

A Model of Emotions for Situated Agents

H. Van Dyke Parunak, Robert Bisson, Sven Brueckner, Robert Matthews, John Sauter

Altarum Institute
3520 Green Court, Suite 300
Ann Arbor, MI 48105-1579 USA
1-734-302-4600

{van.parunak, robert.bisson, sven.brueckner, robert.matthews, john.sauter}@altarum.org

ABSTRACT

In stressful situations such as combat, emotion is at least as important as rational analysis in determining behavior. DETT (Disposition, Emotion, Trigger, Tendency) is a model of emotion for situated agents that captures the essential features of the OCC (Ortony, Clore, Collins) model in a computationally efficient framework. We motivate and describe this architecture, and report preliminary experiments in simulating combat scenarios.

Categories and Subject Descriptors

I.2.0 [Artificial Intelligence]: General—*cognitive simulation*.

I.2.11 [Artificial Intelligence]: Distributed Artificial Intelligence—*multiagent systems*.

J.4 [Social and Behavioral Sciences]: Psychology

General Terms

Algorithms, Experimentation, Theory.

Keywords

Emotion modeling, pheromones, swarm intelligence, BDI.

1. INTRODUCTION

Most computational models of emotion [13] require extensive symbolic reasoning, and are not practical in highly populous real-time domains. DETT (Disposition, Emotion, Trigger, Tendency) captures the essential features of the OCC (Ortony, Clore, Collins) emotion model efficiently, using digital pheromones as the agents' main source of perceptions. It extends current emotional models by defining a Disposition parameter that distinguishes agents' differing susceptibility to various emotions. DETT is designed for situated agents. An agent's emotions are triggered by its percepts, not just by internal reasoning.

Section 2 reviews previous work in computational emotions, particularly in the context of combat modeling. Section 3 describes the DETT model. Section 4 concludes.

2. PREVIOUS WORK

Our work rests on previous research in emotional modeling, and two existing agent-based combat models that can be interpreted as

supporting elements of our approach.

2.1 Emotional Modeling

Research in agent-based modeling and human interfaces (including gaming) has increased interest in computational models of emotion [13], each drawing on different segments of a long psychological tradition [3]. For our purposes, a cognitive perspective on emotions (rather than an expressive or physiological one) is most appropriate, in particular the OCC model [8], where emotions are "valenced reactions to events, agents or objects." That is, the strength of an emotion depends on stimuli in the agent's environment. Their presence is mapped to a "valence," a positive or negative score, by a process called "appraisal."

Emotion can focus attention, increase the prominence of memories, affect cognitive style and performance, and influence judgments [1]. In OCC, "behavior is a response to an emotional state in conjunction with a particular initiating event." We focus on the impact of emotion on an agent's analysis, the process by which it selects intentions from desires. The left side of Figure 1 summarizes the Belief-Desire-Intention [14] model. Beliefs (derived from the environment by Perception) and Desires (constant over the time horizon of our model) feed Analysis, which produces Intentions, which in turn drive actions that change the environment. The right side enhances this model with OCC emotion. Beliefs feed not only Analysis, but also Appraisal, which generates Emotions. These Emotions in turn influence Analysis and Perception. (We do not implement the latter link in our current system).

Gratch and Marsella [4] offer one of the more mature current computational models of agent emotion. Table 1 summarizes the correspondence between the two models.

2.2 Emotional Combat Models

Explicit emotional modeling is rare in combat models, but elements of two recent models anticipate DETT.

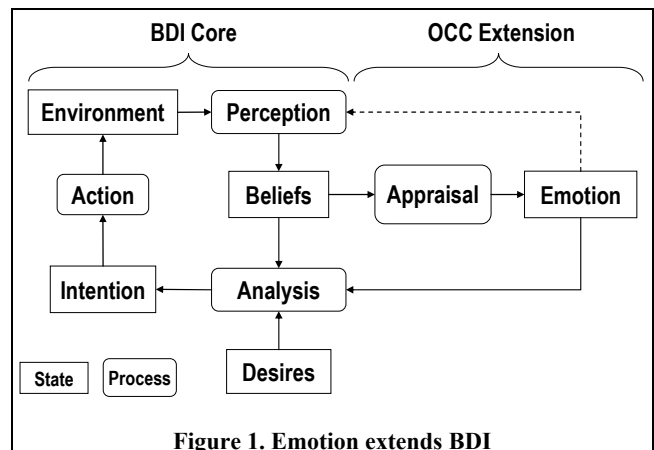


Figure 1. Emotion extends BDI

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.

AAMAS'06, May 8-12, 2006, Hakodate, Hokkaido, Japan.

Copyright 2006 ACM 1-59593-303-4/06/0005...\$5.00.

EINSTEIN [5] represents an agent's personality as six scalars in $[-1, 1]$, describing the agent's response to six percepts: the number of alive friendly, alive enemy, injured friendly, and injured enemy troops within the agent's sensor range, and the agent's distance from its own and its adversary's flag. (Each team seeks to capture the adversary's flag while protecting its own.) A positive weight indicates that the agent is attracted to the entity described by the weight, while a negative weight indicates that it is repelled.

MANA [7] extends EINSTEIN. Friendly and enemy flags are replaced by the waypoints being pursued by each side. MANA includes four additional components: low, medium, and high threat enemies. It also defines triggers (e.g., reaching a waypoint, being shot at, making contact with the enemy, being injured) that shift the agent from one personality vector to another. A default state defines the personality vector when no trigger state is active.

The notion of being attracted or repelled by friendly or adversarial forces in various states of health is an important component of what we informally think of as emotion (e.g., fear, compassion, aggression), and the use of the term "personality" in both EINSTEIN and MANA suggests that the system designers are thinking anthropomorphically, though they do not use "emotion" to describe the effect they are trying to achieve.

EINSTEIN and MANA implement subsets of Figure 1. The personality corresponds to the agent's Desires. EINSTEIN's personality vector guides the agent's decisions, but does not change in response to the agent's beliefs about the events, objects, or agents in its environment. Thus it is not a "valenced reaction." EINSTEIN does not capture OCC emotion. MANA's personality vectors depend on a trigger state, and implement a valenced reaction.

Both EINSTEIN and MANA do analysis by multiplying a vector of percepts by the personality, yielding a movement vector. In both models, the agent has perfect knowledge within a vision radius. These processes are much simpler than those in [4]. The differences reflect the systems' objectives. Gratch-Marsella supports a training environment with few agents. Regular human interaction slows the pace, permitting significant computation. EINSTEIN and MANA manipulate dozens or hundreds of agents in non-interactive simulations, and must minimize execution time.

3. The DETT Model

DETT supports the DARPA RAID program [6], whose objective is to anticipate enemy actions and deceptions to provide real-time support to a tactical commander. Our module [11] evolves agents against observations to learn their characteristics and determine which ones are most likely to reflect future behavior. These agents must execute faster than real time, so they cannot conduct complex symbolic reasoning, but use numerical computation via DETT. We also use the model in another project to automate the reactions of non-combatants with combatants. This capability

Table 1. Comparison of Models	
BDI + OCC	Gratch-Marsella
Environment	Environment
Perception	Causal Interpretation
Beliefs	Causal Interpretation
Appraisal	Appraisal
Emotion	Affective State
Analysis	Coping
Desires	???
Intention	Control Signals
Action	Action

requires us to recognize that non-combatants will have a range of personality types and to incorporate these differences in their behavior. Details are in the full paper.¹

Both applications require an efficient way to include emotions in modeling combat. This reasoning takes place at two locations in Figure 1: Appraisal and Analysis.

3.1 Appraisal

MANA's triggered personality vectors are a useful model for appraisal, but have two

limitations. First, MANA defines vectors and triggers for the squad, all of whose members share the same values. Individual combatants (e.g., new recruits vs. seasoned veterans) will differ widely in their susceptibility to different emotions. To use evolution to learn the characteristics of entities, we must parameterize this kind of difference. Second, MANA assumes that emotions arise and disappear immediately with the appropriate trigger. Empirically, emotions rise rapidly but not instantaneously, and persist after the trigger is removed.

To address the first concern we add a new component, Dispositions, to the model (Figure 2). Emotions and Dispositions correspond one to one. Like Desires, Dispositions are constant over each simulation. A Disposition modulates Appraisal to determine how much a Belief triggers the corresponding Emotion. The Emotion then modulates Analysis to impose a Tendency on the resulting Intention. The main elements of this model are thus the Disposition, Emotion, Trigger, and Tendency (the effect on intentions) (DETT). Table 2 gives two examples.

Agents sense one another through digital pheromones [2], labeled scalars that they deposit in the environment and that diffuse and evaporate over time. An agent believes what it senses in the form of pheromones. Our pheromone vocabulary for RAID includes flavors for live and dead friendly, hostile, and neutral individuals, weapons fire, key sites, and topographical features that provide cover from fire or that enhance mobility.

An agent's desires are values in $[-1, +1]$: ProtectRed (the adversary), ProtectBlue (friendly forces), ProtectGreen (civilians), ProtectKeySites, AvoidCombat, AvoidDetection, and Survive. Negative values reverse the sense: a negative ProtectRed is a desire to harm Red. Table 2 in [9] shows which pheromones attract or repel an agent with a given desire, and how that tendency translates into action. For example, an agent with a high positive ProtectRed will

be attracted to RED-ALIVE, RED-CASUALTY, and MOBILITY pheromone, and will move at maximum speed.

Let $\mathbf{P}$ be the vector of pheromone strengths at an agent's location. The agent's Disposition is a matrix $\mathbf{D}$. $D[i,j] \in [0,1]$ is the relevance of the i th pheromone to the j th emotion. The j th emotion depends (nonlinearly) on the j th element of $\mathbf{P}^T \mathbf{D}$.

A digital hormone [12], one per

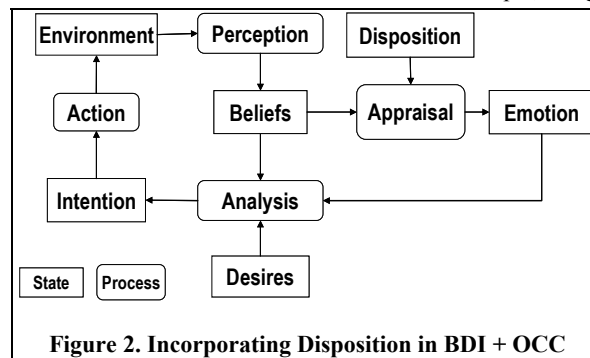


Figure 2. Incorporating Disposition in BDI + OCC

¹ www.altarum.net/~vparunak/AAMAS06EmotionModel.pdf

agent per Emotion, models change in emotion with time. $P^T D$ determines the current deposit to the hormone vector E , so the longer an agent is exposed to a trigger pheromone, the higher the level of the associated emotions. When the trigger is removed, its emotions decay exponentially. The higher the disposition, the more quickly the emotion grows in the presence of a trigger.

3.2 Analysis

Analysis draws on the same pheromone vector P of beliefs as does Appraisal, and takes as input the current state of the emotion vector E . In addition, it considers the values of the agent's vector of Desires or Wants W . The desires we are modeling are Protect Red, Protect Blue, Protect Green, Protect Key Sites, Avoid Combat, Avoid Detection, and Survive. Each has a real value in the range $[-1,1]$, where a negative value indicates that the agent wants the opposite state of affairs described by the desire. A movement matrix M indicates whether a given Desire tends to attract or repel the agent toward a given flavor of pheromone: $M[i,j]$ is 1 if desire j is attracted to pheromone i , -1 if it is repelled, and 0 if the pheromone is irrelevant to the desire.

In the absence of emotions, the agent's behavior is a nonlinear function of $P^T M W$. Emotions modulate these behaviors. Elevated Anger increases movement likelihood, weapon firing likelihood, and tendency toward an exposed posture, while elevated Fear decrease these likelihoods. Level of a particular emotion models the extent to which the emotion modulates the agent's behavior. Someone who experiences high fear, but continues to behave as if he were not afraid, would be modeled as having low fear. We are not trying to model emotion as experienced by an agent, only as perceived by its impact on the agent's behavior.

4. CONCLUSION

Emotion is critical in modeling agent behavior in stressful environments such as combat. The Gratch-Marsella model is a sophisticated implementation of current psychological theories of emotion, but is computationally too expensive for large populations of combatant agents. EINSTEIN and MANA are efficient, but their notion of personality is psychologically naïve. DETT combines the theoretical richness of Gratch-Marsella with the computational efficiency of EINSTEIN and MANA, and adds dispositions, accounting for differences in the emotional susceptibility of various agents by reasoning about the reaction of an internal agent characteristic to the external environment in which the agent is situated. We have demonstrated the basic computational cycle in implemented software and in actual wargame experiments.

The model is still an approximation. It does not implement the known effect of emotion on perception, and does not consider other possible linkages (e.g., between emotion and desire). Such simplifications are in the nature of simulation, and are justified empirically by the notion of "universality": the dynamics of a multi-agent simulation often depend more on the interactions of the agents than on the details of individual agents' reasoning [10].

5. Acknowledgements

This material is based on work supported by the Defense Advanced Research Projects Agency (DARPA) under Contract No.

Table 2. Sample DETT Semantics

Disposition	Emotion	Trigger	Tendency
Cowardice	Fear	Armed enemy Incoming attack	Less attention to orders Tend to avoid threat
Irritability	Anger	Presence of enemy	More likely to fight Tend to move toward threat

tribution Statement "A" (Approved for Public Release, Distribution Unlimited).

6. REFERENCES

- [1] S. Brave and C. Nass. Emotion in Human-Computer Interaction. In J. A. Jacko and A. Sears, Editors, *The human-computer interaction handbook: fundamentals, evolving technologies and emerging applications*, pages 81-96. Lawrence Erlbaum Associates, Inc., Mahwah, NJ, 2003.
- [2] S. Brueckner. *Return from the Ant: Synthetic Ecosystems for Manufacturing Control*. Thesis at Humboldt University Berlin, Department of Computer Science, 2000.
- [3] C. Darwin. *The expression of the emotions in man and animals*. London, John Murray, 1872.
- [4] J. Gratch and S. Marsella. A Domain-independent Framework for Modeling Emotion. *Journal of Cognitive Systems Research*, 5(4):269-306, 2004.
- [5] A. Ilachinski. *Artificial War: Multiagent-based Simulation of Combat*. Singapore, World Scientific, 2004.
- [6] A. Kott. Real-Time Adversarial Intelligence & Decision Making (RAID). 2004. <http://dtsn.darpa.mil/ixo/programdetail.asp?progid=57>.
- [7] M. K. Lauren and R. T. Stephen. Map-Aware Non-uniform Automata (MANA)—A New Zealand Approach to Scenario Modelling. *Journal of Battlefield Technology*, 5(1 (March)):27ff, 2002.
- [8] A. Ortony, G. L. Clore, and A. Collins. *The cognitive structure of emotions*. Cambridge, UK, Cambridge University Press, 1988.
- [9] H. V. D. Parunak, S. Brueckner, R. Matthews, J. Sauter, and S. Brophy. Characterizing and Predicting Agents via Multi-Agent Evolution. Altarum Institute, Ann Arbor, MI, 2005. <http://www.altarum.net/~vparunak/BEE.pdf>.
- [10] H. V. D. Parunak, S. Brueckner, and R. Savit. Universality in Multi-Agent Systems. In *Proceedings of Third International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS 2004)*, pages 930-937, IEEE, 2004.
- [11] H. V. D. Parunak and S. A. Brueckner. Extrapolation of the Opponent's Past Behaviors. In A. Kott and W. McEneaney, Editors, *Adversarial Reasoning: Computational Approaches to Reading the Opponent's Mind*, Chapman and Hall/CRC, 2006.
- [12] H. V. D. Parunak, S. A. Brueckner, R. Matthews, and J. Sauter. Pheromone Learning for Self-Organizing Agents. *IEEE SMC*, 35(3 (May)):316-326, 2005.
- [13] R. W. Picard. *Affective Computing*. Cambridge, MA, MIT Press, 2000.
- [14] A. S. Rao and M. P. Georgeff. Modeling Rational Agents within a BDI Architecture. In *Proceedings of International Conference on Principles of Knowledge Representation and Reasoning (KR-91)*, pages 473-484, Morgan Kaufman, 1991.

NBCHC040153. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the DARPA or the Department of Interior-National Business Center (DOI-NBC).