Guest Editorial Special Issue on Knowledge Extraction and Incorporation in Evolutionary Computation

TO ACQUIRE, understand, and reuse knowledge is one of the most important features of intelligent systems. Unfortunately, knowledge representation in humans and different machine systems could be very different, which makes it difficult to transfer knowledge between humans and machines, as well as between different machine systems. In order for the transferred knowledge to be reused, the knowledge must be represented in such a way that it is understandable to the user. Thus, the definition of interpretability of knowledge is user-dependent, and knowledge that is transparent to a machine system is not necessarily understandable to a human being, and vice-versa. If knowledge is to be transferred between humans and machines, fuzzy logic will play a key role [1].

Knowledge extraction and incorporation in evolutionary systems has received increasing interest in recent years. On the one hand, evolutionary algorithms have proved to be a powerful tool in extracting knowledge understandable to human beings in the form of symbolic or fuzzy rules from data. On the other hand, *a priori* or domain knowledge has shown to be very helpful, and even inevitable in many real-world applications to improve the efficiency of evolutionary algorithms. Knowledge can be incorporated in almost every element of evolutionary algorithms, such as representation, population initialization, crossover, and mutation, reproduction, fitness evaluation, and selection [2].

The target of this Special Issue is to put together the state-of-art and recent advances on knowledge extraction and incorporation in evolutionary computation. In response to our call for papers, 27 papers have been submitted. All submitted papers went through a peer-review procedure, and 14 papers have been selected to be included in the Special Issue based on the reviewers' comments.

The papers in the Special Issue can be roughly divided into two groups. The first group, including two papers and two correspondences, deals with knowledge extraction from data with the help of evolutionary algorithms. In the paper "A distributed evolutionary classifier for knowledge discovery in data mining," by Tan *et al.*, comprehensive symbolic rules are extracted using a distributed evolutionary algorithm, which is able to be implemented in different computers over the Internet. The paper "Agent-based evolutionary approach for interpretable rule-based knowledge extraction" by H. Wang *et al.* employs an agent-based evolutionary algorithm to extract interpretable fuzzy rules, where the tradeoff between accuracy and interpretability of the fuzzy system is addressed from a multiobjective optimization point of view. A fuzzy neural network has been studied in the correspondence "Evolutionary fuzzy neural networks for hybrid financial prediction" by Yu and Zhang to extract fuzzy rules for financial prediction, where a genetic algorithm and a gradient-based method are used in an iterative manner in training to improve the prediction accuracy of the fuzzy model. The last paper in this group, a correspondence titled "Genetic recurrent fuzzy system by coevolutionary computation with divide-and-conquer techniques" by Juang, recurrent fuzzy rules are generated using a coevolutionary genetic algorithm for dynamic control.

Knowledge incorporation into evolutionary algorithms is investigated in the second group, which consists of seven papers and three correspondences. In the paper titled "Evolutionary feature synthesis for object recognition" by Lin and Bhanu, domain knowledge is incorporated to reduce the search space and, thus, to improve the search efficiency of a coevolutionary genetic programming in synthesizing composite features for object recognition. It is shown that by incorporating expert knowledge in genetic coding, the coevolutionary genetic programming is able to discover good composite features to distinguish objects from clutter and to distinguish objects belonging to several classes. In the paper entitled "Knowledge interaction with genetic programming in mechatronic systems design using bond graphs" by J. Wang *et al.*, bond graphics, which are particularly suited for modeling mechatronic systems, are used in the representation of genetic programming for mechatronic systems design to facilitate knowledge extraction and reuse.

In the correspondence "Knowledge-based fast evaluation for evolutionary learning" by Giraldez *et al.*, a data structure is designed using domain knowledge to specify the genetic representation and the genetic operators so that the search becomes more effective and fitness evaluations can be made more efficient. He *et al.* investigate the influence of domain knowledge on the performance of the evolutionary search in the correspondence "A comparative study of three algorithms incorporating different amounts of domain knowledge for node covering problems." On the node covering problems, it is concluded that domain knowledge helps to improve the quality of the solutions, but not necessarily in locating the global optimum.

A more direct approach to acquisition and reuse of domain knowledge is to construct a model for fitness evaluations. This approach is investigated in the paper "Accelerating evolutionary algorithms with Gaussian process fitness function models" by Büche *et al.* and in the correspondence titled "Multiobjective GA optimization using reduced models" by Chafekar *et al.*, where a Gaussian process and a polynomial model have been adopted, respectively. This approach is particularly helpful in

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applications where fitness evaluations are time-consuming (e.g., aerodynamic optimization).

A further step toward guiding a search based on domain knowledge acquired during the search is the Estimation of Distribution Algorithms [3]. This type of evolutionary algorithm builds a statistical model for generating promising offspring instead of crossover and mutation in canonical genetic algorithms. The paper titled "Clustering and learning Gaussian distribution for continuous optimization," by Lu and Yao, proposes a method for automatically detecting the number of optima so that a proper mixture of Gaussian models can be constructed for producing offspring.

Constraining handling is a specific form of incorporating domain knowledge to make the evolutionary search more efficient. Constraining the search, repairing, adding a penalty term to the fitness function, or treating constraints as additional objectives are widely used techniques to handle constraints in evolutionary computation. Constrained-based reasoning is applied to filter out infeasible solutions in population initialization and reproduction for rule extraction using genetic algorithms in the paper "A constraint-based genetic algorithm approach for mining classification rules," by Chiu and Hsu. This is realized by specifying the constraints in the form of a constrained network, which is employed to produce feasible solutions. The paper "An evolutionary algorithm for solving nonlinear bilevel programming based on a new constraint handling scheme" by Wang *et al.* suggests a method for handling constraints so that infeasible solutions are able to move into feasible regions. The method is then used to "repair" the initial population and offspring individuals. Problem-specific crossover has also been designed. The multiobjective formulation of handling constraints is investigated in the paper "Search bias in constrained evolutionary optimization," by Runarsson and Yao. It is shown that the multiobjective approach to constraint handling could fail due to the fact that infeasible individuals may drift into a feasible region if no search bias is included.

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