Agents, Emotional Intelligence and Fuzzy Logic

Magy Seif El-Nasr
Computer Science Department
Texas A&M University
College Station, TX 77844-3112
magys@cs.tamu.edu

John Yen
Computer Science Department
Texas A&M University
College Station, TX 77844-3112
yen@cs.tamu.edu

Abstract

Emotions were proven to lead an important role in human intelligence. Intelligent agents' research produced many emotional agents. Research on human psychology had long considered the notion of an emotion (e.g., happy) to be a matter of degree; however, most existing research on emotional intelligent agents treat emotions as a black-and-white matter. We are proposing a model called FLAME – Fuzzy Logic Adaptive Model of Emotions. FLAME was modeled to produce emotions and to simulate the emotional intelligence process. FLAME was built using fuzzy rules to explore the capability of fuzzy logic in modeling the emotional process. Fuzzy logic helped us in capturing the fuzzy and complex nature of emotions. Throughout this paper we will try to point out the advantages of using fuzzy modeling over conventional models to simulate a better illusion of reality.

1 Introduction

"Human beings, viewed as behaving systems, are quite simple. The apparent complexity of our behavior over time is largely a reflection of the complexity of the environment in which we find ourselves [21]." This very famous quote by Simon marked the birth of Artificial Intelligence. Striving towards replicating human intelligence in a machine, Simon tried to build a model for simulating emotions. Even back then, he recognized that emotions play a crucial role in human cognition. We have been conditioned to think that emotions were not a part of human intelligence, but rather hinder humans' thoughts. This idea has been initiated by ancient philosophers such as Plato. Moreover, Descartes reinforced this idea by his famous statement "I think therefore I am."

Today, new evidence has answered the question that Minsky had posed. Minsky, writing on the human mind, said, "the question is not whether intelligent machines can have any emotions, but whether machines can be intelligent without any emotions [10]." A. Demasio presented some neurological evidence to prove that emotions do in fact play an active and important role in the human decision-making process [4]. The interaction between the emotional process and the cognitive process may explain why humans excel at making decisions based on incomplete information – "acting on our gut-feelings."

Following this major breakthrough, many terms emerged, including "emotional intelligence," "social intelligence," "IQ-based social intelligence," and "EQ-based social intelligence." These terms arose from the theory that emphasizes on the existence of many types of intelligence for what we normally call the human intelligence system. Emotional intelligence was defined as a process by which human beings can reason about their emotions and even use them to achieve their goals. This requires self-awareness, self-control and self-perception. Moreover, this also requires understanding of other people's emotions. Thus, EQ-social intelligence was defined as the use of emotional intelligence to develop a more profound communication pattern between a group of people [5].

Using fuzzy modeling proved to produce a more representative picture of the emotional process, and thus it might produce better believable agents. In the next section, we will discuss the previous models and the problems that can be solved by using fuzzy modeling.

2 Previous Work

Psychology, Neurology, Philosophy and Cognitive Science have been concerned with modeling the mind and its behavior for many years. Thus, it is not surprising to see many papers/books proposing models of emotions and behaviors. Among the neurological models, LeDoux published his book, *The Emotional Brain,* to explore the emotional process in the brain [7]. More recently, D. Goleman explained the idea of emotional intelligence and its importance in [5].

While in the psychology field, D. Price and J. Barrell developed a mathematical model that described emotions in terms of desires and expectations [13]. Pain was modeled by R. Schumacher and M. Velden [18] and again by S. Tayrer's book [24]. Some hormones sent by the brain sometimes inhibit pain; this idea was adopted by Bolles and Fanselow, who tried to understand the relation between fear and pain [3].

Inspired by these psychological models and the growing interest in AI, many models that simulate the human mind have been proposed. A description of models of emotions from early 1960's until the 1980's was presented by R. Pfeifer [12]. However, since the psychology of emotions was not yet complete at the time, it was not easy to find a computational model that describes the whole emotional concept.

By the 1990's, the Japanese researchers were interested in a system that can communicate with humans. Emotions were regarded as one of the most important factors in communication. Thus, by 1994, an effort was made by Masuyma to formulate the human emotions into a set of rules [9]. An attempt was made by S. Sugano and T. Ogata [23] to simulate the human mind through an electrically wired robot. A prototype of the decision-making process was developed by Inoue [6], they used neural networks to simulate behavior.

The topic of emotion was regarded as a very challenging topic, since it was hard to fully understand how we feel and why we do feel that way. Part of the reason for the so-called "mystery of emotions" is due to the fact that most of our emotions occur at the subconscious level [7]. Moreover, it is still unclear how emotions transition from the subconscious to the conscious brain.

Searching for a better solution, researchers on agent's technology began working on emotions. J. Bates is building a believable agent (OZ project) [1, 2, 14] using the model described in *The Structure of Emotions* by Ortony, Clore and Collins [11]. The MIT lab is also producing an emotional multi-agent project [26]. The model only describes basic emotions and innate reactions; however, it presents a good starting point for building computer simulations of emotion. The basic emotions that were simulated in the model are anger, fear, distress/sadness, enjoyment/ happiness, disgust, and surprise.

3 The Model

3.1 Problems with existing models

To talk about the problems with the existing models, we need to look at the previous work in more details. Thus, we will take one of these models, namely the OZ project [15], as an example from which the other models can be understood. In summary, the model first assesses a perceived event as being desirable or undesirable with respect to a goal within the goal structure of the agent. The desirability of the event was measured as a true or false concept.

The model triggered emotions according to the desirability factor. They used Ortony et al.'s model [11] to formulate the rules for the triggering process. Emotions were triggered with different intensities. Intensities are degrees, say a number between 1 and 10, that depicts the strength of an emotion. The intensity degree is then used to map the resulting emotions to a behavior. They followed an interval mapping technique to get an accurate personality.

As you can see, there are two major problems in the techniques employed. Firstly, desirability is measured as a black or white concept, which then raises questions such as what if an event satisfies a goal to a certain degree? The idea of partial goal successes or failures was not employed. Moreover, the idea of an event satisfying multiple goals or satisfying some goals and not the others was not considered. Secondly, the mapping of the emotional states to a behavior was made according to an interval mapping technique. For instance, a rule in the system states that if the anger level towards subject, g, is greater than 0 and the fear value towards this subject, g, is greater than five, then the aggressive value will be a function of both anger and fear. However, if the anger is greater than 0 and fear is less than 5 then the aggressive value will be a function of the anger. What if the level of fear is 4.9, or 4.7? How does that affect the value of aggressiveness?

3.2 A solution

In order to solve these problems we propose the use of fuzzy logic. Using fuzzy logic, we introduced three concepts:

- *Fuzzy Goals*: this concept introduces a degree of success and failure associated with achieving goals.
- *Fuzzy Membership*: the membership of an event to a goal will be a matter of degree, thus an event can be affecting two or more goals with different degrees.
- *Fuzzy Mapping:* the mixture of emotions is mapped to a behavior through the use of a fuzzy mapping technique.

3.3 Overview of System Architecture

To understand the emotional process, we will illustrate the whole process through figure 1. It should be noted that, the figure shows one part of the architecture of FLAME (Fuzzy Logic Adaptive Model of Emotions).

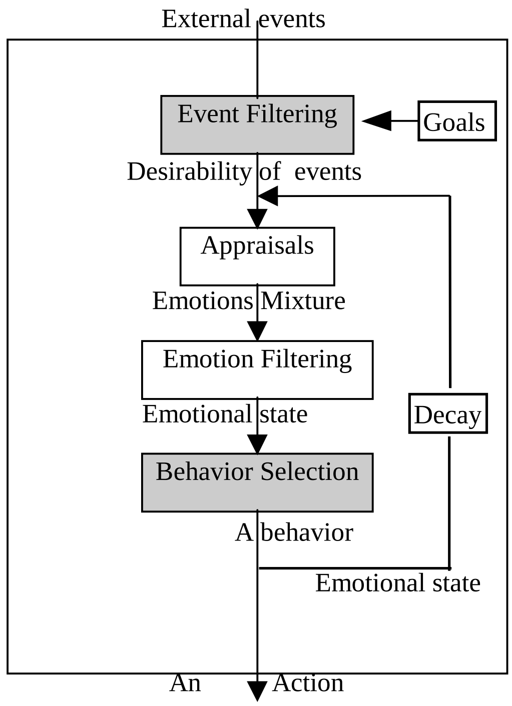

Figure 1. Process of the Emotional Model

In this figure, boxes represent different processes within the model. Information is passed from one process to the other, as shown in the figure. In the figure above the shaded boxes represent the processes where fuzzy logic was used. In the next couple of paragraphs, we will detail the two fuzzy processes, while summarizing the other processes when they become relevant.

Firstly, we need to set a desirability value for each event perceived by the agent. Thus, we need to identify the degree that an event affects a certain goal, which has a certain priority level. The degree by which a particular event impacts a particular goal is simulated using five fuzzy sets with triangular membership functions. The fuzzy sets are *NoImpact*, *HighPositiveImpact*, *Low-PositiveImpact*, *Low-NegativeImpact* and *HighNegative-Impact*. The priority of a goal is dynamically set during the simulation according to the agent's assessment of a particular situation. The priority of each goal is represented using three fuzzy sets of triangular membership functions. The fuzzy sets are termed: *NoImportance, SomeImportance, ExtremeImportance.*

The event is evaluated by the following rule:

IF Affect(G_1,E) is A
AND Affect(G_2,E) is B
…..
AND Affect(G_k,E) is H
AND Importance(G_1) is D
AND Importance(G_2) is F
….
AND Importance(G_k) is I
THEN Desirability(E) is C

where k is the number of goals simulated in the system. This rule reads as follows: if the goal, G_1, is affected by an event, E, to a degree A and goal, G_2, is affected by an event, E, to a degree B, etc., and the importance of the goal, G_1, is D and the importance of goal, G_2, is F, etc., then the desirability of the event, E, will be of degree C. We are using Mamdani's model, discussed in [25], with centroid defuzzification to get a desirability degree, which will be sent to the next process. Mamdani's model uses sup-min to get the matching degrees for the n rules.

After calculating the desirability of an event, we employ a variation of Oronty's model [11] to define the emotion triggered by the situation and the event. For example to get the intensity of joy, we employ the following rule:

Joy = the occurrence of a desirable event.

The joy intensity will be a direct function of the level of desirability produced by the fuzzy model after defuzzification. Moreover, other emotions such as hope, fear, relief, etc., need more than just the measure of desirability; expectations and likelihood play an important role in simulating these emotions. The rule we are using to simulate hope is:

Hope = the occurrence of an unconfirmed desirable event.

We use experience to guide the calculation of the likelihood of events to occur. The intensity of hope will be a function of both the desirability and probability of the event to occur.

After firing the rules and getting a mixture of emotions, we will filter the emotion mixture to get an emotional state. The mixture is filtered using some inhibition factors such as the ones employed by Bolles and Fanslow [3]. The emotional state will then pass through a fuzzy mapping phase to determine a behavior.

Fuzzy logic is used once again to determine a behavior given a set of emotions. The behavior depends on the emotions of the agent and the situation or the event that occurred. For example, consider the following rule:

IF Anger is *High*
AND *dish-was-taken-away*
THEN behavior is *Bark-At-user*

The behavior *barking at user* depended on what the user did and the emotional state of the agent. If the user did not take the dish away and the agent was angry for some other reason, he would not be inclined to bark at the user, because the user might not be the cause of his anger. Thus, it is important to identify both the event and the emotion. It is equally important to identify the cause of the event. In this case, we are assuming that non-environmental events such as *dish-was-taken-away*, *throw-ball*, *ball-was-taken-away*, etc. are all caused by the user. To generalize the rule shown above, we used the following fuzzy rules:

IF emotion$_1$ is A
AND emotion$_2$ is B
…..
AND emotion$_k$ is C
AND Event is E
THEN BEHAVIOR is F

where k is the number of emotions in the system. A, B and C are fuzzy sets defining the emotional intensity as being *HighIntensity*, *LowIntensity* or *MediumIntensity*. Behaviors are simulated as singletons, including *Bark-At-User* and *Play-With-Play*. Likewise, events are also simulated as singletons such as *dish-was-taken-away*, *throw-ball*, *ball-was-taken-away*, etc. After selecting a behavior, the emotional state is then decayed and fed back to the system.

4 Results and Discussions

The system was implemented using Java. The system simulates a pet, a dog, called PETEEI (A PET with Evolving Emotional Intelligence) with sixteen simulated emotions, including sadness, joy, anger, remorse, admiration, fear, hope, relief, disappointment, gratitude, gratification, pride, shame, reproach, love and hate. Figure 2 shows the graphical interface of PETEEI. PETEEI is a virtual pet, which can be seen in the picture. The user can interact with the pet and the environment through actions simulated by buttons, which are shown in the bottom part of the figure. The user can perform several actions to objects within a particular scene such as touching, hitting, talking and looking. The user can also open or close objects and take certain objects.

Objects are entities within the scene such as grass, house, tree, sky, the pet, etc. The user can initiate a talk with the pet using the talk box shown in the bottom right corner of the scene.

PETEEI will initially fear humans, thus it will fear and probably hate the user at first. However, through the interactions with the user these feelings might change for the worse or the better according to the user's actions. If the user keeps ignoring the pet or hitting it then the pet might probably hate the user more and more. Currently, PETEEI's goals are really primitive. At the very high level we have two goals: survival and entertainment. Subgoals of survival are not(hunger), not(thirst), not(pain) and shelter. While, subgoals of entertainment are: not(ignored) and play(toys).

The system was evaluated by collecting quantified questionnaires about the behavior and the believability of the agent. The survey was conducted with 21 users who were first year undergraduates. We chose our users to specifically be first year undergraduates, because this sample of users would not have background knowledge tied to any field, and thus they would not be biased to expect from the simulation things that is tied to their own experience in their fields. The users evaluated three systems. A system that simulated emotions using fuzzy logic, another that used interval mapping to simulate the emotions, and the third simulated random emotions and behaviors to establish a baseline for comparing the user's answers for the other two models. We asked the users to run these experiments and then answer a questionnaire after each experiment. We then compared and analyzed these questionnaires. We found out that the users favored the fuzzy logic model over the other two models, especially when they were asked to rate the system according to their expectations. For example, one of the users, answering the questionnaire on the non-fuzzy system, said that the pet was very moody being aggressive at a moment and then not so aggressive in the next. While in the fuzzy system, the most common answer was that the pet's reactions was very much what you would expect from a real pet. Thus, we concluded that the use of fuzzy logic did improve the believability of the agent simulated.

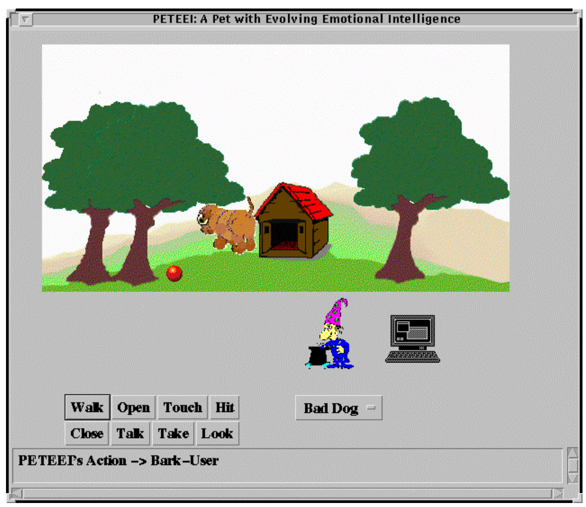

Figure 2. User Interface of PETEEI

5 Future Research

Even though the model simulated emotions in both complex and simple levels, the model is still not complete. What makes the human mind so complex is the interactions between its processes. The cognitive process and the emotional process is not as separate as shown in the model discussed above. In fact, the complexity in the human mind lies in the complexity of the interaction between both the emotional and the cognitive processes.

Thus, to complete the model above, we will have to further study the possible ways of interactions between the emotional and the cognitive models. Nevertheless, we think that our model provides a solution – a step towards achieving that higher goal.

6 Conclusion

In conclusion, we think that fuzzy logic could potentially help in capturing the uncertainty and the complex nature of emotions. We have shown some of the problems that might arise in the current models of emotion, we have also discussed our proposed solution. To further show how fuzzy logic could change and simulate a closer picture to reality, we have shown an implementation of a believable agent, namely a pet named PETEEI. We further proved the advantages of using fuzzy logic by evaluating the system. Additionally, we have identified some possible future research directions.

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