A Commitment Theory of Emotions

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Central to reciprocal altruism is the monitoring of exchanges - the record of whom you owe, who owes you, and how much is owed. (Robert Wright 1994, *The Moral Animal: Evolutionary Psychology and Everyday Life*, p. 275)

Abstract

In the near future, useful software agents or robots will have to evidence a fair amount of autonomy, with the capacity of carrying their own goals and even of setting up their own motives. As complex and expensive tools, they will also have to be endowed with a built-in incentive to protect themselves and endure. As sophisticated «employees», they will eventually have to interact and cooperate with others agents of similar ontology, either from the same company or from other ones. In such a scenario, the ability to establish and maintain solid and trustable alliances, as well as to detect enemies and profiteers, will likely become a matter of sheer survival. The article proposes that establishing and securing commitments between social agents is the key to harness the benefits of cooperation, and that emotions emerged through natural selection precisely to meet such requirements, by insuring commitments management and control. The article concludes by listing some of the minimal specifications that seem required for the implementation of emotions as commitments operators.

The Problem

Imagine a set of companies of, say, computer software, each using as some of their employees a community of robots pretty much tailored along a standard set of specifications. Think of those animats as sophisticated agents, capable of accomplishing a broad variety of tasks, from routine debugging to complete software design. Let's also assume that they evidence «real autonomy», not only in the sense that they could plan and evaluate for themselves the best ways to carry out their job according to the market's demands, but also that they can learn and update themselves so as to guarantee their employer the best performance. Yet, one should realize that there is always a risk that, although expensive, these artificial employees be cast aside, poorly performing robots being dismantled and replaced by better performing ones, whenever such an option would show profitable (Maes 1995). Hence, autonomous robots should have a *built-in incentive to endure,* and their design is likely to have «evolved» so as to evidence self-protection by all means, not only by delivering good work and improving themselves, but also by comparing their own capabilities with that of other robots, and by constantly evaluating their master's satisfaction.

Now suppose further that two different companies, although working within the same field, have developped different pieces of software, that, if exchanged, could «differentially» benefit each other. The robots keeping themselves informed of any elegant software tool becoming available on the market, would likely measure up the advantage, for their company as well as for their own good, of cooperating with the other company's agents. But in this competitive world, it will certainly be in each agent's interest that he tried to get the best of the exchange, which means obtaining the most information while delivering the least. As this kind of sharing is likely to become a current mode of making business and keeping aloft, an optimal level of satisfaction is to be attained from both sides for the agents to pursue the exchange. They will then likely have to find ways of getting along and pleasing each other, but also of deciphering any attempt to cheat, and of retaliating whenever this happens. But they should probably also be designed so as to inculcate themselves to value alliances and frienship, to be careful not to abuse friends - and even to offer reparation, if they think they might have. If such complex cooperation between companies eventually gets to be thus mediated by the robots themselves, actually a rather likely scenario in the not-so-far-away future, the problem is then: what kind of built-in control structure could insure optimal interaction?

Commitment is the Key

Establishing cooperation is a fundamental problem in any social organization (Dawes 1980). According to the law of natural selection, each individual should be genetically programmed to behave so as to maximize its own profit (Krebs 1987). On the other hand, there is often a clear benefit to obtain from cooperating with others. The problem is that, according to the first principle, some individuals might try to increase their own benefits by exploiting the willingness of others to cooperate, without reciprocating themselves. Hence, the adaptiveness and viability of cooperation relies heavily on ways of insuring reciprocity between possible partners. Sociologists indeed noticed the existence of a generalized norm of reciprocity across a large spectrum of human societies, thus appearing «no less universal and important an element of culture than the incest taboo» (Gouldner 1960, p. 171).

This led Robert Axelrod, a political scientist, to investigate how cooperation could ever emerge within such a selfish «Darwinian» world (Axelrod 1984). Using as testbed the Prisoners' Dilemma paradigm from Game theory, he challenged scientists from various fields to propose their best winning strategy on a computer tournament. The clear result was that a very simple cooperative rule, TIT FOR TAT (TFT), came out as the big winner across the two rounds of the tournament. The strategy consisted in cooperating on the first move, and from then on, simply replicating the other's move: cooperating if the other did, but defecting if the other did. Another important result was that «nice» rules, the ones which started benevolently by a cooperating move, all occupied the top half of the ranked strategies.

From the data thus collected, Axelrod could also simulate the «evolutionary fate» of the 63 strategies proposed. He imagined them as various species equally represented within the total population at the beginning of the game, and then ajusted their number of copies («offsprings») in proportion to their respective score on each successive move. Here again, althought no mutations were allowed as in natural evolution, the result was quite clearcut: not only did nice strategies typically fared better, but also «TIT FOR TAT had a very slight lead in the original tournamant, and never lost this lead in simulated generations. By the one-thousandth generation, it was the most succesful rule and still growing at a faster rate than any other rule» (Axelrod 1984, pp. 52-53). The author further demonstrated that no single strategy could invade TFT, provided the game lasted long enough for retaliation to conteract the temptation to defect, this critical time parameter being estimated accurately from the actual payoffs.

Although the strategy proved robust against a *solitary* opponent, additional works showed that some *combinations* of strategies could nevertheless invade TFT (Axelrod and Dion 1988; Boyd and Lorberbaum 1987; Lorberbaum 1993; Nowak and Sigmund; 1994). Yet, these formal demonstrations *all rested on the fact that at least one of the rule had to be «nice», and actually fairly similar itself to TFT.* In addition, various computer simulations performed from an evolutionary standpoint, generally confirmed the robustness of cooperative strategies based on reciprocity, most of them being close variants of TFT (Glance and Huberman 1994; Lomborg 1992; Nowak and Sigmund; 1994).

Hence, cooperation is not only possible, but is likely to evolve naturally, even out of a selfish world, precisely because there are strong benefits and fitness attached to it. *But it has to be carefully harnessed,* for the temptation to defect and cheat will, by the very same logic of maximizing profits, always be present and lurking. *The key is that some commitments be established between the partners, so they constrain themselves to cooperate with each other.* This also requires some powerful device to insure the management and regulation of all the commitments an individual is doomed to entertain with his social surroundings. Such a mechanism should thus specify who is committed towards whom, about what, and until when; it should also indicate when it is useful to create new commitments, how it should best be done, whether there are conditions of derogation, and how to react to defection, from self as well as from others. Those are some of the reasons why distributed artificial intelligence (DAI) has imported the commitment concept from symbolic interactionism in Sociology (Becker 1960; Gerson 1976), and has been thoroughly involved in clarifying its implications for social interactions (Bond 1990; Fikes 1982; Gasser 1990).

What Emotions Have to Do with It?

If cooperation appears so useful in insuring access to additional resources, and if the merits of cooperative behavior have to be protected against defection by instigating and securing commitments between partners, then evolution is likely to have come up with such a regulating mechanism. Building upon Simon's seminal ideas (1967) about the role of emotions as adaptive *interrupt* mechanisms, and upon Trivers' deep insights (1971) into the role of emotions in reciprocal altruism, Aubé has proposed that emotions might have emerged to fulfill the requirement of controlling and managing commitments within animals (and eventually animats) encounters (Aubé 1997a, 1997b; Aubé and Senteni 1995, 1996a, 1996b).

The reasoning basically goes as follows. To be «really» autonomous, as opposed to remain the mere executives of others' intentions, agents have to be able to set their own goals, which means, in the bottom line, that they should be «intrinsically» motivated. Such property, on the other hand, calls for built-in capabilities to search for and gather one's resources of survival. Thus, in our theory, motivation refers essentially to whatever mechanisms insure access to, and control of, required resources. Need systems such as hunger or thirst, for instance, are the motivational systems that insure the necessary access to food and water. We call those «first-order resources», in that they usually can be directly obtained by the organism's own means.

But in certain organisms, like birds' or mammals' offsprings, vital resources, such as food or protection, could only be obtained through some other agents, be they parents or other caretakers. These call for different kinds of management mechanisms. A crucial point here is that, it is not the providing agent itself that is to be counted as a resource, since it might not always necessarily comply to the demand. To become truly resourceful, an agent should be «constrained» by something akin to an attachment structure. In other words, it should be intrinsically «committed» to fulfill the offspring's demand. *Thus, it is the commitments themselves that should be counted as vital,* and this is why we call them «second-order resources».

Again, if this analysis is sound, some powerful management mechanisms should have emerged through natural selection, in order to secure the access to this more complex and likely more elusive type of resources. We contend that emotional structures, at least certain of them, are precisely the kind of mechanisms that fulfill this role. In fact, we envision emotional structures as a more complex layer of control, that is somewhat grounded on top of the needs control structure, much in the spirit of Brooks' subsumption architecture (Brooks 1991). The needs systems register variations within the stock of vital (first-order) resources. When these fluctuations cross a critical threshold, they activate the proper subsystem (hunger, thirst, fatigue, protection, etc.) that has been specifically designed for the replenishment of the dangerously diminishing variable.

In social, or at least nurturing animals, other agents can supply for the missing resources, *provided they are committed to behave in such a way.* In case of emotions triggering, the critical resources here have to do with the commitments that bind the agents together into cooperative behavior. Emotions are designed in to regulate the operation of this new layer. As for needs, these processes are triggered by significant variations in the flow of second-order resources, for instance when there is a threat of breach in commitments or an opportunity for establishing new ones. They then operate so as to establish or create new commitments (joy, gratitude), protect, sustain or reinvest old ones (joy, hope, gratitude, pride), prevent the breaking of commitments by self or others (pride, guilt, gratitude, anger), or call on «committed» others in cases of necessity, danger, and helplessness (sadness, fear).

But Why Restrict Emotions to the Social Domain?

Of course, this theory considers the emotions strictly in terms of social interactions, and moreover it applies only to species like crocodilians, birds and mammals, that are at least capable of attachment or nurturing behaviors. But the necessity of imposing such a distinction should not be too surprising, and within the psychological literature one finds a few similar attempts to disambiguate «emotions proper» from simpler mechanisms. Ekman, Friesen and Simons (1985), for example, have made a convincing argument that the startle reaction, which had once been associated with surprise, was more reflex-like, and should not then be counted as an emotion. Öhman (1986) has also provided suggestive evidence that, among human fears, the various reactions observed should probably be classified into different categories, some of which would rest upon much simpler and evolutionary older structures. Accordingly, our theory would not consider as «fear proper» the escaping reaction of «simpler» animals, such as flies or frogs, which flee or jump simply as someone passes by. But we are not totally disregarding these as irrelevant either: in the model, they would rather pertain to the needs layer of control, insuring in this case the protection of the animal by simpler means that do not require the helpful intervention of a committed agent. The theory thus leaves open many possibilities for their concrete implementation, plausibly not too far away from the kind of behaviors already captured in some insect-like animats (Brooks 1991).

As to the class of behaviors we chose to scrutinize, it so happens that most emotion theorists do also acknowledge that social interactions, and especially intimate relationships, pervade what is generally considered as emotional reactions. Moreover, such behaviors *find their most intense expression when relatives are involved.* To quote but a few:

> The evidence is sufficiently broad [...] to suggest that one of the basic functions of emotion is to regulate behavior so as to form and maintain social bonds. (Baumeister and Leary 1995, p. 508)

> A major component of emotions is social communication and regulation. [They] communicate to other peoples one's needs, wishes, intentions, [...] and likely behaviours. This communication generally promotes both need satisfaction and social coordination. (Fischer et al. 1990, p. 94)

> Many of our more intense and problematic emotions concern plans where mutuality has been sought for, set up, or assumed. (Oatley and Johnson-Laird 1987, p. 43)

> Our most ardent emotions are evoked not by landscapes, spiders, roaches, or dessert, but by other people. (Pinker 1997, p. 396)

> [Our results] replicate earlier findings obtained in a series of intercultural questionnaire studies showing that established personal relationships are the most important source of emotional experience for the basic emotions, except for fear. (Scherer and Tannenbaum 1986, p. 302)

> In human behavior, situations involving interaction with other human beings are characteristically more heavily laden with emotions than any other situations. (Simon 1967, p. 37)

Yet, in spite of the fact that such observations appear as recurrent and systematic across the whole field of emotion research, not many have dared to take the step, as sharply as we do, of restricting these (kinds of) emotional behaviors to the interactive domain. The obvious exceptions are the social constructionists, who would go much farther in considering emotions as mainly (if not purely) social and cultural constructions (Harré 1986; Shweder and LeVine 1984). But their proposal is basically opposing to biological determinism, while we clearly envision emotional structures as evolutionary solutions to the problem of securing reciprocal altruism and cooperative behavior within nurturing (and eventually social) species.

This evolutionary standpoint nevertheless invites one to be cautious and to accept that there plausibly exist many different emotional systems. As LeDoux suggested: «Most likely, attempts to find an all-purpose emotion system have failed because such a system does not exist. Different emotions are mediated by different brain networks, different modules, and evolutionary changes in a particular network don't necessarily affect the others directly» (1996, p. 106). But this situation is no more surprising than what we already know about different perceptual systems, or different motivational systems (Toates 1986), nor than what is now fairly accepted about multiple memory systems (Sherry and Schacter 1987; Schacter 1996). Yet, the fact that there exist different perceptual systems, which differ sensibly in terms of mechanisms and functions, as well as localization inside the brain, does not preclude a theoretical analysis of their common properties as energy transducers. In the same vein, we argue that, in spite of a different history, different brain localizations, and a different physiology, some general theorizing about the common function of *emotions as commitment operators* could still lead to useful advices for an eventual implementation.

And How Could It Be Implemented?

Although we do not have a concrete implementation already, we nevertheless have worked out some of the specifications that seemed mandatory.

First, it should be kept in mind that, according to our theory, artificial emotions only make sense in social animats, «living» in closely interacting groups. Moreover, these beings should all be designed along a similar *ontology*, so they would be compelled to react similarly to the same emotional signals. It is not required that they all belong to the same species, though, provided that these signals can get across the species barrier, as seems to be the case in some birds and mammals, notably between humans and pets, and between some primates.

Second, the emotional system should be envisioned as a kind of *operating system*, set at a very low level of the software architecture, so it could indeed act as a basic control layer whenever vital «second-order resources» are at stake. Moreover, this operating layer should be grounded upon the underneath «need» layer, much in the spirit of Brooks' subsumption architecture (1991), as illustrated in Figure 1. Emotions could thus operate «in-the-service-of» needs, and indirectly substitute for them.

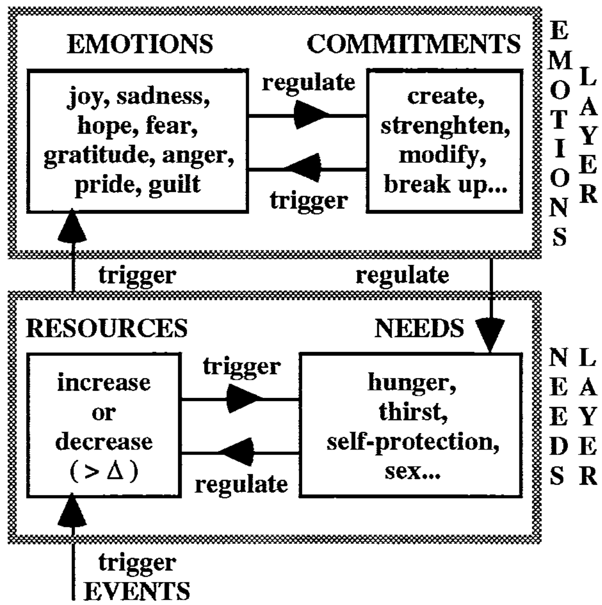

Figure 1. Two Layers of Control for Resources Management. (Adapted from Aubé and Senteni 1996b, and Aubé 1997b)

Third, there should be provision for the carving of *commitments* into a fairly structured and dynamic format. For one thing each commitment should register a few instance variables, such as:

- the list of the *partners* involved (including self);
- the *task* required to fulfill the commitment;
- the *first-order resources* that it insures access to;
- the *scheduling constraints* for its fulfilment;
- the conditions of its *satisfaction* or of its *revocation.*

The resources and scheduling variables should be associated with numerical *threshold* intervals, out of which the commitment should be considered threatened or favored. Each commitment represented should also be attached a kind of *monitoring mechanism*, with a high interrupt priority, to enable detection of any event that might induce a significant variation, in terms of threat to the commitment, or of opportunities for strengthening it. The best interrupt mechanism we have in mind is something akin to the *exception handling system* (Dony 1990) found in some object oriented languages, such as Smalltalk-80. Although we have explored an actor-based representation to capture the kind of dynamism required for commitments, we rather feel that an efficient implementation should be maintained very close to the machine level.

Fourth, *triggering* of an emotion should depend on three dimensions: *valence, agency,* and *certainty*. Eight different *families* of emotions could thus be differentially activated: joy, hope, gratitude and pride on the positive side; sadness, fear, anger and guilt on the negative one (Aubé and Senteni 1996a). Thinking in terms of families of emotions means that neighbouring reactions, such as guilt, shame, embarassment, shyness, regret, and remorse would be lumped under the same label, a grouping undertaken only after a careful scrutiny of various theoretical positions and data sets from the psychological literature (Aubé 1997b).

The first dimension determines whether the emotion will be *positive* or *negative*, according to the direction of the variation (gain or loss). It should be computed by the monitoring mechanism, according to the threshold values associated with its instance variables. The second dimension specifies which partner should be held responsible for the variation induced: *self* (inducing pride or guilt) vs *others* (inducing gratitude or anger). It is directly accessible from the *partner* instance variable attached to the commitment data structure mentioned above. The third dimension only matters when no agent could be held responsible, and discriminates between *actual* vs *anticipated* variations, making for the difference between joy and hope, or sadness and fear.

The elicitation structure is illustrated in Figure 2. In each cell, we have also included, in small letters and between parentheses, the «global» version of each emotion. For instance, if self feels responsible for failing to meet social standards or prescriptions, GUILT will be experienced when the transgression could be restricted to specific acts or behaviors, while SHAME would rather be felt if the whole self is seen as inadequate. ANGER would result from specific wrongdoings attributed to someone else, but CONTEMPT would rather be experienced if this is the whole identity of the wrongdoer that is judged as deficient. Similarly, JOY or SADNESS would be felt respectively in cases of specific pleasant or unpleasant happenings, but HAPPINESS or DEPRESSION would rather be experienced when the pleasantness or the unpleasantness melt over longer periods of time or even over a whole way of life. In the «None-Agency» row, when the global version of a given emotion is prevalent and spreads over time, we will tend to use the term «mood», rather than emotion.

	VALENCE			
	POSITIVE		**NEGATIVE**	
AGENCY	**actual**	**anticipated**	**actual**	**anticipated**
none	JOY (happiness)	HOPE (optimism)	SADNESS (depression)	FEAR (anxiety)
others	GRATITUDE (adoration)		ANGER (contempt)	
self	PRIDE (conceit)		GUILT (shame)	

Figure 2 The Elicitation Structure for Basic Emotions (Adapted from Roseman et al. 1996, and Weiner 1985)

When the computations along these three dimensions result in triggering, a signal is sent to the exception-handling system, which suspends the current computation and invokes a handler to take charge of the commitment involved. Each family of emotion acts as a specific *handler*, aimed at resolving the situation that raised the signal.

Fifth, each family of emotion should be described as a dynamic *script* specifying an *ordered set of preferred actions* to be undertaken in order to regulate the critical variation responsible for the triggering. First among them are *emotional acts*, similar to «speech acts» in conveying specific intentions, except that their format is typically nonverbal and much more primitive. This acknowledges the fact that emotions are higly communicative, typically arise between committed agents, and that, *most often, resolution of an emotional episode is achieved through the exchange of emotional expressions* between the partners involved in the compromised, or exceptionally favored, commitment.

As is the case with the needs subsystems, *the core scripts for each family of emotions should be built-in,* as basic motivational control structures with innate releasers and preferred action plans. Such a requirement however, does not preclude that new patterns of signals and responses could also be learned through experience, and progressively added to the original scripts.

We thus propose these specifications as minimal requirements to meet the kind of demands with which are likely to be daily confronted the community of robots described in the beginning of the article. But indeed, a fair implementation is still required as a concrete test!

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