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An Emotion Model for Video Game AI

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Abstract

Modeling human behavior in computer simulations and games is a subject which draws considerable attention. Despite the increased realism of graphics in games, poor modeling of non-player characters' AI often leads to a shallow and unfulfilling game experience. Recently there has been increased focus on more sophisticated AI routines which have been used in both academic and commercial games. Emotion, however, is often ignored despite being an essential element of human behavior especially under stressful conditions. Research into the use of emotion in agent-based systems seems more concerned with how to convey the emotions of agents to the human player, or how to elicit an emotional response from the human player. Only recently has there been research on modeling emotions in combat simulators. This thesis will describe an emotional model suitable for most computer games which was adapted from the DETT model and significantly expanded.

Keywords

ai, artificial intelligence, computer game, video game, game, emotion

1 Introduction

1.1 Overview

Realistic modeling of human-based agents has many applications from military simulations to video games of all types. Until recently, the development of computer games has focused on improvements in graphics to create more realistic looking environments, however, poor modeling of non-player characters' artificial intelligence (AI) often leads to a shallow and unfulfilling game experience (Fairclough et al. 2001). Currently an emphasis in game design is on improving the AI of the virtual agents that the human player interacts with. Attempts at more sophisticated AI routines, and especially the adaptation of learning algorithms, including behavioral cloning, have been used in both academic and commercial games. Nevertheless most of the best reviewed AI relies heavily on scripting the non-player characters' (NPCs') actions (Schwab 2004).

Emotion, however, is often ignored despite being an essential element of human behavior, especially under stressful conditions (Parunak et al. 2006). Research into the use of emotion in agent-based systems is more concerned with how to convey the emotions of agents to the human player, or how to elicit an emotional response from the human player. Only recently has there been research on modeling emotions in combat simulations for military purposes. In some regards this is surprising, given that war games for many years have included the concept of "morale." Morale can have many different meanings, but in the context of most war games it is a representation of the emotional state of a group of individuals.

Here we present an emotion model suitable for computer games derived from the DETT model. DETT models human emotions at the individual level, and was designed for combat simulations with large numbers of agents. First, we will implement the DETT model in a First Person Shooter game. Second, we will extend the DETT model to reproduce the behavior of multiple agents similar to a morale model common to war games.

Emotions in video games have received interest recently, but the focus of interest is on evoking or conveying emotions to the human player, with an emphasis on movie-like emotional attachment to characters, and therefore movie-like cut scenes in games (Loftus 2005). An interesting, albeit unusual, game that uses emotions is *Facade* (http://interactivestory.net/). In this game the human player interacts with two virtual friends having an argument, and must attempt to diffuse the situation. However, *Facade* is unlike most video games.

1.2 War games and the concept of morale

While many video games ignore emotions all together, war games include a concept which is similar. Traditional war games (i.e., dice based games - not military maneuvers involving live troops) often include a morale model. In many war games the scale of the game is larger than the individual soldier. Therefore, war games have rules that apply to a group of soldiers or equipment, and treat that group as an indivisible unit. Morale represents the emotional state of the unit as a whole. James F. Dunnigan defines morale in war games as: "This is the troops state of mind, or how willing they are to push on in the face of the stresses and horrors of warfare." (Dunnigan 1997, chapter 2)

1.3 Recent Research

War games use the concept of morale applied to a group of soldiers (although in rare cases an individual soldier could compose a unit unto himself). These morale models attempt to model the emotional state of a group of individual agents. Recent research into combat simulations has focused on the individual's emotional state. Gratch (Gratch 2000) mentions a training simulation for Apache attack helicopters. When attacked by ground units military procedure calls for the pilots to request artillery fire or use their own rockets to suppress enemy ground forces. Unfortunately the units in the simulation were fearless and attempting suppression would actually cause them to become more lethal (unrealistically, they change their rules of engagement and start attacking all nearby targets). This might lead trainees to believe, erroneously, that suppression was ineffective (Gratch 2000). Gratch then presents an emotional model using a plan-based approach in which emotions like fear and hope are factored into the agent's goals. His model is called Émile and has five major components: "First, Émile must represent plans and manipulate this representation to determine which actions will further its goals. Second, it must qualitatively appraise how events (mental and physical) relate to its plans and goals. Third, it must assign a quantity to the appraisal. Next, it must integrate a variety of appraisals into an overall emotional state. Finally, it must use appraisals to guide action selection and planning." (Gratch 2000, section 4)

Gratch's Émile is supporting a training environment with few agents, where regular interaction with humans slows the pace so that significant computation can occur (Parunak et al. 2006). It is not well suited for implementation in a video game, especially an action game or first person shooter where reactions have to occur very quickly, and the situation changes so rapidly that there is little time for computationally intensive analysis. Recent work by Parunak et al. (Parunak et al. 2006) describes a new model which captures essential features of the widely-used OCC (Ortony, Clore, Collins) model (Ortony et al. 1988). Their model is called DETT (Disposition, Emotion, Trigger, Tendency), and forms the basis of the work presented here.

1.4 The DETT Model

The DETT model was supported by two DoD projects that require the ability to simulate large numbers of combatants in faster than real time (Parunak et al. 2006). The first of these projects is known as RAID and its objective "is to anticipate enemy actions and deceptions, in order to provide real-time support to a tactical commander."(Parunak et al. 2006, 56) The agents developed for this system were designed to execute in faster than real time, and could not use complex symbolic reasoning (Parunak et al. 2006). The second project, MAROP (Multi-Agent Representation of the Operational Environment), involves the development of "methods to enrich a new military modeling system (Combat XXI) by automating the reactions of non-combatants with combatants."(Parunak et al. 2006, 56)

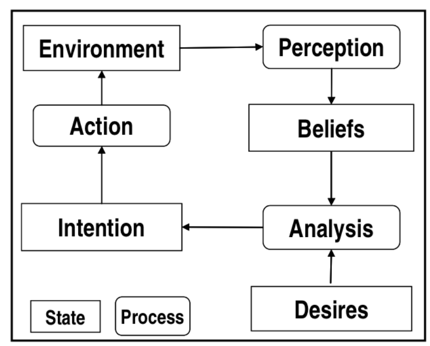


Figure 1: Belief-Desire-Intention (BDI) Data Flow. In this model beliefs and desires form intentions. (Parunak et al. 2006)

Parunak et al. based the DETT model on a modification of the BDI model (Belief, Desire, Intention), called BDI+OCC. The BDI (Belief-Desire-Intention) model can be summarized as follows: "Beliefs (derived from the environment by perception) and Desires (which are constant over the time horizon of our model) feed an analysis process that produces Intentions, which in turn drive actions that change the environment." (Figure 1) (Rao and Georgeff 1991). Adding components of the OCC model, beliefs also feed the appraisal process which generates emotions, which in turn influence analysis and perception (Figure 2) (Parunak et al. 2006).

In the DETT model disposition modulates the appraisal process to determine to what extent a belief triggers a particular emotion (Figure 3). The emotion then modulates Analysis to impose a Tendency on intention (Parunak et al. 2006). Note that in the DETT model emotion has no impact on perception, as it does in the OCC model. The main elements of the model are: Disposition, Emotion, Trigger (beliefs that lead to emotion), and Tendency (effect on intentions). Table I illustrates an example of DETT semantics (Parunak et al. 2006).

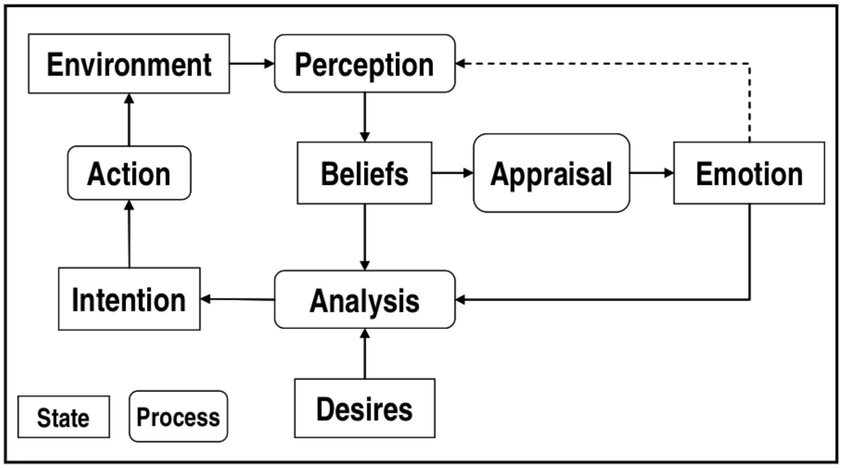


Figure 2: BDI enhanced with OCC (Ortony Clone & Collins). With the addition of OCC to BDI beliefs also generate emotions which influence analysis and perception. In the DETT model emotions do not influence perception. (Parunak et al. 2006)

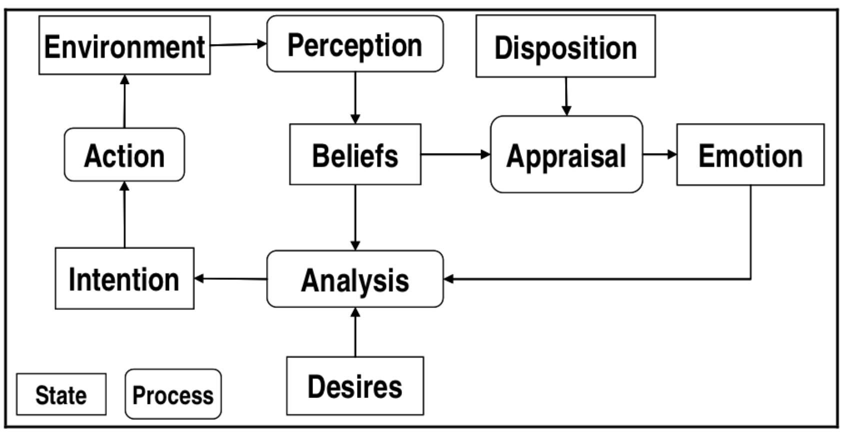


Figure 3: Incorporating Disposition in BDI + OCC. This is the DETT model used by Parunak et al. (Parunak et al. 2006)

Disposition	Emotion	Trigger	Tendency
Cowardice	Fear	Presence of armed enemy, Incoming attack	Less Attention to orders, Tend to move away from threat
Irritability	Anger	Presence of enemy	More likely to engage in combat, Tend to move toward threat

Table I: DETT semantics

1.5 Two Factor Theory of Emotion

The Two Factor Theory of Emotion was developed by Schachter and Singer, and views emotion as having two parts: a physiological arousal, and a cognition which interprets the meaning of the physiological response (Schachter & Singer 1962). Two notable studies provide evidence for the theory: Schachter & Singer 1962, and the High Bridge Study by Aron and Dutton in 1974. These two studies also demonstrate that it's possible to manipulate or change one emotion into another. We will use this theory in our model for changing the emotional state of an agent, based on the emotional states of surrounding agents.

2 Approach

The model presented in this chapter is described in more detail in the thesis *An Emotion Model for Non Player Characters in Computer Games*, by Anthony Campisi, UNM 2009. It is based on the DETT model described in the preceding chapter. In the original DETT model there is a one-to-one mapping between disposition and emotion, and regardless of circumstances an agent can express only one emotion (e.g., a cowardly agent could only express fear). DETT was designed to capture the essential features of the widely-used OCC (Ortony, Clore, Collins) model in a computationally tractable framework that can handle many combatants in faster than real time (Parunak et al. 2006, 51). The simplicity of the DETT model is advantageous for video games, because it does not require large amounts of processor resources, freeing those resources for other aspects of the AI or game engine.

Our model, called Extended-DETT, extends the original DETT model allowing agents to express more than one emotion. Using the Two Factor Theory of Emotion as a guide, we split Emotion in the DETT model into two factors: Emotion and Anxiety. Likewise, studies (Dutton and Aron 1974; Schachter & Singer 1962) into the Two Factor Theory have shown that it is possible to change an emotion (i.e., cognitive interpretation of a physical arousal) based on the behaviors of others. Thus, in our extended model an agent's emotion can be modified by the emotions of surrounding agents.

The original DETT model provides the conceptual framework for our Extended-DETT, but all equations were designed specifically for our model. Extended-DETT adds the concepts of Anxiety (the strength of physiological arousal) and Expressed Emotion (the outward expression of emotion), to the four original concepts from DETT (Disposition, Emotion, Trigger, Tendency).

2.1 Model Design

Our Extended-DETT model is implemented in a First Person Shooter (FPS) game. Therefore the particular emotions modeled are similar to those used by Parunak et al. for their combat simulations. The state of the models is time dependent, and is updated at regular intervals (in this case 1000 milliseconds). Our model assumes that the agents are receiving "orders" instructing their behavior. These orders are considered to be external to the emotion model. In our approach they are viewed as instructions being delivered by an external controller, however orders could also represent "rational" thinking internal to the agent, but still separate from the emotion model. A detailed description of the primary concept of both the DETT model and Extended-DETT follows.

Agents have two sensors: visual and olfactory. The terms are arbitrary, but reflect that they detect different aspects of an agent's environment. The visual sensors detect certain events and conditions within the environment and create Triggers which in turn generate Anxiety (Figure 4). The olfactory sensor detects pheromones that friendly agents generate (the "smell of fear"). The Emotion felt is determined by the agent's Disposition. The combination of Anxiety and Emotion creates a Tendency, which describes the resultant behavior. In the Extended-DETT model, Anxiety and Emotion also generate Expressed Emotions which are communicated to friendly agents as pheromones and influence the Emotions of other agents.

Disposition

Disposition is a personality trait of an agent and represents it's inclination to "feel" a particular emotion. Conceptually it is identical to the original DETT model's definition. Borrowing names from Parunak et al. the two dispositions modeled are *cowardly* (expressing fear), and *irritable* (expressing anger).

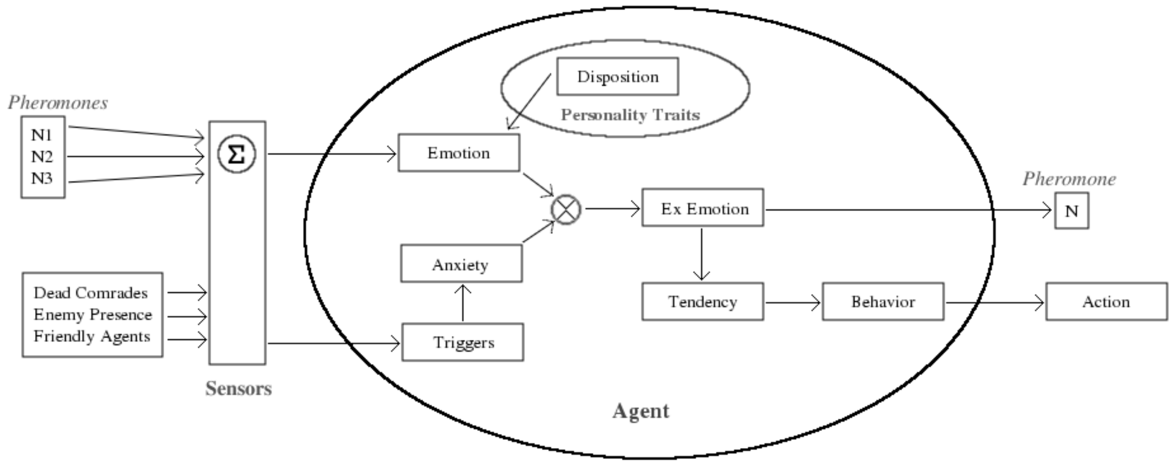


Figure 4: Diagram of Extended-DETT model. The model is implemented in an autonomous agent. Various inputs and internal operations result in not only an action, but also a pheromone that is communicated to other agents.

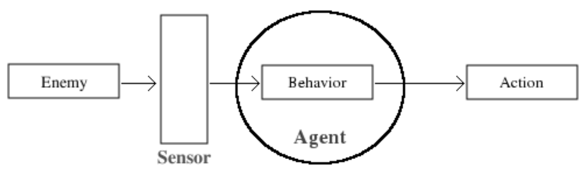


Figure 5: Diagram of Cube 2's original agent, compare with figure 4.

Emotion

Emotion is the particular emotion, or feeling, which the agent "feels." It is not the strength of that feeling. *Emotion* (E) is determined by the agent's *Disposition* and the *pheromones* of the agent's comrades. E is represented by a real number bounded between -1.0 and 1.0. -1.0 represents $fear$, and 1.0 represents *anger*. Values between -1.0 and 1.0 represent a mixture of emotions. An agent's *Disposition* sets the "natural state" of $E(t)$ to the appropriate extreme (e.g., if *Disposition*=*cowardly*, E=-1.0), where t is the time variable.

In the original DETT model, $E(t)$ would remain a fixed value, but in our model $E(t)$ can vary. The *pheromones* of nearby friendly agents ($P_f(t)$) can influence an agent's $E(t)$ shifting it away from its "natural state." However, the agent will resist the shifting of $E(t)$ from its natural state, and return $E(t)$ to its natural state in the absence of any external influences ($P_f(t)$=0). To model $E(t)$'s resistance to being displaced from it's natural state, a spring force ($-kx$) is introduced. How easily the agent is influenced by the expressed emotions of friendly agents is represented by the Impressionable Factor I (also referred to as *Impressionability*).

$$E(t+1) = E(t) - kx + (P_f(t)/100) * I \quad (1)$$

Anxiety

Anxiety ($A(t)$) is the measure of stress, or physiological arousal, that the agent has acquired. It can be interpreted as the "strength" of an emotion. It has no association with a particular emotion. *Anxiety* is not part of the original DETT model, and is a significant component introduced in the Extended-DETT model. There are two forms of anxiety: persistent ($A_p(t)$) - anxiety that is remembered and caused by triggers that represent specific events, and non-persistent ($A_n(t)$) - anxiety caused by triggers in the current environment. Non-persistent anxiety is split into two variables which represent a) negative triggers, triggers that increase anxiety ($A_{ne}(t)$) and b) positive triggers, which decrease anxiety ($A_{nf}(t)$).

$$A(t) = A_p(t) + A_{ne}(t) - A_{nf}(t) \tag{2}$$

An agent also recovers from persistent anxiety (A_p) every time-slice, where r is the recovery rate, and r=0.01.

$$A_p(t+1) = A_p(t) * 0.99 \tag{3}$$

If $A_{ne} = 0$, there is no anxiety producing stimulus in the current environment, and the recovery rate is doubled. So when an agent does not feel threatened it can recover from stress more quickly.

Tendency

The tendency of an agent describes the influence on behavior that the agent displays with regard to anxiety and emotion. Refer to table II for an explanation of tendencies. High *Anxiety* by itself can cause a decrease in an agent's proficiency, such as the ability to aim, independent of emotion (this is sometimes called "buck fever").

Anxiety	Emotion	Tendency
high	fear	move away from threat
high	anger	move toward threat
low	(any)	obey orders (follow other ai)
high	neutral	hold (indecision or "freezing")

Table II: Effect of Tendencies on Behavior

The tendency of an agent is determined by the *ExpressedEmotion* of the agent, but also considers *Anxiety* independently. Two series of thresholds determine how the agent behaves. The first is based solely on *Anxiety* ($A(t)$), if $A(t)$ exceeds the threshold T the agent will no longer follow "orders." The second is based on the *ExpressedEmotion* of the agent, and requires that the agent has already passed the first threshold. There are four negative and positive thresholds (T_n) which result in the agent being assigned one of five behavioral states. Table III shows the relationship between thresholds and states. The states are specific to the implementation and are described below.

Threshold	State
$E_e(t) < T_{-2}$	Rout
$E_e(t) < T_{-1}$	Retreat
$T_{-1} \leq E_e(t) \leq T_1$	Hold
$E_e(t) > T_1$	Advance
$E_e(t) > T_2$	Charge

Table III: Thresholds for *ExpressedEmotions* (E_e) and resultant behavioral states when $A(t) > T$

Trigger

Triggers are events or conditions which modify the anxiety ($A(t)$) of an agent. Witnessing "dead" comrades is a trigger that increases the persistent anxiety ($A_p(t)$). The number of new dead comrades within a radius d is D_n. C_d is a constant.

$$A_p(t+1) = A_p(t) + D_n * C_d \tag{4}$$

Trigger	Anxiety
Witness Dead Comrades	Persistent Anxiety (A_p)
Presence of Enemy	Non-Persistent Anxiety (A_{ne})
Presence of Friends	Non-Persistent Anxiety (A_{nf})

Table IV: Triggers and associated Anxieties

The presence of the enemy increases the non-persistent anxiety. The presence of (living) comrades, however, diminishes non-persistent anxiety. The *Anxiety* triggered by the presence of enemies ($A_{ne}(t)$) is calculated by assigning each enemy agent a constant (e_c), and dividing by the enemy agent's distance (e_d) from the agent, then summing across all enemy agents within a particular radius d_1:

$$A_{ne}(t) = \sum_{e_d < d_1} \frac{e_c}{e_d} \tag{5}$$

The *Anxiety* triggered by the presence of friends ($A_{nf}(t)$) is simply the number of friendly agents(f_n) within a particular radius d_2 from the agent, multiplied by a constant C_f.

$$A_{nf}(t) = f_n * C_f \tag{6}$$

As enemy agents get closer to the agent its anxiety increases, but the knowledge that there are friendly agents nearby reduces anxiety.

Expressed Emotion and Pheromone

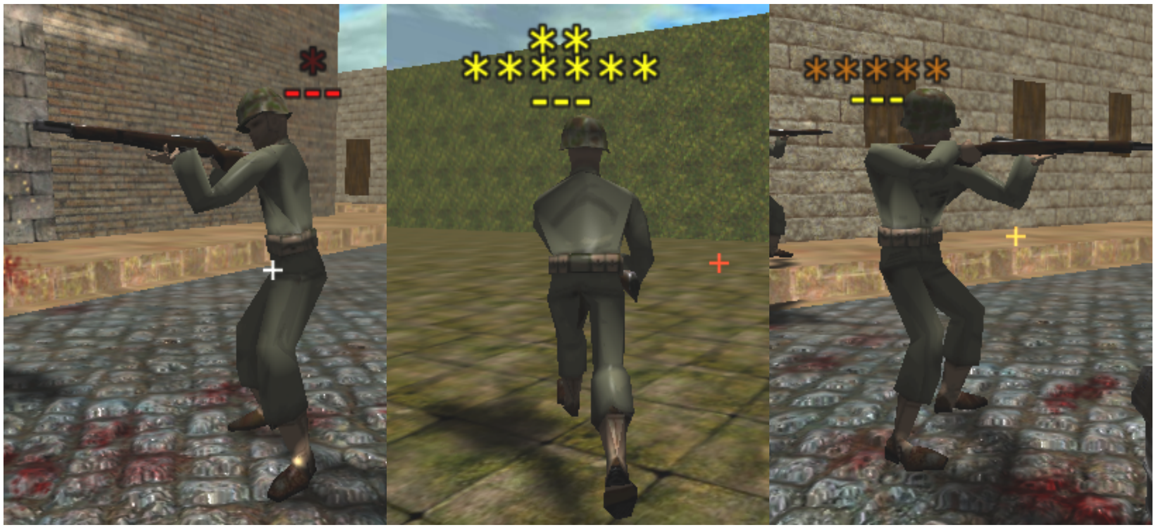
ExpressedEmotion is used to determine the *Tendency* of an agent, and is the *Emotion* of an agent modulated by its *Anxiety*. It also generates a *Pheromone* which is the "show" of emotion that an agent conveys to other friendly agents (although this could be expanded towards enemy agents as well). This represents the various actions, body language, or even spoken language that may be detected by, and influence, another agent. *ExpressedEmotions* and *Pheromones* (P_f) are new to the Extended-DETT model. *ExpressedEmotion* ($E_e(t)$) is the product of current anxiety $A(t)$ and the agent's emotional state $E(t)$.

$$E_e(t) = A(t) * E(t) \tag{7}$$

2.2 Implementation

In Campisi 2009, both original DETT and Extended-DETT are implemented in *Sauerbraten*, also known as *Cube 2* (<http://sauerbraten.org/>). Sauerbraten is an open-source multi-platform first person shooter video game. It has a very basic AI which has the advantage of being easy to modify. Unfortunately the AI is unsophisticated and many common functions and abilities are not available. For example, its path finding routine is simply moving randomly when an AI controlled agent finds the direct path towards its target to be blocked. The computer controlled agents, referred to as "monsters" in the source code and documentation, also have very few states ("monster states"): they are either asleep, or, when alerted to the human player's presence, they switch to a homing mode and walk straight at the player. Monsters with ranged weapons will stop to shoot at random times. The closer the monster is to the player the more likely he is to shoot. In many cases the monster will run all the way up to the player before shooting. Maps, or levels, constitute the playing field, and, if the edges are not secured, monsters and players can fall off the edge to their deaths.

No emotion model had been designed for the game, and modifications were needed to fit an emotion model to the game engine. First, a new human "monster" model was added, to reflect the new human-like qualities we



(a) Calm soldier (b) Fearful soldier running away (c) Confused soldier

Figure 6: Examples of the visual representation of emotional state. The number of asterisks represents the level of Anxiety (A); the color indicates the Emotion (E); and the baseline (—) indicates the agent's *Disposition*.

intend to bestow upon the monster. Then new "monster states" were created to fulfill the requirements of the emotion model. These are: charge, advance, hold, retreat, and rout. The likelihood of shooting was tailored to each state, while still related to distance from the opponent.

Teams were added so that the agents could be set to fight each other rather than just the player. A point on the map can be defined as an objective point. Orders are given to each agent to advance (or retreat) to the objective point or to hold once the agent has reached the objective. Agents will only follow such orders if they are flagged as being trained. Otherwise they default to the hold state. An experience variable was also added, which can reduce the effects that certain triggers have on anxiety.

Initially we implemented the original DETT model in Cube 2, then added components to implement the Extended-DETT model. Agents will attack the nearest enemy, which could be either the human player or an agent on the opposing team. Agents begin in sleep mode, but once alerted to the presence of the enemy they do not return to sleep mode unless all enemies are killed or removed from the map. Agents within Cube 2 only have one desire, to attack the human player (or nearest enemy). As the agent's focus is entirely devoted to its enemy, the tendency could only modulate intentions with regard toward that enemy. Thus the intention of an agent is to move toward or away from its enemy (or to hold). If the agent is flagged as trained, then the intention may be to "follow orders," which changes how the agent moves, but has no effect on the enemy that the agent faces (i.e., the agent will continue to face the nearest enemy). As the agent's anxiety rises it will stop following orders, and act only in relationship to the nearest enemy.

2.3 Visual representation of emotional state

Making use of some of the features of the Cube 2 engine, a visual representation of the emotional state of an agent was developed to assist in analysis of behavior (Figure 6). It consists of a series of asterisks that float over the heads of the agents. The more asterisks present the greater the anxiety. The color of the asterisks displays the expressed emotion of the agent. Red represents anger, yellow cowardice, and in between shades (orange) display indecision or confusion.

2.4 Scenario Design

For development and testing several different scenarios were designed. Level building in the Cube 2 engine is very straightforward and one can become a competent level builder with a few hours of study and practice. The first scenarios designed pitted the human player against several of the computer controlled agents. For these scenarios the agents' aim was adjusted so that they would always miss, giving the player the ability to study the actions of the computer controlled agents up close. Other scenarios were designed with two teams of computer controlled agents fighting one another. These agents could be set to fight over a single point on the map, or simply left on their own with no other goal than fighting the enemy. In all tests the human player was present (there was no alternative), and could interfere with the test to cause a particular outcome (i.e., the player could attack the computer agents). The main testing was conducted with two large teams of twenty computer agents each. For these tests, instead of fighting over a point on the map agents fought over a line. An observation tower was provided for the human player, but the player was not required to stay there. Parameters were determined experimentally, allowing an individual agent to gain a significant amount of anxiety before reacting. By significant, we mean that the human observer was able to study the effects of anxiety, emotion, and pheromones on agents during gameplay.

An agent which travels a large distance from the objective point is flagged as having disengaged. Agents which have disengaged enter the hold state, but are ignored by other active agents. This allows units to retreat from the combat zone without falling off the edge of the map and being counted as dead. A scenario ends when one team disengages all surviving members or all the members of a team are eliminated.

At the end of every scenario the final state of each agent is recorded. After several scenarios the likelihood that an agent survived can be calculated as the percentage of agents that survived the combat. Survival likelihoods can be reported for each team, both dispositions, and both team and disposition (e.g., percentage of cowards that survived on a team with 25% irritable disposition).

3 Results

In this chapter we present the results of the tests. All tests were run on a map with a large empty field and two teams of twenty of agents each. Refer to appendix B for images of the map. The teams are identified as red team and blue team, although there is no distinguishing mark on the individual models to indicate their team. The two opposing teams would be lined up facing each other at a short distance from the objective line. In all these scenarios the agents were flagged as trained, and would follow orders when their anxiety levels permitted. For all the tests anxiety had no effect on aim.

3.1 Parameters

The first battery of tests were conducted with the *Impressionability* turned off (I=0). Therefore, the model was functioning as the original DETT model. The ratio of irritable-to-cowardly agents was adjusted for each team, and listed in the results as the percentage of irritable agents. The dispositions were assigned with a random number generator (uniform distribution) to the members of each team. Five different configurations were tested: 0%, 25%, 50%, 75%, and 100% (irritable). The configurations were then pitted against one another in all possible combinations. Redundant scenarios were omitted (i.e., 0% versus 50% and 50% versus 0%) making the total number of tests fifteen. Each test was repeated fifty times (trials) to generate statistical averages. Dispositions were assigned with a uniform random distribution at the beginning of each trial. Cube 2's built-in random number generator was used. The likelihood of survival was recorded for each side as a whole and for each disposition on each side.

The second round of tests involved the same configurations, but the impressionability factor was switched on, $I = 0.7$. A comparison of tests is presented in the discussion.

3.2 Hardware

All testing was conducted on an Apple single 1.8 GHz PowerPC G5, with 1.5 GB DDR SDRAM, and a 256 MB NVIDIA 6800 Ultra graphics card. The operating system was OS X 10.5.5. The source code was compiled with Xcode 3, and the tests were run with the debugger active.

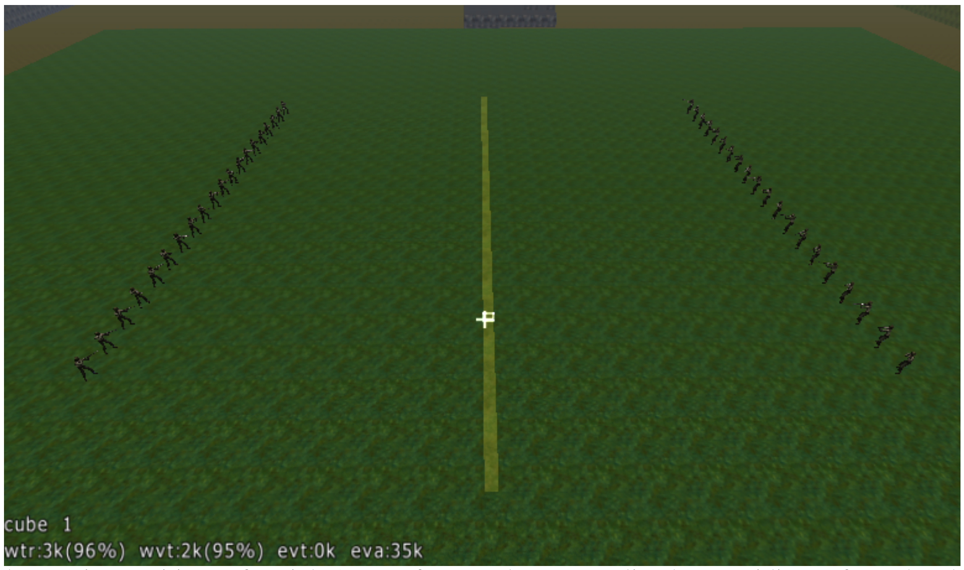


Figure 7: The starting positions of a trial. Agents from each team are lined up equidistant from the objective line in the middle of the screen. (The line on the level itself is only an approximation of the actual objective line)

Figure 8: A trial in progress. Note that both sides have moved toward the objective line. This image was taken from the observation tower.

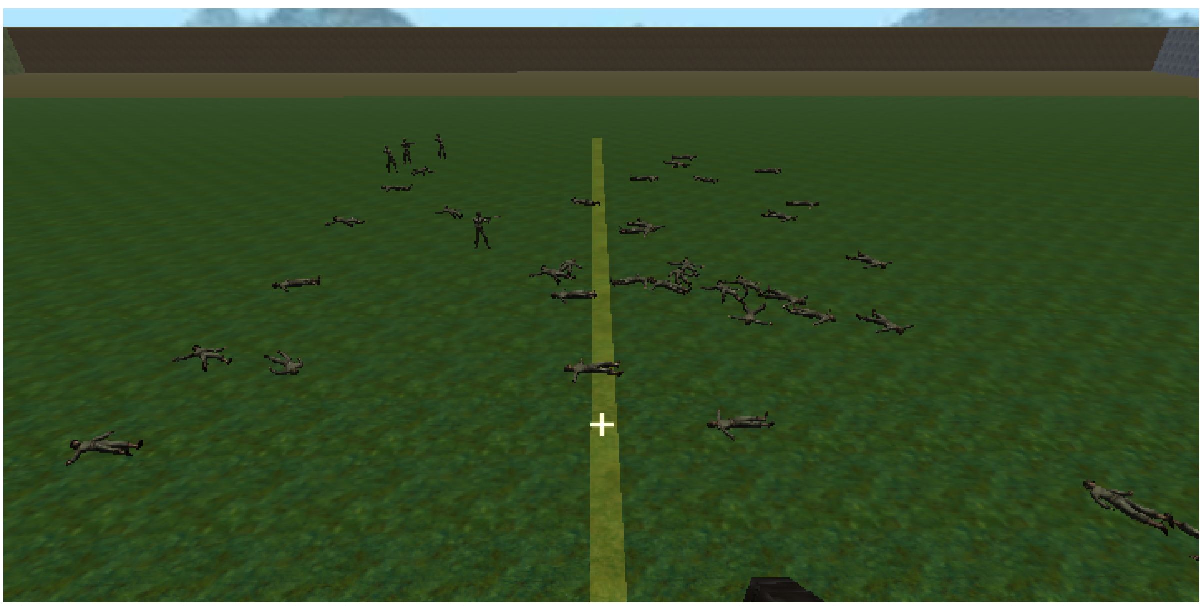


Figure 9: The aftermath of a trial. There is only a small number of agents from one side left “alive” near the objective.

Figure 10: View of a trial in progress from the ground.

Figure 11: View of a trial in progress. Note that the team to the left of the screen has started to retreat. $Impressionability(I)$=0.7.

Figure 12: View of a trial in progress. Note that in the team to the left of the screen some are advancing, while others are retreating. I=0.7.

Figure 13: View of a trial in progress. Angry agents fighting at close range.

4 Discussion

4.1 Observations

During game play with $I(Impressionability)$=0 agents are seen to act completely independently. A lone irritable agent may advance toward the enemy, while nearby friendly agents retreat. In tests with I = 0.7 agents with different dispositions are more likely to show the same behaviors. While independent actions are still observed, groups of agents are seen to retreat or advance rather than single individuals. A team with mixed dispositions would rarely entirely advance or retreat, but often one flank may advance while the other retreats. See the results section for images of the battles.

4.2 Interpretation of Survival Likelihoods

Survival likelihoods reveals two general trends. 1) as the percentage of enemy irritable agents increases the overall survival likelihood decreases. 2) as the percentage of friendly irritable agents increases the overall survival likelihood decreases. Irritable agents are very aggressive and short lived, a result which is congruent with Parunak et al.'s implementation of the DETT model (Parunak et al. 2006). See Campisi 2009, for more detailed analysis of the survival rates of agents in the test.

The survivability of the cowardly agents with $I(Impressionability)$=0.7 is lower than in the corresponding tests with I = 0 (see Figure 15 for a direct comparison). Similarly, the survivability of the irritable agents is higher (Figure 14). This is the effect of the expressed emotions. The cowardly agents are being encouraged to act like irritable ones, and vice versa. The ability of the extended-DETT model to capture features of a morale model can be grasped by looking at survivability rates, but is more easily ascertained by observing the agents. Without impressionability (I=0) agents will act independently, and only show common behavior when they share the same disposition and witness the same events. With impressionability, the agents will influence each other. Some will act independently, but most appear to act in groups.

4.3 Improvements and Future Research

Both the original DETT model and Extended-DETT have capacity for expansion. More triggers can be added which increase or decrease anxiety appropriately. Minor wounds could invoke persistent anxiety, whereas major wounds could invoke non-persistent anxiety (minor wounds and scratches are remembered, major wounds need immediate medical attention). If an agent believes his weapons to be ineffective it could also evoke anxiety, while weapons believed to be effective could decrease anxiety. If the enemy is believed to have a "good" fighting reputation (i.e., especially dangerous) it may increase the anxiety of the opposing agents. Certain triggers could have an associated emotion. There may be some events which are "frightening" to all agents (perhaps a major wound). In Extended-DETT these triggers could generate their own *pheromones*.

Dispositions provide another area of future research. More dispositions can be modeled, or $Disposition$ can become a variable. In Extended-DETT $Disposition$ defines the natural state of the agent's emotion (E = -1.0 if cowardly, E = 1.0 if irritable). However, an agent's disposition could be 50% cowardly ($Disposition$ = -0.5), and therefore have a natural emotion state of E = -0.5. Such an agent would not retreat as quickly as 100% cowardly agents, and would be more easily swayed to anger. Dispositions could also be learned. The (E) of an agent can be recorded and averaged over the course of a scenario, providing a new $Disposition$. The fitness function could be the survival of the agent (according to our results this would lead to cowardly dispositions). Conversely the survival likelihood of the opposing team could provide an alternate fitness function. Finally, instead of learning Dispositions, the ratio of cowardly to irritable agents could be learned.

$Impressionability$ (I) can be assigned independently to each agent. Agents with a low I value will be more independent, and not easily influenced by the emotions of other friendly agents. Others with a high I, will be

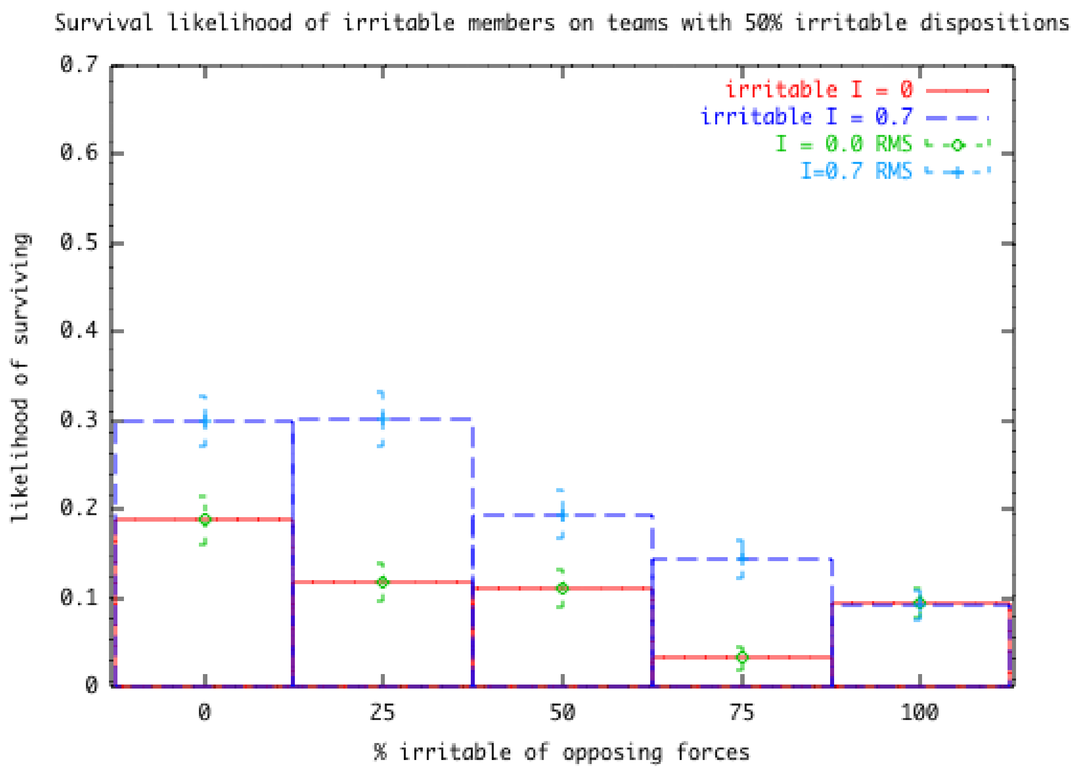


Figure 14: Survival likelihood of irritable members of teams with 50% irritable / 50% cowardly agents, with $I = 0.7$ and $I = 0$, versus teams with 0%, 25%, 50%, 75%, and 100% irritable. More irritable agents survive with $Impressionability(I)$ turned on.

very "impressionable" and easily swayed to follow the group. As the natural counterpoint to *Impressionability*, we could introduce "Expressionability." Particularly charismatic agents (or leaders) may be able to rally other agents to their emotional state, or perhaps even to an emotional state of their choosing. Agents with low "Expressionability" may simply not show much emotion, or perhaps don't communicate well, and other friendly agents would be unaffected by their emotions.

Tendencies could also be enriched. The Cube 2 engine's AI is convenient to modify but lacks detailed behaviors. An AI engine with more sophisticated behavior would allow for greater detail within the modified DETT model. Cowardly agents might seek cover from the enemy rather than simply running directly away. Finally, more emotions can be modeled. In both DETT and Extended-DETT *Emotion* is one dimensional (*fear*/*anger*). Other emotional dimensions could be added (e.g., *love*/*hate*, *happiness*/*sadness*, etc.), appropriate to the game genre. This would add richness to behavior (i.e., tendencies), and allow for more variation.

DETT and Extended-DETT are not limited to First-Person Shooter or combat games. For example, both models would be useful in role-playing games where the human player has to interact with characters of varying emotional states. While important characters would likely have their behavior scripted, minor characters that the player must interact with (e.g., merchants, townspeople, etc.) may have random dispositions assigned to them.

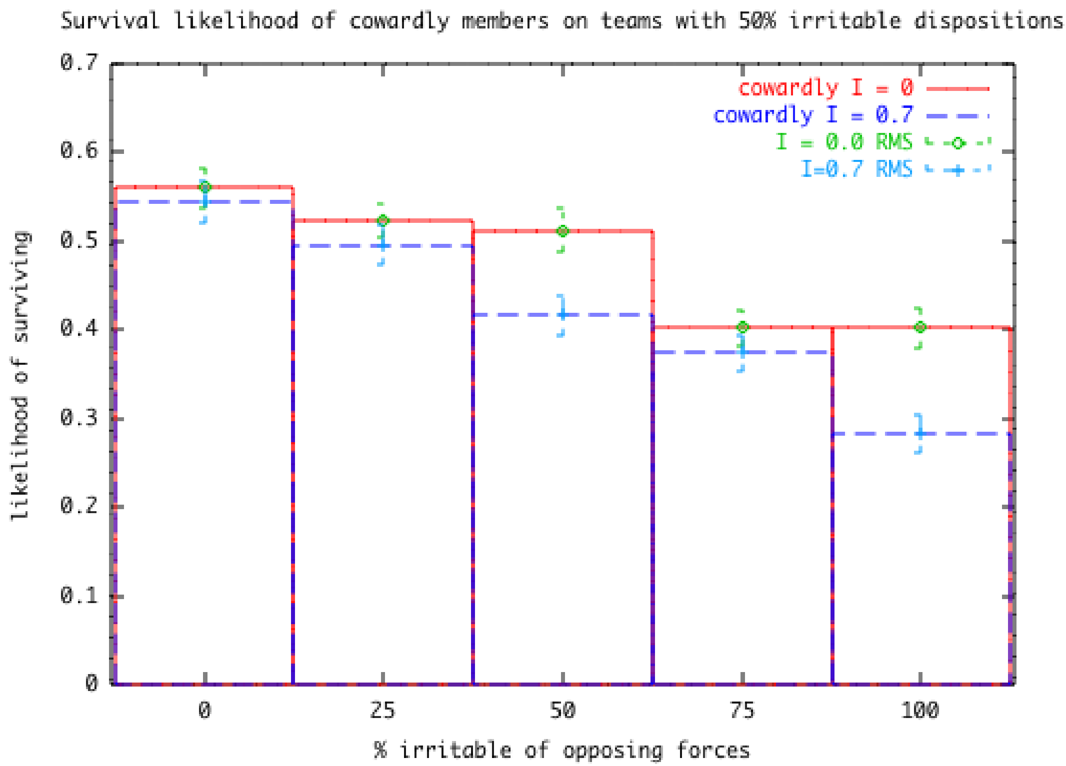


Figure 15: Survival likelihood of cowardly members of teams with 50% irritable / 50% cowardly agents, with I = 0.7 and I = 0, versus teams with 0%, 25%, 50%, 75%, and 100% irritable. Fewer cowardly agents survive with $Impressionability(I)$ turned on.

5 Conclusion

The DETT model provides an emotion model suitable for video games in real-time (or faster than real-time). While the subject of video game AI receives considerable attention, little is paid to modeling emotions. Both DETT and Extended-DETT provide simple models which can be introduced into other game AI engines without demanding large amounts of CPU resources. Other attempts at modeling emotions have been very computationally intensive and could not be easily ported to video games.

Extended-DETT expands the original DETT model by allowing agents' emotions to influence other agents' emotional states. This allows agents who identify with each other to act more like a group, rather than isolated individuals who happen to share the same environment. Thus Extended-DETT encapsulates elements of morale models used in many war games, while still providing an individual emotion model. This is advantageous for a war game which attempts to model the individual soldier within a group. Extended-DETT can also be applied in any game where one agent attempts to influence another through emotions. The basic structure of both models allow for expansion, and can be combined with learning algorithms, which are increasingly being applied to video games.

As AI continues to be the subject of considerable attention in the computer game industry, we expect emotions to play a larger part. Already there is growing interest in conveying emotions in video games, and perhaps modeling emotions within NPCs will be the next step. Our Extended-DETT model provides a useful framework for an emotion model suitable for non player characters with flexibility and capacity for expansion.

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