Chapter XXVIII
Genetic Algorithms for Organizational Design and Inspired by Organizational Theory

Tian-Li Yu
University of Illinois at Urbana-Champaign, USA

Ali A. Yassine
University of Illinois at Urbana-Champaign, USA

David E. Goldberg
University of Illinois at Urbana-Champaign, USA

ABSTRACT

Modularity is widely used in system analysis and design such as complex engineering products and their organization, and modularity is also the key to solving optimization problems efficiently via problem decomposition. We first discover modularity in a system and then leverage this knowledge to improve the performance of the system. In this chapter, we tackle both problems with the alliance of organizational theory and evolutionary computation. First, we cluster the dependency structure matrix (DSM) of a system using a simple genetic algorithm (GA) and an information theoretic-based metric. Then we design a better GA through the decomposition of the optimization problem using the proposed DSM clustering method.

INTRODUCTION

Modularity is ubiquitous (Schilling, 2002). The concept can be found in and applied to many disciplines: biology (Hartwell, Hopfield, Leibler, & Murray, 1999; Andrews, 1998), psychology (Fodor, 1996), social networks (Newman & Girvan, 2004; Guimerà, Danon, Diaz-Guilera, Giralt, & Arenas, 2003), engineering design (Ishii & Yang, 2003; Fixson, 2003), engineering optimization (Altus, Kroo, & Gage, 1996), and software development (Sullivan, Griswold, Cai, & Hallen, 2001), to name a few. Such modular structure in many of these natural and man-made complex systems is believed to improve the functionality, performance, and robustness of these systems (Alon, 2003; Baldwin & Clark, 2000). It allows increased product or organizational variety (Ulrich & Eppinger, 2000), increased rates of technological or social innovation (Baldwin & Clark, 2000), increased opportunities for market dominance through interface capture (Moore, 1999), and increased specialization at firm level which in turn may allow more flexible response to environmental change (Sanchez & Mahoney, 1996).

Therefore, revealing the modular structure of complex systems is crucial for developing performance enhancement techniques. In other words, we first have to discover modularity in a system, and then leverage this knowledge to improve the performance of the system. In this chapter, we first propose a genetic algorithm-based method to discover the modular structure of a decomposed system (e.g., a product or organization), then we propose a new, improved genetic algorithm (GA) based on the modular arrangement of the system.

The proposed clustering method is developed based on a matrix representation of a graph, called the dependency structure matrix or DSM (Yassine & Braha, 2003); the minimum description length (MDL) principle (Rissanen, 1978, 1999; Barron, Rissenen, & Yu, 1998; Lutz, 2002); and a simple genetic algorithm (Goldberg, 1989). The method is capable of partitioning the product (or organizational) architecture into an *optimal* set of modules (or teams) and can be fine-tuned to mimic clustering arrangements proposed by human experts. Our proposed clustering algorithm is an improvement over other existing algorithms for two reasons: (1) existing algorithms are manual, very dependent on human expertise, and consequently hard to automate or replicate (McCord & Eppinger, 1993; Pimmler & Eppinger, 1994; Stone, Wood, & Crawford, 2000; Gonzalez-Zugasti, Otto, & Baker, 2000); and (2) existing algorithms use simple mathematical constructs to discriminate between modules, and consequently these algorithms collapse when confronted with complex product architectures (Fernandez, 1998; Thebeau, 2001; Whitfield, Smith, & Duffy, 2002).

It is interesting that the clustering techniques can help us better design a GA that decomposes the optimization problem by recognizing the modularity between decision variables. Holland (1975) has suggested that operators learning linkage information to recombine alleles might be necessary for GA success. Many such methods have now been developed to solve this including perturbation (Goldberg, Korb, & Deb, 1989; Goldberg, Deb, Kargupta, & Harik, 1993; Kargupta, 1996; Munetomo & Goldberg, 1999), linkage learning schemes (Harik & Goldberg, 1996; Smith, 2002), and model-building schemes (Bosman & Thierens, 1999; Harik, 1999; Pelikan, Goldberg, & Cantú-Paz, 1999). The genetic algorithm developed in this chapter adds to the literature of competent GAs with a method inspired by organizational theory. In particular, the proposed *dependency structure matrix genetic algorithm* (DSMGA) is able to identify building blocks (BBs) with the help of a DSM and accomplish BB-wise crossover. As the experimental results suggest, compared to a simple genetic algorithm, the DSMGA is able to maintain a reliable solution quality under tight, loose, and random linkage with the same amount of function evaluations.

The rest of the chapter proceeds as follows. The next section provides a quick overview of the DSM method. We then propose a metric to evaluate different architectural arrangements