Regulated Activation Networks: A computational model of emotion, cognition, and personality

PhD Research Project Proposal within the FP7 project ConCreTe

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July 10, 2013

1 Motivation and Context

Many human cognition questions still lack an operational computational model counterpart allowing for simulation and testing. How does sensory input data, and any thought or feeling in general, trigger some memory, remind us of some (possibly apparently unrelated) other idea, or spark our creativity? How do our individual thoughts, our emotional and cognitive states, and their continuous dynamic flow, shape what we will feel, pay attention to, and think about next, at several degrees of consciousness? How do the different regulatory patterns in this dynamic flow relate to distinct personality traits? How can we simulate these dynamics in a computer, and relate their parameters to personality, psychopathology and creativity patterns?

Our team is currently involved in the launch of a new FP7 STREPS project on Computational Creativity, starting Oct 1st 2013, called ConCreTe (Concept Creation Technology). The project involves, besides University of Coimbra, 5 other academic institutions (Queen Mary College of London, University of Twente, University of Helsinki, Josef Stefan Institute, Slovenia, Complutense University of Madrid) and a company based in London (Chatterbox Analytics, Ltd). As a whole, the project will investigate computational models for the representation and production of previously unseen concepts, and apply them in context of various forms of creativity (for example, design, narrative and poetry). The consortium will explore the central framework of a simulated cognitive architecture [11], based on a combination of Baars' Global Workspace Theory [1], principles from Shannon's Information Theory [8] and principles from Peter Gardenfors' Theory of Conceptual Spaces [4], making explicit the relationship between creativity and consciousness, and forming an environment within which different kinds of Concept Generators can work competitively in parallel and be compared.

In the context of the ConCreTe project our main contribution will be the development of a computational model which will act as a Concept Generator, but the ultimate goal of the Regulated Activation Networks (RANs) model is to allow us to better understand and simulate the patterns of dynamic co-evolution of perception, feeling, emotion, reasoning and creativity which are central components of the human psyche, thought processes, personality traits, and even psychopathologies.

The main originality of the proposed research project, and its expected results, lies both in the hybrid nature of the computational model to be developed combining together symbolic and sub-symbolic representations, and in its dynamic self-regulatory character. Together, these characteristics will allow the developed model to capture a wide range of psychological and cognitive human features.

2 Background

Knowledge Representation (KR) and reasoning formalisms are at the very core of how we develop artificial intelligence systems, and more and more contribute to how we understand our own human intelligence. Classical approaches to concept representation rely on symbolic and logic-based formalisms. On the one hand these formalisms have always been tightly related to the mathematical foundations of computer science, but on the other they have laid down the theoretical grounds upon which practical domain modeling and problem solving applications have been developed. These logic-based approaches [10], including classical first order, default and non-monotonic, auto-epistemic, modal and temporal logics have provided tools for solving computational problems such as combinatorial search, constraint satisfaction, abduction, diagnosis and planning, and more recently, to interconnect semantically rich descriptions of concepts and relations in a tangled network we call the Semantic Web. Going in the other direction, trying to understand or build brains from the bottom up, neural networks, and more generally, connectionist models, have been developed which allow for sub-symbolic KR, usually associated with pattern matching or classification. Others explore the mathematical concepts of probability, such as Bayesian Networks, and more informally, general fuzzy logic and semantic networks.

Since the late 1990s, with the seminal work [6] of Picard, there has been a growing interest in affective computing and the computational modeling of emotions and all the related challenges [7]. In humans, creative states are usually associated with particular emotional states. The instant-to-instant changing perceptions, the current emotions we experience, and the thoughts that capture our attention, all merge in a cognitive state or context, which conditions, or regulates, how and which other thoughts, emotions and perceptions we give more or less attention to, and which other we create anew, forming a perpetual loop, enriched with further sensory input, or withered with its absence.

While there have been serious efforts [3, 2], with some degree of success, in integrating the connectionist KR models with symbolic logics formalisms, there are still no models for representing and simulating, in a unified manner, the fluctuating and self-regulating dynamic character of the perceptional, emotional, cognitive and attentional state of an agent from which new concepts and behaviors can be created.

3 Contribution and Expected Results

The main goal of this research project is to develop a computational model allowing for the representation and simulation of the dynamic co-evolution of some aspects of the human psyche such as perception, feeling, emotion, memory and reasoning. The model should be applicable to specific use cases allowing the reliable simulation of creativity processes, behaviors and thought patterns typical of some psychopathologies and personality traits.

The work is expected to produce several scientific contributions, either individually and in collaboration within ConCreTe, at several levels:

- A thorough analysis of the State-of-the-Art in Cognitive Modeling and Computational Psychology (e.g., including [9]) methods, models and tools;
- The formal description of the new emotional and cognitive state model, the Regulated Activation Networks;
- The identification of the general properties of the new RAN model and comparison with other existing cognitive models;
- An implementation of a prototype of the RAN model which can be reliably used for simulation of the mentioned aspects of the human psyche;
- The enrichment of the RAN model with various knowledge representation and reasoning principles such as symbolic, and bayesian-like reasoning;
- The specification and exploration of the use case application of the model focusing on simulation of creativity;
- The evaluation of the model regarding plausibility and usability of the results it produces in the creativity focused use case – the evaluation phase will resort to other established models of human cognition

from the Psychology and Computational Cognitive Modeling fields as comparison basis.

4 Research Directions

This model will be a Regulated Activation Network where each semantically-annotated node has a dynamic activation state which changes over time. Simple concepts can be represented by individual nodes whereas complex ones may require a subnetwork. The topology of the semantic network of concepts can be dynamically changed, and their connection-weights updated. Each node has an activation level which is spread to its neighbors (as either excitation of inhibition) and decays locally over time towards a learnable baseline. The dynamic character of the time-sensitive changing of activation state in each node overcomes the limitation of traditional semantic networks in modeling the passage of time.

The local activation level of each node will also be used to model the priming effect thus capturing a mental context which can include an emotional mood. The spreading itself is dynamically regulated by the output activation of other nodes which either exacerbates or inhibits the activation it receives. This regulation, different and independent from the usual weights in connections, is directly inspired by known neuro-anatomical facts such as the axoaxonic synapses where an axon of a neuron ends, not in the dendrites or the soma (body) of another neuron, but on one of its "input" axons from other neurons regulating its incoming signal; and by the wide-range regulatory neurogliaform cells [5] whose "bushy" axons terminate, in a significant proportion of cases, in the extracellular space releasing a "cloud" of neurotransmitters that influence the nearby neurons without a physical synapse.

The dynamic regulation of spreading activation will be used to model emotional states and moods, selective attention, associative memory, and other psychological features. The inhibitory regulation, when applied to sensory perception representing nodes can be used to model states like deep sleep, or anesthesia, and when combined with the exacerbatory regulation of activation between other cognitive and emotional nodes can simulate dream- and delirium-like states which are common in highly creative states and certain psychopatologies.

The detection of novel patterns in inputed stimuli may be parametrized by independent novelty detector mechanisms, possibly related to information theory. Our model will use the degree of novelty to implement a selective conscious attention mechanism by giving extra activation salience to the nodes related to the novel inputs, while simultaneously inhibiting conceptually competing (i.e., semantically mutually exclusive) nodes.

This model will take a hybrid knowledge representation approach by combining the symbolic (logic-based) semantic annotation of nodes with non-symbolic theories, as found in artificial neural networks and Bayesian networks, fusing the two in a unified manner: the model assumes there are only weights regulating how much of the original activation gets passed on, and how fast it does decay within a node before the next spreading round. The semantically-annotated most activated nodes can then be selected for a logical reasoning round simulating a conscious deliberate pondering over the set of ideas that emerged from the sub-conscious spreading of thought and emotion activation.

The inference procedure in this model is thus a combination resulting from the alternation of the usual regulated propagation of activation in the network, which can be injected in selected nodes to begin with, and the symbolic logic inference which results in the injection of yet more (or less) activation to the logical "conclusion" nodes. The network might come to a stable state, an alternation between several states, or a chaotic progression through states as in a complex dynamic system, which can itself be considered a creative generator of novel patterns.

5 PhD Researcher Profile

The successful applicant will have a background in artificial intelligence and/or cognitive modeling and a keen interest in Psychology, and will be a competent programmer, willing to learn new programming languages if necessary. He/she will have adequate mathematical skills to understand Shannon Information Theory, Artificial Neural Networks, and working competencies of symbolic/logic-based knowledge representation and reasoning formalisms. He/she will be a competent communicator, both formally and informally, and will be prepared to collaborate with and travel to partner institutions for extended working periods (not normally longer than 2 weeks). He/she will also be willing to collaborate with other EU projects fund from the same call (Lrn2Cre8, WHIM, and COINVENT) and the associated coordination and support action, PROSECCO. He/she will integrate the Cognitive and Media Systems Group[1] of CISUC [2] and will use resources available in one of its laboratories. The selected applicant may be awarded a research grant given by ConCreTe.

References

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