Hybrid Emotionally Aware Mediated Agent Architecture For Human-Assistive Technologies

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Abstract

Emotionally aware agents used to support human-computer interactions form the basis for our hybrid mediated agent architecture. This paper expands on our framework for an emotionally aware interface architecture that couples with the human user where data is mediated between agent processes for adaptive controlled assistive technologies. We present a hybrid emotionally aware mediated agent architecture that couples human and artificial operators. Agent behaviors in the context of emotion are derived from interactions from human users and interactions with its environment.

Introduction

Destructive emotional responses exhibited by humans are often elicited by various environmental stimuli or internal states. Such responses can be harmful to normal rational decision making processes and can cause irrational or detrimental behaviors. Emotional conditions can be exacerbated by risk, mental defects, genetic predisposition, events, and social interactions and by the environment. As emotions influence many of the decisions we make every day, it is important to understand their influence and to incorporate their basic mechanisms into human-computer interfaces. Our agent architecture for human assistive technologies accounts for emotional influence in the output produced by the human user and attempts to filter out such constructs by utilizing mediation methods between the human output and the output of an artificial agent to produce “better” decisions.

Using simulated emotional states as a heuristic for agent actions is similar to human behavioral motivators providing variations toward goal attainment as events and actions are influenced by temperaments (Bates, 2000). It has been acknowledged that emotional states provide for distinct functions in many activities and can assist in organizing perceptual, cognitive and behavioral actions (Izard & Ackerman, 2000). It is not our goal to facilitate the creation of complex emotions, but to use simplified constructs in order to improve human-agent interactions. Our agents are limited to a finite set of options and values that simulate particular emotional states. Research conducted by Elkman & Friesen (1975) recognized six well-known and cross culturally innate emotional states identified by facial expressions such as: Anger, fear, sadness, disgust, surprise and joy. Our agent architecture utilizes only two states; Anger and joy (which we refer to as happiness).

Emotion-based frameworks

The idea of an emotion-based framework is not new, as many groups implemented their own solutions after the initial roadmap was set by Damasio (1994). Bates (1994) then corroborates the importance of this branch of research by stating that it is important for an agent to have an emotional component, as humans tend to relate more to what is like them.

Although there is no clear categorization that oversees frameworks aimed at emotion-based agency, we suggest that a solution may or may not mimic the findings by Damasio (1994). In damasian frameworks, the primary goal is to create an architecture that resembles the structures introduced by Damasio (1994). In non-Damasian frameworks instead, although the principal inspiration is still based on Damasio’s work, the architecture does not try to adhere to the biological construct of a person’s emotional engine.

Damasian Frameworks

Although many researchers have followed the steps first left by Damasio (1994), we find in the work by Sloman (1998) the most interesting interpretation. While groups such as Ventura and Pinto-Ferreira (1998), Velásquez (1997), Gadanho and Hallam (1998) and others focus solely on the Damasio approach, Sloman (1998) focuses on a model that is created through the evolution of the capabilities of life forms through history and pre-history. The model created by Sloman is the summary of the analysis of several fields unrelated to robotics and agency. He bases his main notions on evolution and the adaptation of the human mind to ever-changing natural conditions. The fields of biology, philosophy, psychology and many more all contributed to the refinement of our understanding of human control modules.

Non-Damasian Frameworks

The application of Camurri and Coglio (1998), based on the model created by Camurri et al. (1997), works in a setting of the performing arts, introduces a framework where the agent works by observing and being emotionally influenced by a dancer, creating outputs of music and rhythm based on its internal emotional state. A macroscopic analysis reveals several components of control. There are five active components: *Input*, *Output*, *Reactive*, *Rational* and *Emotional*. Each component deals with a different aspect of the agent.

Introduction to the hybrid architecture

The work described in this paper is an innovative framework that can fit many scenarios. Although the original work was conceived as a stand-alone agent, described in Vincenti, Braman and Trajkovski (2007), we have extended the first concept to fit a larger set of applications. Figure 1 shows the framework in its full operative setting.

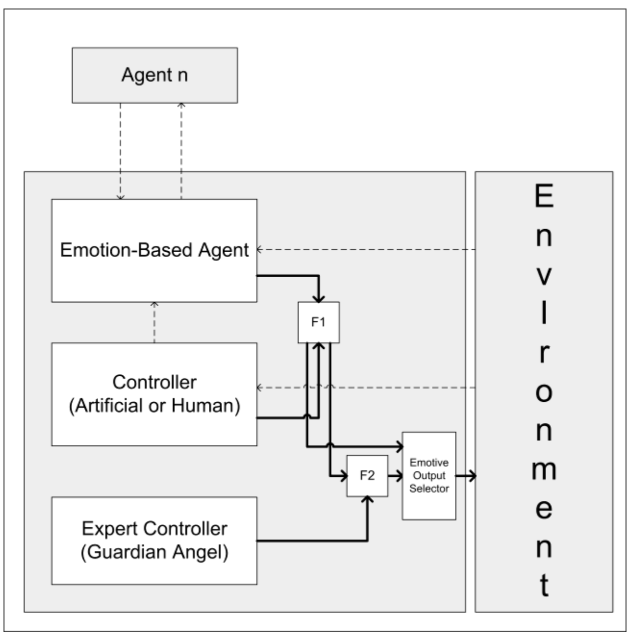

Figure 1: Hybrid emotionally aware mediated agent architecture, with F1 and F2 representing centers of information fusion

This framework is designed keeping modularity in mind. We can allow an agent to function solely on the emotion-based engine, thus bypassing completely both fusions, designated by the labels F1 and F2. It is also possible to allow a human to interact with the emotion-based agent directly, without any safeguarding mechanisms provided through the expert controller process and the second mediation. These last two modules can be utilized, in order to take full advantage of the framework presented in this work. We will now describe each element as an individual component of this architecture.

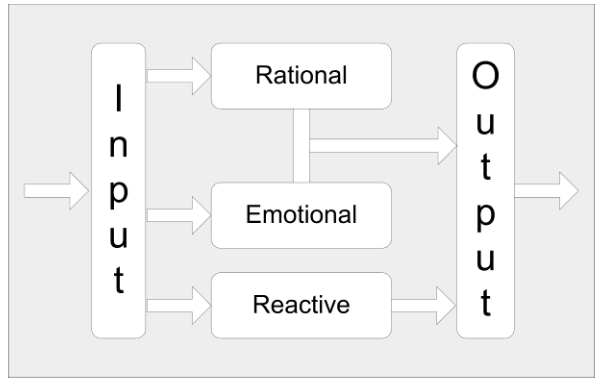

Figure 2: Architecture of the Emotion-Based Agent core

Emotion-Based Agent

The Emotion-Based Agent is the core component of this framework. Leaving out aspects of meta-cognitive states this framework resembles the Camurri architecture (Camurri et al., 1997) as we have adopted the model and modified certain elements as shown in Figure 2. As shown, this model utilizes direct communication between modules which influences the final output of the system, especially with the combination of rational and emotional decisions which influence the agents final output. We believe that the current instance of the agent's emotional state should have a direct influence on the totality of actions which are allowed by the rational module.

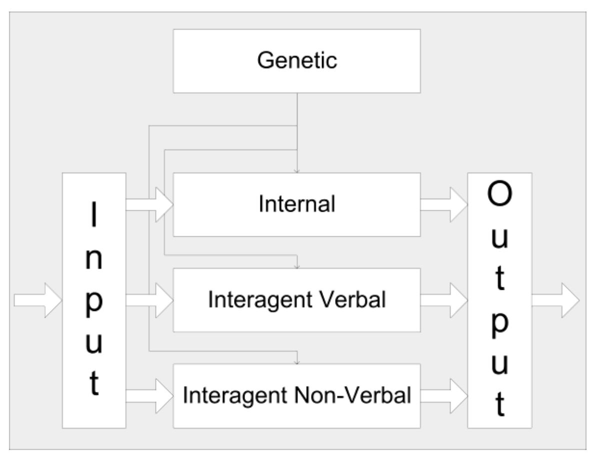

Figure 3: Detailed view of the "Emotional" module

Camurri and Coglio (1998) created a framework that was influenced only by external events. Our approach extends this model to accommodate internal states as well. We believe that this is a crucial extension, especially when operating in a multi-agent environment. Therefore we created an elaborate Emotional module, composed of four components: *Genetic*, *Internal*, *Interagent Verbal* and *Interagent Non-Verbal*. Figure 3 shows the interaction of these modules.

The *Genetic* component works as a mastermind and sets up the other modules by creating a weight system that will be used in order to compute the overall output from the Emotional module. We included this component to add because some people seem to be influenced more by what others say, while some others may be extremely emotionally unstable from personal causes. We felt the need to analyze this relationship among factors and build it into our framework.

The *Internal* component analyzes information about the agent and elaborates part of the emotional state. One aspect that is monitored by this component is, for example, the time elapsed in the simulation, with the agent unable to either find clues or reach the overall goal. As time goes on, the morale of the agent may lower. The rate at which the morale of the agent is affected by internal events is dictated by its genetic predisposition.

The *Interagent Verbal* component instead monitors communications with other agents. Such communications will consist in the exchange of clues. Each clue will be dictated by where the agent "believes" the goal is. Along with the belief, there is a weight assigned to the communication. The weight indicates the emotional state of the agent that is communicating the information. The agent will internalize both the belief as well as the emotional state of the other agent. The emotive component of the communication will affect the agent's own emotional state at a rate dictated by the genetic component.

The *Interagent Non-Verbal* component relies on the concept that, in society, it is often easy to be able to guess what mood a person is in by simply looking at them. Our agents do not only advertise their emotional state through communications, but also visually. When an agent senses the presence of other agents and interacts, this component will analyze and read the apparent emotional state of its peers. Also in this case, the rate at which the agent will internalize emotions is set by the genetic component.

Interfacing the Human and the Artificial Agent

The coupling of the human and the agent happens through direct interaction between the interfaces of the two agents. The interface is based on the notion of an emergent coupling interaction occurring between them. The interface between these agents abstractly is a mediation itself. The non-human agent in the system learns from its interactions with the human agent while utilizing its own knowledge about the current situation and building on its previous knowledge. Agents in some instances may have inborn schemes and understanding of the world, especially in the case of the expert controller agent. The interface between them should be as non-invasive and as natural as possible to create a dynamic and adaptable system where each agent can learn and adjust from various forms of interaction. The impact of the coupling process to the emotion based agent and the controller agent is interpreted and output for use in the meditation 1 module labeled F1 (Figure 1). The parameters that are passed to the mediation one module are derived by: 1. The Emotion based agent senses environmental conditions and various input from the human user (or other agents). 2. The human or controller agent generates data by its interaction with the emotional agent and through its actions caused by interpretations of the environment.

The interface between the emotionally enhanced agent and the human user can be accomplished in several ways. First we can view the Emotion-Based Agent as a meta-agent or a leader agent in a multi-agent system of emotionally enhanced set of agents. In this case the multi-agent system itself is the interface between the human user and the meta-agent, of which both becomes part of the multi-agent system itself. Each agent interacts with other agents or the environment collecting data to be interpreted by the meta-agent whose main goal is to understand the interactions and intentions of the human. Using a multi-agent approach to the interface allows us design flexibility on how data is collected and interpreted by the Emotion Based Agent. In a real world setting, implementing a system based on ubiquitous computing strategies would allow for agents to be deployed in multiple locations surrounding the user while remaining transparent to normal everyday functions. The human user would not need to know the state of the multi-agent system composed of ubiquitous devices. Each agent would interact with other agents either wirelessly or in a wired network fashion, while collaborating with the Meta-Agent (Emotional-Based Agent) about the data is collecting on its human subject.

Yet another possible solution is to use direct input into the system such as text, graphical manipulations, or other detectable hardware input that the system can process. Following previous research conducted with coupling interfaces using simple virtual environments (Trajkovski, Collins, Braman, Goldberg, 2006) we proposed a system where an individual agent and human user coupled collectively to form a multi-agent system where the non-human agent attempts to learn from human input. Depending on the need such human input can be collected directly from physical data manipulations or hardware input (i.e. keyboard, mouse, joystick, steering wheel, break/gas pedals, VR gloves etc.). Input would then drive a simple subsumption architecture where agents would act accordingly in an attempt to learn and react to the human user while actively collaborating with the main Emotional-Agent.

F1

The Fusion one (F1) module is an averaging process that fuses output from both the Emotion based Agent and the human controller as base parameters. The process of which the data is sampled from both agents is dependant on the interface option that was selected for the particular problem domain. This module outputs data to the Fusion two (F2) and to the Emotive output selector. The Emotional based Agent makes decisions based on its own emotional state and from what it senses from the environment and the human user. The averaging of these two outputs are useful because they allow for a equal weighted approach to the decision making process. For example of both agents are "angry" then logically there should be some stressor to both agents for this to occur and we can say that there is a good reason for this emotional state. An "angry" decision made by the human user in this case may be justified and allowed. In contrast if one agent is very happy and the other is very angry then there is some problem in one or the others interpretation of environmental conditions or perhaps there is some underlying internal condition that is cause the emotion. If only the non-human agent is angry or stressed while the human agent is happy, perhaps the human agent in its positive state has failed to detect important environmental conditions. If a multi-agent system approach is being used them there may be an issue in the system itself during the interacting of the agents that have caused extra stress. Averaging the output from both of these agents helps to correct any major differences in emotional states by essentially compromising on a final decision. If the outputs from both agents are similar then outcomes will be relatively equal in control. If output is significantly different then the output is averaged to a mediated outcome.

Expert Controller Process

The Expert Controller Process (ECP), as its name implies, serves as a balancing and "expert" safe-guarding mechanism for the output of the system. As with decisions biased by emotions, we now have several agents that are affected by internal emotional states that are controlling the system. This process is a separate control agent that makes decisions without any emotional considerations. Environmental parameters are sensed by the ECP or through separate agents (that have no emotional bearing) and in a reactive fashion base its decisions on logical deduction schemes. Output from the ECP is directed to the Fusion two module, where it is mediated with the results of the Fusion one module.

F2

The second process that fuses inputs into a single, coherent output (F2) is based on the Fuzzy Mediation model by Vincenti and Trajkovski (2007a). This method is based on the evaluation of the absolute difference between inputs of an expert controller and a novice one. The outcome of this algorithm is a single mediated value to be passed on to the object to be controlled.

This mediation will assume that the guardian angel process is the expert controller, and the output of the first fusion is the value generated by the novice one. Fuzzy Mediation functions in three steps.

The first step, analysis of the inputs, evaluates the difference between two inputs, in our case the outcome of the first mediation and the direction that the guardian angel process computes. The deviation is then translated into a linguistic modifier, chosen from a series of fuzzy sets. A typical breakdown of the numeric range of possible deviations may include the following modifiers: "Similar control", "Slight deviation" and "Wide deviation".

Table 1: Mamdani inference rules

If	***Then***
Inputs are similar	Shift control to the novice
Inputs are slightly different	Maintain the balance unaltered
Inputs are widely different	Shift control to the expert

The second step involves the revision of the weight of control. As the two controllers perform in similar ways, more control is given to the novice. Instead, as the controllers show a wide deviation in the desired direction of the agent, the expert regains control, overriding the weight accumulated by the novice controller. The action taken to modify control is based on the linguistic modifier associated with the deviation found in the first step, and is based on a set of Mamdani-style rules (Mamdani & Assilian, 1975) such as the ones shown in Table 1.

The final step of Fuzzy Mediation is the calculation of the single output. Such value is computed using the formula shown below.

$$MO = \mu_T * EI + \mu_t * NI$$

Where MO is the mediated output, μ_T and μ_t refer to the weights of control assigned to the expert (μ_T) and the novice (μ_t), and finally EI and NI are the original inputs originated by the expert (EI) and the novice (NI).

Previous studies (Vincenti & Trajkovski, 2006; Vincenti & Trajkovski, 2007a; Vincenti & Trajkovski, 2007b) have shown the validity of this algorithm. In situations where the novice is unable to deal with the situation presented at all, the expert gains full control of the object. On the other hand, as the controllers perform more similarly, Fuzzy Mediation allows the novice to control the object without any interference from the expert.

When operating in this setting, the second fusion will take as inputs the directional outputs from the first fusion and the guardian angel process. The single-value output represents the mediated heading of the agent.

It is important to note that, although the first fusion outputs both a <*direction*> and a <*emotive state*> value, the second fusion utilizes only the <*direction*> element. The <*emotive state*> will be used by the Emotive Output Selector for the computation of the final output. Figure 4 shows the flow of information and interaction between fusion processes and the emotive output selector.

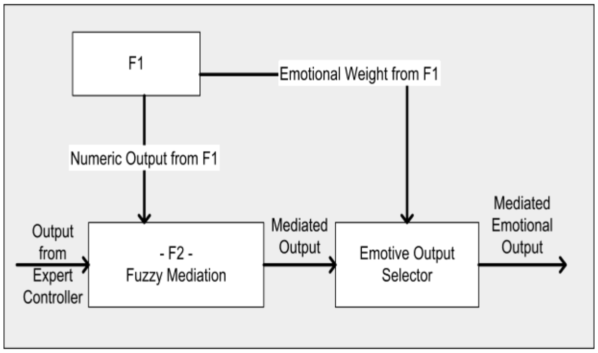

Figure 4: Interaction between fusion processes and the emotive output selector

Emotive Output Selector

In our model an agent's abilities are limited by the current level of emotion. The happier the agent is, the more directions it can take in exploration and goal-seeking (both possible modes of traversal). In other applications this change or limitations in possible directional abilities can be applied to other functions. In an application that utilizes other basic functions, an angry agent may be restricted to only base necessity functions.

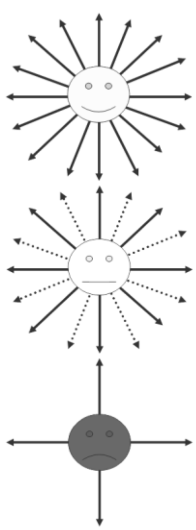

Figure 5: Three levels of Agent Directionality (In order: Happy State, Normal State and Angry State)

In the example of mobile agents in a grid based environment described in Figure 5, an agent in a happy state has sixteen possible movement options available. A angry agent is limited to only four base directions (north, south, east and west). The middle agent as shown depicts an agent in a transitional state where the number of possible directions is at least eight directions (N,S,E,W,NE,NW,SE,SW) but may also contain any subset of directions of a happy agent. As denoted by the dashed lines, these directions are only possible depending on who far away the emotional state if from Happy. We often refer to this state as a transitional or "normal" state as it is not truly angry or happy, but some arbitrary value in between.

Figure 6 illustrates the transitions between states where an agent can take any value between Happy and Angry or have a balanced (normal) state or have a any value in between as predicated by fuzzy sets. We see the limitations imposed by angry agents as altering the motivation of that agent. A more happier agent would be more motivated thus having more abilities or that it would be making more rational decisions.

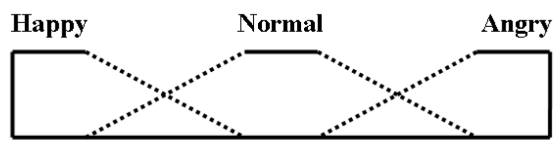

Figure 6: Fuzzy sets representing emotive states

Anger in human subjects can be attributed to that of depression (Pelusi, 2006) which can lead to disruptive behaviors and a decrease in general motivation. Individuals with certain depression disorders have been observed to have a decrease in cognitive flexibility, which relating to emotional instabilities lead to reduced solutions to given problems (Deveney & Deldin, 2006). We have applied this same idea to our agents essentially limiting their search space for a given problem set as their emotional state gravitates toward instability and angry/negative tendencies.

The emotive output selector represents the last level of processing that the data will undergo before being fed to the agent, which will respond by turning to the final heading. The inputs for this module are represented by the <*direction*> computed by the second fusion and the <*emotive state*> from the first fusion, as shown in Figure 4. The emotive state will be mapped to the sets shown in Figure 6. Each emotive state will have a set of actions, which may be represented as a greater or lesser possibility of directions, as shown in Figure 5. The output from the second mediation will then be standardized to the closest available direction, based on the ones available.

For example, if the mediated output directs the agent at a heading of 44°, the agent in a "Normal" state may have the range of motion {0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°}, thus standardizing the output to 45°. If, instead, the agent is in an "Angry" state, with an associated range of motions {0°, 90°, 180°, 270°}, the final output will be standardized to a heading of 0°.

In the case of the emotional state being mapped to two sets, then the agent will have at its available number of possible headings that is dependent on which emotive state is closest to. So, if the emotive state leans more towards a "Normal" state than a "Happy" state, although it will not have the range of motions associated with "Happy", it will have the ones available to "Angry" and then a portion (chosen randomly) of the ones additionally available with the next emotive state.

Possible applications

We envision a wide range of potential uses for emotional agents in several settings which include human assistive technologies. One such usage is the display of information in adaptive display interfaces. It has often been observed in situations where users are required to process large amounts of information rapidly, information overload and confusion can occur. Information can be more effectively utilized when it has been restructured to fit the needs of the user with minimal effort (Shneiderman, 2005). As noted in experiments by Trajkovski et al (2006), distinct users interpret the same interface differently depending on their own conceptualization of the interaction or their particular "goal" of using an interface. With the same concept of interface adaptability, we foresee an interface that can successfully change menu structure or particular features for the user accordingly to their particular emotional state. In an effort not to overlook the affect of a user's mental state during interaction with a technological artifact we can attempt to include an emotive selector as part of the functional design of an application interface. For example, consider computer security at the business level where a firm maintains sensitive information. Security ricks are not always caused by the typical viruses, natural disasters or computer hackers, but can be caused accidently or intentionally by the employees of the system itself (Loch et al, 1992). Also consider angry employees who intentionally compromise company information or security in an act of vengeance towards their employer or fellow coworkers (Quigley, 2002). Limiting a user's control and functionality based on sensed negative attributes could restrict actions of a user in which they may later regret, while also protecting the company from unwanted damages or potential security threats. Automatically demoting access rights to key features or information access is one simple way to achieve this goal.

Another application could be used if emotionally aware agents were embedded in cars where they could be used to sense internal and external forces and monitor driver interactions. Using the car as an emotive based multi-agent system could be used to enhance safety of passengers and drivers as well as be used as a safety measure in the prevention of road rage. Road rage is a growing problem and often linked to aggression and anger in the emotional state of the driver (Depasquale et al, 2001). Other applications as applied in assistive technologies could help users in everyday activities such as in embedded components in environmental control components, signaling and monitoring systems, communications devices and sensors. Educational devices could also benefit from having tightly coupled adaptive interfaces that tune towards the current state of the user. Medical equipment or monitoring devices could also adjust as changes in mood or behavior occur.

Future works

Previous experiments based on architectures that are special cases of the one elaborated on in this paper motivate us to continue the simulated studies of agents based on this framework. We intent to expand our research into further implementations to account for mediated emotive outputs for agents as they adapt for various input. Future plans for our implementation include the expansion of previous adaptive interfaces that attempt to account for user states in the realm of angry and happy moods. The development of external sensors that monitor human conditions will also factor into the agent architecture.

The group dynamic aspect of emotionally enhanced agents are a particular interested for future projects to show the viability of cooperating agents in this context to complete complex tasks. Having mediated output based on the emotional state of the human user and the combined states of the agents in various social and interaction contexts are of importance. We plan to incorporate the various factors and internal components as outlined in this paper for agents to be embedded into assistive devices.

Conclusions

Here we have outlined our architecture for emotionally aware mediated agents as a hybrid interaction between human users and non-human agents and its possible application for assistive devices. We have also expanded our previous model in this paper as we prepare for further experiments. We see emotion as a powerful function not only for human interaction, but useful in human computer interactions as well. By employing such an emotional architecture we wish to research the affects of altering functionality of human users to produce improved results in various types of interactions and situations. Through our approach we wish to include basic aspects of emotion while paying attention to aspects such as genetic predispositions, internal states and interagent verbal and non-verbal interactions. Such conditions in our agents coupled with human interaction provide the basic framework for our emotive mediated output by altering available actions.

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