A Sociopsychological Perspective on Collective Intelligence in Metaheuristic Computing

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ABSTRACT

In studies of genetic algorithms, evolutionary computing, and ant colony mechanisms, it is recognized that the higher-order forms of collective intelligence play an important role in metaheuristic computing and computational intelligence. Collective intelligence is an integration of collective behaviors of individuals in social groups or collective functions of components in computational intelligent systems. This article presents the properties of collective intelligence and their applications in metaheuristic computing. A social psychological perspective on collected intelligence is elaborated toward the studies on the structure, organization, operation, and development of collective intelligence. The collective behaviors underpinning collective intelligence in groups and societies are analyzed via the fundamental phenomenon of the basic human needs. A key question on how collective intelligence is constrained by social environment and group settings is explained by a formal motivation/attitude-driven behavioral model. Then, a metaheuristic computational model for a generic cognitive process of human problem solving is developed. This work helps to explain the cognitive and collective intelligent foundations of metaheuristic computing and its engineering applications.

Keywords: *Behavior Models, Cognitive Computing, Cognitive Informatics, Cognitive Processes, Collective Behaviors, Collective Intelligence, Computational Intelligence, Metaheuristic Computing, Social Psychology*

INTRODUCTION

Metaheuristic computing is an emerging computing methodology and technology (Geem et al., 2001; Blum & Roli; 2003; Glover & Gary; 2003; Talbi, 2009) developed in the field of genetic, evolutional, autonomous, and search-based computing (Holland, 1975; Goldberg, 1989; Wang, 2008a, 2009c). The advances of metaheuristic computing are "higher-level problem solving without the hassle to design problem-specific operations each time a new application appears" (Yin, 2010).

In order to rigorously convey the concept of metaheuristic computing, the fundamental terms in metaheuristic computing are analyzed below.

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Definition 1. *A heuristic is a reasoning methodology in problem solving that enables a solution to a problem is derived by trial-and-error and/or rule of thumb.*

Definition 2. *A metaheuristic is a generic or higher-level heuristics that is more general in problem solving.*

Definition 3. *Computing in a narrow sense is an application of computers to solve a given problem by imperative instructions; while in a broad sense, it is a process to implement the instructive intelligence by a system that transfers a set of given information or instructions into expected intelligent behaviors.*

On the basis of Definitions 1 through 3, the concept of metaheuristic computing can be described as follows.

Definition 4. *Metaheuristic computing is an adaptive and/or autonomous methodology for computing that applies general heuristic rules, algorithms, and processes in solving a category of computational problems.*

It is recognized in abstract intelligence (αI) (Wang, 2009a) and cognitive informatics (Wang, 2002a, 2003, 2007b, 2009b; Wang et al., 2009; Wang, Zadeh & Yao, 2009), there are three categories of intelligent behaviors known as the *imperative, autonomic (adaptive),* and *cognitive* intelligent behaviors. In a certain extent, metaheuristic computing intends to implement autonomic/adaptive intelligent behaviors beyond those of imperative ones in computational intelligence.

In order to explain the cognitive and sociopsychological properties of metaheuristic computing and it engineering applications, a transdisciplinary study between metaheuristic computing and collective intelligence are presented in this article. Parallel with studies in genetic algorithms, evolutionary computing, and ant colony mechanisms in metaheuristic computing and computational intelligence, the higher-order forms of collective intelligence are human groups and societies. This work turns the attention to the collective intelligence of human societies and its applications in metaheuristic computing. This article presents a rigorous treatment of human social mechanisms in the context of collective intelligence. Collective behaviors in groups and societies underpinning collective intelligence are explored via analyses of the basic human needs. The constraints of collective intelligence are explained by social environment and group settings by a formal motivation/attitude-driven behavioral model. Then, the cognitive process of generic problem solving is formally described as a metaheuristic computing model for cognitive computing and computational intelligence.

COMPUTATIONAL INTELLIGENCE FOUNDATIONS OF METAHUERISTIC COMPUTING

As a preparation, the concept of metaheuristic computing is modeled using concept algebra. A formal model of genetic algorithms for metaheuristic computing is described via Real-Time Process Algebra (RTPA). A computational intelligence perspective on metaheuristic computing is presented, which synergizes metaheuristic computing with studies in collective intelligence.

The Concept Algebra Model of Metaheuristic Computing

Major metaheuristic computing concepts and techniques, according to Wikipedia, are such as genetic algorithms, evolutional algorithms, random optimizations, local search, reactive search, greedy algorithm, hill-climbing, best-first search, simulated annealing, ant colony optimization, stochastic diffusion search, harmony search, and variable neighborhood search (Wikipedia, 2009). Therefore, the intension of metaheuristic computing is a set of generic