# Designing Adaptive Cooperating Animats Will Require Designing Emotions: Expanding upon Toda's Urge Theory

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*[...] the majority of human emotions are social in nature, specifically developped so as to make the active group cooperation feasible (p. 261). Cooperation is too abstract a concept to be implemented as a single urge (p. 269).*
(Toda 1985)

**Abstract**

In the early 1980's, Masanao Toda proposed that emotions be envisioned as a set of rational survival programs, tailored through evolution so as to provide organisms with the opportunity to handle critical situations in reasonable time. To render these ideas more concrete, Toda created the concept of «fungus eaters», imaginary animats to be sent in space for uranium mining. He further proposed to design them with a set of «urges», defined as «built-in motivational subroutines for making decisions and executing the chosen action plan». Most of the urges proposed happened to be of social nature. Although this proposal proved interesting, one nevertheless feels some uneasiness with aspects of the structure. Thus some of the urges identified, like startle or hunger, should probably not be considered as genuine emotions; besides, all the urges specified in the model do not stand at the same conceptual level, some being more behavioral, and some more abstract. The article presents briefly Aubé's theory of emotions-as-commitments-operators which shows striking similarities with Toda's system. The article then concludes by stressing how the concept of commitment as a second-order resource could help simplify Toda's proposal, and clarify the whole domain of emotions.

## Toda's Seminal Ideas

In the early 1980's, Masanao Toda proposed that emotions be envisioned as a set of *rational survival programs*, specifically tailored through evolution so as to provide the organisms with the opportunity to handle critical situations in reasonable time. In his opinion, «a principle or rule is rational if and only if it makes the system function (almost) optimally for a given context and under given constraints» (Toda 1982, p. 208). Accordingly, he considered emotions as decision routines to be triggered when something happens that might be detrimental for the organism, or that could offer it unforeseen opportunities for survival. This proposition rested upon the idea that certain classes of critical events were recurrent enough that through natural selection individuals could have become endowed with appropriate detectors for recognizing them. Once activated, these procedures would rapidly select from an ordered list of preferred actions the best ones to be pursued, in the current context, so as to help resolve the crisis at hand.

To render these ideas more concrete, Toda created the concept of «fungus eaters», biological robots to be sent in space for uranium mining. These imaginary animats were conceived to be well equipped for perception and locomotion in a wild environment, and confronted with the problems of insuring their own nutrition and protection. They were thus supposed to feed upon certain mushrooms abondantly found on distant planets, but also to detect hungry predators and flee from them. The question was then to engineer proper solutions to manage such constraints.

Toda's proposition was to design a set of «urges», which he defined as «built-in motivational subroutines for making decisions and executing the chosen action plan» (Toda 1982, p. 138). The author prefered to call them «urges», because he felt that the term «emotions» was too much endowed with naive preconceptions and subjective connotations. He went on identifying as many types of urges as seemed mandatory to render the organism well equipped for survival in its complex environment. Figure 1 presents the set of urges originally proposed by Toda.

There are certain urges that make the animat forage and explore its environment (CURIOSITY and HYPOTHESIS-TESTING URGES), others that make it cautious and watching for possible threats or dangers (STARTLE, FEAR and ANXIETY URGES), others that make it look for sources of replenishment (HUNGER URGE). Clearly, the list is far from complete, and one could easily imagine other useful urges, such as thirst, or sex, or fatigue, that most organisms seem to be equipped with.

Yet, one could readily see that most of the ones that have been proposed by the author happen to be of social nature. Indeed, in societies of animats, the environment is itself largely «social», others providing most ressources for feeding, sheltering, protection and even cognitive stimulation. But some others could also be dangerous, exploiting or greedy, which calls for means of detecting cheaters and profiteers, and of insuring cooperative friends and trustable allies.

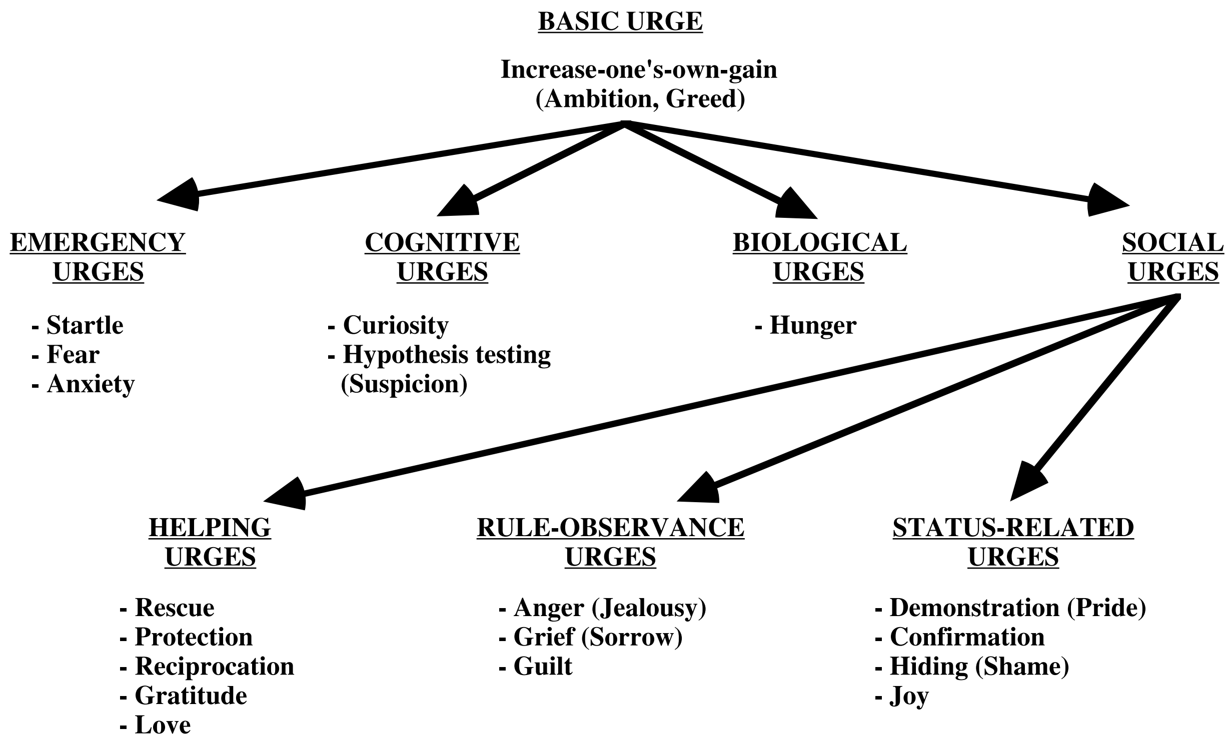


**Figure 1.** Toda's System of Urges (Adapted from Toda 1982, 1985)

In a «Darwinian world», maximizing one's profits is the rule (INCREASE-ONE'S-OWN-GAIN URGE), and cooperation is always a tricky and risky business. In order to gain profit from cooperation, an organism should take risks, and there should thus exist some built-in incentive to help others (RESCUE and PROTECTION URGES), collaborate with them (RECIPROCATION and GRATITUDE URGES), and eventually get deeply involved in long-term mutual plans (LOVE URGE). On the other hand, there should be mechanisms to prevent self as well as others from cheating and breaking rules (ANGER, GRIEF and GUILT URGES). Furthermore, since the ability to protect self from cheaters and to attract others as partners often rests on status and reputation, there should also exist some incentive to advertise one's valor (CONFIRMATION and DEMONSTRATION URGES), and to hide when one is deserving of blame (HIDING URGE). Finally, there should also be some way of rewarding increase in status, and success in joining with cooperating others: that is precisely the function attributed in the theory to such an urge as JOY.

## Some Problems with Toda's System

Interesting as this theoretical proposal might be, one nevertheless feels some uneasiness with aspects of the structure and with certain of the urges identified. Thus, FEAR appears in a class of its own (EMERGENCY URGES), while one of its useful function is to call upon the help of others, just as for GRIEF (which rather appears with RULE-OBSERVANCE URGES, such as ANGER and GUILT). On the other hand, Ekman, Friesen and Simons (1985) made a convincing argument that the STARTLE reaction is more reflex-like, and should not then be counted as an emotion. Ortony, Clore and Collins (1988) considered CURIOSITY, as well as surprise, interest or attention, not as emotions proper, but as cognitive accompaniments to other emotions, a view shared with a few researchers in the psychology of emotions (Johnson-Laird and Oatley 1989; Stein, Trabasso and Liwag 1993). Also, HUNGER, which in most psychological theory is rather seen as a «need», is more or less lumped here with emotions, a rather unsatisfying decision.

Finally, many terms refer to behaviors or «action tendencies» (Frijda 1986), that are mere components of an emotional episode, rather than to the emotions themselves. Contrast for instance the urge of ANGER with others, such as RESCUE or DEMONSTRATION. It is clear that these two do not deal with the same level of conceptualization: these terms would rather correspond to some preferred ways of reacting from the list of actions attached to a given URGE, than to the whole process of detecting a problematic situation and deciding how to handle it adaptively. In the model, they appear at the same level as ANGER or FEAR, while they rather belong conceptually to such behavioral accompaniments as FIGHTING or FLEEING. In the following sections, we will thus propose a few modifications to Toda's system of urges that could insure a more coherent and more satisfying account of emotions, while preserving at the same time the gist of his beautiful insight.

## A Basic Difference between Needs and Emotions

The first useful distinction to make is between motivation and emotions. Motivation is more or less the psychological analog of *force* in Physics. It is an hypothetical construct that accounts for any change in «psychological inertia»: if a behavior is suddenly arrested or modified, or if it is sustained in spite of fatigue or obstacles, then one could infer that some motivational «force» is at work (Valleyrand and Thill 1993). Emotions occupy a subset of the whole motivational field, as do needs, and possibly other subclasses of motivation systems. Aubé and Senteni (1995, 1996a, 1996b) proposed that motivation essentially has to do with resources management: it refers to the set of systems - *some of which necessarily have to be built-in* - that insure access to resources of survival and to their control. These authors also introduced an important distinction between two different kind of resources. A lot of them, such as food, water, shelter, etc. could be obtained directly by the organism itself: they are called *first-order resources.*

But sometimes, access has to be mediated by a cooperating agent. Suppose that two Chimps know from watching and experience that some delicious insects nest under a heavy piece of rock. None of them can lift the rock up alone, but together they could. Clearly there is an additional resource involved here, besides the food itself. One may first be tempted to identify it with the agents themselves, but non cooperating agents would certainly be of no use! Likewise, a newborn can only get access to food, water or protection through the willingness of its parents or caretakers to provide them. But irresponsive (and irresponsible) parents would be totally useless, and *the proper resource here has to do with the attachment structure that binds parents and offsprings* into a supportive unit. Aubé (1997, 1998) has used the concept of «commitments» to specify and describe the peculiar resources that rest upon helpful and reciprocating others, and has termed them *second-order resources.*

Now, these peculiar resources being critical for survival in social species, there has to be motivational structures to promote access to them, and to insure their management. The distinction proposed between first-order and second-order resources automatically provides a very clear and very precise criterion for distinguishing between the two main classes of motivations, NEEDS and EMOTIONS. Needs - such as hunger, fatigue or thirst - are the motivational control structures that insure access to and management of first-order resources. Emotions - such as anger, guilt or pride - are the motivational control structures that insure creating, promoting and protecting commitments, that is second-order resources. Figure 2 illustrates the relations between these two control structures.

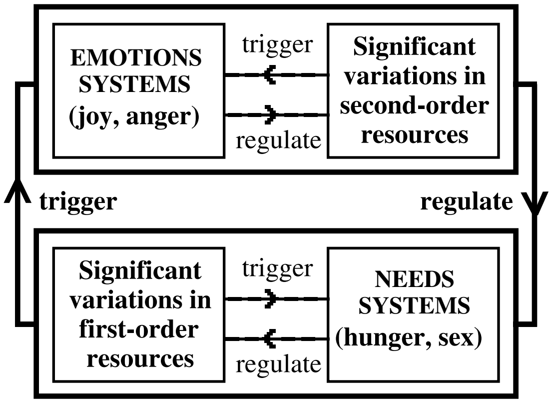


**Figure 2.** Two Layers of Control for Resources Management (Adapted from Aubé and Senteni 1996b, and Aubé 1997)

It is believed that emotions appeared later than needs in evolution, following the requirements of social interaction, and that they were superimposed upon the control layer for the management of first-order resources, much in the spirit of Brooks' subsumption architecture (Brooks 1991). Consider for example the pleasure you get from finding by yourself a valuable objet (food, money, jewell...) and the much greater one that comes from receiving the same object from a friend or a close relative. A sensible difference is indeed invariably felt: in the «finding scenario», you merely get access to first-order resource, while in the «gift scenario», you create, in addition, a new commitment (second-order resource), or you strengthen an old one. Dog owners well know the difference in sheer pleasure that is manifested by their pet when they take them for a walk - a kind of gift or reward that strenghtens mutual affection - as compared to the same stroll taken by the dog alone. The very clear difference in the joy felt comes from the additional resource thus gained. Hence the two control structures work «hands-in-hands» to facilitate access to the desired resources. When the more primitive needs are not sufficient, a call is made to emotions so as to secure access via the help of a committed agent. And in the long run, commitments generally result in a significant increase in first-order resources.

## Emotions as Commitments Operators

We thus propose either to eliminate such urges as startle, hunger or curiosity from Toda's original list, and to restrict the term to «emotions-as-commitments-operators», or to equate Toda's urges more generally with «motivations» rather than with «emotions» proper. Our proposal may seem radical in restricting emotions to the social and interactive domain, but actually, most researchers in the psychology of emotions do acknowledge this imbalance towards the social (Baumeister and Leary 1994; Fisher, Shaver and Carnochan 1990; Lazarus 1991; Oatley and Johnson-Laird 1987; Pinker 1997; Scherer and

Tannenbaum 1986; Simon 1967), as we have seen Toda doing it himself. Our model presents the advantage of clarifying the situation from a strong and coherent theoretical standpoint, yet without excluding NEEDS from the motivation field, but by associating them with the kind of resources management they seem to have been patiently tailored for. Our theory also postulate that different reactions that have been lumped under the same label - such as different types of fears or phobias - actually belong to different control mechanisms, with different evolutionary histories (Ledoux 1996; Ohman 1986, 1993; Pinker 1997).

Since emotions in our model are specifically triggered as handlers or operators whenever some commitment is seriously at stake, we see commitments as the critical hidden variable behind any emotional reaction, just as the concept of force in physics is understood as the general cause to be invoked whenever a change in motion is observed. You want to understand why such and such an agent had a given emotional reaction? Find the commitment involved! Reciprocally, any significant modification (weakening, strengthening...) concerning a known commitment should raise an emotion, even if its expression is not immediately apparent. By resting so heavily upon the concept of commitment, we have to specify more clearly what it encompasses, and eventually how it should be implemented.

Commitments within animats should be represented as fairly dynamic entities, such as computational agents or «actors», so they could «watch for» significant events that could bear consequences upon their being fulfilled or broken. As such, they should register as instances variables who is committed to whom, about what, until when, as well as the conditions of satisfaction and of revocation. «To whom» also means keeping a count of the levels of commitment one has with frequently encountered others. We do not consider attachment as an emotion, but as a commitment structure, or as «stored commitments», in a similar way that first-order resources could be accumulated and stored for later use. «About what» typically refers to quantifiable first-order resources that the commitment insures access to, or to appropriate tasks for getting these resources. «Until when» means that a commitment is generally attached a precise schedule for its fulfillment. The notable exceptions have to do with attachment or power structures, which rest essentially, as we mentioned above, upon stored commitments, the schedules of which could combine to extend the conditions of fulfillment for an arbitrary long period of time: love or submission could indeed have long lasting effects, and thus recurrently recruit a large variety of emotions as regulators.

## Mapping Social Urges onto «Emotions-as-Commitments-Operators»

Our conception of emotions being contingent upon the concept of commitments as second-order resources, it imposes certain constraints upon the way these handlers or decision modules should be elicited. First of all, as motivations that react essentially to variations in resources, emotions are doomed to fall into two broad classes, *positive* and *negative*, according to whether there has been a significant gain or loss. Second, as commitments involve interacting agents, it should matter whether *self* or *others* are responsible for the gain or the loss incurred, since one of the function of emotions is to act, through various behavioral expressions, upon the responsible agent as the cause of the variation.

Finally, when no responsible agent could be identified or acted upon, there is still the possibility to call to committed others for help and support. In this case, though, there is a significant temporal dynamics, and distinguishing between *actual* and *anticipated* gain or loss, makes for the difference between JOY and HOPE, or between FEAR and SADNESS, with different resolving strategies. Figure 3 thus depicts the elicitation structure for the main families of emotions, and is pretty consonnant with many proposals from appraisal theorists (Ellsworth and Smith 1988a, 1988b; Frijda 1986; Frijda, Kuipers and ter Schure 1989; Ortony, Clore and Collins 1988; Roseman 1991; Roseman, Aliki Antoniou and Jose 1996; Scherer 1988, 1993; Smith and Ellsworth 1985) and from attribution theorists (Weiner 1982, 1985; Wong and Weiner 1981). As mentioned, each cell incorporates whole families of emotions, rather than single ones, so that emotions similar in shades and tones, such as guilt, shame, regret, remorse, etc., have been lumped together. Aubé (1997) has thoroughly argued that these eight categories of processes, clearly and carefully carved as commitments operators, would provide a satisfactory account for most of emotional behaviors.

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

**Figure 3.** The Elicitation Structure for Basic Emotions (Adapted from Roseman et al. 1996, and Weiner, 1985)

In each cell, we 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. GRATITUDE would be associated with the receipt of some goods or favors from someone else, but if generalized over the whole person, this feeling could well turn into love and ADORATION for the benefactor. PRIDE accompanies specific positive outcomes attributed to self, but CONCEIT would come out when it is the whole self that is praised and seen as responsible for all the good that is resulting. 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. HOPE and FEAR would characterize anticipated positive or negative outcomes, but OPTIMISM or ANXIETY would result from generalizing these feelings over longer periods and less specific classes of events. 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.

Most of Toda's «social urges» thus fit pretty well in our scheme. Figure 4 establishes the correspondance between the two approaches. From Toda's list, only RESCUE, PROTECTION and RECIPROCATION have been left out, because they rather represent the kind of reactions that are attached to «genuine» emotions, such as FEAR, GRIEF, or LOVE. It should be mentioned that in this figure the terms in parentheses refer to synonyms or variants. Thus Toda uses interchangeably DEMONSTRATION or PRIDE, GRIEF or SORROW, and HIDING or SHAME. On the other hand, JEALOUSY is considered by this author as a mere variant of ANGER. In our theory, though, jealousy would rather qualify a complex scenario wherein many different emotions (such as anger, fear, sadness, guilt) could intervene, together or in succession, depending on which commitment is threatened by whom.

| | **VALENCE** | | | |
|---|---|---|---|---|
| | **POSITIVE** | | **NEGATIVE** | |
| **AGENCY** | **actual** | **anticipated** | **actual** | **anticipated** |
| **none** | JOY | | GRIEF (SORROW) | FEAR ANXIETY |
| **others** | GRATITUDE LOVE | | ANGER (JEALOUSY) | |
| **self** | DEMONSTRATION (PRIDE) CONFIRMATION | | HIDING (SHAME) GUILT | |

**Figure 4.** Mapping Toda's Urges upon the Elicitation Structure for Basic Families of Emotions

Another significant point of departure is our inclusion of FEAR and ANXIETY as commitments operators, while Toda did not consider them as «social urges». But quite possibly we are both right! As Pinker (1997) pointed out, «fear is probably several emotions. Phobias of physical things, of social scrutiny, and of leaving home respond to different kinds of drugs, suggesting that they are computed by different brain circuits (pp. 386-387). Öhman (1986, 1993) has also provided evidence that human fears should be classified into different categories, some of which rest upon much simpler and evolutionary older structures. It is thus likely that some of the reactions that have been identified as fears are more primitive in nature, and rather belong to the category of needs, insuring access to the first-order resources of security and self-protection. Members of nurturing species, though, inherited a more complex control structure which promotes protection by committing others into help through the use of distress cries and alarm calls.

Finally, HOPE is the only emotion from Aubé's proposal that is not considered at all as an urge by Toda, but it is also the emotion that has been the less studied by researchers in the psychology of emotions, so little in fact that Lazarus (1991) has even classified it as a problematic emotion.

## Conclusion

We have made a brief analysis of Toda's urges theory and found many promissive ideas for the design of *emotional animats*. Yet we noticed certain difficulties with aspects of the structure and some ambiguities with certain of the urges identified. We then compared with Aubé's theory of «emotions-as-commitments-operators», and found striking similarities between the two approaches, especially when one considers social urges which constitute the crux of Toda's argument. The concept of commitment was introduced as a special kind of resource, requiring a special kind of motivational control structure. It thus helped considerably in clarifying the set of urges or emotions that are mandatory, if one is to build adaptive cooperating animats, capable of surviving within a complex social environment, mostly populated with others animats of similar design.

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