Emotions for Strategic Real-Time Systems

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Abstract

Strategic real-time systems are of high potential and their applications are growing, although they are mostly prevalent in video games, military training, and military planning. We propose a paradigm to advance current systems by introducing emotions into the simulated agents that make decisions and solve situations cooperatively. By utilizing emotional reactions and communication, we hope to advance these systems so that the decision process better mimics human behavior. Since our system allows sharing of emotions with nearby agents it utilizes both internal and external emotional control.

Introduction

Real-Time Artificial Intelligence has been investigated for over a decade (Musliner *et al.* 1995). A system is considered to be a Real-time AI system if it is able to make decisions within a guaranteed response time and thus meet domain deadlines. These systems face many challenges, including working with partial information, choosing the most crucial action if there are multiple scenarios to react to, and working continuously for an extended period of time without failure. These systems are usually created as expert systems, as they are used for a specific domain. However, they should be able to handle a vast majority of scenarios that occur, not just the specified test scenarios. The results must be returned in a timely fashion (Musliner *et al.* 1995).

Real-Time Strategy (RTS) is an offshoot of general purpose real-time AI. RTS refers specifically to systems where the primary purpose is to create strategy, usually in a competitive atmosphere. For instance, military training on how to engage the enemy done via simulation is a RTS system. Only training that with a computer strategy aspect is included however, since it is not a RTS system if only the human controls strategy. Currently the military uses simulations heavily for training, and therefore it is crucial for them that these systems advance (Herz & Macedonia 2002).

Also, many popular video games such as Starcraft and Warcraft incorporate Real-Time Strategy if at least one player is the computer. These games all simulate war among multiple players in which all but at least one player may be computer controlled. Although advances may be made in the AI of these systems, they do not seem to influence the military training development. However, many groups are working to combine the two groups so that meaningful work can be done to advance both fields at once (Herz & Macedonia 2002; Buro 2004). Ideally, the creation of war-related video games will be able to influence the military training simulations in years to come (Buro & Furtak 2003).

Although they may at first seem unrelated, emotions can play a large part in strategy especially when time is limited. Emotions are believed to improve our response time, increase our memory capacity, and provide quick communication (Rolls 2005). We are able to notice things that we fear quicker than things we enjoy or are indifferent about, showing fear to be crucial to our response time. Remembering an emotion may enable a memory to be more useful for us later, as we can react to the emotion of the experience without needing to remember all of its details. Emotions help us convey our experience to another person; for instance, they will realize danger quicker from noticing our fear than by hearing our explanation. Thus, we propose to include emotion with RTS algorithms to enhance our strategy.

Our system utilizes a current RTS gaming engine as well as its included AIs. We will then provide emotions for these units, and determine how those emotions affect the game play. We anticipate that emotions will enhance the ability of the units to react to their environment and influence other units, thus increasing the performance of the AI. One of our main contributions is the creation of an Emotion Map that enables units to communicate their emotions with any surrounding units. This Emotion Map saves the emotion of units and diffuses it for a period of time, enabling other units to feel the emotion of their peers.

Related Work

Many exciting advances in computer science are systems that must function in real time. For example, a model of ship damage control has been created that relies on real time decision making. This model determines the best course of action given the state of the ship and its many control systems. Tested in a simulation environment against actual Navy captains, the model vastly outperformed the humans. This example shows that Real-Time AI can even be valuable in situations where humans are already available to perform the task (Bulitko & Wilkins 2001).

One type of real time strategy system is the RTS game, which can tackle many different fundamental AI issues. For instance, game AI is closely related to adversarial real-time planning, decision making under uncertainty, opponent modeling, spatial and temporal reasoning, resource management, collaboration, and pathfinding (Buro & Furtak 2004). One system that is working to improve gaming in all of these aspects is ORTS. This system is an open source game that is utilized in a competition each summer to encourage AI experts to test their skills and create software with a usable combination of solutions. Although we will use a similar system called "Globulation," our enhancements could also be applied to ORTS.

Another way to create an RTS game is by controlling characters in games such as Quake. Laird et al. creates bots that can strategize through first person shooter games to beat human players. They create their bots using real-time AI algorithms, giving them the ability to anticipate another player's action, make smart decisions on where to go, and make smart decisions on what actions to take. This type of strategy is different from the type of strategy we will investigate, as it is only a single entity moving in a world against other similar entities (Laird 2001).

Although there are currently no RTS systems that incorporate emotions that we are aware of, other software systems do exist with them. For instance, the digital life simulation game, the Sims, includes emotions. These emotions control the behavior of in-game agents; an example being that an unhappy agent is less likely to obey the commands of the controlling player. Many other examples of emotions being used in computer systems relate to the field of human-computer interactions (HCI). A great amount of work has been done on improving a computer's ability to detect a user's emotions, and then using that information to change its interaction with the user. Much of this work is in the affective computing field (Picard 1997; aff 2007), and tends to relate to voice and facial recognition. A RTS system used for training can benefit from this work, but it is beyond our current scope.

Globulation

There are currently a few open source RTS platforms, including ORTS (http://www.cs.ualberta.ca/m̃buro/orts/) and Globulation (http://www.globulation2.org/wiki/Main_Page). Both of these systems run on similar premises, designed as strategy war games where the characters can be controlled by the AI. We chose to work with Globulation, a multi-player game where players compete for resources and territory. A player loses the game if all of their units have been destroyed. A particularly novel aspect of the game is the lack of control over each individual unit, an approach taken by nearly every RTS. Instead, players can control units by defining the behavior of units at each square on the map (E.G., forbidden, harvest, defend, etc.). This allows players to focus on more general strategies as opposed to testing their point and click skills.

Globulation has multiple Artificial Intelligences (AIs) that can be chosen as a player in the beginning of a game. The AI will thus control the actions of its assigned player so that no human intervention is needed. It will not only make overall player choices, but each unit is also given its own set of decision processes. There are many different AIs available for Globulation, each with a different focus, level of detail, and success rate. The AI we will test against is named "Nicowar" and has the highest success rate of all the AIs.

To allow our work to concentrate on the emotional aspect, we define emotions such that they can be ported to any of the AIs that already exist for the game. Thus, the decision processes for units will be a combination of a previously created AI and our emotional paradigm. When designing our emotions we examined the deficiencies of Nicowar. Although it is the most human-competitive AI in the game, its flaws include bottlenecks with pathfinding when dealing with a large numbers of units, avoiding enemy units (defensive units), and finding enemy units (offensive units). We will seek to address all of these flaws with our emotional system.

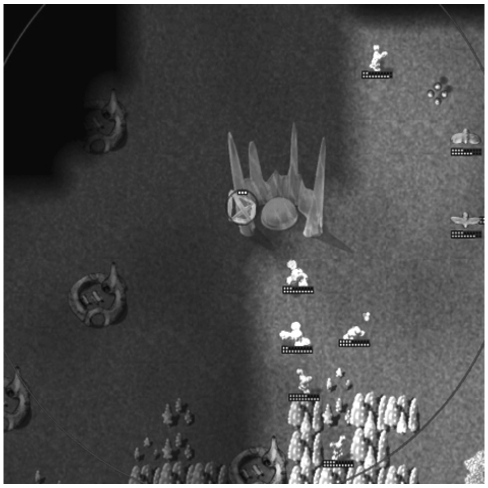


Figure 1: A view of a portion of the Globulation map. The darkly shaded area is area that has not been explored, and therefore cannot be seen. The large item in the middle is a building, whereas the smaller items just south of it are workers. The cluster of items at the bottom are a resource that needs to be gathered.

Units Each player in the game has their own units that can either be controlled by the human or by the AI. The units include warriors, workers, and explorers. Each unit has a numerical amount of health that can decrease if it is injured or increased if it is healed. Each unit is also affected by a need to eat, and has a base desire to do work. All units are capable of movement in 2-dimensional space within the map boundaries. They will make decisions on what actions to perform based on what they encounter as they move through the map, see Figure 1.

Each unit has its own purpose in the game, and the three types serve very different functions. The workers exist to gather resources, which are needed for the player to build buildings, create more units, and feed the current units. The warriors exist for defending the player's buildings and attacking the opponent's buildings and units. The explorers will wander around the map to determine the locations of enemies and resources. The warriors need the workers to gather resources for them, whereas the workers need the warriors to defend them. The workers and warriors both need the information the explorers discover to be able to see an oncoming attack, where to go to attack, and the location of additional resources for when current supplies run low.

Emotions

Types of Emotions Modeled

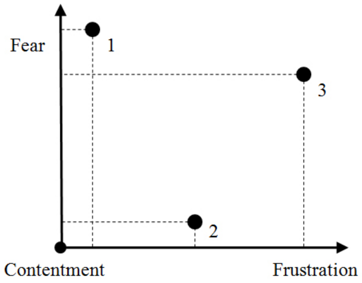


Figure 2: The plane representing the range of a unit's emotions and 4 possible emotional stages: the origin is no fear or frustration, representing contentment; point 1 represents a unit with little frustration but high fear; point 2 is a unit with low fear and medium frustration; and point 3 represents a unit with high frustration and high fear.

We chose to model two different negative emotions which will be the same in each unit type, although each unit type will be affected differently by their emotions. Although we did not choose all of the 6 basic emotions (happiness, fear, frustration, anger, sadness, relief) (Rolls 2005), we chose a two of them coupled with a more advanced emotion. The first basic emotion that we modeled was fear. Fear is increased when a unit is attacked by an enemy unit, a unit is very damaged and close to death, or the player is running low on resources. The first two causes are obvious, and the last cause is due to the fact that the units will die if they do not have food, which is a resource. The second basic emotion modeled is frustration. Frustration is increased when a unit is unable to perform the task allotted to it or the unit has been on the same task for a significant amount of time (details in the Simulation Details section).

Technically the lack of these two emotions also constitutes an emotion: contentment. For instance if there is little or no fear the unit feels content as the world seems safe. Also, if the unit has little or no frustration then it is content because everything is working well. Although units do not make decisions based on the combination of their 2 negative emotions, their emotional state at any time can be represented by a point on a plane with fear as the y-axis and frustration as the x-axis. A lack of emotion corresponds to contentment, as seen at the origin in Figure 2. However, without the the emotion map explained below emotions would be entirely internal and not shared.

Effects on Unit Actions

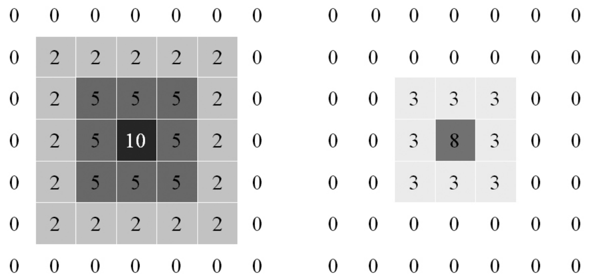
Each emotion affects units in ways related to five of Eckman's seven characteristics of emotion: Quick onset, automatic appraisal, commonalities in antecedent events, brief duration, and unbidden occurrence (Eckman 1994). Emotions occur based on events in a unit's neighborhood immediately when that event occurs. The unit does not have time to decide that its surroundings are a problem, but instead there is a quick onset due to automatic appraisal of the situation. For all units of a particular type the same antecedent event types will cause the same amount of the same emotion. Also, emotions are brief unless the same event continues to occur, in which case the emotion will continue to build at a slow rate. Emotions are not consciously caused, as only outside events or the sharing of emotions from another unit can cause them. The two characteristics that we do not relate to do not apply to our situation (presence in other primates, distinctive physiology) (Eckman 1994). Actions that are taken due to an emotion are however decided upon only once the emotion reaches a specified threshold. Once that threshold is reached then the unit acts according to both its current situation and the fact that the particular emotion is strong.

An emotion's effect on each unit is homogeneous throughout that unit type, although it differs between unit types. The effects of emotion on our units are based on the idea of approach vs. withdraw (Davidson *et al.* 1990). In this theory, an emotion will elicit one of two responses: approaching toward the stimuli, or withdrawing from it. If a worker experiences enough fear, it will move in a direction toward less fear until its fear falls below the required amount for it to withdraw. If possible, it will continue to move in a direction that will decrease its fear. This effect minimizes the problem with the AI that causes units to not escape their enemies. A warrior, however, will advance toward the cause of its fear (up to a specific threshold) in hopes of vanquishing the source. This reaction causes a warrior to move toward nearby enemy units and attack, which is beneficial in both offense and defense. This effect will improve on the AI's problem of not moving toward enemy units often enough. However, if a warrior's fear level crosses a higher threshold it will retreat, improving on it's ability to survive. The definition of "higher" was tested to determine an appropriate level, and is discussed in the Simulation Details section.

The unit reactions are similar for frustration. If a worker is feeling frustrated it will look elsewhere for work, which will usually involve looking for resources to gather. If the worker is already in a location with resources but still feels frustration, it is likely due to a large number of workers gathered who are causing a bottleneck for retrieving resources. If a warrior has frustration it will explore to look for enemies or will wander around acting as a lookout, as frustration is likely a result of no danger in its current location. Frustration directly combats the AI's problem of failed pathfinding. The AI already has a built-in check for "boredom" that verifies that a worker is not idle for a long period of time. Frustration, however, will solve the problem of workers being crowded together at a single entrance to an area with resources, or otherwise needing to move to continue succeeding toward their goals. Thus frustration can create a more efficient resource gathering mechanism for workers, and a higher likelihood of encountering enemies for warriors.

The baseline for each unit is to have no fear and no frustration (i.e. be content). Over time, any emotion felt will decrease until it reaches this baseline or a new experience replenishes the emotion. For example, if a worker is running from an enemy unit and is not chased, its fear level will continue to decrease with each time step until it no longer has fear. However, if the enemy chases it such that they continue to be the same distance apart the unit will maintain the same amount of fear. If the enemy is moving closer to the unit, the fear will increase.

Emotion Map



0	0	0	0	0	0	0
0	2	2	2	2	2	0
0	2	5	5	5	2	0
0	2	5	10	5	2	0
0	2	5	5	5	2	0
0	2	2	2	2	2	0
0	0	0	0	0	0	0

(a) Immediate emotion diffusion

0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	3	3	3	0	0
0	0	3	8	3	0	0
0	0	3	3	3	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

(b) Decay of emotion after 1 time step

Figure 3: Approximate diffusion concept. The map in 3(a) depicts the values in the squares under and surrounding a unit that just experienced an emotion of strength 10. The map in 3(b) depicts the values in those same squares after a single time step, assuming that no unit is present to modify the emotions of its surroundings with emotions having a decay value of 2.

For emotions to be most effective there must be a mechanism for units to infer each other's emotions. For humans, emotions are exceptionally useful as a way to communicate. A unit's emotion is therefore influenced by the emotions of other units under the same player via an Emotion Map and gradient. Unit emotions cannot be interpreted or felt by an opponent's units. At each time step, a unit's emotion will be saved to the map. Fear and frustration are kept separately on the emotion map. The emotion map affects a unit's emotions and is updated by a unit's emotions at every time step. This frequency is because emotions are vital to a unit's decision making, so it is therefore necessary that the both the map and the emotions felt by a unit from other units are as accurate as possible. The unit's emotion will be added to the emotion on that square, and will be diffused out to the adjacent sets of squares within a specified cityblock distance. A distance of 2 is shown in Figure 3(a), assuming an emotion with value 10 was just experienced. Given a max_radius that defines the furthest distance an emotion can travel and a $value$ of the emotion being felt, the amount of emotion that will be saved on the map at a location that is a $distance$ away from the original point of the emotion is

$$\frac{value - \frac{value}{max\_radius}}{distance}. \tag{1}$$

The emotion on the map will decrease over time in the same way that the individual unit's internal emotions will decrease over time. At each time step, the current emotion will decrease as shown in Figure 3(b), and then any new emotions will be added.

Each unit can see a gradient of the map, and is therefore affected by this gradient with each decision made. The unit's own emotion is affected by the map such that a small percentage of each of its emotions is derived from the emotions on the map from the end of the previous time step. The map therefore allows units to communicate, since the emotions held on the map are due to another unit's recent emotions. Therefore, if a unit recently encountered an enemy in a particular location, all close by units will be aware due to the emotions on the map. Also, any other units that come to the area within a short time span will be aware as well. This use of the emotion map can be equated to people hearing each other yell in fear or anticipation of a fight, or grunting from boredom. An example of the emotions being used can be seen in Figure 4.

Simulation Details

Globulation Set-Up

Simulations were run with version 0.9.1 of Globulation 2. Evaluations were performed on the map Muka, which is a one player versus one player map. Each player has all necessary resources contained within a region that is connected to the opponent via two land bridges (at the top and bottom). The map wraps from right to left, creating a land bridge from the left side to the right side of each player's region. Both players also have an additional smaller peninsula containing resources. The map is essentially symmetric although it was created by hand due to limitations of the map editor.

Emotion Controls

All emotions exist on a scale of 0 to 100. Both emotions on the emotion map are initialized to 0 at every location. Emotions then decay linearly at a rate of 1 every time step, although they cannot decrease below 0. The constant diffusion radius for both fear and frustration is 5. An example emotion map changing over time can be seen in Figure 4. Both fear and frustration were discounted by a factor of 0.1, meaning that 10% of the previous emotion level is added to the current emotion level. Fear is affected by two factors: medical condition and surrounding enemy units. Fear is increased by 1 every time step that the unit is damaged, and increased by 10 for every surrounding enemy unit. Frustration is increased in a particular unit by one tenth of the amount of time spent continuously performing the same task. This increase of frustration allows units stuck in a location to free themselves by moving away from the frustration gradient.

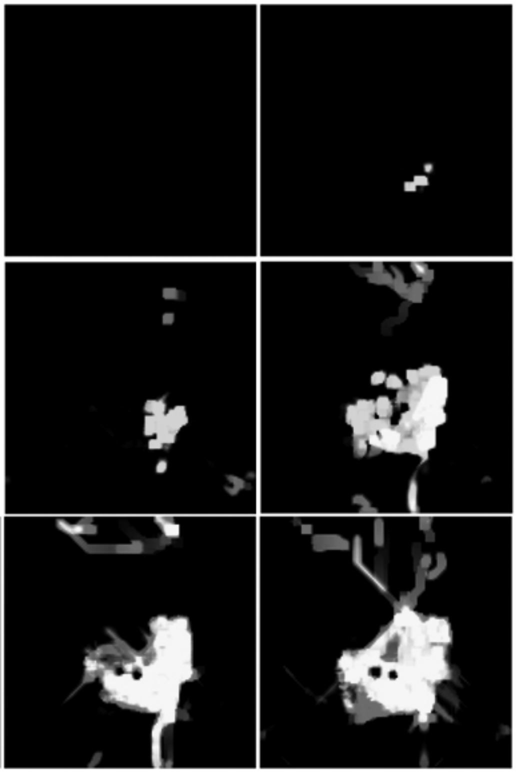


Figure 4: A series of images demonstrating an emotive agent's emotion map changing over time. Images are taken every 4,000 time steps. Frustration is shown in the middle shade of gray, fear is shown in the darker shade, and the lightest shade is the overlap of the two emotions. Images are organized chronologically from left-to-right and top-to-bottom. Initially frustration is experienced by workers in the home base of the agent. Eventually the opponent attacks the agent and the agent's home base is filled with both fear and frustration.

Thresholds were required for specifying emotion controlled behaviors. Worker and warrior units surpassing their frustration threshold will begin to move in the opposite direction from the frustration gradient. For both workers and warriors, the frustration threshold is 85. Worker units with fear greater than 75 attempt to evade the source of the fear by moving in the opposite direction of the fear gradient whereas warrior units with fear greater than 55 are drawn toward the source of fear, following the fear gradient. Once a warrior's fear increases above 90 it will retreat as well. These values were determined via tests on AI Nicowar with emotion.

Unit Decisions

Each unit has two sets of controls that are the same across all AIs: the built-in decision controls, and the emotion-based decision controls. The built-in decision controls check for life threatening situations and are executed first. Without the emotion-based decision controls, units would choose an action randomly if there was no life threatening situation (high need for medical care or food). However, AIs that utilize emotions use the emotion-based decision controls if no other decision has been made by that unit. The built-in and emotion-based controls are mutually exclusive for each time tick, i.e. a decision is made by either one or the other for each unit.

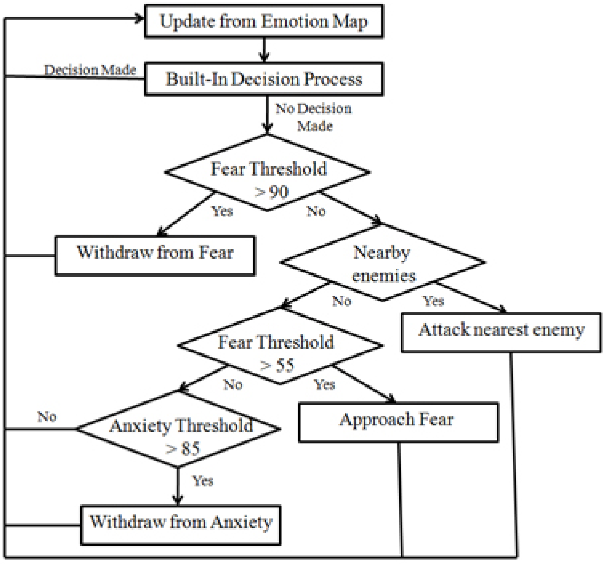


Figure 5: The decision tree for a warrior at each time step.

Each unit uses a specific decision tree when determining what action to perform each time step. The decision tree for the emotion-based controls on warriors can be seen in Figure 5. These decisions are primarily based on the thresholds discussed previously in the paper. All updates from the emotion map occur at the beginning of each time tick. Thus, the fear (F) of a unit at time t in location λ if it is surrounded by ϕ enemies is shown in Equation 2 if $Map(Fear, \lambda)$ refers to the amount of fear on the Emotion Map in location λ and ω is a binary number that is 1 if the unit is damaged and 0 otherwise.

$$F(t) = 0.8 \cdot F(t-1) + 10\phi + \omega + 0.1 \cdot Map(F, \lambda) \quad (2)$$

A unit's frustration (A) at time t can be similarly set as seen in Equation 3 if χ is a binary number that is 1 if actionTickTimer represents the time the unit has been doing the same action, $(actionTickTimer > 50)$, and $(actionTickTimer/10)$.

$$A(t) = 0.8 \cdot A(t-1) + \chi + 0.1 \cdot Map(A, \lambda) \quad (3)$$

Results

To analyze the success of a game we can examine the hit points (HP) per unit for each player, with units referring to regular units and buildings. HP represent the health of a unit, which decreases as a unit is injured and increases when it is healed; if a unit reaches 0 HP it dies. A high HP per unit ratio

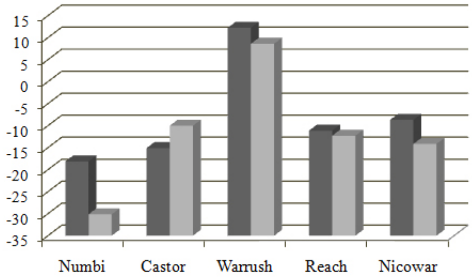


Figure 6: The difference between the average number of hit points per unit on the player's team versus the same average for Nicowar. Each label on the X-axis represents an AI that was tested with and without emotions against Nicowar (without emotions). The dark series is when the AI had emotions and the light series is for no emotion. AI Numbi and AI Nicowar improved the most from adding emotions.

can signify that either the player has a high number of units in various stages of health, or that all units have high HP. HP also rises as the level of a unit increases, so high HP can signify more powerful warriors as well. Since all of these scenarios can represent a successful game, they also imply good performance. We can therefore use the ratio of HP to units to determine whether the emotions improved the AI. Since each of these games is an AI playing against Nicowar, we can take the difference of their ratios at each time step and then average them. This average represents how much better the HP/unit ratio for the AI was over Nicowar for the duration of the game.

For our initial tests we played each AI both with emotions and without emotions. Each test consisted of a game against the Nicowar AI, ending when either player was defeated. For all tests the Nicowar AI won the game, however the time and unit count differed between the emotive and non-emotive trials. As can be seen in Figure 6, many AIs do not have a significantly higher difference in ratios between the emotive and non-emotive runs although all but one (Castor) do improve. However, Nicowar is one of the most improved AIs, which is as expected since the emotions were designed specifically to improve it. Notably, Numbi was also improved significantly with the addition of emotion.

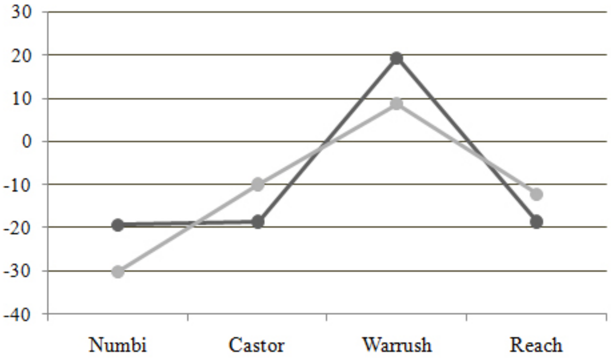


Figure 7: The difference between the average number of hit points per unit on the player's team versus the same average for Nicowar with emotions. Each label on the X-axis represents an AI that was tested without emotions against Nicowar. The dark line is when Nicowar had emotions and the light line is for no emotion. Nicowar with emotion improved against Castor and ReachToInfinity.

We can also examine the success of Nicowar with Emotion against the other original AIs without emotion. These results are essentially the reverse of the previous results, as we are now comparing whether Nicowar with emotion beats the other original AIs more effectively than it did without emotion. Thus the Nicowar without emotion results are the same as the results in Figure 6 for each AI without emotion. Figure 7 demonstrates that Nicowar with emotion is more successful than Nicowar without emotion against the Castor and ReachToInfinity AIs and less successful against the other two. This difference may imply that our emotions paradigm is stronger against less aggressive opponents, possibly due to the influence of the emotion map when a player's base is overrun with enemy units.

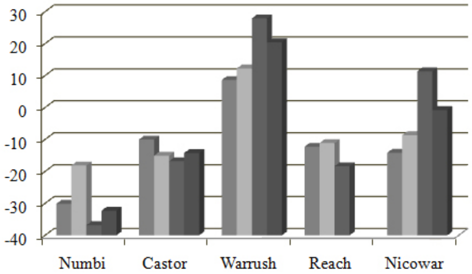


Figure 8: The difference between the average number of hit points per unit on the player's team versus the same average for Nicowar without emotions. Each label on the X-axis represents an AI that was tested in different scenarios against Nicowar without emotions. The series represent those 4 scenarios from left to right: no emotion, both emotions, only frustration, only fear.

Testing an AI with only fear or only frustration can aid in determining when each emotion is most beneficial. We thus test all AIs with only frustration against Nicowar with no emotion. As can be seen by the results in Figure 8, both Warrush and Nicowar tested with only frustration improve significantly over their tests with no emotions and with both emotions. In addition, Nicowar with only frustration wins against Nicowar with no emotion; this is the only scenario where an AI beats Nicowar.

We find similar results for tests with only fear (Fig. 8). Nicowar with only fear has a higher value than Nicowar with both emotions, but less than Nicowar with only frustration. Warrush is also improved with only experiencing fear when compared to no emotion or both emotions, but is not better than when it only has frustration. Castor improves slightly by only having fear over all of its other emotion trials, although none of its emotion tests were better than its non-emotive test. Numbi with only fear only improved over its success with only frustration, and ReachToInfinity was unable to be tested for only fear due to an error in the open-source code that was beyond our control.

Conclusions

The addition of emotions have shown an overall improvement in the performance of the AIs tested against Nicowar. As expected, some AIs improved more than others and responded more favorably to certain scenarios. For instance, the AI Warrush improved significantly more with only frustration or fear as opposed to utilizing both. These results suggest that the two emotions may conflict in certain scenarios. One such scenario is enemies in the base area, as the workers fear may stop the warriors from attacking or the warrior frustration of constant attacks may influence worker movement patterns. Depending on the scenarios likely to occur, different emotional influences should be utilized for different AIs.

The Nicowar AI also improved substantially more with only frustration than it did with both emotions, to the point that it won against the regular Nicowar AI. As both emotions were designed specifically to counteract problems in the Nicowar AI, this may imply that a more advanced emotional system for fear may be necessary to fully deal with those problems. These results also suggest that emotions designed for a specific system will improve that system's functionality the most although it may also improve similar systems. For real-time AI this implies that emotions should be explored for designing new decision processes.

We also conclude that an emotion map is an efficient way to allow agents to communicate emotion with neighbors. It does not require direct communication but is more reminiscent of cellular communication. Since the interactions and social constructs that arise from emotion sharing are one of the key aspects of emotions, such an ability is necessary. We are currently continuing this work to increase the success of the emotions in controlling the agents by adding other emotions and modifying the emotional reactions of agents. It seems reasonable to utilize these fairly simple constructs to improve an agent's decisions.

The spatio-temporal evocation of emotion can be seen visually in Figure 4 at a few critical points in time. From these images it is possible to see that emotional evocation occurs during relevant times during the game play. Given that the expression of emotion occurs in the proper situations and that results show performance improvements for the emotive case, it is reasonable to conclude that an emotional framework will benefit the AIs in Globulation. Since the tested paradigm shows improvement over no emotion, more complex emotional systems should be examined. The relative success of our system demonstrates that adding emotions to a real-time system is entirely feasible and warrants further study.

Acknowledgments

This research was performed under an appointment to the Department of Homeland Security (DHS) Scholarship and Fellowship Program, administered by the Oak Ridge Institute for Science and Education (ORISE) through an interagency agreement between the U.S. Department of Energy (DOE) and DHS. ORISE is managed by Oak Ridge Associated Universities (ORAU) under DOE contract number DE-AC05-06OR23100. All opinions expressed in this paper are the author's and do not necessarily reflect the policies and views of DHS, DOE, or ORAU/ORISE.

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