

The Role of Emotions in Environmental Decision Making: A formal modeling framework

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Abstract

Environmental decisions are affected by the complex interactions among the characteristics of environmental problems, the attributes of the decision maker, and the situation in which decisions occur. In this complex scenario, emotionality plays a central role to understand the environmental decision process. This article proposes a formal modelling framework based in modal logic to build multi-agent models related with the environmental decisions problem in an emotional context. The formulation is based in the ideas proposed by Howard about the influence of emotion in decision making process, Ortony *et al.* (1988), about a cognitive model of emotions, and the Vining's (1987) discoveries about mechanisms that affect environmental decisions.

9.1 Introduction

Nowadays, environmental problems are a central issue for governments, industrial firms, academic institutions, public organizations, communities and so for. Degradation of natural environment is a consequence of uncontrolled and bad planned human economic activities. Scarce resources as water, strategic minerals, forests, etcetera, must be managed correctly to allow future economic growth, and social development with equity.

Environmental planning is a fundamental process to management in a correct way the complex interactions between humans activities and natural environment. However, this is a very complex duty. There are a number of factors that must be faced in planning process. For example, in 2003 during the evaluation to build a new airport for Mexico City there was an important environmental decision, *i.e.* one of the optional places for the new airport was the surplus of the historic Texcoco Lake, who is one of the last natural reserves for Mexico City. In this decision, the environmental impact to biodiversity had to share relevance with different aspects such as political climate, publicity, demographic characteristics of the target population, the economic interests of building firms, and so for.

There is a constant in the environmental decision process: together with technical information available for decision makers there are a lot of political climate information that hit on their decisions. Decision maker can have sympathy for one social group's propose, or maybe be afraid about the impact of decision in his/her political life. These emotional aspects have been recognized as central factors that affect the environmental decision process (Miller, 1983; Vining, 1987).

In other way, there is a great tradition about decision process modeling to study different aspects of decision as either bounded rationality (Simon, 1951) or organized anarchies (Cohen, *et al.* 1972). We think that emotional and environmental decisions can be studied through the use of a decision model that faces emotional aspects. With this intention, we found useful Howard's model of decision making with emotions. Specifically, we believe that some fundamental ideas taken from Howard's model can be used to propose a formal framework to develop a multiagent based simulation environment.

In the following section we explain the relation between emotions and the environmental decision-making process. Next, we introduce the underlying frameworks for our duty: Howard's model (Howard, 1993), and Ortony's emotional ontology (Ortony, *et al.* 1988). Next, we propose a formalism using modal and temporal logic for our multiagent framework. In our conclusions we argue how this mathematical formalism can be useful to build a computational model.

9.2 Emotions and environmental decision-making processes

Traditionally, emotions have been conceptualized as a contradiction to rational behavior. In this context, emotions are seen as dysfunctional factors into the process of decision making, which is considered as inherently rational (Howard, 1993, p. 121). Nevertheless, in the last years, several disciplines as sociology and economy have increased their attention in the influence of the emotions in the rational behavior (Elster, 1996; Loewenstein, 2000). Also, there are a great evidence of historical and cultural variability of the meaning, expression and regulation of the emotions (Thoits, 1989:319; Fineman, 1996, p. 550). This historical and cultural variability suggests an important degree, that subjective experiences and emotional beliefs are socially acquired and structured (Thoits, 1989, p. 319). Actually, emotions are conceptualized as a prerequisite for rational behavior (Trappl & Payr, 2002, p. 1) and as a factor that chance the rationality (Fineman, 1996).

But how an emotion can affect rational behavior? There are four basic items of a rational decision-making process (Elster, 1996, p. 1391): a) desires; b) beliefs; c) information; d) action. Under this scheme a decision is rational if it is the best way to achieve agent's desires under the agent's set of beliefs. Beliefs for a decision are formed under two basic mechanisms: a) they are result of the information available for the agent; b) they are result previous beliefs into agent's mind (Miller, 1983). If beliefs about a decision problem are founded in wrong knowledge the result of rational decision process is a no optimal decision (Elster, 1997, p. 112). Of course, information affects beliefs, but also emotions affect the belief formation process. As Frijda and Mesquita (2000, p. 72) argue:

“Emotions influence beliefs, by creating beliefs and by strengthening beliefs, in particular in making them resistant to change. These influences are in part the direct result of acute emotions, in part from emotions anticipations, and in part from standing dispositional emotions or sentiments”.

Emotions no only affect beliefs, Elster argues that there are at least seven different ways in which emotions can fit into the decision making process (Elster, 1996, p. 1991) making it so complex to model it. In our problem we depart from a belief affection point of view.

In other way, emotionality plays a central role in environmental decision process. This is because emotionality is sensible to the way in which information and opinions about problem are presented (Vining, 1987, p. 15). The same problem can be presented to decision maker in different emotional context. For example: in the decision process to give a permission for a gold mine in open sky the information about the project is so relevant but it can be presented in a way that increase sympathy about project, for example an excess of optimism about economic benefits for the government and population but omitting the injurious effects with respect to the contamination of land and underground water. In another hand, an ecologist group can present information that does emphasis in the social problems that can be generated as land rights conflicts, upper population pressure in a site without acute infrastructure, inequity treatment to vulnerable social groups, etcetera. All these factors influence decision maker's emotionality in the sense that he/she perceives future political problems about his/her decision. As Vining (1987, p. 15) argue:

“Environmental decisions and judgments result form a complex interaction among the characteristics of the problem, the person resolving the problem, and the context in which the resolution occurs...One problem characteristic is the way in which the problem is presented, or information about it is supplied”.

Vining (1987, p.16) identified three variables related with emotionality involve in information that affect decision:

Decision is influence by the issue that has more information available. Decision maker trend to take as more valuable those issues that has more representation in information.

Decision is affected by the style in which information is presented. A “hot emotional style” has more change to generated emotional plea in decision makers that a “cold objective style”.

Context affects the decision and the process in which it is made. Perceptions about problem importance or consequence of a decision involve emotional evaluation. Also, the fact to take a decision can put to decision maker in a stressful situation that triggers an emotional response.

As can be seen, environmental decisions are affected by emotional factors that are generated or transmitted by information about environmental problems. To resolve the complex effects of emotions into environmental decision-making process we must first explain the Howard's model of decisions with emotional factors.

9.3 The Howard's model of decision with emotions

Howard (1993) argues that a decision-making process can be seen as a theoretic soft game, where the basic elements of the game are actors, options and scenarios. Actors have a set of options which it may or may not decide to implement. For each actor a future decision is a particular scenario (Howard, 1993, p. 617). The relevance of the model is the interaction between actors before the options are taken. In this interaction actors try to influence other's behavior. In Howard's model joint decision could be conceptualized as the coincidence of future scenarios between the participants of the game, *i.e.* each actor in the game has a specific output from the desire-beliefs-information-action system which match with a mutual scenario. Actors propose scenarios to joint implementation of an action. Emotions play the role of significance schemata which make true or false a message (either threat or promise) exposed by one of the actors to another. Emotions either increase or inhibit the beliefs about the proposed scenario, decision is then taken.

We found Howard's model useful for the task of proposes an environmental decisions model, but it is necessary to make a few specifications and modifications. First, Howard's model does not specify a correct ontology about emotions. Second, emotions are simplified to be preferences about one scenario. Third, Howard's model was developed for join decisions, but we are interested in environmental decisions where information is a relevant factor together with the emotionality of decision maker. However, we think that Howard's model is relevant for the following issues:

- a) Actors use their emotionality to influence over decisions of others actors. This is the idea underlying in the mechanisms explained by Vining (1987).
- b) Emotionality reinforces the system's function rules when one actor makes explicit either one promise or one threat to other actor.
- c) Promises or threats of the emitting actor have influence on perception and emotionality of the receiving actor. This mechanism can be extended to the cognitive level in with the appraisal about a situation is done.
- d) The affectation of actor's emotionality goes to a reconfiguration of possible action scenarios which allows an adequate behavior of the actors (Schütz, 1993). All this processes can be seen as a learning mechanism.

If we use an adequate cognitive model for emotions, Howard's model can be converted in a useful framework for environmental decisions. We found that the model proposed by Ortony *et al.* (1988) is useful for this task.

9.4 The emotional model of Ortony, Clore and Collins

Ortony, *et al.* (1988), and O'Rorke and Ortony (1994) propose a cognitive model to explain the emotional behavior. This model is based in the cognitive aspects of human behavior and can be formulated as a computational model. Cognitive aspects of the emotions imply appreciation, comparison, classification, inference, attribution, and appraisal. Emotions are viewed as valence reactions towards objects, events, agents and their actions. (Ortony *et al.*, 1988, p. 13).

According to the model of Ortony, *et al.* (1988), and O'Rorke and Ortony (1994, pp. 289-291), different kinds of emotions are groups or sets of conditions which cause emotional behaviors and that can be coded in some computational language:

- a) The simplest emotions are the well-being emotions, labeled as joy and distress. These emotions can be understood like the positive and negative feedbacks that individuals have before desirable and undesirable happen events.
- b) The second group of emotions is referred to the fortune of others. This group includes four kinds of emotions: happy for, gloating, resentment and sorry-for. Each kind in this group is a combination of pleasing or displeasing aspects respected to a specific event, which is presumed to be pleasant or disagreeable for another person.
- c) The third group is the prospected-based emotions, which includes six specific kinds of emotions: hope, satisfaction, relief, fear, fears-confirmed and disappointment. Each kind represents a reaction to a desirable or undesired event that has been either confirmed or not.
- d) The fourth group is concerned with attributions and it covers four kinds of emotions: pride, admiration, shame and reproach. Each attribution emotion kind generates a reaction (positive or negative) to either any type of own action or actions conducted by others.
- e) The fifth group is related to attraction. This group refers to reactions that individuals have towards objects. The two emotions in this group are the momentary feelings of liking or disliking an object. The final group includes eight elements that constitute the result of the Cartesian product "*well-being*"? "*attributions*". This kind of compound emotions does not correspond to the co-occurrence of their emotional components. Union logical function is used to resolve when a compound emotion is valid in the computational model (O'Rorke and Ortony, 1994, pp. 289-291).

In general, the conditions of "production" of an emotion are given in terms of the variables that contribute to increase the activity of emotions. Theory specifies global variables that affect all the emotions and local variables that affect only subgroups of the emotions (Ortony, *et al.*, 1988, pp. 68-81). The variables have values and weights associated to emotions and theory suggests that an emotion is experienced simply when certain levels of the thresholds of the emotion are exceeded.

We will use this classification of emotions (for us this is an ontology) to build emotional mechanisms for the Howard's models. In the next section we explain our model with its formal framework.

9.5 The formalism

In this section, we present our formal definition of the environmental decision-making process in emotionality contexts. Our formalism uses modal and temporal predicate framework (Bell, *et al.*, 2001) as is proposed by Wooldridge (2000). An agent is an entity able to communicate and to do something. To define the decision systems we take the simple idea of decision making process from the garbage can model developed by Cohen, *et al.* (1972). The idea in our simple organization is that each agent has a set of problems that must be resolved. Each problem needs a set of solutions. This can be defining as:

Definition 5.1. Let $\Theta = \{\alpha_1, \dots, \alpha_k\}$ a group of agents. Let $P = \{p_1, \dots, p_m\}$ a set of problems that must be resolved by agents. Let $S = \{s_1, \dots, s_m\}$ a set of possible solutions for problems. We define a “decision structure” $\Theta \circ P \subseteq \Theta \times P \cup \Theta \circ S \subseteq \Theta \times S \cup S \circ P \subseteq S \times P$, where $\Theta \circ P$, $\Theta \circ S$, and $S \circ P$ are equivalence relationships.

Decision structure works as follow. Each agent can have either one of two rolls: a) decision maker, or b) member of a group of interest. Each decision maker has a set of problems to resolve. Each member of a group of interest has a set of solutions that desire to be implemented to resolve problems. Each decision maker receives a set of solutions from several members of interest groups. These set of solutions conform a proposal and decision maker must choice one of the solutions. Solutions do not resolve problems in a perfect way. Indeed, solutions can reinforce the strength of a problem. Each decision making process w has a duration time defined as $W \circ T \subseteq W \times T$ where $T = \{t_0, t_1, \dots, t_k\}$ is a set of time periods and $W = \{w_1, \dots, w_k\}$ is a set of decision making process. Of course, there are an equivalence relationship between W and P . In a simple way, each decision maker has only on decision making process, but this is not a restriction.

Each member of an interest group sends its solution to the assigned decision maker. Decision maker has a specific time to do its decision. In a rational way, a decision about what solution must be taken for a specific problem involves the following elements. Each decision maker has a set of desires,

$$D = \{desire()_{political}, desire()_{ecological}, desire()_{social}, desire()_{personal}\}$$

to be achieved. Each desire has a specific dimension of the decision. Decision maker tries to achieve all its desires, but these also can be formulated as contradictory. Also, a decision maker has a set of beliefs about effectiveness of solutions to resolve problems. These can be defined as $B_{agent} = \{belief_1(p_i, s_j), \dots, belief_k(p_i, s_j)\}$. Information is a function that changes beliefs. In a similar way, members of an interest group also have a set of desires and beliefs, but these are formulated in a simple way. Beliefs for members of an interest group are defined in function of the impact of kind of message in decision maker beliefs, *i.e.* $B_{member} = \{belief(\alpha, \text{“hot”}), belief(a, \text{“cold”})\}$.

We are interested in conflictive situations, *i.e.* where beliefs of decision makers do not make match with the beliefs of members of an interest group and solution is rejected. This conflict situation can be resolve using a negotiation process between decision makers and members of the interest group.

Negotiation mechanism works as follows. For an specific period of time, if the decision is not yet taken and the solution proposed by agent A has been rejected, then agent A who is a member of an interest group, sends a message to the agent B , who is the decision maker. There are two kinds of messages that a member of an interest group can send, “hot emotional” and “cold objective”. These messages affect the information function which changes beliefs. Agent B , who is the decision maker, can decide that the solution suggested by agent A does not achieve he/she desires because beliefs about the effectiveness of solution still to be unchanged. This can be formalized as:

Definition 5.2. Let $A = \{Accept(), reject()\}$ the set of actions to can be taken for a decision maker. Predicate $Accept(\alpha, s)$ accepts solution s proposed by agent α , predicate $reject(\alpha, s)$ rejects solution s proposed by agent α .

Let $M = \{m_{agent,hot} \ m_{agent,cold} \ m_{agent,accept} \ m_{agent,reject}\}$ a set of messages between agents.

Definition 5.3. We use the following modal logic predicate formula to determine an action, $Accept(a_i, s) \stackrel{\text{def}}{=} \Box \exists w_{\alpha_i} (p, s) \in W \wedge \Diamond \exists desire(belief(p, s)_k \in B_{\alpha_j}) \in D_{\alpha_j}$

Where the modal logic predicate $belief(p, s)$ is determine by a function $f_{\alpha_j} : \{\top, \perp\} \rightarrow belief(p, s) \in B_{\alpha_j}$. In this sense, beliefs are possible worlds that make true desires.

Definition 5.4. In a similar way, reject action is defined as follows:

$$reject(a, s) \stackrel{\text{def}}{=} \Box \exists w_{\alpha_j} (p, s) \in W \wedge \Diamond \neg \exists desire(belief(p, s)_k \in B_{\alpha_j}) \in D_{\alpha_j}$$

Any action has as consequence that decision maker sends a message to members of an interest group. If message is a solution rejected then the member of the interest group send a message that can be either “hot emotional” or “cold objective”. The action of these messages can be defined as:

Definition 5.5. The action to send a hot message to agent α (decision maker) who rejects solution s can be defined as: $Send(m_{\alpha hot}) \stackrel{\text{def}}{=} \Diamond \exists belief(\alpha, hot)$, in a similar way, $Send(m_{\alpha cold}) \stackrel{\text{def}}{=} \Diamond \exists belief(\alpha, cold)$.

Information is the mechanism to change beliefs. Information can act in two ways: a) increasing the importance of a solution proposed; b) changing the emotional beliefs of a decision maker. The kind of message impacts in the information. A “cold objective” message increases the importance of solution. A “hot emotional” message change beliefs about solution.

Emotionality is introduced as an appraisal process that can modify $accept()$ and $reject()$ predicates. Of course, the way to do that is through a change of beliefs. Taking Ortony’s (1988) ideas about emotions, we identify three relevant emotional aspects in decision: a) agent’s prospects-based emotions; b) agent’s fortune-or-others emotions; and c) agent’s fortune-of-self emotions. First kind of emotions deals with aspects as hope or fear about what acute is solution s to resolve problem p . Second kind deals with aspects like liking with respect the interest group. Third kind deals with aspects about well-being emotions. Agent can be either pleased or displeased about an event. The event in which we are interested is message.

Definition 5.6. Emotional decision rules are determined as follows:

1. $likelihood(hope, s) \stackrel{\text{def}}{=} \exists m_{\alpha_p, hot} \wedge \Diamond \exists \neg belief(p, s) \rightarrow accept(\alpha_p, s)$
2. $likelihood(fear, s) \stackrel{\text{def}}{=} \exists m_{\alpha_p, hot} \wedge \Diamond \exists \neg belief(p, s) \rightarrow reject(\alpha_p, s)$
3. $OtherHappiness(fear, s) \stackrel{\text{def}}{=} \exists m_{\alpha_p, hot} \wedge \Diamond \exists \neg belief(p, s) \wedge \Diamond liking(\alpha_j) \rightarrow reject(\alpha_p, s)$. Where there is a function $f_{\alpha_j} : \{\top, \perp\} \rightarrow liking(\alpha_j)$.
4. $SelfWellBeing(joys, s) \stackrel{\text{def}}{=} \exists m_{\alpha_p, hot} \wedge \Diamond desirable(joys, s) \rightarrow accept(\alpha_p, s)$
5. $SelfWellBeing(distress, s) \stackrel{\text{def}}{=} \exists m_{\alpha_p, hot} \wedge \Diamond \neg desirable(distress, s) \rightarrow reject(\alpha_p, s)$

To determine true values of $belief()$ statement and emotional statements $liking()$, and $desirable()$, we can use a possible worlds semantics like was proposed by Kripke (cited in Bell, *et al.* 2001, p. 180). The underlying idea is that one agent has different emotional states which impact their emotional response to one message. For example, one simple possible world can be the existence of a desirable emotional state with an emotional value of “joy” for one specific option s , this possible world will have a true value. Another possible world is the same desirable emotional state but with emotional value of “distress”, then the true value will be false. These possible worlds can be complex. A formal way to define it is as follow:

Definition 5.7. Let \hat{O} an Ortony’s ontology, *i.e.*, $\hat{O} \neq \emptyset$ and $\hat{O} = \{\Psi_1, \dots, \Psi_n\}$, where Ψ_k is an emotional state according to it was defined in section 9.4. Let $\Omega_{\Psi} = \{\varphi_1, \dots, \varphi_r\}$ the domain of emotional values for emotional state Ψ . A possible world will be $m = \{x : x = \Psi \upharpoonright_{\varphi}\}$. The set of possible worlds will be M . There area a function $f : \{\top, \perp\} \rightarrow m \in M$. Of course, researcher is free to propose combinations of the Ortony’s emotional ontology to define possible worlds and function f .

9.6 Summary and Conclusions

Environmental decision process is affected by the complex interactions among the characteristics of environmental problems, the attributes of the decision maker, and the situation in which decisions occur. In this complex scenario, emotionality plays a central role to understand the decision process. We defined a formal framework for environmental decision making process in an emotional context. Authors think that the formulation is useful to develop practical software models of environmental decision problems. The main advantage in our formulation is the use of a formal logic approach. As Wooldridge (2000, p. 163) argue logic formulation is simultaneously: a) a specification language; b) a programming language; and c) a verification language. In respect to other formulations about emotion modeling, our formulation uses a cognitive formulation of emotions (see for example Cañamero, 2002, and Ball, 2002). This cognitive formulation is a natural way to think about emotions. Also it is easy to code in a modal logic framework (For example, O’Rourke and Ortony, 1994, uses a situational calculus framework which is a derivation from modal logic). One specific

advantage of our formulation with respect to Howard's model is that emotions are explicit in our formulation and the emotional mechanism can be reformulated in one easy way. With respect to environmental decisions the model is relevant because used an explicit way the mechanism founded by Vining (1987). As the last point, we belief that our formulation can be useful to develop a computational models using general purpose available software as PROLOG or specific modal logic language as METATEM (Wooldridge, 2000, p. 168) This is a question that we will answer in a future work.

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