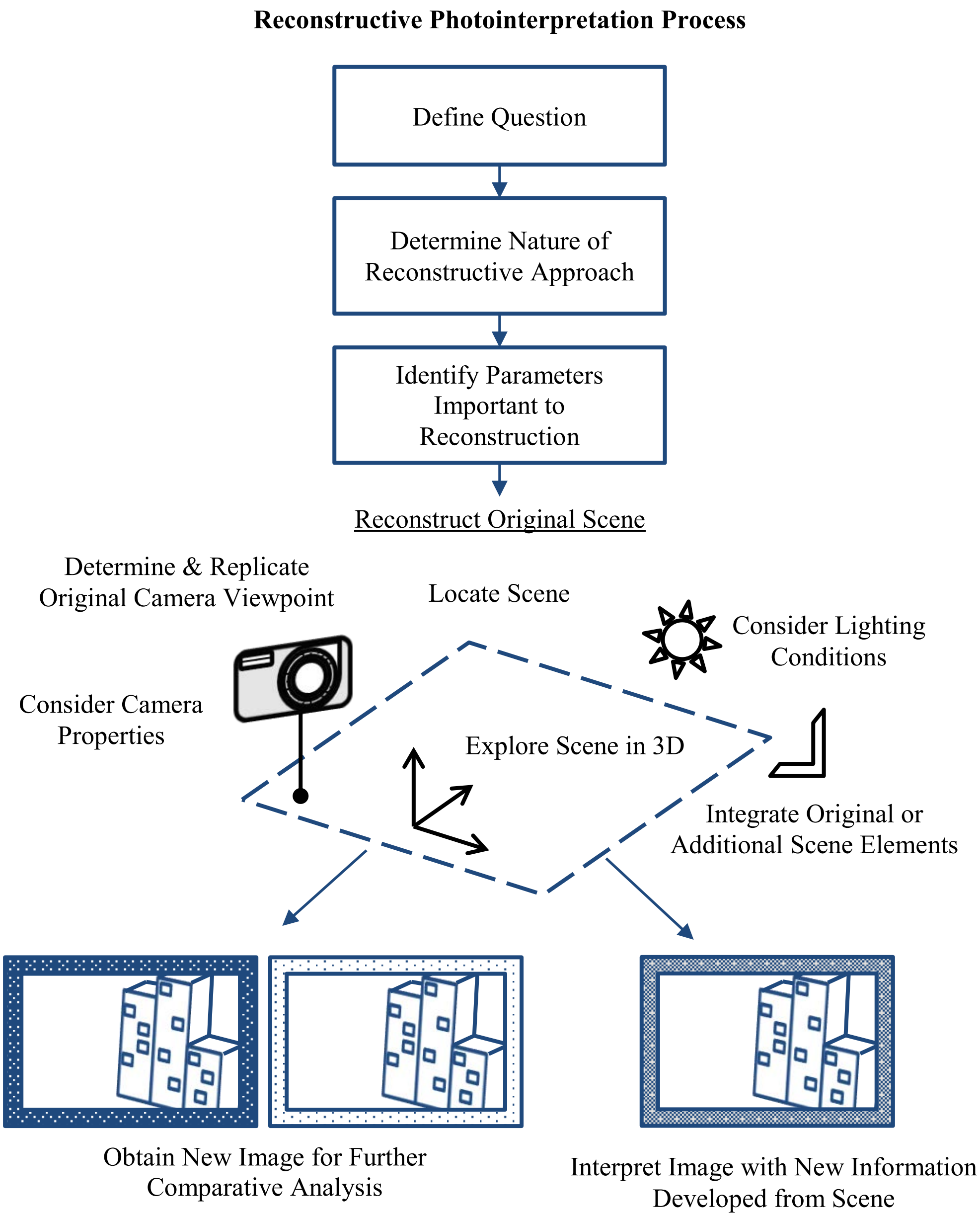


Figure 8.2: Diagrammatic representation of key methodological components required for consideration during photographic reconstruction practice.

The development of an appropriate hypothesis or question to guide reconstructive based image examination is important as it assists to determine the most appropriate adaptation of the technique and can focus attention towards specific considerations such as camera or scene parameters, required for performing the analysis that ensures critical questions are addressed. The questioned asked should also remain within the expertise of the analyst conducting the reconstruction.

The end product of a photographic based reconstructive analysis generally results in either the production of a new image based on the reconstructed scene which can be used for further comparative purposes or the development of information regarding the original scene that can better inform understanding concerning the questioned image.

8.6 Applications of Reconstructive Image Interpretation

8.6.1 Timeline & Event Reconstruction

A degree of overlap exists between some functionality that can be considered to fall under the umbrella of reconstructive image analysis and that of the crime scene reconstruction method. This overlap concerns the establishment of timeline and event sequences based on images examined from sources such as CCTV or personal camera devices.

Milliet *et al.* [2015] demonstrate a range of image based event reconstruction techniques to support crime scene reconstruction efforts. One technique used is the establishment of a time line using image metadata and visual content to temporally align a sequence of photographs or footage obtained from multiple sources. Discrepancies in internal camera time were overcome by synchronising the image sequence to noticeable visual events such as a ‘camera flash’ that was apparent across multiple perspectives. This approach can provide an excellent source of intelligence for assisting investigative efforts. The establishment of an image timeline and/or event reconstruction that links multiple perspective can provide a level of context that can greatly assist to clarify certain details or develop understanding within questioned images by enabling examination from a different viewpoint.

8.6.2 Reconstruction for Supporting Visual Analysis

Reconstruction can be conducted with the intent of supporting further visual analysis of questioned images [SWGIT 2013]. A reconstruction with such a goal is useful for assisting to address questions regarding representation such as:

- Is subject X the same or different to subject Y?

When colour and structural information is important to an examination, photointerpretation reconstructions need to carefully consider parameters such as time of day, available lighting and the source camera's spectral sensitivity, which might not be necessary for other reconstructive tasks.

The work undertaken by Denny [2015] illustrates the importance of replicating exact photographic conditions when attempting to create a 'like-for-like' exemplar image for supporting other examination techniques such as comparative analysis. Denny demonstrated the need for considering the spectral sensitivity of the camera and lighting environment, not just viewpoint and perspective, when capturing comparable images. In Denny's work, several garments were photographed using a standard DSLR camera and a CCTV camera with near infra-red (NIR) capability under standard and low level lighting conditions. Visual differences between the DSLR and CCTV camera under standard lighting were dramatic. Tonal variations were observed as several dark/black toned garments were reproduced with a noticeable bluish cast through the CCTV system. The same garment, captured with the same camera (CCTV) under different lighting environments (low lighting forced camera to switch to NIR or 'night-vision' mode) resulted in even greater visual variance. Apart from a loss of colour information, low level lighting resulted in the altered appearance of several garments including changes to the visualisation of distinctive components such as stripes and bands of fabric.

Denny expressed the importance of understanding and appropriately considering the potential for the differential appearance of objects in real life compared to photographs, particularly when this information might be relayed to investigative units looking to locate the object. The connection between real life and photographic representation could only be established through the appropriate contextualisation of the questioned photographs as nothing implicit within the questioned image could otherwise elucidate this link.

Another example of reconstruction based image examination that focussed on addressing the question of visual representation was the investigation conducted by Porter [Porter 2011b, p. 150], as part of a wider case study. Porter conducted a reconstruction of a photographic scene in order to determine the approximate distance the subject of interest was recorded from the camera. Through a combination of physical scene attendance and use of visual clues, the location of the original camera and positon of the subject was established. This enabled the measurement of subject 'u' distance which could not otherwise be conducted from image alone. The empirical measurements obtained from the reconstruction informed an assessment regarding the comparability of the questioned images to associated exemplar images. It was found that the exemplar material was captured at a 'u' distance significantly different than the questioned images. Through further research, Porter demonstrated that the difference in perspective could produce noticeable changes in morphological representation, questioning the reliability of any comparative examinations conducted.

The reconstruction undertaken by Porter did not require explicit consideration of camera properties or lighting conditions, the inclusion of original scene elements or the necessity to photographically re-document the scene. What the reconstruction enabled was the development of further information regarding the subject's positioning within the photograph which assisted the development of a greater understanding regarding subject representation.

8.6.3 Reconstruction for Geolocational Information Development

The increasing prevalence of self-manufactured, self-incriminating imagery being distributed through channels such as social media [Yar 2012] may require the involvement of a photographic reconstruction approach for the determination/verification of locational data. Thompson [2008] states:

> *...photographs taken by individuals of themselves breaking the law are being used progressively more by the police, and they are now being found increasingly on the internet – particularly file-sharing or social networking sites such as YouTube and MySpace. These are often serious crimes, and include violent behaviour, public disorder and vandalism [Thompson 2008, p. 11].*

A reconstruction with a focus on location information can be useful for assisting to address questions such as:

- Is scene X located at/near location Y?

The determination of location may be important for supporting a number of forensic or investigatory activities such as:

- Development of criminal intelligence regarding the location of illegal sites;
    - Horswell [2004, p. 366] provides an example of a case involving the recovery of a photograph from the possession of a suspect that depicted an allegedly illegal drug crop. The location of the site was determined based on the depicted tree line in the background of the image despite the crop being removed at the time of investigation. A reconstruction of the original photograph assisted the verification of the location.
    - A recently dismissed legal case involving a mining company seeking to explore a site in New South Wales (NSW), Australia, was initially instigated when it was discovered that photographs submitted as part of the company's application process did not accurately reflect the actual location they wished to engage [Woodburn 2016]. In this instance, the owner of the site reported the inconsistency of the images however, a verification process for locational photographs used for official purposes

may be a reasonable future response which would require the implementation of reconstructive photointerpretation concepts.

- Determination of the location where criminal activity may have occurred or offender whereabouts;
    - The identification of the site depicted in an image portraying an offence may be useful for the location of offenders and prevention of further transgressions, or the determination of the relevant jurisdictions responsible for investigating the alleged offence, if an offence has indeed occurred according to said jurisdiction.

- Determination of site related changes over time;
    - Grip, Grip & Morrison [2000] canvas various applications aerial photography can offer for supporting environmental forensic investigations. A number of the image based interpretive techniques described require the comparison of images taken of the exact same location at different dates. The process of acquiring a new photograph of a specific location at a different time can be considered an act of reconstruction. The comparison of a previous image to a later photograph enables information to be developed over the 'time' domain. Precise locational information is needed to enable this process which is often provided by an integrated GPS coordinate system. The examination of exacting scene photographs over a period of time can be useful for the identification of environmental damage or pollution.
    - Communication with Police [personal communication Queensland Police, Australia, 2013] has indicated incidences where speeding fines have been attempted to be contested by way of 'photographic proof' depicting conflicts regarding

speed limit signage. Location based photographic reconstruction could assist to uncover whether photographs of speed signs are genuine or doctored.

- Identification of second-generation images.
    - Also previously discussed *(5.1.5 Global Positioning System (GPS) Metadata*), discrepancies between the depicted location in an image and the location indicated by GPS coordinates may suggest that an image is a second-generation reproduction.

When undertaking a reconstruction with a specific focus on location, positional information embedded within the questioned image should first be attempted to be extracted. If embedded GPS coordinates are present, an examination of satellite imagery may be a first step for assisting to locate the scene. Errors in GPS accuracy and/or map coordinate registration need to be factored into this process. The physical visitation of a suspected location may be necessary for site verification.

In the absence of GPS data, any form of visual information that can assist determine location should be considered such as the examination of buildings, architectural style, vegetation, key landmarks and other objects within the questioned image. Lastly, time related discrepancies between image and a reconstructed scene, such as deviations in the appearance and density of vegetation, also need to be considered.

8.6.4 Reconstruction for 3D Space & Perspective Interpretation

Photographic reconstruction can be conducted for supporting analysis concerned with spatial and perspective related questions. A reconstruction with such a focus is useful for testing hypotheses such as:

- Was event/object X or Y observed/not observed?

Kim *et al.* [2012] present a complex case involving a series of accusations put forth by two parties against each other based on the photographic documentation of a construction site. Kim *et al.* examined the claims from both sides to test their validity through the use of a photographic reconstruction process that employed a 3D model. A computer generated three-dimensional scene substitute was required for analysis because at the time of the investigation, the site of contention had undergone considerable change due to development which prevented comparable visual and photographic examination being conducted of the scene. The researchers determined that a model based on available photographic information could adequately assist their investigation. The 3D model enabled the placement of a virtual camera within the scene which resulted in the development of an understanding regarding perspective and photographic representation. This provided a depth of insight that ultimately clarified that the claims made by one of the parties was a direct result of perceptual error.

Another example of an investigation that involved questions of observation, 3D modelling and photographic reconstruction is the 'Waco investigation' [Klasén 2001]. The incident involved a siege between Untied States law enforcement and a religious sect (Branch Davidians) who resided at a complex located in Waco, Texas, U.S. The crux of the investigation was centred on whether FBI agents were shooting sect members. Footage obtained from an FBI surveillance aircraft depicted a series of flashes near the complex. Questions arose regarding whether the flashes observed in the footage were in fact gun fire or simply specular reflection.

Klasén was tasked with investigating the footage:

> *The hypothesis for this work was that the flashes instead were caused by specular reflections and the technical approach was to analyze and compare the flashes spatial and temporal appearance. The result showed that the flashes were mainly caused by specular solar reflections and thereby they could not form evidence of gunfire. Further, the result highlights the importance of considering the characteristics of the imaging system within investigations that utilizes images as information source. This is to separate real data from other phenomena (such as solar reflections), distortions and artifacts in a correct manner [Klasén 2001, p. 1].*

The researcher employed 3D modelling to examine and compare the spectral characteristics of the flashes to the properties of the camera, including flight path and speed. Several calculations, observations and comparisons to footage obtained of a similar event, informed the investigator about the nature of the observations within the questioned imagery.

The concept of examining perspective to gain a better understanding of depicted events can be extended to many situations. For example, perhaps an investigation concerning an alleged physical assault between two parties which was caught on CCTV requires greater clarification regarding whether the two individuals involved were actually located close enough to each other to support the allegation of assault. One party may deny making any gesture of physical contact while further suggesting they were not even proximal enough to make contact. They might further claim the other person simply tripped or fell down. A slow CCTV camera framerate might make it difficult to ascertain if any motion characteristic of an assault took place. The combination of camera angle and focal length may well indeed compress spatial representation and artificially portray scene elements closer together than in reality. A reconstruction could assist to determine the likely proximity of the individuals in such a scenario.

8.6.5 Reconstruction for Dimensional & Temporal Interpretation

Photographic based reconstructive examinations may also enable the physical measurement of elements depicted in the scene. A technique known as 'reverse projection photogrammetry' can enable the relocation of important scene elements (such as evidential items) back to their original positions at the time of capture, through the implementation of a photograph based guiding system. Once the scene is reconstructed according to the photograph, any measurements obtained enable a greater understanding regarding the physical relationships between scene items [Robinson 2007]. The measurement of fixed scene objects as a reference point can also be used for suspect height determination purposes [Criminisi *et al.* 1999; Lee *et al.* 2008]. Lastly, an examination of image metadata combined with a dimensionally focused scene reconstruction can also assist to estimate variables such as vehicle speed or distance travelled [Porter 2007].

8.7 Chapter Discussion

When reflecting on the methodological approach of reconstructive based photointerpretation, the photograph is understood and considered as a representational window into a moment in history which requires a connection to the broader elements of the physical scene in order to support understanding and supplement examination. The contextualisation of the image evidence is recognised as beneficial in these circumstances.

There is a danger that future efforts concerned with the development of forensic science practice will lose focus on the importance of advancing robust human-centric examination processes and principles, and instead create examination workflows specifically for the purpose of bias elimination. The result of such restricted practice could be the significant reduction to the depth of information obtainable as a result of evidence examination or a restriction to the range of evidence material considered examinable. The ensuing problem would be that forensic experts no longer consider certain types of examination. Untrained jurors would still be exposed to such forms of evidence or (e.g. impressions, marks, photographs) and consequently make dangerous assumptions. Such a state would essentially negate the functional role of forensic science. A system that is aware and attempts to limit the harmful effects of bias would mitigate this.

8.8 Chapter Conclusions

This chapter presented reconstruction based photointerpretation as a technical approach for interpretive image analysis. The application of the approach was explored through several examples from the literature enabling the conceptualisation of important photointerpretation values.

This work addressed the following questions:

- What values integral for developing photointerpretation principles are exemplified and/or inspired by reconstructive image examination?

This work developed the following values important for supporting photointerpretation based methodological approaches:

- **Question:**
    - The question being asked of the image needs to be defined prior to undertaking a photointerpretation based analysis to ensure the steps undertaken are conducive towards adequately addressing the question asked of the image.
- **Application:**
    - The particular photointerpretation methodology selected for assisting examination needs to be appropriately applied for addressing the defined question. The same approach might need to incorporate or focus on different details or nuances depending on the goals of the analysis.
- **Context:**
    - Context can offer important knowledge necessary for supporting various photointerpretation tasks. Situating an image within its appropriate context can greatly assist understanding and evidence development.

The following thesis discussion chapter addresses the primary research question through the development of key methodological and conceptual photointerpretation principles catalysed by the integration of findings developed throughout this thesis within the discussion medium.

Chapter 9

9.0 Discussion

Although the pursuit of photographic evidence in science and law is nearly as old as the medium, the underlying concepts of evidence and documentary expression have been frequently challenged. These contests of meaning – and all such disputes – are as much part of photography's history as are its technical accomplishments.

Mary Warner Marien [Marien 2014, p. XIV]

The critical role and prevalence of photographic evidence within the justice system will continue to advance as society and technology follow the current evolutionary trend towards a visual culture that supports and embraces the mass consumption of visual media. The advent of innovative new pathways for the acquisition of photographs combined with the wide spread adoption and ease of use of modern image sharing platforms equates to the increased likelihood that more and more photographs will see application in evidentiary roles. It is of great importance that the courts and forensic science practice are adequately prepared for this future.

The connection between photograph and evidence is not always straightforward. While an image can at times unambiguously communicate fact; a disconnect or convolution exists along the conceptual pathway that extends between image and truth or more importantly evidence reliability. Photographs have the potential to both reveal more than the obvious and less than the suggested. The lay observer's strong familiarity and experience engaging in every day visual communication conventions contributes towards the increased propensity for such audiences to apply an unsubstantiated level of trust to a form of representation that can be deceptive or illusionary. Unreliable photointerpretation evidence poses a great risk to a fair trial particularly due to this lessening of a critical view by evaluators. Deficiencies and inadequacies regarding current legal safeguards for photographic evidence further deepens the potential for danger.

Various scholars have recognised that forensic evidence derived from the interpretation of photographs requires practical and theoretical support to maximise evidence reliability, minimise harm from weak or misleading evidence and ultimately prevent serious miscarriages of justice [Edmond 2013; Edmond *et al.* 2009; Edmond *et al.* 2010; Edmond & Roque 2012; Edmond & San Roque 2013; Edmond & San Roque 2014; Evison 2014; Mallett & Evison 2013; Mnookin 1998; Porter 2007, 2011a, 2011b, 2012, 2013; Porter & Doran 2000; Porter & Kennedy 2012].

9.1 Principle Based Forensic Photointerpretation Framework

The outcome of this research is a conceptual model built around a central theme of critical photointerpretation principles. The model consists of six key principles as depicted in Figure 9.1. Each principle is supported by a series of critical photointerpretation values (Figure 9.2). The principles and values were distilled from the research findings presented in Chapters 4 through to 8.

This discussion explores the pragmatic photointerpretation model through the identification of the six key principles followed by further examination of the values within each principle.

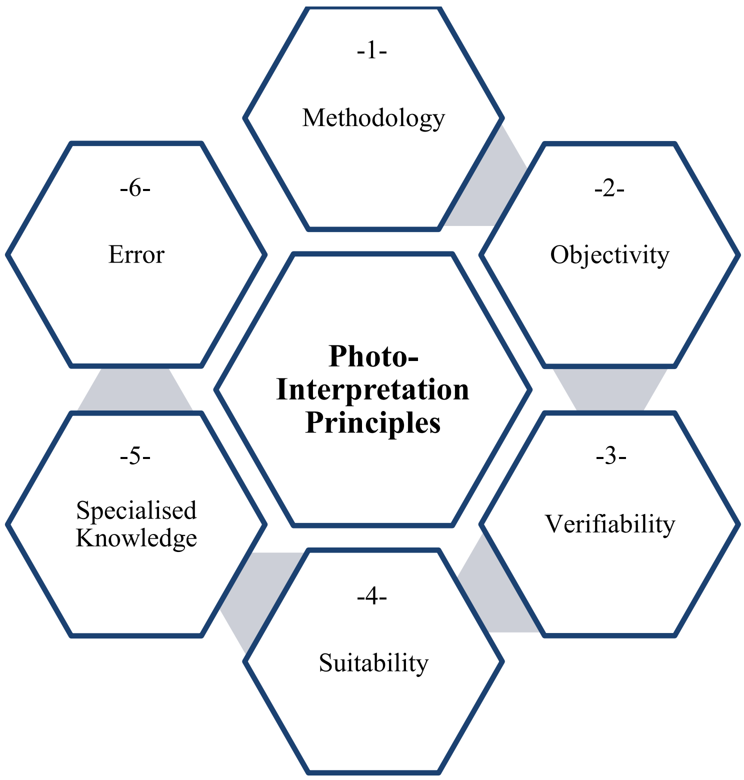


Figure 9.1: The six key photointerpretation principles developed through this thesis for supporting robust forensic photointerpretation methodologies.

The presented set of principles can be considered in isolation, viewed as a unified whole or regarded as a network of interrelated ideas. The numerical order associated with the principles bears no relationship to rank or importance and is simply a tool to assist systematic exploration and discussion.

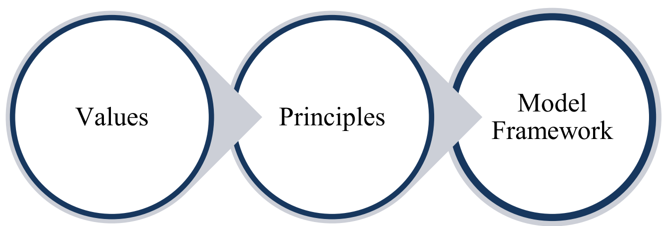


Figure 9.2: The principles within the presented model photointerpretation framework are supported by a series of values.

9.1.1 Discussion Convention

The six key principles of the proposed photointerpretation model are unpacked in this chapter through a process of diagrammatic representation and discussion.

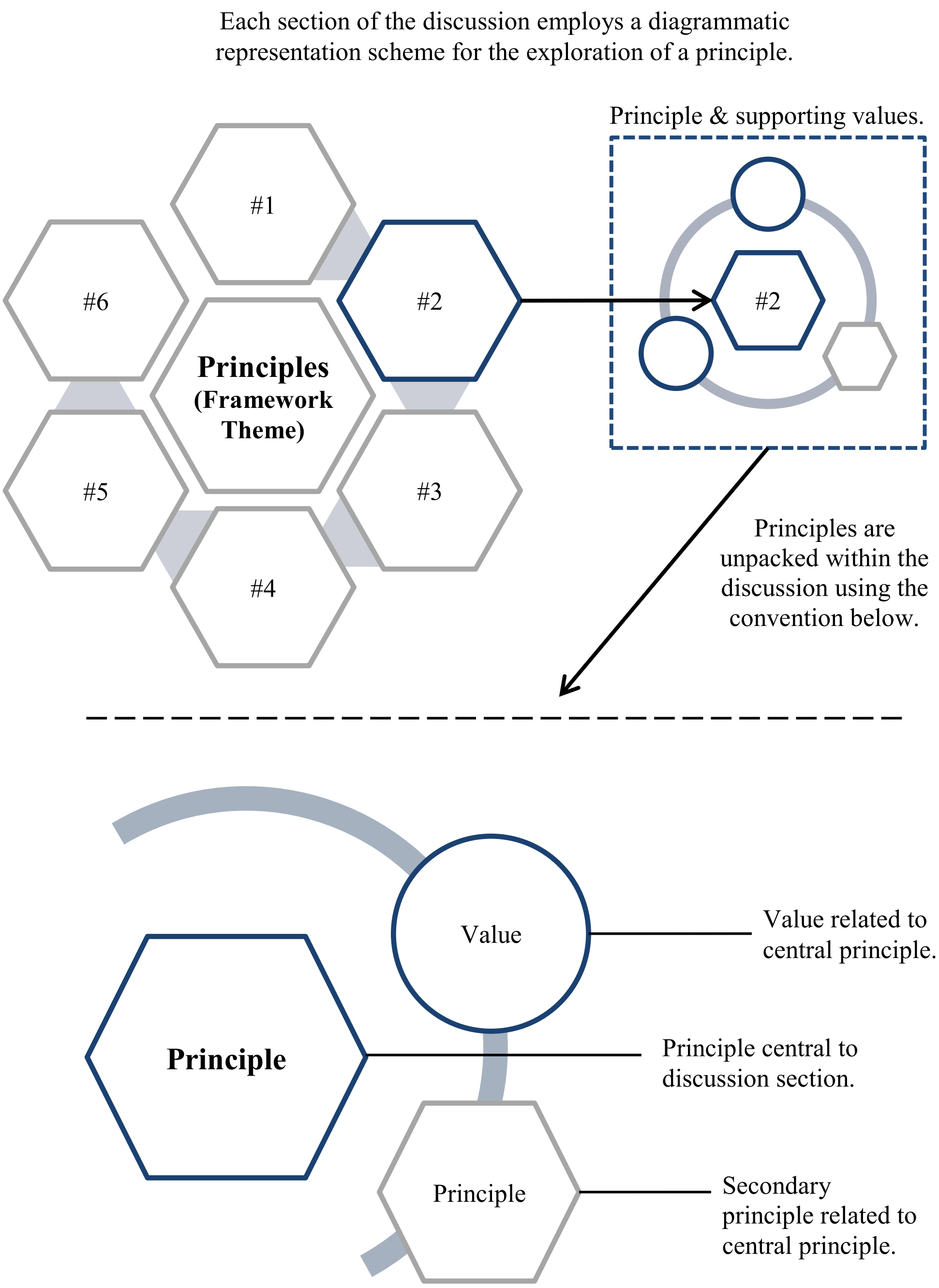


Figure 9.3: Diagrammatic convention used to assist discussion of key principles.

The convention employed to conceptually communicate and explore the photointerpretation principles (Figure 9.3) and related ideas is as follows: the central hexagon represents the principle of focus; radial circles represent important values related to the principle and radial hexagons indicate a reference to an external principle whose associated values are also particularly important to the current focal principle.

9.1.2 Key Principles

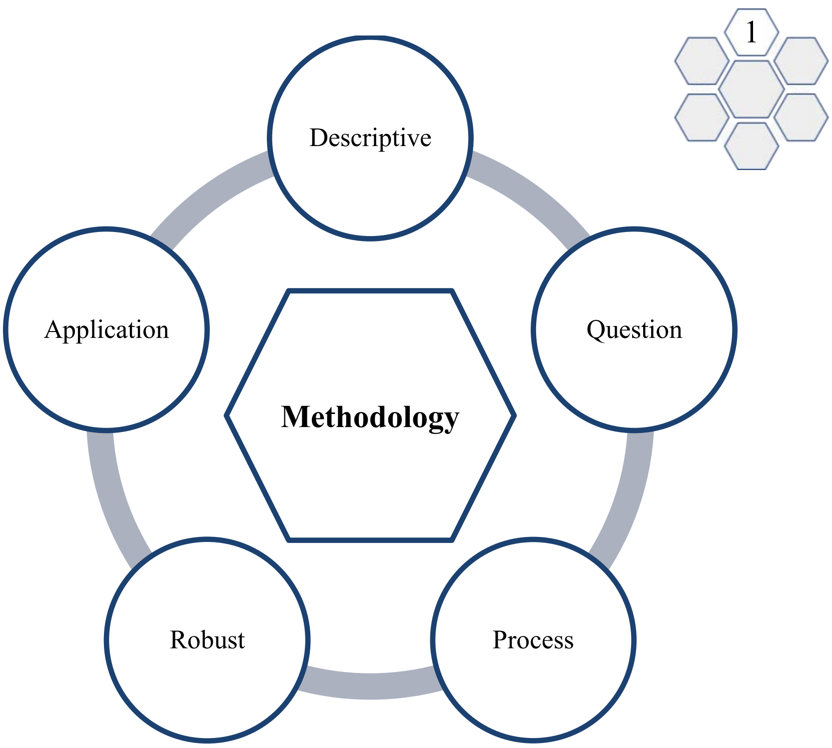


Figure 9.4: Photointerpretation principle of 'methodology' and major associated values.

The first principle within the proposed photointerpretation framework is **'methodology'**. The principle is concerned with whether the approach adopted for addressing a photointerpretation question or task is suitable and appropriately applied to the examination of images. The current lack of standards makes the development of formal and reliable photointerpretation methods an important endeavour for ensuring the provision of fair evidence and the establishment of the foundation necessary for furthering technique development and the advancement of the field.

This thesis unpacked three methodological approaches to photointerpretation practice. Real world cases may suffice with the implementation of any one approach or require a combination of several approaches. Regardless of the method(s) employed, serious consideration needs to be given to how methods can be implemented to maximise the reliability of examination.

The values pertaining to the photointerpretation principle of methodology are:

- **Process.** All methods applied must align with core forensic science evidence analysis principles including concepts of evidence integrity and continuity regardless of the physical nature of the evidence. It is important that any clerical, standard operating procedures (SOPs), requirements for chain of custody records, evidence exhibit registries and further related processes that are considered mandatory for other forms of forensic evidence, are also applied and maintained to photographic evidence. This requirement extends to notetaking procedures including the establishment and documentation of digital image adjustment/processing history logs;

- **Question.** The question being asked of an image needs to be clearly articulated. This consideration enables the determination of the most suitable method(s) for addressing the question asked of the photographic evidence and assists to ensure the most appropriate 'application' (expanded further below) of said methods. In each of the three approaches examined within this work, the question being asked of the image played an integral part in guiding analysis. Defining the question also assists to communicate the scope of examination;

- **Descriptive.** It is integral that the method or approach selected for assisting photointerpretation is adequately described through whichever medium is employed for the articulation of the processes undertaken and the reporting of findings. Description should strive to be as accessible as possible to all parties who might require an understanding of the details of the technique such as lay jury members, legal professionals and other imaging or external experts. Thorough and comprehensible description is important for the communication and evaluation of photointerpretation processes which further underpins other key principles;

- **Robust.** Photointerpretation methodologies should be tested to ensure outcomes are reliable and limitations and errors known. Despite testing, case-by-case nuances will be prevalent due to the complex nature of this type of evidence. Nevertheless, testing provides insight into the general ability of the method to perform as suggested and how best to adapt the approach to any case specific circumstances that may arise. The notion of testing a method is further reflected in the principle of 'verifiability';

- **Application.** The photointerpretation methodology selected for assisting examination needs to be appropriately applied or adapted for addressing the specified question. The same methodological approach might need to incorporate or focus on different variables depending on the end goals of the analysis. The investigation into reconstruction based photointerpretation (Chapter 8) demonstrated this concept. Reconstruction for dimensional based interpretation required a focus on a set of considerations which solely concerned scene and object location. This contrasted with the stringencies associated with reconstruction applied to the development of comparative material which required the precise consideration and replication of multiple details including image perspective and the spectral sensitivity of the camera.

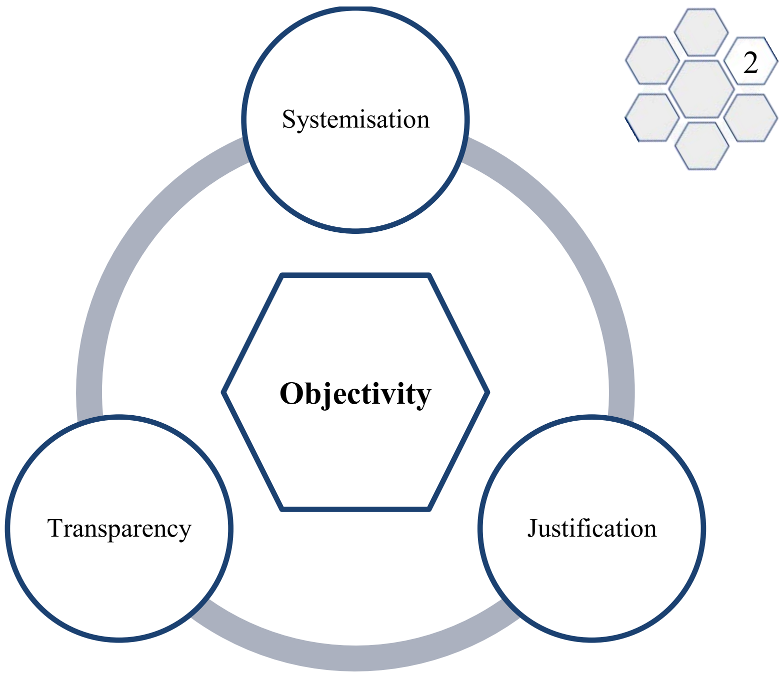


Figure 9.5: Photointerpretation principle of 'objectivity' and major associated values.

The second key principle of the model photointerpretation framework proposed by this thesis is **'objectivity'**. This principle addresses issues of subjectivity and resonates with the notion of a coherent, well-structured, transparent and justified approach to photointerpretation tasks. Many forms of instrument driven examination such as spectrophotometry, chemical and DNA analysis require human based interpretation of output visual and empirical information, e.g. graphs. These disciplines are also affected by the issue of objectivity versus subjectivity and attempt to address concerns through the implementation of standards, calibrated instrumentation, specialised training and systems of experimentation and monitoring. A primary distinction between photographs and other sources of evidence such as chemical or biological traces, is the absence of a significant quantitative basis for grounding interpretation. The photointerpretation process relies largely on qualitative information because this is the inherent nature of photographic representation.

When a photograph is examined for the extraction of evidence based solely on the opinion of a human expert rather than the mechanical reading of data, it is important that the complete level of subjectivity afforded to the process is minimised or made obvious in order to bolster reliability. Approaching or considering an examination through the principle of objectivity can limit the potential pitfalls that could transpire if an expert were to rely exclusively on the internalised and inaccessible faculties of experience and judgement, no matter how these qualities may relate to specialised knowledge.

The values pertaining to the photointerpretation principle of objectivity are:

- **Systemisation.** A systematic and structured approach to examination can reduce the likelihood of error or procedural omissions and maximise the repeatability of analysis, which is also important for verification purposes;

- **Transparency.** Transparent reporting of methodological processes or steps undertaken during examination should be an integral component of all forensic evidence development practices. This value underpins several photointerpretation principles. The open communication of the thinking process employed during interpretive analysis, including the disclosure of any speculation or assumptions relied on during analysis (as suggested by the principle of 'error'), can assist to strengthen the responsibility and culpability of the expert through the facilitation of scrutiny by external parties. Transparency can further bolster confidence in the approach used for examination through third party support and further assist to prevent miscarriages of justice through the identification of potential contentions or misapplications of methodology not considered by the current examiner;

- **Justification.** The justification of the elements involved in a photointerpretation process (e.g. criteria, observations, calculations, procedures) further assists to support evidence reliability through the communication of the reasoning employed by an examiner. Justification helps to clarify the link between practice and specialised knowledge and to overcome the dangers of completely internalised opinion development.

The photointerpretation approach of 'criteria based image examination' explored throughout Chapters 4 and 5 provides an excellent example of the principle of objectivity applied to an interpretive task which would normally reside solely within the domain of subjectivity. The employment of a criteria centric approach to the detection of second-generation images enabled the transparent breakdown of factors considered important during decision-making. The approach also assisted to limit the scope of the involved level of subjective analysis, restricting judgement primarily to a series of systematic binary decisions that in summation informed the overall finding.

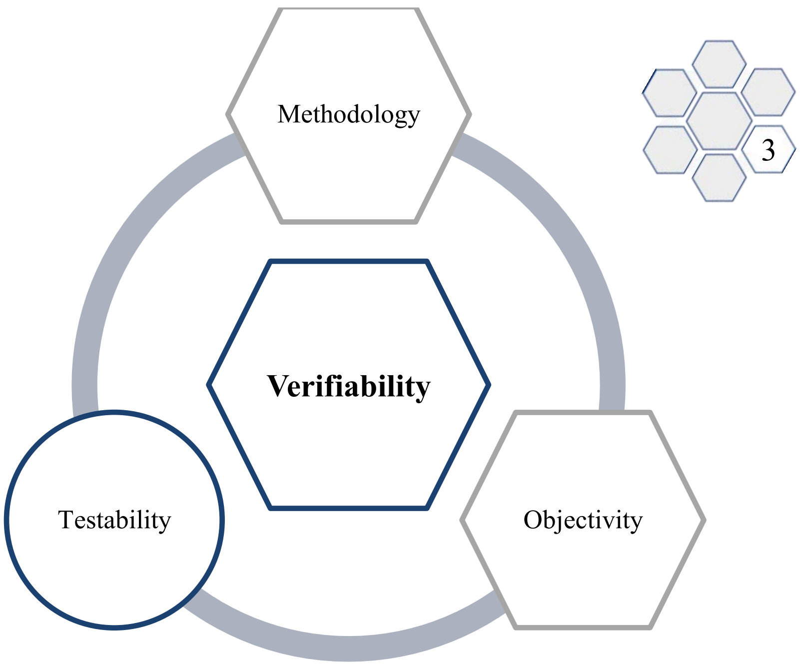


Figure 9.6: Photointerpretation principle of 'verifiability' and major associated values.

The third principle of the photointerpretation model is **'verifiability'**. The principle relates to the capacity to assess whether a photointerpretation approach can perform in the manner suggested. Verification can shift the position of a proposed method from educated assumption to the status of a practicable fact finding tool. Verification should not be confused with 'validation study', which is a far more strenuous and empirically driven process for gauging the reliability of a technique used under controlled and consistent conditions.

Some scholars have suggested that the reliability of forensic science practices including photointerpretation tasks should be assessed through a combination of empirical validation studies that involve ground truth, examiner proficiency testing, standards, blind review and numerical error rate determination [Edmond & San Roque 2014]. While this reasoning is sound and applicable to a wide scope of forensic analytical techniques, a significant difficulty experienced by photointerpretation is that it is often subject to highly variable and uncontrolled input data and not necessarily reliant on scientific instrumentation or statistical processes which can more readily accommodate or conform with the stringent conditions required to validate scientific processes.

A crude example to illustrate some of the strictures involved with the validation of a scientific technique would be a generic forensic chemical analytical test for detecting the presence and concentration of a certain substance from within a sample. In order to validate the technique, large amounts data and controlled experimentation would be required involving the unadulterated target chemical, the recording and monitoring of the exact settings and parameters associated with the instrumentation used, the working conditions the instrument and sampling processes are conducted under, the effects of the matrix the target chemical is typically encountered within, the process used for calibrating the instrument, the quality of the materials sourced for calibration and the consideration of various sources of variation including sampling, operator based, systematic and random errors. A large number of controlled and repeated experiments would eventually provide enough data to determine an empirically based error rate that would reflect the typical range of variation that could be expected to be observed when performing the technique under exactly the same conditions as tested. This information can then be used to determine whether the technique is sensitive enough for the intended use of the data.

The concept of verifiability is subtly different than validation. Verification does not necessarily result in the same representation of 'error' as does a validation study.

The principle of verification presented in this chapter is more so about processes and frameworks for increasing the reliability of a method as opposed to determining its exact rate of performance. Certainly, some aspects of photointerpretation practice can be empirically validated, but not all.

When contemplating real world case scenarios, there is a need to reconcile that a vastly incalculable array of photointerpretation situations can arise requiring expert consideration. Each and every photographically documented scene, face, object, person or subject in conjunction with associated photographic and lighting conditions, properties and environments; presents a unique set of highly variable technical challenges for interpretive image analysis. New questions are also continually being asked of images. Numerical based error estimations cannot be relied on to reflect real world photointerpretation performance in these situations. An error rate based on an examiner being able to successful identify a face under a certain number of conditions (high resolution, colour calibrated, evenly illuminated images) cannot be relied upon to reflect the ability of the examiner to perform an analysis under a different set of conditions (e.g. a change in lighting direction, camera positon, perspective and resolution). It would also be impractical to test every combination of these influential parameters.

Nevertheless, the difficulty associated with photointerpretation methodologies to undergo validation studies in a manner comparable to other scientific forensic methods does not mean an effort cannot be made to make interpretive image examination approaches verifiable.

The values pertaining to the photointerpretation principle of verifiability are:

- **Testability.** An important concept integral to the verifiability of a photointerpretation approach is whether the technique permits testing. A testable method is one that can enable aspects of the processes relied upon during interpretation to undergo some form of peer review or experimental based evaluation. As previously suggested, external scrutiny can provide independent support for techniques or the reasoning employed during examination and further assist to prevent miscarriages of justice through the identification of any deficiencies or contentious applications of methods.

The principles of 'objectivity' and 'process' together with their associated values such as systemisation, transparency and justification, in combination with a technique that is testable, reflect a photointerpretation methodology that can be considered verifiable.

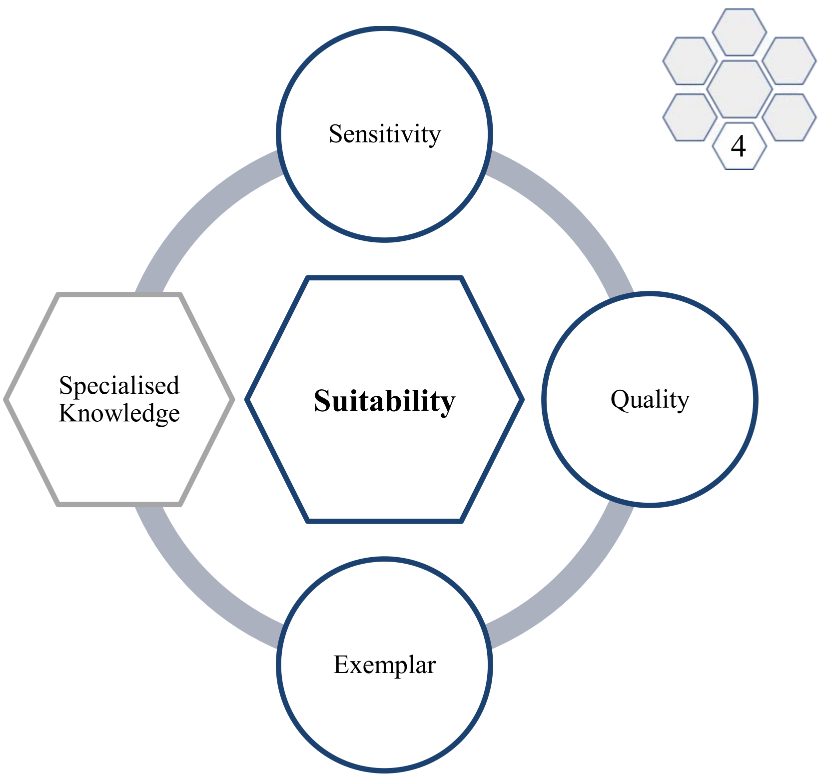


Figure 9.7: Photointerpretation principle of 'suitability' and major associated values.

The fourth photointerpretation principle within the proposed model is **'suitability'**. This principle is concerned with the evaluation of the properties or characteristics relied upon during the interpretive analysis of photographic material. If a photograph is deemed unsuitable, any analysis performed could be considered unreliable or valueless. Specialised knowledge regarding photographic and image science concepts are imperative for understanding and assessing notions of suitability regarding photographic representation. Additional domain specific expertise may also be required for evaluating information regarding detail, e.g. understanding what features are important for visualisation for the identification or differentiation of various objects.

The values pertaining to the photointerpretation principle of suitability are:

- **Sensitivity.** If a photointerpretation examination is concerned with differentiating between subjects, then any distinguishing features considered important to the examination need to exhibit an appropriate level of sensitivity or resolution that enables successful discrimination between said subjects. The sensitivity required can change depending on the nature of the subject and goals of the analysis (Chapter 7). It is vital that this concept is understood and appropriately applied by the examiner;

- **Quality.** The quality of the photographic material undergoing analysis needs to be sufficient to unambiguously communicate or resolve the characteristics targeted for analysis. Photographic resolution, distortion, insufficient focus, depth of field, perspective and lighting can all impact the ability of the photograph to depict detail. Specialised photographic knowledge is critical for understanding the influence of these properties on the suitability of evidential material to undergo analysis;

- **Exemplar.** Any exemplar material utilised during a photointerpretation examination is required to be obtained, compared or analysed in a 'like-for-like' manner to ensure fair and meaningful assessment. A 'like-for-like' analysis is critical due to the influence photographic properties have on visual representation. Exacting conditions when comparing photographs assists to ensure that any analogous observations are likely genuine occurrences.

Figure 9.8: Photointerpretation principle of 'specialised knowledge' and major associated values.

The photointerpretation principle of **'specialised knowledge'** is related to concepts surrounding the knowledge requirements of examiners undertaking photointerpretation. The principle also considers the legal requirement for specialised knowledge to be the source from which admissible expert evidence is based (s 79 *Evidence Act 1995 NSW*).

The values pertaining to the photointerpretation principle of specialised knowledge are:

- **Relevancy.** Expert opinion evidence is only legally admissible in Australian court's if it is based wholly or substantially on specialised knowledge. A major consideration the legal system has been struggling with is defining what exactly constitutes specialised knowledge when dealing with evidence derived from photographs. There are currently no established knowledge requirements stipulated by the courts specific to photointerpretation and the thinking regarding what such knowledge might encompass remains ambiguous. This situation is why qualified practitioners such as anatomists have been allowed to testify in Australian courts on matters involving photointerpretation evidence. The findings of this research supports the viewpoint echoed by several scholars within the literature that suggest that the body of specialist knowledge explicitly relevant to photointerpretation methodologies should include the inter-related fields of forensic photography, photographic science, forensic practice and visual culture [Edmond *et al.* 2009; Porter 2007, 2011a, 2011b, 2012, 2013; Porter & Kennedy 2012; SWGIT 2013];

- **Qualification, Training & Experience.** The legal system needs to be able to differentiate and recognise the relationship between photographic evidence and depicted subject matter (e.g. a *photograph* of a human v. a physical anatomical human subject). When considering legal gatekeeping mechanisms such as s 79 of the *Evidence Act 1995*, the knowledge requirement for evidence derived through photointerpretation should reflect the relevant skill set outlined above under the value of 'relevancy' in all situations that involve photographic evidence, unlike the state of affairs exhibited by cases such as *Honeysett v R* [2014] where the failure of this condition came under deliberation.

In Edmond & San Roque's [2014] paper *'Honeysett v The Queen: forensic science, 'specialised knowledge' and the uniform evidence law'*, the scholars explain the following contentions were raised during the *Honeysett* appeal that related to the dangers of unreliable photointerpretation evidence and insufficient specialised knowledge:

> *The defence objections to the admission of this evidence, raised on the voir dire, focused on the poor quality of the images, the relevance of the opinion evidence, and whether the evidence satisfied s 79. The defence called two rebuttal witnesses to challenge both the susceptibility of the images to meaningful interpretation, and the conclusions proffered by Professor Henneberg [Edmond & San Roque 2014, p. 327].*

...

> *The defence also called Dr Porter, a photographer and image specialist working in Forensic Science at the University of Western Sydney, and formerly employed by the Australian Federal Police. Porter's evidence focused on the difficulty of interpreting colours, particularly skin colour, and problems created by image distortion…[Edmond & San Roque 2014, p. 327].*

The expert examining the photographic evidence in *Honeysett* did not have specialised knowledge appropriate for interpreting images as evidence. This was recognised in the appeal, hence the importance of any qualification, training or experience relied on for interpreting photographs be related to knowledge deemed relevant to photointerpretation as expressed under the value of 'relevancy';

- **Additional Expertise.** Supplementary sources of expertise such as anatomical, engineering or medical knowledge that might be necessary for supporting certain photointerpretation tasks should always be conducted in collaboration with an expert possessing relevant specialised photographic knowledge. The SWGIT [2013] guidelines also recognise the central need for specialised photographic knowledge to be had in conjunction with further supplementary subject matter expertise for enabling reliable photographic analysis;

- **Context.** Context offers an important source of knowledge and support for assisting photointerpretation processes. Contextual information relevant to photographic evidence should be appropriately considered and not isolated from photographic evidence examination (Chapter 8).

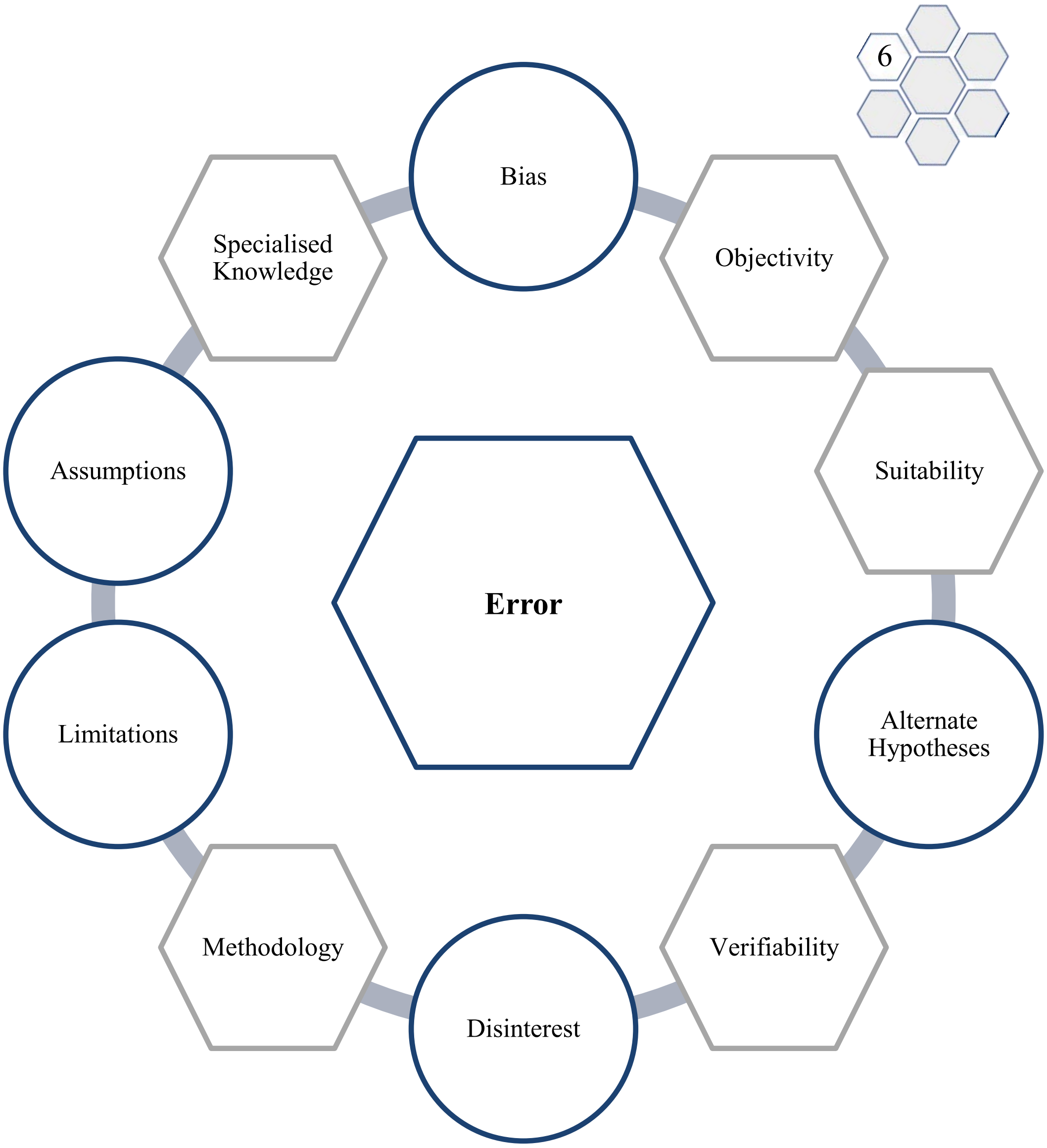


Figure 9.9: Photointerpretation principle of 'error' and major associated values.

The photointerpretation principle of **'error'** reflects the cautions taken throughout a photointerpretation examination specifically to reduce the likelihood of developing unsound evidence. The principle of 'error' is not the equivalent of the scientific concept of 'error rate' (an empirical statistic that communicates the probability that the use of a technique will result in an error [Edmond *et al.* 2009, p. 351]), but a reflection of a pragmatic framework or ideology focussed on supporting the reliable development of interpretive evidence.

The consideration and application of each of the previously defined principles contributes towards minimising the likelihood of unreliable photointerpretation evidence. Essentially, error can be reduced through the application of photointerpretation methodologies that maximise objectivity, ensure the suitability of examined photographic material, verify the ability of the methodological components relied on during the interpretation process and integrate expertise with appropriate specialised knowledge.

The values pertaining to the photointerpretation principle of error are as follows:

- **Bias.** The issue of bias needs consideration when undertaking photointerpretation tasks. The format, order of process and selection of material during examination and presentation of findings may have an influence on analysis and perception of evidence significance (Chapter 7). An awareness and acknowledgement of such prejudices is important to maintain and may assist the minimisation of potentially unsound practice during the interim period before future research efforts develop and advance processes specifically devised to address bias concerns. For example, understanding the negative influence poorly resolved images can have on the ability to discriminate between subjects (while artificially exaggerating apparent similarities), may help to promote more conservative examinations and minimise misidentification when considering such evidence;

- **Alternate Hypotheses.** Any plausible alternate explanations for observations or conclusions reached during image analysis need to be comprehensively deliberated and communicated alongside results. Specialised photographic knowledge is essential for supporting the capacity to develop and assess alternate hypotheses pertinent to photointerpretation tasks;

- **Disinterest.** Examiners engaging in photointerpretation should remain impartial and disinterested in results or conclusions, as expected of all professional engaging in forensic science practice. This is important because of the inherent vulnerability associated with subjective forms of analysis. Any agendas or underlying aspirations associated with potential findings could unconsciously and unfairly skew perceptions;

- **Limitations.** The limitations of photointerpretation techniques employed need to be fully realised during examination. Applying a technique outside of its scope would likely result in unreliable evidence;

- **Assumptions.** Any assumptions or speculation relied on by an examiner during interpretation must be clearly communicated. For example, an examiner might base an analysis on the assumption that time and date information were accurate during the period of digital image capture. There might be no practical means for the examiner to test the accuracy of such information. Communicating the status of such data as assumption may assist the clarification or remedy of future discrepancies that may arise when the assumed information is found to be incorrect.

Expert reports concerning photointerpretation evidence tendered to court need to reflect how the values pertinent to the principle of error were addressed.

The six principles resultant from this research are important for supporting the fair and responsible application of forensic photointerpretation methodologies when applied as evidence within the criminal justice system. The following chapter presents a final summary of the findings of this work.

Chapter 10

10.0 Conclusion

Notwithstanding, photographic evidence can provide useful information to a court if used appropriately and incorporating safeguards against misinterpretation and misrepresentation. The issue is: what are the safeguards for photographic evidence?

Glenn Porter [Porter 2012, p. 48]

This chapter addresses the primary research question, aims and secondary questions of this thesis through the summarisation of the key findings presented in the thesis discussion and preceding chapters.

The study employed a mixed methods research design and integrated several knowledge sources including forensic science and photographic theory and practice, Australian evidence law, photographic science and photointerpretation literature in conjunction with research findings in pursuit of the primary research question. The work has developed new knowledge and perspectives regarding essential considerations required for supporting reliable photointerpretation methodologies. The thinking introduced provides a basis for furthering the development of robust and dependable image interpretation strategies relevant to both forensic science practice and legal applications.

The following sections respond to the research questions.

10.1 Primary Research Question

What are central or critical principles for establishing robust forensic photointerpretation methodologies within forensic science practice and the criminal justice system?

This research developed and unpacked six key forensic photointerpretation principles. The principles were presented and explored within the thesis discussion in Chapter 9. Their totality addresses the primary research question (Table 10-1).

Table 10-1: Summary of research findings – key photointerpretation principles

Key Principles:
Methodology
Objectivity
Verifiability
Suitability
Specialised Knowledge
Error

This work approached the primary research question through the examination of complex, subtle and varied nuances associated with the interpretation of photographs. Insight into these complexities was achieved through the exploration of photointerpretation methodologies, case studies, experimental work, literary reflection and evidence-based discussion resulting in the articulation of several critical values important for consideration. Drawing on the values distilled throughout the research components undertaken throughout this work, critical conceptual and pragmatic principles were ultimately elucidated that are necessary for supporting robust forensic photointerpretation methodologies when applied as photographic evidence.

10.2 Other Research Questions

Further to the central question, this work also examined the following secondary questions:

What values integral for conceptualising forensic photointerpretation methodological principles are exemplified or inspired by:

- ***A criteria based approach for forensic image examination?***
- ***Comparative image analytical techniques?***
- ***A scene reconstruction approach to photointerpretation?***

This research derived several critical values (Table 10-2) from the work undertaken in Chapters 4 through to 8 with several additional values developed within the broader context of the main thesis discussion.

From a conceptual standpoint, the 'values' uncovered within this work are what fundamentally make up or support the key principles central to the model framework proposed by this research. These values reflect a series of associated complex concepts presented throughout this body of work and are fundamentally necessary for supporting robust forensic photointerpretation methodologies when applied as photographic evidence.

Table 10-2: Summary of research findings – photointerpretation principles & associated values

Key Principle:	Values:
Methodology	Process; Question; Descriptive; Robust; Application.
Objectivity	Systemisation; Transparency; Justification.
Verifiability	Testability; '*Methodology*'; '*Objectivity*'.
Suitability	Sensitivity; Quality; Exemplar; 'S*pecialised Knowledge*'.
Specialised Knowledge	Relevancy; Qualification; Training; Experience; Additional Expertise; Context.
Error	Bias; Alternate Hypotheses; Disinterest; Limitations; Assumptions; '*Objectivity*'; '*Suitability*'; '*Verifiability*'; '*Methodology*'; '*Specialised Knowledge*'.

Note: Italicised values represent interrelated principles whose values are also critical to the current principle.

10.3 Achieved Research Aims & Objectives:

This thesis successfully achieved the following research aims through the investigative research work undertaken:

- Provided new knowledge regarding the application of photointerpretation methodologies for developing evidence for use in a court of law;

- Determined critical concepts and principles integral to the development of a framework for supporting forensic photointerpretation practice;

- Recognised and clarified gaps in knowledge and practise regarding current forensic photointerpretation methodologies;

- Developed critical principles that can improve the reliability of the application of forensic photographic evidence within the justice system and support current and/or future forensic expert image analysis.

This work also achieved a number of additional objectives including the introduction of the notion of a criteria based approach to photointerpretation (Chapter 4) and the development of a novel approach for detecting second-generation images based on the criteria approach (Chapter 5); exploration of comparative image analysis (Chapter 6) and investigation of the comparative analysis approach in regards to photointerpretation practice through a unique case study focused on facial comparison (Chapter 7); and the consideration and exploration of reconstruction as a methodological approach for assisting forensic photointerpretation tasks (Chapter 8).

10.4 Conclusion

This research has unpacked the complexities and challenges associated with forensic photointerpretation evidence and provides new thinking regarding how reliable and comprehensive photointerpretation methodologies can be established through the consideration of six key principles important for supporting sound photointerpretation practice.

This work has significant benefits to both wider society and the forensic science professional and academic communities. The work also provides a strong body of scholarship as this thesis was original in its aims, perspective and investigative approach; developed new knowledge specific to the field of forensic photointerpretation; provided a model framework for navigating research findings; and has important future implications for supporting the development of reliable evidence.

The photointerpretation principles presented in this thesis can be easily conveyed to a broad scope of photographic evidence stake holders including lawyers, legal professionals, lay members of the jury, judges, investigators, experts or any other persons concerned with or interested in reliable photointerpretation evidence.

The proposed model photointerpretation framework is valuable and can inform and influence the development of future law enforcement practices, organisational standard operating procedures and expert analysis methodologies concerned with interpretative based image analysis. The results of this work provide the criminal justice system with greater insight regarding how to move forward with photointerpretation evidence by illuminating quality ways for approaching forensic photograph examination.

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Appendices

Appendix A

Abbreviations Used in Thesis

Abbreviation:	**Definition:**
CCTV	Closed Circuit Television
DNA	Deoxyribonucleic Acid
DSLR	Digital Single-Lens Reflex
EV	Exposure Value
IR	Infrared
ISO	International Standards Organisation
EXIF	Exchangeable Image File Format
GPS	Global Positioning System
HCA	High Court of Australia
n	Population Sample Size
NAS	National Academy of Sciences
NIR	Near Infra-Red
NSW	New South Wales
NSWCCA	New South Wales Court of Criminal Appeal
NSWSC	New South Wales Supreme Court
R	Regina (The Queen)
SOP	Standard Operating Procedure
v	Versus
WWII	World War Two

Appendix B

Volunteer Instructions for Second-Generation Image Sample Collection

Second Generation Digital Images & Camera Phones

Volunteers will be requested to take photographs using their camera phones. The photos obtained will be submitted for analysis as part of doctoral research investigating images as forensic evidence.

Instructions:

1) Specific pairs of hardcopy 6"x4" sample photographs will be available to you for this task.
2) Using your camera phone (if applicable), photograph the specified image pairs - to the best of your ability.
3) You are permitted to take as many photographs as you want, but are required to only submit your best copy of each of the specified images.
4) When you are satisfied with the quality of your photographed images, please submit them via email attachment to:

   [redacted]

   Specify the subject title with the name of the pair of images you are submitting.
   There is no need to rename your image attachments.
   If possible, please attach both images that form a pair in a single email.

5) When attaching your images please attempt to send an uncompressed version (for iPhone select the 'Actual Size' option when sending).
6) Submitted data will remain anonymous.
7) Thank you for your contribution! Your input will help towards furthering forensic science knowledge ☺

Note: Participation is voluntary. Not participating in this exercise will have no impact on your learning experience or relationship with the researchers.

Exposure Value Data Collected for Determining EV of Lighting Environments

EV Values for Industrial & Office Interiors (Fluorescent)					
Metering Mode: Ambient Light - Shutter Speed Priority Mode					
Sample #1					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	6		100	1/15	2.4
2	4		100	1/15	1
3	6		100	1/15	2
4	6		100	1/15	2.4
5	7		100	1/15	2.8
Average:	6	1			
Sample #2					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	6		100	1/15	2
2	4		100	1/15	1
3	5		100	1/15	1.4
4	4		100	1/15	1
5	5		100	1/15	1.4
Average:	5	1			
Sample #3					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	8		100	1/60	2
2	8		100	1/60	2
3	8		100	1/60	2
4	8		100	1/60	2
5	8		100	1/60	2
Average:	8	0			
Sample #4					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	9		100	1/60	2.8
2	8		100	1/60	2
3	9		100	1/60	2.8
4	9		100	1/60	2.8
5	8		100	1/60	2
Average:	8	1			
Sample #5					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	6		100	1/15	2
2	5		100	1/15	1.4
3	6		100	1/15	2
4	5		100	1/15	1.4
5	6		100	1/15	2
Average:	5	1			
Sample #6					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:

1	8		100	1/60	2
2	8		100	1/60	2
3	5		100	1/60	0.7
4	6		100	1/60	1
5	11		100	1/60	5.6
Average:	7	2			
Sample #7					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	7		100	1/60	1.4
2	7		100	1/60	1.4
3	7		100	1/60	1.4
4	7		100	1/60	1.4
5	7		100	1/60	1.4
Average:	7	0			
Sample #8					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	7		100	1/60	1.4
2	7		100	1/60	1.4
3	6		100	1/60	1
4	8		100	1/60	2
5	8		100	1/60	2
Average:	7	1			
Sample #9					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	9		100	1/60	2.8
2	9		100	1/60	2.8
3	9		100	1/60	2.8
4	8		100	1/60	2
5	9		100	1/60	2.8
Average:	9	0			
Sample #10					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	8		100	1/60	2
2	8		100	1/60	2
3	8		100	1/60	2
4	8		100	1/60	2
5	8		100	1/60	2
Average:	8	0			
Total Average:	7	1			

EV Values for Domestic Interiors (~60W Tungsten)

Metering Mode: Ambient Light - Shutter Speed Priority Mode					
Sample #1					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	5		100	1/15	1.4
2	6		100	1/15	2
3	4		100	1/15	1
4	4		100	1/15	1
5	5		100	1/15	1.4
Average:	5	1			
Sample #2					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	6		100	1/15	2
2	4		100	1/15	1
3	4		100	1/15	1
4	5		100	1/15	1.4
5	7		100	1/15	2.8
Average:	5	1			
Sample #3					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	8		200	1/30	2
2	7		200	1/30	1.4
3	6		200	1/30	1
4	4		200	1/30	0.5
5	6		200	1/30	1
Average:	6	1			
Sample #4					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	6		200	1/30	1
2	6		200	1/30	1
3	7		200	1/30	1.4
4	7		200	1/30	1.4
5	7		200	1/30	1.4
Average:	6	1			
Sample #5					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	6		200	1/30	1
2	8		200	1/30	2
3	8		200	1/30	2
4	6		200	1/30	1
5	6		200	1/30	1
Average:	7	1			
Sample #6					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	7		200	1/30	1.4
2	7		200	1/30	1.4
3	7		200	1/30	1.4

4	7		200	1/30	1.4
5	7		200	1/30	1.4
Average:	7	0			
Sample #7					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	4		100	1/15	1
2	4		100	1/15	1
3	4		100	1/15	1
4	3		100	1/15	0.7
5	3		100	1/15	0.7
Average:	3	1			
Sample #8					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	6		100	1/15	2
2	6		100	1/15	2
3	5		100	1/15	1.4
4	5		100	1/15	1.4
5	6		100	1/15	2
Average:	5	1			
Sample #9					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	6		100	1/15	2
2	5		100	1/15	1.4
3	5		100	1/15	1.4
4	4		100	1/15	1
5	4		100	1/15	1
Average:	5	1			
Sample #10					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	4		100	1/15	1
2	4		100	1/15	1
3	4		100	1/15	1
4	5		100	1/15	1.4
5	4		100	1/15	1
Average:	4	0			
Total Average:	5	1			

EV Values for Direct Sunlight					
Metering Mode: Ambient Light - Shutter Speed Priority Mode					
Sample #1					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	15		100	1/60	22
2	15		100	1/60	22
3	15		100	1/60	22
4	15		100	1/60	22
5	15		100	1/60	22
Average:	15	0			
Sample #2					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	15		100	1/60	22
2	15		100	1/60	22
3	15		100	1/60	22
4	15		100	1/60	22
5	15		100	1/60	22
Average:	15	0			
Sample #3					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	15		100	1/60	22
2	15		100	1/60	22
3	15		100	1/60	22
4	15		100	1/60	22
5	15		100	1/60	22
Average:	15	0			
Sample #4					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	15		100	1/60	22
2	15		100	1/60	22
3	15		100	1/60	22
4	15		100	1/60	22
5	15		100	1/60	22
Average:	15	0			
Sample #5					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	15		100	1/60	22
2	15		100	1/60	22
3	15		100	1/60	22
4	15		100	1/60	22
5	15		100	1/60	22
Average:	15	0			
Sample #6					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	15		100	1/60	22
2	15		100	1/60	22

3	15		100	1/60	22
4	15		100	1/60	22
5	15		100	1/60	22
Average:	15	0			
Sample #7					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	15		100	1/60	22
2	15		100	1/60	22
3	15		100	1/60	22
4	15		100	1/60	22
5	15		100	1/60	22
Average:	15	0			
Sample #8					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	15		100	1/60	22
2	15		100	1/60	22
3	15		100	1/60	22
4	15		100	1/60	22
5	15		100	1/60	22
Average:	15	0			
Sample #9					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	15		100	1/60	22
2	15		100	1/60	22
3	15		100	1/60	22
4	15		100	1/60	22
5	15		100	1/60	22
Average:	15	0			
Sample #10					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	15		100	1/60	22
2	15		100	1/60	22
3	15		100	1/60	22
4	15		100	1/60	22
5	15		100	1/60	22
Average:	15	0			
Total Average:	15	0			

EV Values for Open Shade					
Metering Mode: Ambient Light - Shutter Speed Priority Mode					
Sample #1					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	11		100	1/125	4
2	11		100	1/125	4
3	11		100	1/125	4
4	11		100	1/125	4
5	11		100	1/125	4
Average:	11	0			
Sample #2					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	12		100	1/60	8
2	11		100	1/60	5.6
3	11		100	1/60	5.6
4	11		100	1/60	5.6
5	11		100	1/60	5.6
Average:	11	0			
Sample #3					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	11		100	1/60	5.6
2	11		100	1/60	5.6
3	10		100	1/60	4
4	11		100	1/60	5.6
5	11		100	1/60	5.6
Average:	11	0			
Sample #4					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	11		100	1/60	5.6
2	12		100	1/60	8
3	11		100	1/60	5.6
4	12		100	1/60	8
5	11		100	1/60	5.6
Average:	11	1			
Sample #5					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	13		100	1/60	11
2	13		100	1/60	11
3	12		100	1/60	8
4	11		100	1/60	5.6
5	11		100	1/60	5.6
Average:	12	1			
Sample #6					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	11		100	1/60	5.6
2	12		100	1/60	8

3	12		100	1/60	8
4	11		100	1/60	5.6
5	12		100	1/60	8
Average:	11	1			
Sample #7					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	11		100	1/60	5.6
2	12		100	1/60	8
3	12		100	1/60	8
4	11		100	1/60	5.6
5	11		100	1/60	5.6
Average:	11	1			
Sample #8					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	11		100	1/60	5.6
2	12		100	1/60	8
3	12		100	1/60	8
4	12		100	1/60	8
5	13		100	1/60	11
Average:	12	1			
Sample #9					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	11		100	1/60	5.6
2	12		100	1/60	8
3	13		100	1/60	11
4	12		100	1/60	8
5	12		100	1/60	8
Average:	12	1			
Sample #10					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	11		100	1/60	5.6
2	11		100	1/60	5.6
3	11		100	1/60	5.6
4	11		100	1/60	5.6
5	11		100	1/60	5.6
Average:	11	0			
Total Average:	11	0			

EV Values for Partially Cloudy					
Metering Mode: Ambient Light - Shutter Speed Priority Mode					
Sample #1					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	13		100	1/60	11
2	13		100	1/60	11
3	13		100	1/60	11
4	13		100	1/60	11
5	13		100	1/60	11
Average:	13	0			
Sample #2					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	14		100	1/60	16
2	13		100	1/60	11
3	14		100	1/60	16
4	13		100	1/60	11
5	13		100	1/60	11
Average:	13	1			
Sample #3					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	11		100	1/60	5.6
2	12		100	1/60	8
3	12		100	1/60	8
4	12		100	1/60	8
5	12		100	1/60	8
Average:	12	0			
Sample #4					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	12		100	1/60	8
2	12		100	1/60	8
3	12		100	1/60	8
4	12		100	1/60	8
5	12		100	1/60	8
Average:	12	0			
Sample #5					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	12		100	1/60	8
2	12		100	1/60	8
3	11		100	1/60	5.6
4	12		100	1/60	8
5	12		100	1/60	8
Average:	12	0			
Sample #6					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	12		100	1/60	8
2	15		100	1/60	22

3	12		100	1/60	8
4	12		100	1/60	8
5	12		100	1/60	8
Average:	12	1			
Sample #7					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	14		100	1/60	16
2	14		100	1/60	16
3	15		100	1/60	22
4	15		100	1/60	22
5	15		100	1/60	22
Average:	14	1			
Sample #8					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	15		100	1/60	22
2	15		100	1/60	22
3	14		100	1/60	16
4	14		100	1/60	16
5	14		100	1/60	16
Average:	14	1			
Sample #9					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	11		100	1/60	5.6
2	12		100	1/60	8
3	12		100	1/60	8
4	11		100	1/60	5.6
5	12		100	1/60	8
Average:	11	1			
Sample #10					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	13		100	1/60	11
2	14		100	1/60	16
3	14		100	1/60	16
4	15		100	1/60	22
5	13		100	1/60	11
Average:	14	1			
Total Average:	13	1			

EV Values for Overcast Days					
Metering Mode: Ambient Light - Shutter Speed Priority Mode					
Sample #1					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	12		100	1/60	8
2	12		100	1/60	8
3	12		100	1/60	8
4	11		100	1/60	5.6
5	12		100	1/60	8
Average:	12	0			
Sample #2					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	12		100	1/60	8
2	12		100	1/60	8
3	12		100	1/60	8
4	12		100	1/60	8
5	12		100	1/60	8
Average:	12	0			
Sample #3					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	12		100	1/60	8
2	12		100	1/60	8
3	12		100	1/60	8
4	12		100	1/60	8
5	12		100	1/60	8
Average:	12	0			
Sample #4					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	12		100	1/60	8
2	12		100	1/60	8
3	12		100	1/60	8
4	12		100	1/60	8
5	12		100	1/60	8
Average:	12	0			
Sample #5					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	13		100	1/60	11
2	13		100	1/60	11
3	13		100	1/60	11
4	13		100	1/60	11
5	13		100	1/60	11
Average:	13	0			
Sample #6					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	13		100	1/60	11
2	13		100	1/60	11

3	14		100	1/60	16
4	14		100	1/60	16
5	14		100	1/60	16
Average:	13	1			
Sample #7					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	13		100	1/60	11
2	13		100	1/60	11
3	13		100	1/60	11
4	13		100	1/60	11
5	13		100	1/60	11
Average:	13	0			
Sample #8					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	12		100	1/60	8
2	12		100	1/60	8
3	12		100	1/60	8
4	12		100	1/60	8
5	12		100	1/60	8
Average:	12	0			
Sample #9					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	14		100	1/60	16
2	14		100	1/60	16
3	14		100	1/60	16
4	14		100	1/60	16
5	14		100	1/60	16
Average:	14	0			
Sample #10					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	10		100	1/60	4
2	10		100	1/60	4
3	11		100	1/60	5.6
4	10		100	1/60	4
5	10		100	1/60	4
Average:	10	0			
Total Average:	12	1			

EV Values for Bright Street Scenes at Night					
Metering Mode: Ambient Light - Shutter Speed Priority Mode					
Sample #1					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	8		800	1/15	1.4
2	8		800	1/15	1.4
3	7		800	1/15	1
4	7		800	1/15	1
5	7		800	1/15	1
Average:	7	1			
Sample #2					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	8		800	1/15	1.4
2	8		800	1/15	1.4
3	8		800	1/15	1.4
4	8		800	1/15	1.4
5	8		800	1/15	1.4
Average:	8	0			
Sample #3					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	8		800	1/15	1.4
2	8		800	1/15	1.4
3	7		800	1/15	1
4	8		800	1/15	1.4
5	8		800	1/15	1.4
Average:	8	0			
Sample #4					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	8		800	1/15	1.4
2	8		800	1/15	1.4
3	8		800	1/15	1.4
4	8		800	1/15	1.4
5	8		800	1/15	1.4
Average:	8	0			
Sample #5					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	8		800	1/15	1.4
2	8		800	1/15	1.4
3	8		800	1/15	1.4
4	8		800	1/15	1.4
5	8		800	1/15	1.4
Average:	8	0			
Sample #6					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	9		800	1/15	2
2	8		800	1/15	1.4

3	8		800	1/15	1.4
4	9		800	1/15	2
5	8		800	1/15	1.4
Average:	8	1			
Sample #7					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	10		2000	1/15	2
2	10		2000	1/15	2
3	9		2000	1/15	1.4
4	9		2000	1/15	1.4
5	10		2000	1/15	2
Average:	10	1			
Sample #8					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	7		800	1/15	1
2	7		800	1/15	1
3	8		800	1/15	1.4
4	8		800	1/15	1.4
5	6		800	1/15	0.7
Average:	7	1			
Sample #9					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	8		800	1/15	1.4
2	7		800	1/15	1
3	7		800	1/15	1
4	7		800	1/15	1
5	7		800	1/15	1
Average:	7	0			
Sample #10					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	8		800	1/15	1.4
2	8		800	1/15	1.4
3	8		800	1/15	1.4
4	8		800	1/15	1.4
5	8		800	1/15	1.4
Average:	8	0			
Total Average:					

EV Values for Sports Arena					
Metering Mode: Ambient Light - Shutter Speed Priority Mode					
Sample #1					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	12		800	1/15	5.6
2	12		800	1/15	5.6
3	11		800	1/15	4
4	11		800	1/15	4
5	11		800	1/15	4
Average:	11	1			
Sample #2					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	6		100	1/60	1
2	7		100	1/60	1.4
3	6		100	1/60	1
4	5		100	1/60	0.7
5	5		100	1/60	0.7
Average:	6	1			
Sample #3					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	7		100	1/60	1.4
2	8		100	1/60	2
3	8		100	1/60	2
4	7		100	1/60	1.4
5	8		100	1/60	2
Average:	7	1			
Sample #4					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	10		400	1/15	4
2	10		400	1/15	4
3	10		400	1/15	4
4	10		400	1/15	4
5	10		400	1/15	4
Average:	10	0			
Sample #5					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	10		400	1/15	4
2	10		400	1/15	4
3	11		400	1/15	5.6
4	10		400	1/15	4
5	10		400	1/15	4
Average:	10	0			
Sample #6					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	10		400	1/15	4
2	10		400	1/15	4

3	10		400	1/15	4
4	10		400	1/15	4
5	10		400	1/15	4
Average:	10	0			
Sample #7					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	8		400	1/15	2
2	8		400	1/15	2
3	8		400	1/15	2
4	8		400	1/15	2
5	9		400	1/15	2.8
Average:	8	0			
Sample #8					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	8		400	1/15	2
2	8		400	1/15	2
3	8		400	1/15	2
4	8		400	1/15	2
5	9		400	1/15	2.8
Average:	8	0			
Sample #9					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	8		400	1/15	2
2	8		400	1/15	2
3	7		400	1/15	1.4
4	7		400	1/15	1.4
5	7		400	1/15	1.4
Average:	7	1			
Sample #10					
Replicate No:	EV:	Std. Dev:	ISO:	Shutter Speed:	*f*/Stop:
1	10		400	1/15	4
2	9		400	1/15	2.8
3	10		400	1/15	4
4	10		400	1/15	4
5	9		400	1/15	2.8
Average:	9	1			
Total Average:	9	2			

Appendix C

Image references for comparative analysis exemplar material presented in Chapter 7.

Exemplar Image:	Reference:	Access Date:
H1	http://spartacus-educational.com/GERhitler28.jpg	18/12/15
H2	http://www.allydirectory.com/Biographies/wp-content/uploads/2013/09/Adolf-Hitler-Biography.jpg	18/12/15
H3	https://c2.staticflickr.com/4/3062/2865398363_ba996e4e0d_b.jpg	18/12/15
H4	http://leeillo.com/wp-content/uploads/2014/05/adolf-hitler_00378567.jpg	14/03/16
H5	http://conservativebyte.com/2011/05/usama-bin-laden-adolf-hitler-both-declared-dead-on-may-1/	18/12/15
H6	https://urbanmonkey1.files.wordpress.com/2011/12/10635.jpg	18/12/15
H7	http://www.museumsyndicate.com/images/artists/12.jpg	18/12/15
H8	http://1.bp.blogspot.com/rSJjEjbtiys/VRQz1738E9I/AAAAAAABYbY/ONMRNd9tU08/s1600/Adolf%2BHitler%2B(11).jpg	14/03/16

Exemplar Image:	Reference:	Access Date:
B1	https://s-media-cache-ak0.pinimg.com/564x/da/72/1f/da721f74b14b8a1e4e8f3279c3502117.jpg	15/02/16
B2	http://i.dailymail.co.uk/i/pix/2011/10/17/article-0-01C8345F0000044D-297_306x542.jpg	15/02/16
B3	http://iranianshistoryonthisday.com/photos/eva-braun-ed.jpg	15/02/16
B4	http://www.geneticmatrix.com/resources/photos/Braun-Eva.jpg	15/02/16
B5	http://img00.deviantart.net/7f7e/i/2012/325/2/a/eva_braun_by_shitdeviant-d5ljm4b.png	15/02/16
B6	http://www.age-des-celebrites.com/photos/B/eva-braun.png	15/02/16
B7	https://craigforrest.files.wordpress.com/2012/09/eva_braun_6.jpeg	15/02/16
B8	http://cdn1.scmp.com/sites/default/files/styles/980w/public/2014/04/06/f3380760b7fda6c7e929096b2e4fd1d6.jpg?itok=bn27suqN	15/02/16