Exploring the Role of Emotions in Rational Decision Making

Fahd Saud NAWWAB, Paul E. DUNNE, Trevor BENCH-CAPON
Department of Computer Science, The University of Liverpool, U.K.

Abstract. Our focus in this paper is to explore how emotional factors can complement rationality in decision making. Our approach is to develop a model of the situation and use this model to generate arguments for and against the actions that an agent can perform. Actions are then chosen by evaluating this set of arguments according to the subjective preferences and emotional state of the agent concerned. A mechanism to control and balance the extent of emotional effects is also introduced. We illustrate our approach with an extended case study based on an implemented system embodying this approach.

Keywords. practical reasoning, emotion, decision making with argumentation.

1. Introduction

People very often take decisions influenced by emotional factors, and this influence can be beneficial [4,6]. We certainly behave differently to our family and friends, and this difference cannot easily be explained simply in rational terms. Also the goals we choose to give priority to may depend on our mood, and how anxious or encouraged we have become by recent failures and successes [5]. In this paper we discuss the realisation of the approach to incorporating emotions into the argumentation based model of decision making described in [7] first sketched in [8]. Our experiments show in practice how the decisions of an agent can be improved if it considers emotional aspects.

We draw extensively of the work of others for our conception of emotions. The underlying model is OCC [9]. We adapt mechanisms for the generation, storage, decay and behavioural effects of emotions from [10]. Our formal structure for representing emotions is based on the formalisation of OCC given in [11]. We extend this body of work to incorporate particular emotions in the decision making model. By implementing the methodology we hope to be able to give a better understanding of the work on emotions and the formalisations presented in [7,8]; show the applicability of this work to agent systems; and explore different setups and scenarios where conditions and reactions from the environment differ, to allow an analysis of the effects of emotions on the decision-making process and analyze the effect of different setups. Section 2 gives some necessary background, section 3 discusses emotions and decision making, section 4 describes the case study and discusses its results. Section 6 offers some concluding remarks.

2. The Decision Making Model

The model of agent decision making is based on the approach of [1], which was further developed in [7]. The approach relies on argumentation techniques: candidate actions are identified by providing *prima facie* justifications for them by instantiating a particular argumentation scheme on the basis of an underlying state transition model. This justification can then be critiqued by a set of characteristic counterarguments, and the decision is then made by choosing a defensible set of action justifications, according to the preferences of the decision maker. In [7] (which contains full details of the five steps and their formal underpinnings) the following methodology was proposed:

1. *Formulating the Problem*: A representation of the problem scenario in terms of an Action-Based Alternating Transition System (AATS) [12]. A particular feature of the AATS is that the transitions are *joint* actions (a joint action is composed from one action from each agent in the scenario), and so whether the agent will reach the state intended when selecting an action depends on what the other agents present in the scenario do.

2. *Determining the Arguments*: Instantiations of the argument scheme justifying actions in terms of the AATS, and counter arguments based on critical questions appropriate to that scheme are identified. A formal description of the argument scheme and critical questions can be found in [1]. A particular feature of this argument scheme is that it associates arguments with social values, things such as equality, liberty and fraternity, for the sake of which the actions are performed. Some social values, like equality, represent common goods and are calculated for the group of agents as a whole, while others, such as happiness, are calculated with respect to each individual agent.

3. *Building the Argumentation Framework*: Using the values associated with the arguments by the argument scheme, the arguments and counter arguments identified in the previous step are formed into a Value Based Argumentation Framework (VAF) [3]. A VAF allows for attacks from one argument to another to succeed or fail according to the relative weight given to the values associated with them by the audience concerned.

4. *Evaluating the Framework*: The particular subjective value ordering of the agent concerned is now used to identify the preferred extension of the VAF for that agent. This identifies the arguments that withstand the critique from the perspective of the decision making agent, and actions justified by this set are those that the agent will wish to perform.

5. *Sequencing the Actions*: The set of actions justified in the previous step are now sequenced for execution. Actions are sequenced according to the *safety* (the subsequent actions remain possible even when the intended action fails), *threats* (consequences of the joint action not being as expected) and *opportunities* (possible actions they enable) associated with them.

Once the actions have been sequenced, the agent will attempt to execute the sequence. In the absence of emotions, the agent will continue to execute the sequence as long as it is possible to do so, and so will replan only if the joint action

reaches a state in which the preconditions for the next action are not satisfied. This already requires the agent to monitor the effect of actions, and to respond by updating its beliefs to take account of the change in state. We further include at this point an emotional response: the particular emotions generated will be according to whether the joint action was such as to reach the state intended or not. Our idea now is that the emotional state will impact on the degree to which values are thought worth pursuing, causing the agent to prize some values more and some less. For example, if another agent acts so that the joint action leads to an undesired state, our agent is likely to favour the happiness of that agent less. At some points, these changes in weights on values can lead to a change in the ordering of values. At this point the subjective preferences of the agent will have changed to an extent which could impact on the arguments justified by the VAF. Such a change thus provides an additional trigger for replanning.

3. Emotions

We take as a starting point a formalisation of the the OCC model of emotions adapted from [11]. We have changed some of the emotion names so that *love* and *hate* have become *like* and *dislike*, to make it clear that our emotional states need not be extreme. We also subscript the goals to make clear which agent they are goals of.

Definition 1 (Emotional Fluents); The set Emotions is the set of emotional fluents, which is defined as follows:

Emotions =

$joy_i(k_i),$	$distress_i(\neg k_i),$
$hope_i(\pi, k_i),$	$fear_i(\pi, \neg k_i),$
$satisfaction_i(\pi, k_i),$	$disappointment_i(\pi, \neg k_i),$
$relief_i(\pi, k_i),$	$fears-confirmed_i(\pi, \neg k_i),$
$happy-for_i(j, k_j),$	$resentment_i(j, k_j),$
$gloating_i(j, \neg k_j),$	$pity_i(j, \neg k_j),$
$pride_i(\alpha_i),$	$shame_i(\alpha_i),$
$admiration_i(j, \alpha_j),$	$reproach_i(j, \alpha_j),$
$like_i(j),$	$dislike_i(j),$
$gratification_i(\alpha_i, k_i),$	$remorse_i(\alpha_i, \neg k_i),$
$gratitude_i(j, \alpha_j, k_i),$	$displeasure_i(j, \alpha_j, \neg k_i),$

Where i and j are distinct agents, α_i and α_j are actions available to these agents, π a plan of agent i expressed as a sequence of actions, and k is a partial state of affairs, so that k_i is a goal of agent i and K_j is a goal of $agent_j$.

Note that these emotions can be directed towards two *agents*, which we shall refer to as *self* and *other* respectively, a *plan*, which in our model relates to the sequence of actions identified in step 5, and a *goal*. Since, however, in our model the agent is only interested in goals because they promote values, we will use values rather than goals in this role. Here we will only consider those emotions relating to the values of self: our model does not yet embrace the identification of the values pursued by the other agents.

The emotions form eleven pairs of emotions, each pair comprising one positive and one negative emotion. The emotional response will depend on whether the joint action was such as to promote the value for the sake of which the agent chose its own action. If the value is promoted positive emotions will be experienced, otherwise negative emotions will be experienced. We will consider the negative emotions: *mutans mutandis* the positive emotions are similar. If the value had not been promoted, one or more agents will have acted other than as was required by the anticipated joint action. Self will feel displeasure and reproach towards them in respect of their action. This in turn will increase feeling of dislike towards those agents. Since self's choice was not effective, self will feel remorse in respect of that choice, which in turn give rise to feelings of shame. Because the value was not promoted feelings of distress will increase, and because part of the plan has failed disappointment will be experienced. Remember, too, that the action chosen was part of a sequence. Since the failure of the action may threaten the plan, fear is felt in respect of the values to be promoted by the remaining actions. If some actions become impossible, fears-confirmed will be experienced. Thus the various emotions can be generated by comparing the state reached with the state intended.

Emotions can, however, be experienced with varying degrees of intensity. OCC identified a number of variables affecting intensity, but we follow [10] in simplifying the model and consider only two factors, *importance* and *unexpectedness*. The importance of success will reflect the degree of importance associated with the value aimed at. We extend the VAFs of [3] by associating a weight with each value for each agent, reflecting the importance of the value to that agent. The value order is formed by arranging the values according to these weights. The importance of the success of an action will also be calculated on the basis of these weights. Unexpectedness is derived from expectations as to what the other agents will do. In the absence of other information, we could regard each possible joint action as equally likely. Often, however, we can see that the actions in the joint actions would be advantageous to the other agents: in such cases we would expect them to comply and so would find a failure unexpected. So it can be possible to estimate the probability of the actions being chosen by the other agents and to use this estimate to calculate unexpectedness. The more sophisticated our model of other agents, the more reliable will be the probability, but even poor estimates can be used to determine the intensity of the emotional response: it is after all the subjective estimate of the agent concerned.

We must now consider the storage of emotions. Again we follow the treatment of [10]. Some emotions are momentary: gratitude and displeasure, for example, are experienced with respect to particular events, but others, such as joy, distress, like and dislike, persist through time, subject to a decay factor, but modified by events. Thus the emotion of liking for another agent will reflect the cumulative effect of a series of past actions giving rise to gratitude and displeasure. In order to calculate the effect on values, the various emotions are combined into *behavioural features*, such as general mood, or friendliness towards other agents. Rules to modify the value weights are then expressed in terms of these behavioural features. Definitions relating to the intensity, storage and decay of emotions were given in [8]. We will now illustrate the approach by considering a case study.

4. Case Study

In this section we describe the case study. We will describe the set up of the study and explore some particular executions in detail. Our agent is a head of an academic department (HoD) in a university, and he is faced with a dilemma of choosing how to allocate the department's budget in the light of departmental and individual interests. Our agent (HoD) has requests relating to travel funding to attend two specific conferences. He received requests from three different students and needs to decide which of them to send. Students S_1 and S_2 are new students. S_1 is asking to go to a nearby conference, which will be cheaper financially; S_2 is asking for an overseas conference, which will cost more, but S_2 has prepared a good paper that might help the department's publication rate. Student S_3 is an experienced student asking to be sent to the local conference. Although she did not prepare a paper for submission, she is an excellent networker who is likely to impress other delegates and so promote the reputation of the department. The conferences are on different topics, so S_3's paper would not be suitable for the local conference, but both conferences are of equal standing. The budget only allows two students to be sent. Our first step is to formulate the problem in terms of an AATS.

4.1. AATS

An AATS, requires a number of elements. We instantiate each of them for the case study.

- *A set of states.* States are composed of propositions. The propositions of interest are: the available budget, whether each of the three student has been sent to a conference or not, whether each of the three students has written a paper and whether each of the three students has previously attended the conference. We write this as $B-C_1C_2C_3-W_1W_2W_3-A_1A_2A_3$. The initial state where the budget is 3, no students have been sent, only student 2 has written a paper and only student 3 has previously attended a conference is thus: 300-000-010-001. The remaining states can be generated by considering all possible combinations of values for these propositions.
- *A set of Agents.* We have four agents: the Head of Department and three students. Thus the set of agents in $\{H, S_1, S_2, S_3\}$.
- *A set of actions for each agent.* These are shown in Table 1, and the joint actions that can be formed from them in Table 2.
- A precondition function. The preconditions for each action are shown in Table 1.
- A transition function giving the result of joint actions. The post conditions of each joint action are shown in Table 2.
- A set of values. We consider the Publication and Esteem of the Department and Happiness and Experience of each of the three students. This the set of values is $\{P, Est, H_1, H_2, H_3, E_1, E_2, E_3\}$.
- A description of how values are promoted and demoted. This is shown in Table 3. The device of increasing A_n to show that a student does well is a workaround to cater for the fact that the value is promoted in virtue of

the action rather than in virtue of moving to the target state. A treatment of such issues can be provided by using the action state semantics of [2].

Agent	Action	Reference	Precondition
HoD	Send Sn to a conference	$\alpha1(n)$	Cn = 0
HoD	Asks Sn to write a paper	$\alpha2(n)$	Wn = 0
Sn	Student n does well at the conference	β_n	none
Sn	Student n does poorly at the conference	$\beta_n\prime$	none
Sn	Student n writes a paper	γ_n	Wn = 0
Sn	Student n does not write a paper	$\gamma_n\prime$	Wn = 0

Table 1. All Possible Actions

Joint Ac	Combination	Description	Postcondition
$J1_n$	$\alpha1(n), \beta_n$	HoD sends Sn to a conference and she does well	If n = 2 then B = B -2 else B = B-1. Cn = 1. An := An + 1
$J2_n$	$\alpha1(n), \beta_n\prime$	HoD sends Sn to a conference and she does poorly	If n = 2 then B = B -2 else B = B-1. Cn = 1.
$J3_n$	$\alpha2(n), \gamma_n$	HoD asks Sn to write a paper and she does	Wn = 1
$J4_n$	$\alpha2(n), \gamma_n\prime$	HoD asks Sn to write a paper and she does not	

Table 2. All Possible Joint Actions

Value	Source State	Target State	Sign
P	Wn = 1, Cn = 0	Cn = 1	+
Est	An $\geq$ 1, Cn = 0	Cn = 1. An increases	+
Hn	Cn = 0	Cn = 1	+
Hn	Wn = 1, Cn = 0	Cn = 0	-
En	Cn = 1. An = 0	An = 1	+

Table 3. Changes affecting Values

This gives all the information required to construct the AATS and produce the arguments and counterarguments as in [7]. If we ascribe a value order to the HoD we can evaluate the resulting VAF. For example, the Value Order ($VO_0 = Est > P > (E_1 = E_2 = E_3) > (H_1 = H_2 = H_3)$), will justify the set of actions $\{ask(S_3), send(S_3), send(S_2)\}$. This will also be the sequence in which the actions should be performed, since in is better to ask a student to write a paper before sending him, so that there is an incentive to comply, and sending S_3 promotes more values and commits less budget than sending S_2.

4.2. Adding Emotions

We next add the components required for an emotional response. In the implementation actual numbers are used. The precise numbers, however, are not of much significance: what does matter is their relative values, and different num-

bers only affect when things happen rather than what can happen, which is our concern here. For a particular application, particular numbers can be chosed and tuned to give the required behaviour, for example whether the agent is very responsive to emotional effects, or relatively impassive. We will therefore attempt to summarise the experiments by talking in qualitative terms, rather than by reporting the numerical outputs.

First we need to produce estimates of the importance of values and the probabilities of the students performing as hoped. Each of the values are assigned degrees of importance reflecting the the value order of the HoD, V_0. For the purposes of our experiments we assigned probabilities to the various students succeeding in writing a paper and performing well at the conference. In our experiments we ordered the actions as follows, starting with the most probable: $(\beta_1 = \beta_2) > \beta_3 > \gamma_3 > (\gamma_1 = \gamma_2)$. This reflects that it is easier to write a paper than to make an impact at an international conference: that the more independently minded and experienced student is less likely than the new students to write a paper but more likely to perform well at the conference. Of course, other assumptions could have been made.

Initially all the emotions and behavioural features are set to 0. However as emotions will be generated and stored in the scenario we need to consider the rate of decay for each emotion. The rules for decay are shown in Table 4.

Emotion	Decay
Joy(G)	50% with each transition
Distress(G)	50% with each transition
Hope(j,G)	Decays to 0 when a student is sent to a conference and attends
Fear(j,G)	Decays to 0 when the other student S writes and attends a conference
Satisfaction(j,G)	Decays to 0 when Joy(G) becomes 0
Fears-Confirmed(j,G)	Decays to 0 when Distress(G) becomes 0
Pride(α)	50% with each transition
Shame(α)	50% with each transition
Like(S)	30% with every transition
Dislike(S)	30% with every transition
Admiration(S,α)	50% when Pride(α) becomes 0
Reproach(S,α)	50% when Shame(α) becomes 0

Table 4. Decay functions of the Example study

Next we need to assign weights to the values of the HoD. We gave the HoD the initial Value order ($VO_0 = Est > Publication > Experience > Happiness$). The weights will have two components, one to reflect the intrinsic worth of the values and one to reflect their relative worth. We want the Departmental values of Publication and Esteem to be able change places, but to be always preferred to the student directed values of Experience and Happiness. We also wish to allow quite ready movement between the student directed values, and especially the order in which a particular value is directed towards different students. Thus Esteem and Publication will be given high intrinsic worth TI_H, and Experience and Happiness medium intrinsic worth (TI_M). To give emotions a moderate influence on the decision-making process, we place a medium threshold (TR) between the different

values. TR will be multiplied by a factor indicating the rank of the value in the value order. The weights of values can be given as:

$VO_0 = Esteem_{TI_L+(3\times TR)} > Publication_{TI_L+(2\times TR)} > (E1_{TI_M+(1\times TR} = E2_{TI_M+(1\times TR} = E3_{TI_M+(1\times TR}) > (H1_{TI_M+(0\times TR)} = H2_{TI_M+(0\times TR)} = H3_{TI_M+(0\times TR)}).$

The final part of the set up to accommodate emotions is that we link emotions to values through behavioural features. The connection between the emotional state of the agent (HoD) and the decision-making methodology is made by setting the different behavioral features and linking them to the Values in the value order. We identify four behavioural features and link them to values using rules.

The Behavioural Features are:

1. Mood = (Joy(G) - Distress(G) + Hope(G)) / 2
2. Friendliness(S) = (Mood + (Like(S) - Dislike(S)))/2
3. Defensive(S) = (Dislike(S) + Reproach(S,α_S))/2
4. Worried(G) = (Fears-confirmed(π,G) + Fear(π,G) /2 + Distress(G) - Relief(π,G)

The effect of these features on values is given by the following rules:

- $H_S = H_S$ + Mood + Friendliness(S)
- $E_S = E_S$ - Defensive(S) + (Friendliness(S)/3)
- P = P + Worried(P)
- Est = Est + Worried(Est) + Mood

We are now ready to execute the first action, observe the outcome, and calculate the emotional response.

4.3. Effects of Particular Actions

In the following sub-sections we will consider the possible responses to various actions.

4.3.1. Asking S_3 to Write a Paper

Recall from section 4.1 that the initial plan was {ask(S_3), send(S_3), send(S_2)}. So the Hod wants $J3_3$ to be performed, but it is possible that $J4_3$ will be the actual joint action. Suppose the joint action is $J3_3$. This will give rise to an emotion of admiration (rather than gratitude, since no values are yet promoted) towards S_3, increasing the emotion of like towards S_3. It is also a step in the plan, and gives the possibility of promoting P, and so gives hope with respect to P. Behaviourally the mood of the HoD will improve, and the friendliness towards S_3 will increase. This in turn will raise the weight of the happiness of all students (through mood) and experience in respect of S_3 (through friendliness). Finally the mood will also increase the importance of esteem. The only possible change in the value order than can result (whether it does or not depends on the precise numbers chosen) from this is that the Happiness of students 2 and 3 rise above their experience. This will not affect the plan, since S_3 will still be chosen in the hope of promoting Esteem as well as Publication, and the increased weight of Happiness and Experience relating to S_3 can only reinforce the decision.

Suppose, however, that S_3 fails to produce a paper, so that the actual joint action is $J4_3$. This will mean that the HoD experiences reproach towards S_3, increasing dislike of S_3 and fear with respect to Publication. These emotions decrease the friendliness towards S_3, make the HoD defensive towards S_3 and make him worried with respect to Publication. These behavioural features will not affect the values relating to the other students, but the happiness and experience of S_3 will get less weight. Additionally the worry will cause the weight on the value of Publication to rise. These changes will have an effect on the plan if the increase in the value of Publication is sufficient to push it above that of Esteem. If this is so, then the Hod will ask S_1 to write a paper as this is the best way to promote publication. Sending S_2 will also promote publication, but will be sequenced after asking S_1 to write as sending S_2 remains possible even if S_1 fails. If, however, Esteem remains preferred to publication, the plan will continue. So at the second step, the HoD will either send S_3 or ask S_1 to write a paper.

4.3.2. Sending S_3 to the Conference

Now the Hod wants $J1_3$ to be performed, but it is possible that $J2_3$ will be the actual joint action. Suppose $J1_3$ happens, realising the value of Esteem, and, provided S_3 wrote a paper in the first step, Publication also. Now the HoD will experience both gratitude (since at least one value was promoted) and admiration towards S_3, increasing his liking of S_3. Additionally he will experience joy, hope, and satisfaction with respect to Esteem, and possibly Publication. His mood will improve, as will his friendliness towards S_3. Since Esteem is an important goal and success was less likely than S_3 writing a paper in the previous step, the liking for S_3 will more than compensate for any dislike generated if S_3 failed in the previous step. Thus the happiness and experience of all students will rise in importance, and those in respect of S_3 will move ahead of those in respect of the other students. Esteem will also increase in importance because of the improved mood. None of this should affect the plan, and so in the next step the HoD will complete the plan by sending S_2 to his conference.

Suppose, however, that S_3 does not perform well, so that the joint action is $J2_3$. There are two cases: one where S_3 wrote a paper in the first step and one where she did not. First suppose that she did. Now although Esteem is not promoted, publication is. Thus the HoD will experience joy with respect to publication and distress with respect to esteem. But because it is the more important value that has failed, the distress will outweigh the joy and the mood will become worse. The mood will decrease the weight given to the happiness of all students, and more so in the case of S_3 as friendliness has decreased. The importance of Esteem will rise because the worry in respect of that value will offset the effect of mood. None of this, however, will affect the value order or the plan.

If, however, the paper has not been written, the effect of the failure to achieve esteem will not be ameliorated by the success of publication. The mood will become worse, the friendliness to S_3 even lower, and the defensiveness towards S_3 higher. Finally the fears confirmed with respect to publication will increase worry with respect to that value. This will depress the happiness and experience of S_3 below that of the other students, and may have the effect of raising publication above esteem. This will not, however, change the plan: the budget is now too small

to send both S_1 and S_2 and so publication is most safely promoted by sending S_2 who has already written a paper.

Note that the worst outcome is where HoD persists with the plan after the first step has failed. If the second step also fails it has become too late to rectify matters. The opportunity to replan given by the emotional response to the failure of the first step, provides a way of avoiding this. Replanning would have led to S_1 being asked to write a paper.

4.3.3. Asking S_1 to Write a Paper

This action is performed when S_3 failed to write a paper and the emotional response moved the value of publication above that of esteem. Now the HoD wants $J3_1$ to be performed, but it is possible that $J4_1$ will be the actual joint action. If S_1 succeeds, the situation will be similar to that where S_3 succeeded in step 1. Admiration will be felt towards S_1. Mood will improve, because of the hope with respect to P, and friendliness towards S_1 will increase because of liking increasing. Now within the values of happiness and experience the students are ordered $S_1 > S_2 > S_3$, that of S_1 having risen at this step and that of S_3 having fallen at the previous step. Esteem rises in line with the improved mood, while Publication remains unchanged. Note, however, that this will not cause Esteem to return to being preferred to Publication, since the relative expectedness of S_1 writing compared to S_3 writing will mean that the hope engendered at this stage does not compensate for the worry at the previous stage. The preference for the happiness and experience of S_1 over S_2 will mean that S_1 is sent.

Suppose, however, S_1 fails to write the paper. Now the experience will be similar to that when S_3 failed at step 1. Fear with respect to publication will increase further, and so to will worry with respect to that value. The weight placed on the happiness and experience of S_1 will fall, and because success was rather expected, will fall below that with respect to S_3. In consequence the HoD will in this case choose to send S_2 as the next action.

4.3.4. Sending S_1 to the Conference

Suppose that S_1 succeeded and is sent to the conference. $J1_1$ is intended, although it is felt that $J2_1$ is more likely to be the actual joint action. Since S_2 has written a paper either outcome will promote publication giving a small boost to the relevant emotions (small because with the paper already written it was expected). If the joint action is $J2_1$ there will be a variety of effects, similar to those resulting from the failure of S_3 when sent in step 2, but relatively small, since the Hod did not expect much from S_1. There will be little impact on the value order, except to decrease the relative happiness and experience relative to S_1. As a result HoD will press on with his plan and send S_2, which will certainly promote publication, whereupon his budget will be insufficient to do anything further.

Perhaps, however, S_1 will have an unexpected triumph, so promoting Esteem as well as Publication. Because this was not anticipated, it will have a big effect of the emotions, greatly increasing admiration and gratitude towards, and hence liking for, S_1. This will further boost the HoD's preference for his happiness and experience. The joy resulting from the unexpected promotion of esteem will also

improve the mood of the HoD, raising the importance of the happiness of all three students, and also impacting on the weight given to esteem. Given the intensity of the emotions, and the relief felt with respect to publication, this may return esteem to being the most preferred value. If this is the case, then whereas the original plan was to next send S_2, the renewed importance of esteem, and the cancellation of the effect on the happiness of S_3 consequent on the changed mood, may lead the Hod to send S_3 so as to promote esteem. From the point of view of Departmental values this is certainly the right thing to do, but S_2 may well feel hard done by.

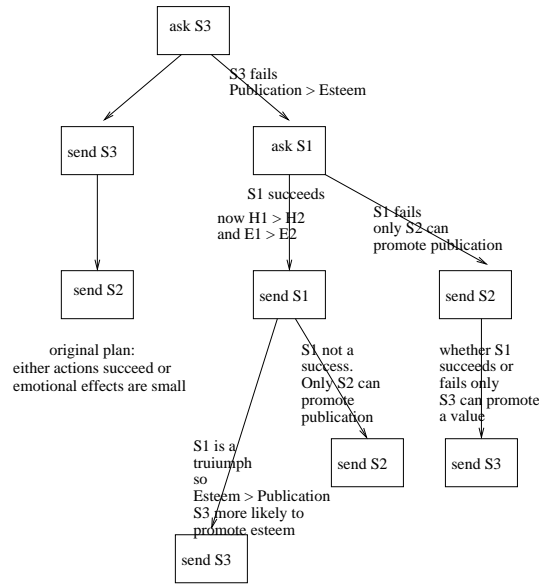The various routes through the scenario are shown in Figure 1.

Figure 1. Variations arising from emotional influences

Emotions can influence the decision making at three points in the above scenario:

1. If S_3 fails to write a paper. Worry about publication may mean that S_1 is asked to write a paper instead of esteem being pursued by sending S_3.
2. If S_1 writes a paper. Now liking for S_1 will mean that S_1 is sent before S_2.
3. If S_1 succeeds at the conference. Relief with respect to publication, together with the improved mood after this unexpected bonus may mean that esteem again becomes the priority and S_3 is sent to pursue this value.

Of particular note is the way in which the emotional response prevented staying with a failing plan and instead sought an alternative way of promoting key values in step 3, and caused a refocus on important Departmental goals in response to to the unexpected success of S_1 in section 4.3.4. It may appear that S_2 suffers, because he is given no opportunity to impress the HoD. We may think this is appropriate as the aims of the Department are furthered. However, if we

wish to give the interests of S_2 more weight, we could increase the liking for S_2 in the initial position, to reflect that he already had a paper written.

5. Summary

This paper presented an approach to enabling emotions to have an influence on rational decision making, illustrated with a detailed case study. One purpose of providing this example was to give a comprehensive explanation of the mechanisms by using an example relevant to the topic. The key role of emotions in our approach is to trigger replanning through a change in value ordering, either because the performance of a given agent has altered its standing with respect to other agents, or because success (or failure) has led to a change in priorities. These changes are controlled by thresholds representing the volatility of the agent.

Consideration of emotions might also help in developing cooperation amongst agents. This aspect was not implemented nor studied thoroughly in this work, in which the focus was on the decisions of only one of the agents in the scenario, but is a topic for further research using scenarios in which the decision making of all the agents concerned is modelled. If agents considered the emotional impact of their actions on one another when deciding what to do this might have an influence on their choice of action. When S_3 refused to write a paper at the beginning of the case study scenario, this affected future considerations about whether she should be sent to a conference (not related directly to her failure, but to the emotional response of the HoD). This in turn means that S_3 fails to promote her happiness, which may be presumed to be an important value for her. If S_3 had anticipated that failing to write will have emotional effects to the HoD she would have had a stronger reason to write the paper. Thus awareness of the emotional impact and its consequences can help to foster cooperation.

References

[1] K. Atkinson and T. Bench-Capon. Practical reasoning as presumptive argumentation using action based alternating transition systems. *Artif. Intell.*, 171(10-15):855–874, 2007.

[2] K. Atkinson and T. Bench-Capon. Action-state semantics for practical reasoning. In *AAAI Fall Symposium. Technical Report SS-09-06*, pages 8–13, 2009.

[3] T. Bench-Capon. Persuasion in practical argument using value-based argumentation frameworks. *Journal of Logic and Computation*, 13(3):429–448, 2003.

[4] A. Damasio. *Descartes' Error*. G P Putnams Sons, 1994.

[5] N. Frijda, A. Manstead, and S. Bem. *Emotions and beliefs*. CUP, 2006.

[6] N. H. Frijda. *The Emotions*. Cambridge University Press, Cambridge, 1986.

[7] F. S. Nawwab, T. Bench-Capon, and P. E. Dunne. A methodology for action-selection using value-based argumentation. In *COMMA 2008*, pages 264–275. IOS Press, 2008.

[8] F. S. Nawwab, T. Bench-Capon, and P. E. Dunne. Emotions in rational decisim-making. In *Proceeding of Argumentation in Multi-Agent Systems*, 2009.

[9] A. Ortony, G. Clore, and A. Collins. *The Cognitive Structure of Emotions*. CUP, 1988.

[10] W. S. Reilly. *Believable social and emotional agents*. PhD thesis, CMU, 1996.

[11] B. R. Steunebrink, M. Dastani, and J.-J. C. Meyer. A logic of emotions for intelligent agents. In *AAAI*, pages 142–147, 2007.

[12] M. Wooldridge and W. van der Hoek. On obligations and normative ability: Towards a logical analysis of the social contract. *J. Applied Logic*, 3(3-4):396–420, 2005.