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Computer-assisted creativity: Emulation of cognitive processes on a multi-agent system

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ABSTRACT

For creativity to be computed, it is paramount to understand the cognitive processes involved, which have been elucidated by either surveying creative people or discovering regions of the human brain that activate during creative endeavors. From this scattering, the author proposes a holistic framework to describe them and their interaction. Hence, creativity can be regarded as a meta process which coordinates autonomous cognitive processes such as planning or divergent thinking. To represent the interplay of cognitive processes around creativity, models are developed in the Agent Unified Modeling Language (AUML). Then, the execution of each process is delegated to autonomous agents and a global coordination protocol is devised. The implementation of the MAS is done on the JADE platform. Two modules of the resultant system are exemplified: *opus planning* and *divergent exploration*. The coordination protocol is also presented. The domain in which the software system is tested is the creation of musical pieces.

1. Introduction

Human beings posses the ability to visualize and materialize innovative constructs, either artistic or scientific, tangible or intangible. This is broadly labeled as creativity. Artificial Intelligence theorists and practitioners question whether it is possible to compute creativity. One line of thought argues that any computer system must be considered creative when it goes beyond doing the bidding of a programmer, that is to say, when the system transforms the search space embedded in the algorithms or when the idea produced by the system was not influenced by a human counterpart (Jennings, 2010). On the other hand, in computer-assisted creativity there is a direct interaction between the processing system and the human creator. The human being changes parameters of certain algorithms until the resultant *opus* pleases her/him. Nevertheless, to compute creativity it is paramount to understand its mechanics i.e. the cognitive processes involved.

To elucidate the cognitive processes around creativity, two approaches have been followed. One favors surveying creative subjects such as musicians, scientists or artisans. The other is based on analyzing the actual activation of brain areas by means of Positron-Emission Tomography (PET), Electro Encephalograms (EEG) and similar scanning techniques. Even though such findings have been reported separately, they lead to regarding creativity as a meta process i.e. a process that triggers and coordinates autonomous cognitive processes. Planning, divergent thinking, accessing to knowledge stored in long-term memory, and selective attention are among them.

To compute creativity, the author proposes a model based on cognitive processes and their relations. The resultant system is implemented on the agent-oriented approach because autonomous agents are fit to be responsible for executing each cognitive process. In this sense, agents are enabled possess the necessary intelligence and algorithms that emulate them. Coordination among agents is achieved by a communication protocol. The creative subject makes decisions that concern primarily with the outcome of each autonomous process. Altogether, the multi-agent system and the creative subject interact to complete the meta-process of creativity.

This paper is organized as follows. Section 2 contains theoretical notions surrounding creativity. Section 3 presents the cognitive processes involved in creativity. Next, the agent-oriented models are described in Section 4. Then, the actual performance of the software is exemplified in Section 5. Two modules are presented i. e. *opus planning* and *divergent exploration*. A discussion comes in Section 6. Finally, conclusions and future work are drawn. Creation of musical pieces is the chosen domain to exemplify the proposals.

2. Theoretical basis

Some notions are borrowed from Dietrich (2004) to elaborate on deliberate and spontaneous creativity.

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2.1. Deliberate creativity

This type of creativity is the result of deliberate information processing, consequence of effortful, constructive problem solving. This occurs due to the activation of the prefrontal cortex of the brain, which plays a major role in complex cognitive processes such as mental planning of future activities, selective attention, categorization, or supervision of working memory (Smith & Kosslyn, 2007). Boden's influential ideas that creative thinking is the conscious exploration and transformation of a conceptual space (Boden, 1998) concurs with deliberate creativity. Insights of what a conceptual space is and to what extent it can be transformed are presented in Graeme (2006). Professional scientists, artists, and musicians make a living out of conscious exploratory activity i.e. by manipulating a conceptual space in their domain. Information that is retrieved deliberately and is explicitly available for conscious manipulation is, nevertheless, restricted to the capacity limit of the human's working memory. Findings appear to support the contention that creative behavior is achieved through focused work in an area of considerable personal interest, resulting thus, in greater task commitment (Plucker & Zabelina, 2009).

Deliberate creativity can be enabled by computer systems that permit the conscious manipulation and transformation of conceptual spaces.

2.2. Spontaneous creativity

It is also stated in Dietrich (2004) that spontaneous creativity is not initiated by prefrontal cortex activation associated to preconceived mental paradigms (or knowledge). Since this type of activation is not guided by the prefrontal cortex, information processing is not restricted to the capacity limit of working memory. According to Smith and Kosslyn (2007) automatic processes are neither initiated nor operated deliberately. Paradoxically, even without the guidance of the integrative prefrontal cortex, spontaneous ideas are unlikely to be irrational because the brain attempts to make sense out of the activation by means of the prefrontal hypo-function. A coherent something emerges, presumably due to an underlying associative process. This type of creativity might be closely related to imagination, since imagination is an attempt of the brain to integrate the self with the environment from which emerges an experience of the world by merging sensory data and filling gaps (Pelaprat & Cole, 2011). This occurs even though *images* might not reflect conscious data processing. Spontaneous images depend on the phylogenetic development of human beings, the individual's cultural experience, and a process of *active reconciliation* (Pelaprat & Cole, 2011). Associative combinational activations during altered states play a vital part in the creative process. Curiously, the *frontal lobule syndrome* is a conduct alteration due to a lesion of the prefrontal cortex. It is characterized by lacking self-control (inability to see one self as part of the world), deficiencies to change the focus of attention (sometimes resulting in compulsive-obsessive behavior), and impossibility to planning (Smith & Kosslyn, 2007). However, the spontaneous creative process is not related to brain damage but to a certain capacity, explicit or implicit, to inhibit consciousness.

Even though spontaneous creativity occurs, how can it be facilitated by computer programs? Further questions arise. Is creativity achieved only deliberately or only spontaneously? Are these types of creativity mutually exclusive? The author of this article contends that both, deliberate and spontaneous creativity take place in a combined, hybrid way, where these two apparently conflicting notions of creativity can be reconciled in a framework called *Human in the loop*.

2.3. Human in the loop creativity

Muller elucidates an informal model intended to enhance creativity, by using computer-based tools, which fits into human in the loop creativity (Muller, 1993). The model, thought up after having interviewed creative people, highlights the dynamic iterative nature of the creative process. Creativity is triggered by an impulse or motivation to solve a *thorny problem*. An initial, vague solution appears, which is revisited as the creative process continues, leading to *interim creations*. A final creation is the one on which a decision is taken. Success depends on the correct setting, retention and modification in the creator's mind of the project's constraints. These processes are deliberate and conscious. However, it is suggested that once the problem is identified and the motivation is alive, the mind *appears to be primed* to watch out for anything that could be thought as a useful outcome even though it was not devised a priori. This clearly adjusts to spontaneous creativity.

As reported on a study of cognitive styles, iterative work over a creation influences creativity (Eaglestone, Ford, Holdridge, Carter, & Upton, 2008). The study consisted in surveying electro-acoustic musicians composing with software tools. Cognitive styles are defined as tendencies displayed by individuals to adopt a particular type of information processing strategy. Two styles were devised: holists and serialists. Holists tend to adopt a global approach to learning, examining, and concentrating on a broad plan into which detail could be added. Parallel, gestalt-type processing is characteristic of the holist subjects. Serialists tend to use a predominantly local learning approach, examining one thing at a time, and concentrating on separate topics and the logical sequences linking them. Despite these different planning strategies, holist and serialists carry an iterative process which leads them to assess, select and discard *interim creations*. This is called *refinement* by the authors. A creative activity is ultimately resolved by a *synthesis* mechanism. The study leads to witnessing how deliberate and spontaneous creativity occur while manipulating computer-assistance tools. The authors question if software interfaces could be better suited to composers and hence provide more fertile environment for their creativity.

Henceforth, the creative subject must manipulate a conceptual space repeatedly, either as a process of *imagination* or as conscious usage of a given tool i.e. a computer program. With every iteration the initial conceptual space is transformed. The human's working memory keeps whatever information is needed and gathers data already stored in long-term memory, such as declarative knowledge or memories associated to emotions, which influence how to transform the conceptual space. Regardless, the individual discerns what is suitable and what is not, maintaining some parameters while spurning others. Being these processes closely related to the activation of the prefrontal cortex, it can be said that deliberate creativity takes place. As the resultant conceptual space is shaped on-line, an *interim creation* surges. Like it or not, the individual comes up with a design. Yet, as iterations over a focused work continue, the guidance of the prefrontal cortex activation diminishes, promoting associative combinational creativity, where non preconceived ideas are aggregated to transform every interim creation. When the human being values the resultant opus as satisfactory, this hybrid process halts.

It can be said that deliberate creativity is facilitated by objective manipulation of a conceptual space. Also, the iterative process that triggers spontaneous creativity can be promoted by computer programs that transform repeatedly interim creations, while a creative subject judges their value. This iterative activity leads to preserve, change, combine or erase parameters as thought convenient. Therefore, computer-assisted software must facilitate both, deliberate and spontaneous creativity. To do so, cognitive processes associated to creativity, as well as their complex interplay, must

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