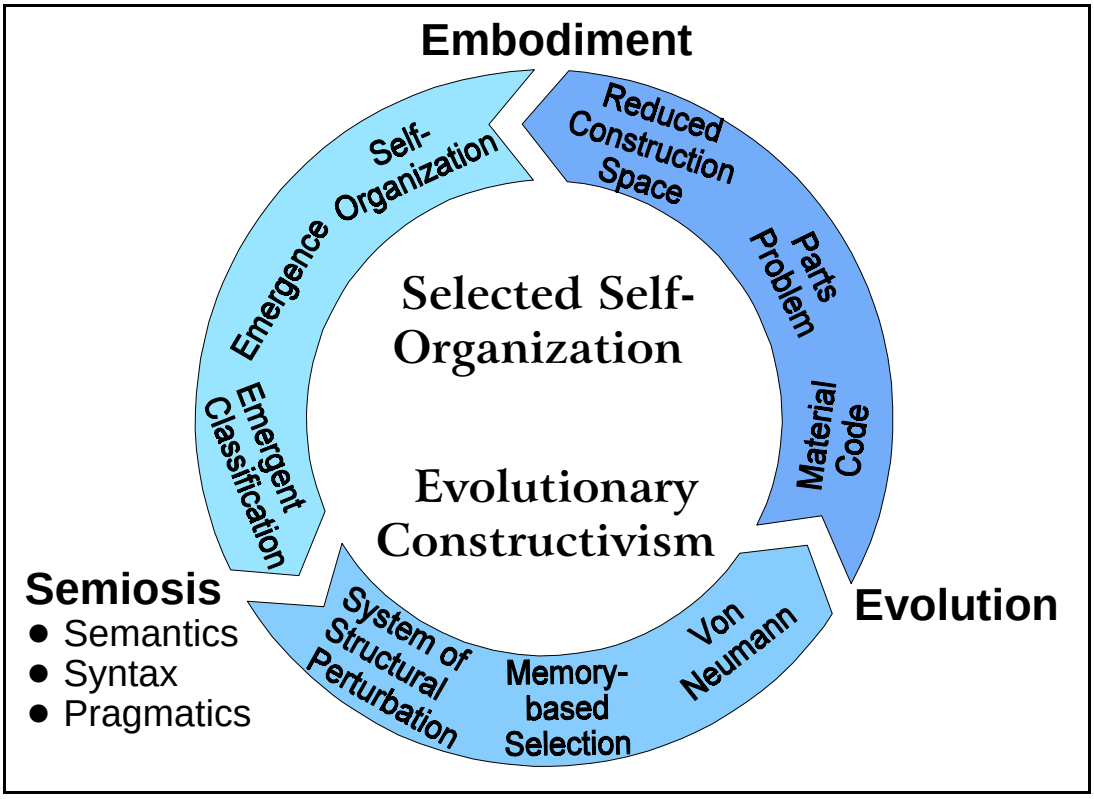
EVIDENCE SETS AND *CONTEXTUAL GENETIC ALGORITHMS*

EXPLORING UNCERTAINTY, CONTEXT, AND EMBODIMENT IN COGNITIVE AND BIOLOGICAL SYSTEMS



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DISSERTATION

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Abstract

This dissertation proposes a systems-theoretic framework to model biological and cognitive systems which requires both self-organizing and symbolic dimensions. The framework is based on an inclusive interpretation of semiotics as a conceptual theory used for the simulation of complex systems capable of representing, as well as evolving in their environments, with implications for Artificial Intelligence and Artificial Life. This evolving semiotics is referred to as Selected Self-Organization when applied to biological systems, and Evolutionary Constructivism when applied to cognitive systems. Several formal avenues are pursued to define tools necessary to build models under this framework.

In the Artificial Intelligence camp, Zadeh's Fuzzy Sets are extended with the Dempster-Shafer Theory of Evidence into a new mathematical structure called Evidence Sets, which can capture more efficiently all recognized forms of uncertainty in a formalism that explicitly models the subjective context dependencies of linguistic categories. A belief-based theory of Approximate Reasoning is proposed for these structures, as well as new insights as to the measurement of uncertainty in nondiscrete domains. Evidence sets are then used in the development of a relational database architecture useful for the data mining of information stored in several networked databases. This useful data mining application is an example of the semiotic framework put into practice and establishes an Artificial Intelligence model of Cognitive Categorization with a hybrid architecture that possesses both connectionist and symbolic attributes.

In the Artificial Life camp, Holland's Genetic Algorithms are extended to a new formalism called Contextual Genetic Algorithms which introduces nonlinear relationships between genetic descriptions and solutions for a particular problem. The nonlinear relationship is defined by an indirect scheme based on Fuzzy Sets which implements the simulation of dynamic development after genetic transcription. Genetic descriptions encode dynamic building blocks that self-organize into solutions. Since the self-organizing process may depend on environmental information, the process is thus contextualized. The main advantage of this scheme is the ability to reduce dramatically the information requirements of genetic descriptions, it also allows the transformation of real-encoded to binary-encoded problems. The scheme is used successfully to evolve Neural Network architectures as well as Cellular Automata rules for non-trivial tasks. It is also used to model the biological process of RNA Editing. Contextual Genetic Algorithms are an instance of the semiotic framework proposed and of Selected Self-Organization in particular.

Keywords: Complex Systems, Systems Science, Adaptive Computation, Evolutionary Algorithms, Artificial Intelligence, Artificial Life, Data Mining, Information Technology, Fuzzy Logic, Interval-Valued Fuzzy Sets, Dempster-Shafer Theory of Evidence, Uncertainty, Cognitive Categorization, Context, Relational Databases, Embodiment, Constructivism, Self-Organization, Natural Selection, Evolutionary Systems, Semiotics, Representation, RNA Editing, Development, and Situated Cognition.

Dedication

To my family

who cultivated in me the notion of knowledge as power,

and

who gave me all the support and love needed to try to achieve it.

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