Machine Learning and Cognitive Algorithms for Engineering Applications

Leonid Perlovsky, Harvard University, Cambridge, MA, USA
Gary Kuvich, Open Group Master Certified IT Architect, Brooklyn, NY, USA

ABSTRACT

Mind is based on intelligent cognitive processes, which are not limited by language and logic only. The thought is a set of informational processes in the brain, and such processes have the same rationale as any other systematic informational processes. Their specifics are determined by the ways of how brain stores, structures, and process this information. Systematic approach allows representing them in a diagrammatic form that can be formalized. Semiotic approach allows for the universal representation of such diagrams. In that approach, logic is a way of synthesis of such structures, which is a small but clearly visible top of the iceberg. The most efforts were traditionally put into logics without paying much attention to the rest of the mechanisms that make the entire thought system working autonomously. Dynamic fuzzy logic is reviewed and its connections with semiotics are established. Dynamic fuzzy logic extends fuzzy logic in the direction of logic-processes, which include processes of fuzzification and defuzzification as parts of logic. The paper reviews basic cognitive mechanisms, including instinctual drives, emotional and conceptual mechanisms, perception, cognition, language, a model of interaction between language and cognition upon the new semiotic models. The model of interacting cognition and language is organized in an approximate hierarchy of mental representations from sensory percepts at the “bottom” to objects, contexts, situations, abstract concepts-representations, and to the most general representations at the “top” of mental hierarchy. Knowledge Instinct and emotions are driving feedbacks for these representations. Interactions of bottom-up and top-down processes in such hierarchical semiotic representation are essential for modeling cognition. Dynamic fuzzy logic is analyzed as a fundamental mechanism of these processes. Future research directions are discussed.

Keywords: Cognition, Dynamic Logic, Emotions, Hierarchical Diagrammatic Representation, Implicit Symbols, Knowledge Instinct, Semantic and Syntactic Streams, Semiotics Models

1. INTRODUCTION

Mind processes were studied since civilization started. But because thought is tightly coupled with language and logic, such studies were reduced mostly to language and logic until relatively recent rise of cognitive and information sciences (Wang, 2012a,b; Wang et al., 2011).

Ancient Greeks intensively studied and promoted logical ways of thinking. Logic was appreciated in their disputes, and widely used to prove their cases in courts. They also started educating their youth thinking in the same logical ways. Although Aristotle discussed nonlogical mechanisms of the mind (Perlovsky, 2010), this aspect of his theories has been lost, while logical

DOI: 10.4018/ijcini.2013100104
schemas and ways of thought formed the basis of educational system of Western Civilization.

Even if we have a well formalized logic, we are still in the middle of nowhere until we have developed an overall mechanism that could apply this logic in a proper place. Same refers to language. There were many efforts to build intelligent system purely upon the language models. These directions followed a simplified understanding of the brain-mind as a logical system, and none of such systems possess necessary qualities that make them working in a human way.

There is nothing surprising. The human brain-mind combines language and thinking, but past systems used language and logic without adequate modeling of language-thinking interaction (Perlovsky, 2004). Mind uses context from cognitive and perceptual processes, motor memories, prediction models, etc. Understanding and simulating mind processes requires understanding of the entire system context.

2. SYSTEM THINKING AND SEMIOTIC KNOWLEDGE REPRESENTATION

Cognitive and computer sciences have accumulated multiple models of intelligent processes. It would be possibly wrong to say that brain plays such models. But the right statement is that those models reflect some brain processes. Assume that we need to design a system, where human mind is a prototype. To start building, we need to provide its specifications that are based on some rationale. This is needed for Use Cases that describe how system may work. It would be also smart to reuse what is already accumulated in other areas. And if we try to apply experience that has been accumulated in cognitive and computer sciences and software and computer industries, we shall notice some interesting analogies.

Virtual reality and modern computer games become more and more sophisticated, and closer to real life. We are trying to build more and more sophisticated game engines. But it would be no mistake to state a trivial on the first sight thing: life is also a game. Could our brain use same principles that a sophisticated intelligent game engine would be using? The life game engine needs to drive a core life cycle that consists of perception, cognition, prediction, decision, and action. (Figure 1) This process is not completely linear, and there are sub-cycles, and feedbacks. Cognition builds situation model for the prediction process from perceptual information and other cognitive models, which also include linguistic models with help of Synthesis – Analysis cycle. Third component of this cycle – Search – is not shown.

Outcomes of prediction process transform via Goals into Decision. Emotional components (Kuvich, 2005; Perlovsky, Deming, & Ilin, 2011) play role of positive or negative feedbacks to generate a Decision upon the cognitive models. Language models are inseparable part of the cognitive models, and they are shown here as such. Decision turns appropriate Action on, and cycle repeats.

The predictions must be accurate and fast. Real life doesn’t give another chance to replay. The path of the processes should be optimal, combining acceptable time with needed quality. Predictions cannot be done until we have some knowledge. Knowledge can be accumulated, and it is stored in memory. Also, to make fast decisions, we need to avoid computational complexity. And this means that knowledge/memories have to be organized in a certain way that allows for fast access to relevant information and creation of relevant models.

So what would be the requirements for such a system?

- Knowledge should be stored in the format that allows for creation of effective models. Optimal case would be same representation for perception and cognition, which are part of the loop. And conversions will be avoided.
- Knowledge models format should allow for fast and effective decision making.
- Knowledge should be ordered in some optimal way, which allows for fast access.