INTEGRATING PERSONALITY AND EMOTION FOR HUMAN CROWD SIMULATION

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ABSTRACT

Existing research attempts to create realistic crowd simulations by incorporating personality and emotion into intelligent agents. However, personality and emotion were considered separately in existing studies, where the interactions of them are ignored. The main objective of this paper is to propose and implement a framework for crowd simulation with integration of the impacts and interactions of personality and emotion. An interactive solution based on the proposed framework is also developed for visualizing the crowd navigation behavior and collecting the related trajectory data. Three simulated scenarios: pass through , narrow passage, and emergence situation are used to validate the framework and compare the results with recent studies.

Keywords: Crowd simulation, agent behaviour, emergency scenario, agent emotion, decision making.

INTRODUCTION

Developing human like crowds is a challenging problem in crowd simulation. This is because it requires a balance between realism and computational efficiency, as well as to consider many different components such as group behavior, cognitive modeling, motion synthesis, crowd movement and rendering [5] .

Affective aspects, such as emotion and personality, influence human decisions and behaviors. Pelechano et al [11] state's that including affective aspects into crowd simulation can create individual differences among the agent's, hence producing realistic heterogeneous agents with natural behaviors. Personality is a combination of physical, emotional and social features that define an individual. Personality can be expressed in the form of behaviors and influence our behaviors as well as the way we make decisions. For example, people that are introverted generally prefer to have greater interpersonal distances, as they do not feel comfortable interacting with other people. They also tend to be resistant to any visual interaction with others. People who are mix of neurotic and introverted have more self-control, rigid behaviors and tend to display an increase in uncoordinated movements [11].

Modeling of personalities can create more realistic agents and because personality can be expressed in the form of behavior, intergrading personalities in crowd simulation will lead to more realistic behaviors in different situations [11].

Emotions are personal characteristics that are influenced by mood, personality and motivation. Some of the most commonly known emotions are joy, sorrow, hate and fear. Emotions are commonly known to effect facial expression. However, Stamatopoulou et al [12] state's that emotion can influence an agent's ability to perceive, learn, behave and communicate within an environment.

Existing research attempted to create realistic crowd simulations by incorporating personalities [3] [6] [7] [10] [13] and emotion [9] [12]. However these aspects were considered separately in existing studies [6] [12]. However, personality and emotion wil l affect each other internally. Personality will define one's emotional profile. While personality is not easily changed by itself in a short period of time, emotions are considered more dynamic and depend on different situations. Situations like agent interaction and communication can cause emotional contagion [6]. An integrated framework is missing and interactions of these aspects are ignored. The combination of personality and emotion can improve realistic crowd simulations and reveal emerging behaviors.

The purpose of this project is to investigate how to integrate affective aspects into crowd behaviors effectively. This project aims to investigate and implement 1) the influence of affective aspects on agent's behaviors in crowd simulation, 2) a crowd simulation framework that can incorporate personality and emotion to an agent's parameters and decision process, 3) an interactive application to demonstrate the simulation framework.

RELATED WORK

Personality and emotion play a significant role in human decisions and behaviors. The inclusion of individual differences of personality and emotion in agents is believed to be able to create more realistic characters with natural behavioral differen ces [11]. Exiting crowd simulation studies considering the impact of affective aspects to agents behavioral are mostly scenario-specific and focused on only a few personality traits or emotions [7].

Personality

Various personality models have been integrated in crowd simulation studies attempting to achieve more realistic and human like crowd behaviors by creating heterogeneous agents with different personality profiles [3] [6] [9] [13]. Turkay et al. [13] proposed a behavioral model for crowd simulation, which incorporated one personality trait, aggressiveness. The model uses analytical behavior maps to control agent behaviors with agent-crowd interactions. In their simulation, an agent's behavior is composed of its behavior state and behavior constants. Behavior state is determined by the behavioral values assigned to each cell in the 2D grid behavior map. Agents in the same cell will share the same behavioral values. These values can be altered temporally and spatially representing agent-crowd interactions. Behavioral constants are agent-specific values presenting the agent's personality attributes. They proved the validity of their simulation model by comparing the simulated results to a real-world scenario of 60 students evacuating a room in an emergency situation.

The Eysenck 3-Factor personality model and the 6 personality trait theories aggressive, assertive, active, impulsive, shy and tense have been used to simulate heterogeneous crowd behaviors [6]. Eysenck 3-Factor personality model is a biologically based model of three factors of personality called psychoticism, extraversion and neuroticism. Based on perceived personality data collected from user study with users watching videos of different crowd simulation scenarios, different personality traits are mapping with different values of agents parameters such as neighbor distance, maximum number of neighbors, planning horizon, radius and preferred speed. The simulation demonstrated emerging behaviors produced by agents with different personalities. For instance, shy agents would stay behind and allow the other agents to exit first. Similarly, in the evacuation scenario when a group of aggressive agents would slow each other down causing them to exit the building slower than the other agents with different personalities [6]. The OCEAN model is another popular personality model used in crowd simulation [3]. The OCEAN model describes five dimensions of personality that are used to define human personality. OCEAN stands for openness, conscientiousness, extroversion, agreeableness and neuroticism.

Although personality has been included in pervious studies, it is considered as a fixed characteristic of the agents remain the same during the simulation. However, human decisions and behavior can be changed by more situational factors such as emotion.

Emotion

Similar to personality, emotion is considered as an independent factor in crowd simulation in pervious studies. Stamatopoulou et al. [12] used one of the basic emotion's horror in their crowd simulation. In the study, horror was represented by 6 different levels: calm, alarm, fear, terror, panic, and hysteria. An agent's horror level is based on the situation and the environment, for example when a calm agent perceives that there is danger the horror level increases and its horror level will be changed from calm to alarm. The horror level was tested in an evacuation scenario. The evacuation scenario revealed that agents who got lost on their way to the buildings exit increased their horror level to the state of hysteria preventing them from following the buildings evacuation plan.

Nguyen et al. [8] uses a behavior table that map particular mood levels to a list of expected behaviors. The emotion studied by is aggression. The levels of aggression used are avoidance, neutral, curious, aggressive posture, aggressive non-lethal and aggressive lethal action. Each aggression level is linked to specific list of expected behaviors. For example, at neutral level, the expected behavior of an agent is wandering, at avoidance level, the agent's expected behaviors include throwing rocks, pushing, hand-to-hand fighting, and shooting. Ahn et al. [1] considers emotions of Non-Player Characters. They used fuzzy functions and rules to control the conditions of emotion and reasonable inference is implemented to determine the control value of an agent 's actions such as speed and direction.

Most of these studies focused on emotions only. Even though emotions are dynamic and are affected depending on the situation they do not combine it with any other type of affective aspect. Also most studies focus on affecting emotions in single type of way, but to make real human like simulations we need to consider multiple ways of affecting the agents emotions [8].

FRAMEWORK DESIGN

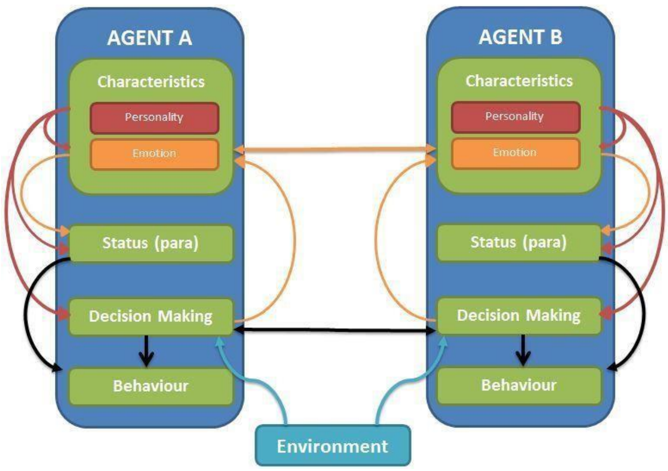


Figure 1. The proposed affective aspect framework.

The proposed framework developed for this project is shown in Figure 1. This frame work defines how personality and emotion affects an agent's decision-making, status and behavior. This framework also describes how communication and interaction between two agents affect each other's emotions and decisions. In this framework an agent's behavior is affected by its decision-making, agent status, and the dynamic environment. While the static agent's affective characteristics such as personality will affect an agent's decision making, the dynamic affective characteristic such as emotion is affected by the decision making at the same time influencing the agent's status. Between two agents their decision making and emotions will affect each other. An agent's emotions (Agent A) can affect other agents (Agent B) when those emotions are strong enough.

The operation of the framework starts by defining the personality values an agent will have. Then the personality values are sent to the agent's status module, which determines the agent's parameters. The agent's personality is then sent to the emotion module to set the agents emotional parameters. An agent then determines their path to their goal using the decision making module. Agent's personality values are sent to the decision making module to influence the path chosen by the agent. For example agents with an aggressive personality would take the most direct path to their goal while an agent with a shy personality would take a path to their goal that has the least amount of people in their way.

Once the decision making module has determined what path will be taken, instructions are then sent to the behavior module. The behavior module will then move the agent down that chosen path. The environment can affect an agent's path with different situations, for example a path being blocked or dangerous situations like fires present in the environment. When a situation occurs within the agent's perception range, the agent will be influenced by that situation. The decision making module will then process the situation to determine what problem occurred. Once the problem is determined, the decision making modules may interact with the emotion module instructing the agent to respond accordingly. If an agent's emotions reach a certain level the agent's emotions then affect the agent's parameters in the agent status module. Also once the problem is determined the agent's decision making module will calculate a new path to take to the goal.

IMPLEMENTATION AND DETAILS

This section presents the implementation details of the proposed framework.

Behavior Module

One of the fundamental problems needed to be handled in crowd simulation is how agents solve collision with both static and dynamic obstacles. Reciprocal Collision Avoidance 2 (RVO2) [2] library is an easy-to-use implementation of the Optimal Reciprocal Collision Avoidance (ORCA) formulation for multi-agent simulations. This tool provides the ability to setup crowd simulation scenarios by setting agent default parameters (Max. neighbors distance, max. number of neighbors, planning horizon, obstacle planning horizon, agent radius and max. speed). Table 1 shows the default agent parameters.
Although RVO2 is a useful library it does not provide any path finding capabilities as it only allows agents to move directly to a goal using the preferred velocity.

Table 1. Agent parameters used to create the agents personalities.

Agent Parameters	Default Parameters
Max. Neighbors Distance	15
Max. Number of Neighbors	10
Planning Horizon	10
Obstacle Planning Horizon	10
Agent Radius	1.0
Max. Speed	2.0

Decision Making Module

The decision making module focuses on how the agents choose their path to a goal. For this project, a local path finding method is implemented due to its realistic reflection on the situation in which individuals in crowds may not have full knowledge of the environment. The local path finding used for this project is a point to point network in which the agents move around the environment from one point to another point that has a connection to it; in this case it is called neighboring point. At the start of a simulation the agents move to the closest point from where they were spawned, from there on they rely on their personality to determine the next point for them to get closer to the goal. An agent's path can be interrupted when situations such as an obstacle or dangerous events (fire) blocks their path to their target point. This forces the agent to return to its previous point it came from and revise through the neighboring points to take an alternate path.

Personality Module

Personalities are represented in existing studies [3] [6] [9] [11] [13] by variations of agents parameters to provide the abi lity to simulate heterogeneous agents behaviors when different agents encounter the same situation and environment. In this implementation, personality is not only directly mapping into the agents parameters, but also can influence an agent's preferences in path finding decisions.

Table 2. The agent parameters for each personality.

Traits	Max. Neighbors Distance	Max. Number of Neighbors	Planning Horizon	Obstacle Planning Horizon	Agent Radius	Max. Speed
Aggressive	15	20	31	31	0.6	1.55
Implulsive	30	2	90	90	0.4	1.55
Shy	15	7	30	30	1.1	1.25
No Personality	15	10	10	10	1.0	2.0

Guy et al. [6] provides agents with different RVO2 agents parameters to represent different personalities. However, they did not provide a path finding approach to the RVO2 library, forcing agents to go to the goal directly without thinking of the best path or a path picked based on their personality. This implementation adds a path finding solution to RVO2 that considers an agent's personality to model more realistic decisions processed in crowd simulation.

Three personality traits were implemented in developing realistic agents; these were shy, impulsive and aggressive. The aggressive and shy personalities were chosen due to being opposites of each other, while impulsive was selected as a medium. Guy et al. [6] had already mapped the RVO2 parameters to each of these personality traits. The only difference between Guy et al. and this implementation is that the radius of each personality has been cut in half allowing better movement between agents in large crowds. Table 2 shows the agents parameters mapping for each personality used in this implementation. Each personality trait determined different preferred paths or types of paths an agent will pick in order to reach their goal. An agent with an aggressive personality will look for the quickest path to the goal. This has been developed into the path finding by selectin g the closest point to the goal from a list of neighboring points that were given to the agent from its current point. Agents with an impulsive personality don't go for the quickest path to the goal but go for a more adventures path [14]. The path finding incorporates the impulsive personality by selecting alternative paths to the goal allowing impulsive agents to take a more adventurous path, except when there is only one path to the agent's goal the impulsive agent will then take that path instead . Agents with a shy personality looked for a path to their goal that has the least amount of agents to interact with. The path finding determined this by how many agents are between the current point and each neighboring point using a detector that has been place between each one. A shy agent then takes the point that has the least number of agents between them, which can end up making shy agents move further away from their goal. An agent's personality was also visually represented using 4 different colored clothes in the implementation. These 4 colors were red for aggressive, green for impulsive, yellow for a shy, and blue for no specific personality.

Emotion Module

Emotions have been implemented in crowd simulations in different ways. Emotion can be represented by discrete level or category system [12]. For example, a single emotion such as horror is represented by several levels of horror starting from calm, to alarm, fear, terror, panic and all the way up to hysteria. Emotions can also be represented by continuous values like the stress level modeled in [7]. However, both these representations of emotions and mapping to corresponding behaviors ignore the fact that individual regulate emotion formation internal to an individual and emotion expressed an individual depends on one's personality [4]. Agents' emotions can be affected by different situations in the environment and other agents as long as the situations and the other agents are within an agent's perception range. For example a fire breaks out on o ne side of a town, the people on that side are emotionally affected but the people on the other side far away from the fire may not be emotionally affected. Other agents can also affect agent emotions in different ways such as emotions propagation from the agents around them.

This study improves the representation of emotion taking account the difference of emotion formation and emotion expression. A threshold system is used to represent multiple agent emotions for the project. The threshold values vary depends on the personality of an agent. The threshold system works by using two opposite emotions like happy and sad or angry and calm and setting a high threshold to one and a low threshold to the other. Each two opposite emotions are modeled with a shared value that can be increased or decreased based on different situations and with corresponding threshold pairs monitored. If that value reaches or passes one of the thresholds, the corresponding emotion will start to affect an agent's decision and behavior.

Six emotions were used and split into three pairs of opposite emotions. These emotions were happy and sad, stressed and relaxed, angry and calm. These emotions are used, as they are most relevant for crowd simulation and can co -exist with the other. For example an agent can be happy about something, angry towards something and stressed at the same time [8].

Situations were implemented to influence an agent's emotion values; they were danger, time pressure, obstacle interference, and interaction with other agents. Dangerous situations are things that can threaten an agent's life such as natural disasters (fire, floods, earthquakes, etc.). Danger affects the emotion values in this implementation by increasing the stressedRelaxed and angryCalm values and decreasing the happySad value. Time pressure is the attempt to reach a goal by a particular time frame. If an agent does not reach its goal within a certain time frame the stressedRelaxed value is increased and the time frame starts again.

Obstacle interference is when an obstacle or barrier blocks an agent from taking a particular path to their goal forcing that agent to go back. When an agent is blocked by an obstacle the angryCalm and stressedRelaxed values will be increased bring them closer to their angry and stressed threshold.

When a threshold is reached an agent's parameters, which is the agent's status are changed to reflect the impacts of that emotion. But not every parameter is affected for each emotion. For example when bored, an agent's planning horizon, planning obstacle horizon will change. When an agent is stressed all parameters are affected. Emotion propagation is when agents who have already reached an emotional threshold affect other agents around them. They affect the other agents by slowly increasing their values of that particular emotion threshold. Heterogeneous agents are initiated in this framework by randomly generating the emotional thresholds for each opposite emotion pairs with a defined range based on an agent's personality. Different personalities each have different levels in which a person can tolerate and control their emotions (See Table 3). For example an agent with aggressive personality is less likely to be able to control their anger compared to an agent with a shy personality. Similarl y an impulsive agent can get excited quicker than an aggressive agent.

Table 3. The min and max for each emotional threshold for each personality.

Traits	**Happy**	**Sad**	**Stress**	**Relaxed**	**Angry**	**Calm**
Aggressive	15	20	31	31	0.6	1.55
Impulsive	30	2	90	90	0.4	1.55
Shy	15	7	30	30	1.1	1.25
No Personality	15	10	10	10	1.0	2.0

TEST SETUP AND RESULTS

Test Setup

Three testing scenarios are created to evaluate the implementation of the proposed framework. These three scenarios are pass-through, narrow passage and emergency. The environments were developed to see if any emerging behaviors as observed in previous studies and expected by theories can be produced by the implementation of the proposed framework. For example Guy et al. [6] found that each time a new aggressive agent was added to the environment the average speed of the aggressive agent's changed. The aggressive agents began to exit the room slower than non-aggressive agents. This emerging behavior is known as "faster is slower".

The pass through scenario comprised group of 144 agents of a single personality passing through the other group of 288 agents with no personality. 4 tests were run with a group of shy agents vs a group of agent with no personality, a group of aggressive agents vs a group of agent with no personality, a group of agents with impulsive personality vs a group of agent with no personality, and vs a group of agent with no personality vs another group of agent with no personality with no personality.

The narrow passage scenarios is developed to observe any emerging behavior with a crowd of agents with different personalities and agents with no personalities would get through a narrow exit about 3 meter wide. The narrow passage environment was set to simulate 324 individual agents in each test and multiple tests have been run with different personality distribution of the agents. The emergency scenario is developed in order to demonstrate the emotion formulation and propagation among agents with different personality traits. The emergency scenario has a dangerous element in the form of a fire. A room with blocked exits is used in this scenario. 64 agents (16 aggressive, 16 impulsive, 16 shy, and 16 without personality) are evenly allocated at the four corners of the room and set to make their way to one of the two exits located on the opposite sides of the room.

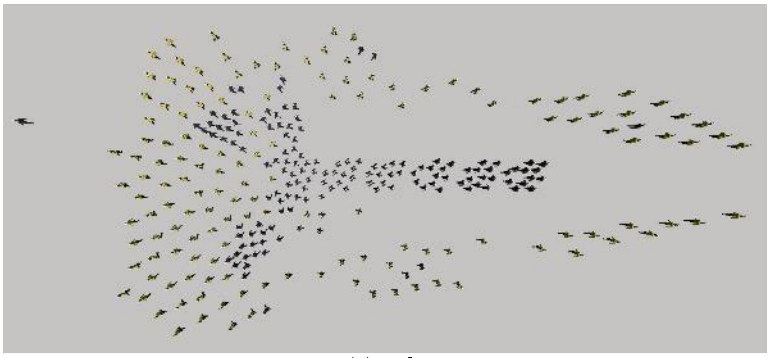
Test Results

In the pass through scenario, the test of two groups of agents passing through each other revealed differences in agents' personality results in a very different formation when the two groups of agents pass through each other. Figure 2 shows the screenshots of the simulation when the two groups of agents passing through each other. For example, aggressive and impulsive agents had the tendency of taking a direct path through the agents with no personality without having to change their route (See Figure 2a and 2b). The aggressive agents would also form a straight line in order to move through the crowd. Agents with a shy personality tended to go around the agents with no personality to avoid them (See Figure 2c).

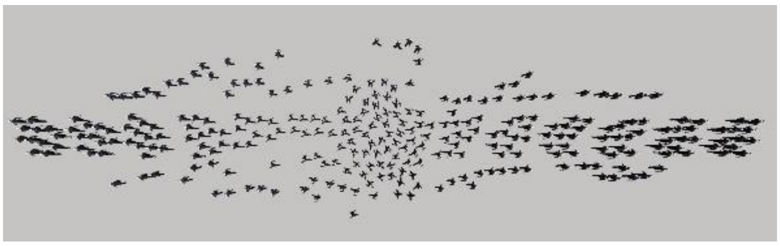
For the narrow passage scenario, 3 tests were conducted with the narrow passage environment 324 agents in each test. Each of the agent's personality was selected randomly for the test. The narrow passage environment tests revealed that all agents would easily get through the narrow passage until some shy agents held back near the end of the narrow passage forcing aggressive agents to go around them or they were forced to go back until they were able to find a way around. The impulsive agents got through the crowd easily by forcing their way through the other agents. This was proven in one test by three impulsive agents actually appearing late during the test and was able to get through the remaining agents and exit before any other agents could. Agents with no personality tended to stay away from the center of the crowd by making their way through the narrow passage from the left and right sides (See Figure 3). After all the tests it was found that the quickest was the impulsive agents as they were all able to get through the narrow passage first. The second quickest was the aggressive agents and then the shy agents.

(a) Aggressive

(b) Impulsive



(c) Shy



(d) Without personality

Figure 2. Groups of agents with different personality pass through group of agents without personality.

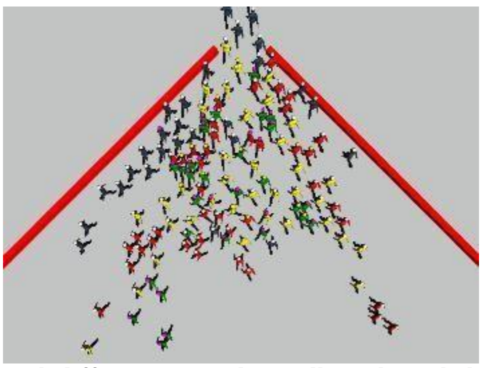


Figure 3. Agents with different personality walking through the narrow passage.

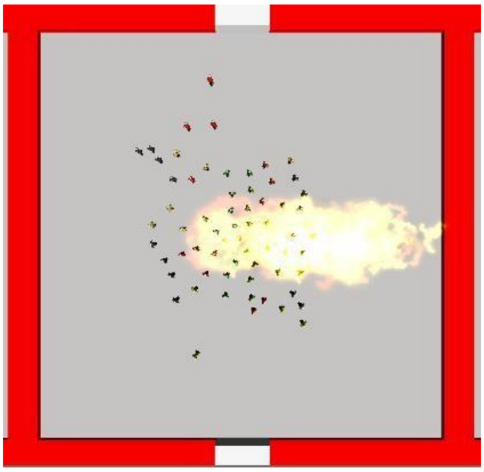
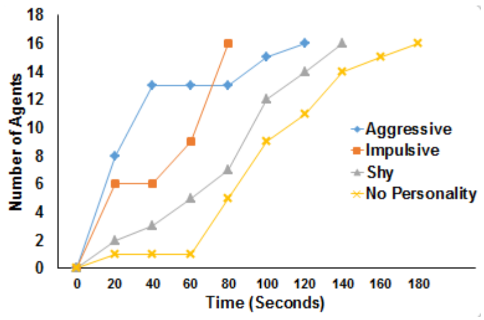
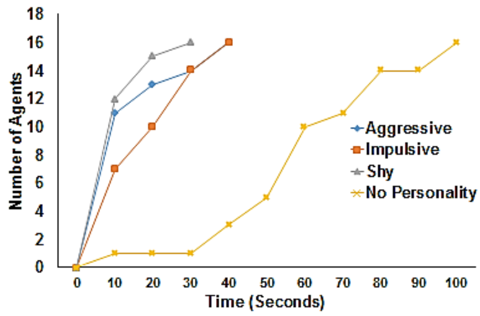


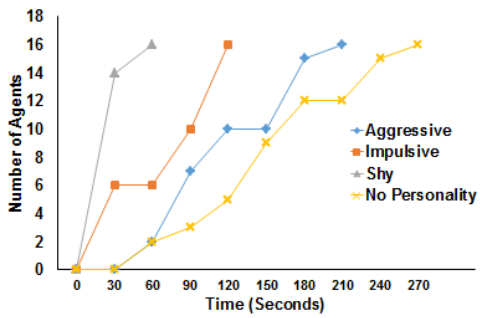
Figure 4. Emotion formation of agents with different personality across time.



(a) stress



(b) anger



(c) sadness

Figure 5. Emotion formation of agents with different personality across time.

Figure 4 shows a screen capture of the emergency scenario. A fire was started in the middle of the room at the beginning of t he simulation. Figure 5 shows the results of the emergency scenario. The figure shows that agents with different personality traits have different rate of emotion formulation, showing the proposed framework with the interaction of personality and emotion influence agent's behavior is working properly.

CONCLUSION

This project does have some limitations. The current implementation only used the variations allowed by the RVO2 library; future research may implement the proposed framework with other collision avoidance and simulation methods to see if there are any differences or more realistic behavior are possible by overcoming some limitation of the RVO2 library. For instance, RVO2 lacks the ability to allow agents to move up or down a 3D environment; this is because RVO2 uses 2D vectors to move the agents. Future research may extend the navigation capability to 3D environments like multi-story buildings and 3D terrains.

This study implemented a simple local path finding by using a point-to-point network; other local path finding techniques can also be implemented compare the efficiency and realism of the simulation. The proposed fra mework may also be extended by giving the ability to agents to memorize the paths they have visited and the ability to learn from the environment, past behaviors and other agents.

The main goal of this project was to integrate personality and emotion into crowd simulations with an integrated framework. Three personalities were implemented and integrated into the path finding and agent parameters; these provide a framework and foundation to be easily extended to include more personality aspects in crowd simulation.

Similarly, the emotional threshold system implemented in this study provides a solid framework to allow additional emotion dimension to be added to the simulation. Future research can consider the impacts of emotions on behaviors and actions other than navigation of crowd.

Like many simulation studies, evaluating the similarity and validity of the simulation to reality are desired. Future research may try to compare crowd behavior data extracted from mass event videos to the data generated by the implementation used in this study. The current study not only proposed a crowd simulation framework that incorporates personality and emotion but also improved different aspects in existing crowd simulation approaches by: 1) integrated the impacts of personalities in path finding, 2) implemented the concept of emotion regulation with a new way of integrating emotions to crowd simulation through a threshold system, 3) extended emotion formation for crowd simulation to allow agents to have multiple emotions at the same time.

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