Simple Concepts for Complex Systems: A Model of Emotions as Energy Management Systems Adapted to Social Life

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Abstract

Complex systems require that new concepts be developed or be used in novel ways if they are to be understood fully. We have been working on a computational theory of human and animal emotions inspired in the concepts of complex systems and the methodology of agent-based modeling [3]. We treat organismic agents as indivisible and incompressible entities as is done in particle physics. However, contrary to what is done in particle physics, agents in our model have internal structure and multiple types of forces are exert on them.

The forces exerted on each agent are driven by the emotional mechanisms of the agent's cognitive architecture. These mechanisms respond to external stimuli created by the presence of other agents. Namely, each agent is subject to attraction and repulsion forces created by the presence of all other agents in the arena. The magnitude of these forces is dependent of the internal structure of the agents. For each pair of agents there are several forces involved, one for each emotion considered. This way, each emotional mechanism works as a reactive behavioral module that is used by the organism as a strategic component. Each such strategic component allow the agent to manage effectively the stock of stored energy used to perform survival and reproduction activities [1].

To model the attractive/repulsive effects of each emotional sub-system we have introduced several new concepts that can be seen as laying at the interception between the physical, the natural, and the social sciences. The concept of *energy distribution* is equated with the amount of energy stored by the organism to be used to perform work. This energy distribution has both an aggregate quantity as well as a quality. Computationally speaking, we model this energy distribution simply as an array of scalar values each for a energetic component. Comparing this concept with more well know concepts used in the psychology we can say that the energy distribution determines individual personality, character, and/or preferences.

The concept of *(energetic) affinity* represent a measure of resonance between the energetic distributions of two agents. We equated affinity with complementarity. This complementarity is measured as the difference in *subjective well-being* that an observed agent creates to the observer when compared to the previous well-being of the observer. Subjective-well

being is operationalized as a measure inversely proportional to the variance of the value of the energy components of the agent. Thus, we endorse a holistic perspective, and assume that the well-being of an organism depends an adequate balance of energy values in all its sub-systems [2].

The model captures the working of several emotions. The first to be investigated where *seeking*, *fear*, *love*, and *discrimination* [5, 6]. To specify the magnitude of the forces we use a mathematical expression that depends on four elements: 1) the average energy value of the observer (average quality) M_i; 2) the average quality of the agent observed M_j; 3) the (square of the) distance between the observer and the observed agent d_{ij}^2; 4) the affinity between the observed and the observer AF_{ij}. The second and third element is used to compute the intensity of the stimulus produce by the observed agent and detected by the observer, i.e. it is a sensation magnitude S_{ij} (in psychophysical sense of the word). The first and the fourth element are used to compute the response to this stimulus, i.e. it is a gain G_{ij}. To formalize this, we write the magnitude of the emotional force generated by the emotional mechanism k in agent i in response to the presence of agent j as: $FE_{ijk} = S(M_j, d_{ij}^2) \cdot G(M_i, AF_{ij})$.

The concrete force magnitude generated by each emotion depends on the form of functions for stim-AFijulus intensity and gain. Our intuition made us consider the following hypotheses:

- *Seek:* This emotion is used for an agent to approach energy sources or conspecifics that can potentially provide energy sources. Therefore, an agent is more motivated to seek individuals of high quality since they are more likely to provide energy. An agent is also more likely to provide energy is there is a high affinity with the recipient. Addi-AFijtionally, an agent is more likely to search for energy sources when its internal energy is low. Formally, we write:

$$FE_{ij,seek} \propto \frac{M_j}{d_{ij}^2} \cdot \frac{1}{M_i} Max(0, AF_{ij})$$

- *Fear:* This emotion is used by an agent to avoid conspecifics that can be hostile to the agent and may induce a loss of energy. We assume that an agent is motivate to run away due to fear from other agent the higher the quality of that other agent and the lower the affinity value between the two agents. Additionally, an agent is more likely to search for energy sources when its internal energy is low. Formally, we write:

$$FE_{ij,fear} \propto -\frac{M_j}{d_{ij}^2} \cdot \frac{1}{M_i} Max(0, -AF_{ij})$$

- *Love:* This emotion is used by an agent to give energy to other agents it cares about. This may include kin or other individuals involved in reciprocity relations with the agent. We assume that agents are motivated to give energy the higher their energy stock and the lower the energy level of the recipient. Moreover, high affinity makes agents more motivated to give energy. Formally, we write:

$$FE_{ij,love} \propto \frac{1}{M_j} \frac{1}{d_{ij}^2} \cdot M_i Max(0, AFij)$$

- *Discrimination:* This emotion is dual to seeking, and is used by an agent to avoid low quality individual who might demand energy from the agent. We assume agents are more likely to avoid others the lower the quality of the other agents, the higher its own quality, and the lower the affinity between the agents. Formally, we write:

$$FE_{ij,descr} \propto -\frac{1}{M_j}\frac{1}{d_{ij}^2} \cdot M_i Max(0, -AF_{ij})$$

Other emotions can be accommodated in our model, but we limited our initial modeling to the above four emotions to simplify analysis. Using our model it is possible to study what agent structures and patterns of interaction lead to stable social structures and why. We consider three types of study: 1) Settings involving only two agents are used to verify model correctness [4]; 2) Settings involving three agents are used to observe the common pattern of interaction and study non-linearities; 3) Settings involving N agents are used to study the formation of local spatial clusters (groups) and measuring their stability.

We conclude our paper by advocating that a computational oriented approach inspired in the theory of complex system is a very valuable approach in the study of human and animal emotions. Moreover, this approach can provide considerable more rigor and insight than is possible using verbal theories of emotions.

References

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