TrustE
An Emotional Trust Model for Agents

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Abstract. Trust and reputation have been proposed in the Multiagent Systems area as a way to assist agents to select good partners in order to improve interactions between them. As well as trust, agent emotions have been studied with the aim of making the actions and reactions of the agents more like those of humans. In this paper, we present a trust model based on emotions. It is a hybrid mathematical and symbolical model designed to capture the complexity of reasoning. Quantitative and qualitative evaluations are combined through the incorporation of some emotional elements in the trust evaluation.

Keywords: Agents, Trust, Reputation, Emotions.

1 Introduction

The study and modelling of trust have attracted the interest of researchers in several fields such as psychology, sociology, philosophy and economics. Trust has great importance in social and commercial relationships [1]. In Computer Science the interest is primarily in Multiagent Systems (MAS).

Computer systems are becoming large-scale systems, open, dynamic and distributed, containing a large number of agents who act in their own interests [2]. In open Multiagent Systems, new agents can join the system at any time. This feature makes it difficult for an agent to check if others who have newly joined the system are reliable, because there is insufficient information about them. Trust and reputation models are a way to ameliorate this difficulty, providing reliable information to help the decision making of the agent [2–4], in fact, the use of trust and reputation in these systems is essential for effective interactions among agents [5].

Most models of trust and reputation, however, adopt essentially numerical approaches [6], not taking into account the complexity of humans' reliance on each other. For humans, emotions directly influence the act of trust. This requires a subjective evaluation of trust. Furthermore, the models in the literature determine through metrics the relevance of the information from other agents used in the measurement of trust, becoming the action of trust dissociated from the personal history and from the context in which the agent is embedded.

In this paper, we propose a trust model, named TrustE, which uses information of symbolic nature directly related to the context in which the agent is embedded. Such information induces sensations or emotions that allow the agent to associate qualitative or subjective evaluations to the quantitative or rational evaluations, depending on the result of introspection on situations experienced by the agent.

The paper is organised as follows. Section 2 introduces trust and reputation models in the context of agents. Section 3 introduces the concept of emotions in agents and some models of emotions in agents. The proposed model is presented in Section 4. Section 5 concludes the paper.

2 Trust Models for Agents

There are several trust and reputation models proposed in the literature [6]. Among them we can cite the Marsh's model [7], which considers only the trust dimension, the Spora model [8], which considers only the reputation dimension.

Despite of the definition of trust and reputation remain unclear, some of them blend the two approaches: the Regret model [3], the Referral Network [9] and the Travos models [2] take into account both trust and reputation, combining these values to get degree of trustness. Finally we cite the Fire model, which introduces two additional concepts: role-based trust and certified reputation [5].

From these models, Regret was chosen as the base for the TrustE model (as presented in Section 2), once it possesses some characteristics that allow us to easily incorporate symbolic evaluation in the form of emotions. In the sequence we present the Regret model.

2.1 Regret

In this model, reputation is seen as the opinion or view of an agent about something, being formed and updated over time through interactions with other agents in the system. Interactions consequently provide *impressions* that are recorded by the agents and reflect how they evaluate their experiences with others. Reputation in this sense is more subjective, once each agent possesses a different opinion of the others [3].

The outcome o_b of an interaction related to a business transaction between two agents a and b, from the viewpoint of the agent buyer b, could be:

$$\begin{aligned} o_b = (&DeliveryDate =_c 10/02 \wedge Price =_c 2000 \wedge \\ &Quality =_c A \wedge DeliveryDate = 15/02 \wedge \\ &Price = 2000 \wedge Quality = C) \end{aligned}$$

In this example, the variables with the subscript c represent the initial agreement, i.e, the contract between the two agents. Thus agent b expected a good quality product (A) but received a poor quality product (C), and received it five days late.

The model uses the term Individual Reputation (IR) to represent the direct trust between two agents, and Social Reputation (SR) to represent the reputation itself. The decentralised approach implemented by this model allows each agent to calculate the

IR and SR from another agents, and to use both IR and SR, or just one of them to arrive at a final result.

Social Reputation takes into account three sources of information: (i) the interaction of the agent a (trustor) with members of the group to which agent b (trustee) belongs, expressed by $R_{a\to B}(\varphi)$, as presented in equation 1; (ii) what the members of group A (the group of the agent a) think about agent b, denoted by $R_{A\to b}(\varphi)$, as presented in equation 2; and (iii) what the members of group A think about the other group B, denoted by $R_{A\to B}(\varphi)$, as presented in equation 3.

$$R_{a\to B}(\varphi) = \sum_{b_i \in B} \omega^{ab_i} . R_{a\to b_i}(\varphi) \tag{1}$$

$$R_{A\to b}(\varphi) = \sum_{a_i \in A} \omega^{a_i b} . R_{a_i\to b}(\varphi) \tag{2}$$

$$R_{A\to B}(\varphi) = \sum_{a_i \in A} \omega^{a_i B} . R_{a_i\to B}(\varphi) \tag{3}$$

where φ is the item from the outcome under consideration. These three values are combined with the agent's IR, denoted by $R_{a\to b}(\varphi)$, to calculate the final value of trust, represented by, $SR_{a\to b}(\varphi)$ as presented in equation 4.

$$\begin{aligned} SR_{a\to b}(\varphi) = {} & \xi_{ab} . R_{a\to b}(\varphi) + \xi_{aB} . R_{a\to B}(\varphi) + \\ & \xi_{Ab} . R_{A\to b}(\varphi) + \xi_{AB} . R_{A\to B}(\varphi) \end{aligned} \tag{4}$$

where $\xi_{ab} + \xi_{aB} + \xi_{Ab} + \xi_{AB} = 1$, representing the importance of each information's source to the trustor agent. These values are application dependent, i.e., they are chosen during the project of the system.

That characteristic allow us to incorporate the results of some symbolic evaluation, i.e. emotions. In this sense, we proposed that those values can be determined by the internal state of the agent, simulating an emotional state. Next section presents concepts of emotions of agents, which together with the Regret model, form the basis for the proposed $TrustE$ model.

3 Emotions

The study of emotions is part of various disciplines like Psychology, Economics, Cognitive Neuroscience, and, in recent years, research on Artificial Intelligence and Computer Science. This study aims to establish systems for emotional interaction, such as robots with emotional behaviour and virtual agents for entertainment [10]. Nowadays more and more artificial agents integrate emotional skills to achieve expressiveness, adaptability and credibility [11]. In psychological studies, the emotions that influence the deliberation and practical reasoning of an agent are considered as heuristics to prevent excessive deliberation [12].

The following section describes the OCC emotions model [13]. This model is widely used by Artificial Intelligence researchers who are developing systems for reasoning about emotions or that incorporate emotions in artificial agents [11, 14].

3.1 OCC Model

The psychological model of emotions proposed by Ortony, Clore and Collins (OCC) [13], classifies 22 types of emotions, both positive and negative. The quantitative aspects of emotions are described in terms of *potentials*, *thresholds* and *intensities*. For each of 22 emotions, the model provides a list of variables that affect the intensity of the emotion and if the condition which causes the emotion is guaranteed.

The OCC hierarchical model has three branches, each representing an evaluation of a different type of stimulus for certain actions and an evaluation of a determined variable. These branches are subdivided into groups of emotions caused by similar conditions, and are classified as:

- Event-based emotions (e.g. joy, pity)
- Agent-based emotions (e.g. pride, shame)
- Emotions Based on Aspects of Objects (e.g. love, hate).

The three branches of the model are described below. We pay greater attention to event-based emotions and agent-based emotions since they are essential in modelling emotions in agents and are strongly related to events and the agents' own actions. Object-based emotions are only mentioned in brief, since they are not as significant as other two types of emotions [11].

3.2 Event-based emotions

The emotions in this branch are induced from the evaluation of an event with respect to the agent's goals. The *desirability* of the event occurring or not is the main variable of intensity of this kind of emotion. The agent will only want events to occur if they assist with its goals. Thus, if the event occurring is desirable for the agent it will feel positive emotions; otherwise it will feel negative emotions. This branch is subdivided into:

- **Well-being emotions** - triggered according to the desirability of the agent itself, that is, it is a feeling that only depends on the desire for a certain event to occur. Example: The agent felt joy about winning money.
- **Prospect-based emotions** - focused on the desirability of the agent itself in an expected event (uncertain) that could happen. This type of emotion uses a local variable of intensity- *likelihood* - which represents the probability of the event happening. Example: The agent hopes to make money.
- **Fortunes-of-others emotions** - derive from the supposed desire for another agent. These emotions utilise three local variables of intensity: *desirability for others*, *merit* and *liking*. The *desirability for others* is the evaluation of the desirability of the event to the other, *merit* represents how much agent *a* believes that agent *b* deserves what happened and *liking* represents the attitude of agent *a* relative to agent *b*. Example: Agent *a* became resentful because the agent *b* had lost its money.

3.3 Agent-based emotions

These emotions are based on the judgment of the praiseworthiness of an action in relation to 'moral standards': that is, an action is praiseworthy when it follows the standards. The emotions of this group refer to both the agent's own action and the action of another agent.

– **Attribution emotions** - focused on the approval of the action of an agent. In this type of action there are two local variables of intensity, *strength of unit* and *expectation deviation*. The first applies the agent's own emotions to represent the degree to which the agent identifies with the author of the action. The second is the degree to which the action performed differs from what is normally expected, according to the social role. Example: The agent felt ashamed about stealing money.

3.4 Emotions Based on Aspects of Objects

The last brach considers mainly emotions related by the **attraction** that an agent feels by something or someone. This kind of emotion has only one local variable of intensity: *familiarity*. According to the OCC model, the more familiar a pleasing object is to the agent, the more the agent will love it, and in turn the more familiar is an unpleasant object, the more the agent will hate it. Example: Agent *a* loves agent *b*.

Additionally, some of these branches can be combined to form a group composed of emotions, based on the result of events and actions. Well-being emotions and attraction emotions can be combined, resulting in complex emotions. Example: Agent *a* felt gratitude to agent *b* because it returned its lost money.

3.5 Emotion Models for Agents

In Artificial Intelligence research, emotions have begun to receive more attention, and are more prominent in interactions between humans and machines focusing on expressing or feeling emotions. Recent works investigate the reasoning of common sense, but research on the application of emotions by decision making in agents is still very limited. The complexity of modelling the emotional behaviour of the human being in artificial agent is yet the biggest barrier [15]. To overcome this limitation, some researchers have worked on the development of logical structures for formal specification of emotions [10–12, 16–18].

In the great majority of these works, emotions are modeled in a qualitative way; however, some authors suggest a quantitative approach to emotions, that is, through the assignment of numerical values to emotions' intensity, e.g.,[19].

In this paper, we consider the introduction of numerical values representing the intensity of the emotions in the Regret Model. Despite of its qualitative nature, emotions are mapped to quantitative values that will compose the trust and reputation calculi. In the next section we present the Steunebrink's model that will be the basis for the TrustE model.

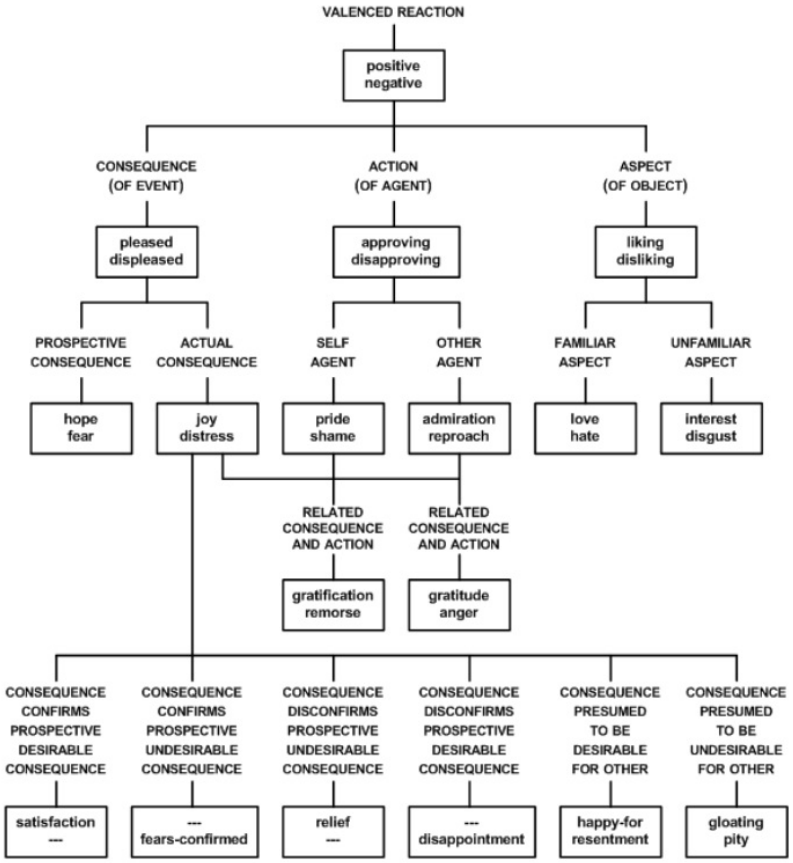

Fig. 1. Hierarchy based on inheritance of emotions from Steunebrink et al [14]

3.6 Steunebrink's Model

In order to formalise the 22 types of emotions present in the OCC model, Steunebrink at al. [14, 19] started by identifying ambiguities in the logical structure. These ambiguities were removed and some changes were consequently made to obtain a computational framework to emotion. This framework is based on inheritance and is present in Figure 1.

One of the major changes in the structure of the OCC model was the hierarchy had an explicit inheritance, with labels at each point of the hierarchy and each child node was a superset of its parent nodes. From this new structure were created new specifications of types of emotions. Analyzing the model hierarchy, we note that the feelings of begin pleased and displeased, approving, disapproving, liking and disliking are the basis for all other emotions.

3.7 Emotions Intensity

The intensity of an emotion is defined by subtracting the *threshold* of its *potentiality*. The *threshold* refers to the minimum value needed for the emotion to have some intensity and therefore interfere with an agent's behaviour. In turn, the *potentiality* of an emotion depends on the list of variables which affect it. The larger the *potentiality* of the emotion, the greater the chances of it occurring.

The OCC model does not specify how to calculate the *thresholds* of emotions, but it is believed that they depend on global variables indicating the mood of the agent [19]. For example, if an agent is in a cheerful mood, the thresholds of negative emotions increase, causing a decrease in the intensity of this emotions. When the necessary condition to trigger an emotion is present, but its *potentiality* is below its *threshold*, an agent can recognize that the emotion was triggered but it will have no affect: for example, 'the mood of the seller agent was so good that even though it sold a shoddy product, it was not affected by shame'.

The *intensity* of an emotion is calculated from the *intensity function*, which is composed of *function potentiality* and *function threshold*. The way these functions are calculated is application-dependent; however, in general, the *intensity function* can be expressed as:

$$I(P(E), L(E), t) \rightarrow \mathbb{R}^{+} \tag{5}$$

where $P(E)$ is the *function potentiality* of emotion E, $L(E)$ is the *function threshold* and t is the current time. As a result, the function returns a positive real, including 0 (zero), representing quantitatively the intensity of the emotion. Section 4.2 presents how these values could be calculated in the TrustE model.

4 TrustE Model

The TrustE model proposed in this work adds emotions to calculation of trust and reputation for agents. All models found in the literature make use of algebraic analysis to determine the act of trust, which makes such models essentially mathematical and disconnected from the agent's history. The proposed TrustE model permeates the trust model with estimates derived from symbolic reasoning, making the act of trust more dynamic and dependent on the agent's history.

The incorporation of emotions in trust models can be done in several ways; however, we chose to incorporate emotional factors in the Regret model (section 2.1), once (i) this model mixes both Individual Reputation and Social Reputation to obtain a final measure of trust; and (ii) this model uses weights noted by ξ and ω (see equations 1 - 4) that are defined by the programmer and are application dependent. These values are good candidates to represent *emotions' intensities* of the agent, going to be updated in run time.

By its nature, the process of trust should result in a numerical value. Therefore, emotions intensities are aggregated to the model as numerical values representing the strength of emotions at a given time t. This allows the model to accept each of the 22 existing emotions in OCC model (section 3.1), requiring only the qualitative and

quantitative aspects of each of the emotions to be modelled. The qualitative aspects can follow the same ideas as the models proposed by [10–12, 16–18] or be adapted according to the needs of each system. Quantitative aspects are obtained from each emotion, which is calculated from an *intensity function* (see equation 5), and can follow the concept presented in [19] or be reformulated according to the application's needs. This flexibility is a key feature of the proposed model.

Figure 2 shows the TrustE Model. Two blocks compose the coalition between trust and emotions. The *trust model* (TM) is responsible for calculating the Individual Reputation (IR) and Social Reputation (SR), which together will result in the trust final value (TV). The *emotions model* (EM) contains the emotion's intensity functions, denoted by $I(E)$, and agents' emotion memory (AEM). Each agent has its own AEM where all current emotion intensities of the agent are stored.

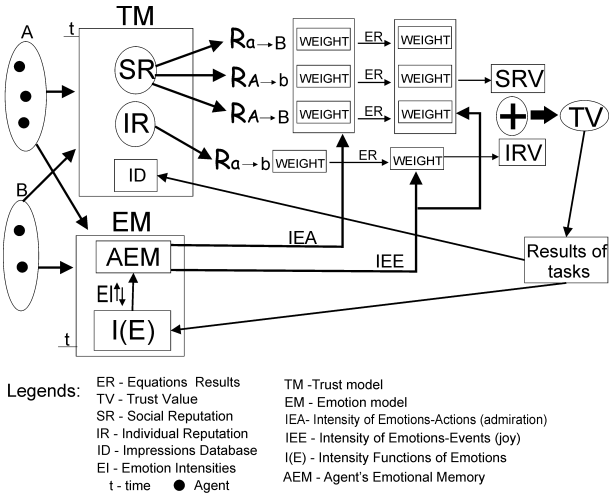

Fig. 2. The TrustE Model

As presented in section 2.1, the Regret model has four values which form the final trust, represented in Figure 2 by $R_{a\to b}$, $R_{a\to B}$, $R_{A\to b}$ and $R_{A\to B}$. The first weight used in the calculation of RI, i.e.$R_{a\to b}$, is the same as that used in Regret, which assigns higher values to the ratings given recently by trustor agent. Already the first weights in SR $R_{a\to B}$, $R_{A\to b}$ and $R_{A\to B}$, are calculated from the *Intensity of Emotions triggered by Actions* (IEA). This group of emotions involve the emotions that are based on the judgment of an action's praiseworthiness, i.e, *agent-based emotions* in OCC model. So it is possible that each agent can evaluate the other taking into account the emotions related to each of them. After calculation of these four R values, they are combined to form the *Trust Value* (TV). The weights used in this part of the computation take into account the *Intensity of Emotions triggered by Events* (IEE), that are related with the evaluation of an event with respect to the agent's goals, i.e. *event-based emotions* in

OCC model. This group of emotions is not directly related to any specific agent but are the events that change the emotional state of the agent.

4.1 Formalisation of Emotions

As introduced above, emotions in the TrustE model are divided in two groups: *Emotions triggered by Events* and *Emotions triggered by Actions*. For each one of these groups we choose a set of four kinds of emotions from the OCC model. They are:

- Emotions triggered by Events: *hope*, *fear*, *joy* and *distress*.
- Emotions triggered by Actions: *pride*, *shame*, *admiration* and *reproach*.

The formal modelling of these emotions has been simplified to suit the model and makes calculating of the *intensity* of each of these emotions easy. The following will be presented qualitative formalisation of these emotions taking into account certain adjustments made in OCC model 3.6. Let a and b be agents, X an event, Y an action, $positive$ a positive reaction in relation to something, and $negative$ a negative reaction in relation to something.

- $Action_a(Y)$: an action Y performed by a.
- $Prospective(X)$: an event X which is prospective.
- $Actual(X)$: an event X which is actual.
- $Pleased_a(X)$: a is $positive$ about a consequence of X.
- $Displeased_a(X)$: a is $negative$ about a consequence of X.
- $Approving_a(Y)$: a is $positive$ about an action Y of some agent.
- $Disapproving_a(Y)$: a is $negative$ about an action Y of some agent.

Emotions triggered by Events These emotions are felt by the agents depending on the occurrence of a certain event and are independent of the actions of other agents. For this reason they were introduced in the TrustE model (see Figure 2) from the functions' values IEE.

The emotions in this set are defined as (where the syntax has the usual meaning):

$$Hope_a(X) \leftrightarrow Pleased_a(X) \wedge Prospective(X) \tag{6}$$

An agent feels hope if it is pleased about the expected event. Example: *The agent expects that the product purchased will be of good quality*.

$$Fear_a(X) \leftrightarrow Displeased_a(X) \wedge Prospective(X) \tag{7}$$

An agent feels fear if it is displeased about an expected event. Example: *The agent was afraid of not receiving the purchased product*.

$$Joy_a(X) \leftrightarrow Pleased_a(X) \wedge Actual(X) \tag{8}$$

An agent feels joy when it is pleased about an actual event. Example: *The agent was happy to have received the product before the stipulated time*.

$$Distress_a(X) \leftrightarrow Displeased_a(X) \wedge Actual(X) \tag{9}$$

An agent feels distress when it is displeased about an actual event. Example: *The agent was distressed by the poor quality of the product received.*

Emotions triggered by Actions These emotions are felt by agents as a result of actions taken by other agents. For this reason they were introduced in the TrustE model (see Figure 2) from the functions' values *IEA*.

The emotions in this set are defined as:

$$Pride_a(Y,a) \leftrightarrow Approving_a(Y) \wedge Action_a(Y) \tag{10}$$

An agent feels pride if it approves of its own action. Example: *The agent was proud of having sold a high-quality product.*

$$Shame_a(Y,a) \leftrightarrow Disapproving_a(Y) \wedge Action_a(Y) \tag{11}$$

An agent feels shame if it disapproves of its own action. Example: *The agent felt ashamed of having delivered the product late.*

$$Admiration_a(Y,b) \leftrightarrow Approving_a(Y) \wedge Action_b(Y) \tag{12}$$

An agent feels admiration towards another agent if it approves of this agent's action. Example: *The agent was stuck by the honesty of the seller.*

$$Reproach_a(Y,b) \leftrightarrow Disapproving_a(Y) \wedge Action_b(Y) \tag{13}$$

An agent feels reproach towards another agent if it disapproves of this agent's action. Example: *The agent deplored the fact that the seller agent did not answer your questions.*

The following section explains the *intensity function* used in the TrustE model.

4.2 Emotion Intensity in TrustE

To model the emotion intensities in TrustE, we chose a simple and effective equation as follows:

$$I_a(E,t) = max(0, P_a(E,t) - L_a(E,t)) \tag{14}$$

Where $I_a(E,t)$ is the *intensity function* of emotion E of the agent a at time t; E could be one of the eight emotions as presented before (however any of the 22 emotions of the OCC model could be used); $P_a(E,t)$ is the *potentiality* of E; $L_a(E,t)$ the *thresholds* of E and t the current time.

The value of intensity of emotions triggered by events of agent a at the current time will be denoted by $I_a(E)$ and the value of intensity of emotions triggered by actions of agent a in relation to agent b will be denoted by $I_a(E_b)$.

The values of $P_a(E,t)$ and $L_a(E,t)$ are recalculated each time E is triggered again, so these values does not persist over time. The value of $I_a(E,t)$ persists over time and tends to decrease over it, until to stabilise in the default value. To support the temporality of the value of $I_a(E,t)$, each agent must have a memory (AEM) that stores the values of each of the emotions felt by it.

The *function potentiality* $P_a(E,t)$ is calculated using the formula:

$$P_a(E,t) = \frac{\sum_{i=1}^{N} VI_i}{N} \tag{15}$$

where $VI \in [0,1]$ are the values of the variables that affect the *intensity* of emotion E and N is the number of variables.

To fit the model we assigned the function $L_a(E,t)$ values in the range $[0,1]$ representing the 'emotional profile' of agent a. Agents in a 'cheerful mood' have a lower *threshold* value for positive emotions and a higher one for negative emotions, and an agent in a 'bad mood' will have a higher value for positive emotions and a lower one for negative emotions. Thus, an agent in a 'cheerful mood' will feel positive emotions with greater ease than an agent in a 'bad mood'.

Since the values of $P_a(E,t)$ and $L_a(E,t)$ are in the range $[0,1]$, the function $I_a(E,t)$ also has values in the range $[0,1]$.

4.3 Conceptual View

Figure 3 shows a conceptual view of TrustE model where the flow of actions of agents is presented. To explain the model let us create a scenario in which agent a wants to buy a good quality (A) product from agent b, taking into account the characteristics presented in Table 1. To simplify the example, the values of *threshold* and *potentiality* are fixed.

Table 1. Characteristics of agents.

Characteristics	Agent a	Agent b
mood	bad	cheerful
time t	0	0
potential-positive emotions	0.5	0.7
potential-negative emotions	0.8	0.4
threshold-positive emotions	0.8	0.1
threshold-negative emotions	0.2	0.9
good quality product	A	A or B
$I(joy)$	0.5	0.5
$I(reproach)$	0.5_b	0.5_a
$I(fear)$	0.5	0.5

Agent a chooses a sales agent from all existing sellers (step 1). To decide whether or not to buy the product from b, it will calculate the trust in b (step 2). If the trust value is low, a will look for another sales agent; if it is high, a will buy the product from b (step

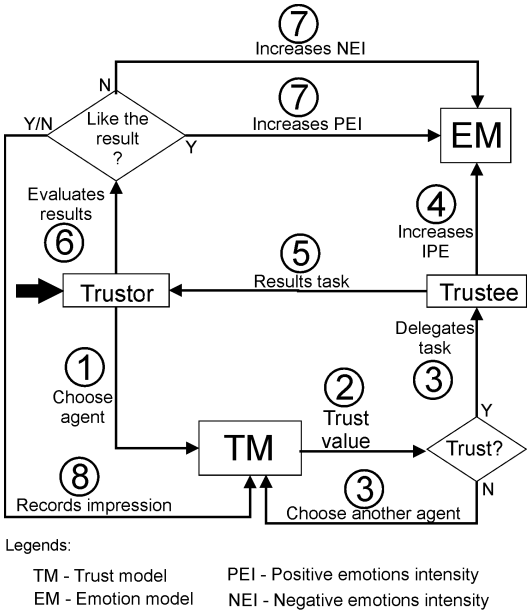

Fig. 3. TrustE conceptual view

3). Upon receiving the trust of a, agent b will increase positive emotions (step 4). For example, b was happy to have sold a product and felt joy. If $I_b(joy,1) > I_b(joy,0)$ then the emotion intensity will change in agent's AEM. As $I_b(joy,1) = max(0,(0.7-0.1)) = 0.6$ e $0.6 > 0.5$, the value of $I_b(joy)$ is changed to 0.6.

After some time, b will deliver the product to agent a (step 5), and a in turn will evaluate the quality of the product (step 6). As agent b delivered a quality product B from the point of view of agent a, and a expected a quality product A, it will feel *reproach* in relation to the attitude of b. Now $I_a(reproach_b,2) = max(0,(0.8-0.2)) = 0.6$ and $0.6 > 0.5$ the $I_a(reproach_b)$ is changed to 0.6 (step 7) and their evaluation with respect to b will be negative (step 8). If the product was quality A, the positive emotions (e.g. admiration) of agent a would increase and their evaluation with respect to b would be positive.

At the beginning of the transaction agent a could feel *fear* about not receiving the product. As soon as $I_a(fear,1) = max(0,(0.8-0.2)) = 0.6$ and $0.6 > 0.5$ the $I_a(fear)$ is changed to 0.6.

When agent a calculated the trust in b (step 2), the value of IEA was 0.5, since $I_a(reproach_b,0) = 0.5$. The value of IEE was the function value $I_a(fear,0) = 0.5$. As these values changed after the transaction with b, if immediately afterwards agent a were to purchase another product from b, the values of IEA and IEE would both be 0.6.

5 Conclusions

This paper presented a preliminary proposal of a hybrid model, TrustE, which is a trust model based on the Regret model and the OCC model. TrustE considers emotions in the trust calculation. The incorporation of emotions aims to capture, in a simple way, the complexity of human reasoning. Our idea is to introduce some qualitative elements into the quantitative evaluations performed by the trust model.

We believed that the inclusion of emotions and their intensities makes the model more realistic because the decision-making process of the agent will be directly linked to its emotional state. We illustrate this process by a scenario of negotiation between agents.

Future works include the implementation and the validation of this model. We also intend to explore other possibilities to include emotions in trust/reputation models, as well as to expand the present model to include a greater number of emotions.

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