Chapter 36

A Sensitivity Analysis of Critical Genetic Algorithm Parameters:
Highway Alignment Optimization Case Study

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ABSTRACT

Genetic Algorithms (GAs) have been applied in many complex combinatorial optimization problems and have been proven to yield reasonably good solutions due to their ability of searching in continuous spaces and avoiding local optima. However, one issue in GA application that needs to be carefully explored is to examine sensitivity of critical parameters that may affect the quality of solutions. The key critical GA parameters affecting solution quality include the number of genetic operators, the number of encoded decision variables, the parameter for selective pressure, and the parameter for non-uniform mutation. The effect of these parameters on solution quality is particularly significant for complex problems of combinatorial nature. In this paper the authors test the sensitivity of critical GA parameters in optimizing 3-dimensional highway alignments which has been proven to be a complex combinatorial optimization problem for which an exact solution is not possible warranting the application of heuristics procedures, such as GAs. If GAs are applied properly, similar optimal solutions should be expected at each replication. The authors perform several example studies in order to arrive at a general set of conclusions regarding the sensitivity of critical GA parameters on solution quality. The first study shows that the optimal solutions obtained for a range of scenarios consisting of different combinations of the critical parameters are quite close. The second study shows that different optimal solutions are obtained when the number of encoded decision variables is changed.

INTRODUCTION

Optimizing highway alignments (Jong & Schonfeld 2003; Jha, Schonfeld, Jong, & Kim, 2006) involves selection of the best alignment among many alternatives based on specified objectives while satisfying various design and operational constraints. Since there are numerous factors (such as topography, right-of-way, environmental and socio-economic characteristics, to name a few) that influence location of highway alignments, a comprehensive formulation of the objective function and selection of a good search algorithm is highly desirable. Our previous efforts (see Table 1) have been largely devoted to: (i) objective function development; (ii) genetic algorithm development for search and optimization; and (iii) studying problems with different characteristics that represent real-world scenarios. Recently, we have also investigated bi-level and multi-objective approaches to the highway alignment problem (Kang, Yang, Schonfeld, & Jha, 2010; Maji & Jha 2009). Many details of the highway alignment optimization problem, such as impact of the topography on alignment selection has been skipped here since those can be found in previously published works. A brief reference of previously published works by our research team in the field of highway alignment optimization is shown in Table 1.

Three types of models have been developed for optimizing highway alignments (Jha et al., 2006; Jong & Schonfeld, 2003): (i) models for horizontal alignment optimization, (ii) models for vertical alignment optimization, and (iii) models for simultaneously optimizing horizontal and vertical alignments. Within those models, seven search algorithms have been used, including calculus of variations, network optimization, dynamic programming, enumeration, linear programming, numerical search, and Genetic Algorithms (GAs). Among the seven search methods each have some limitations, except the genetic algorithms, for application to the highway align-

ment optimization (HAO) problem whose cost function is non-differentiable, noisy and implicit (e.g., user costs cannot be calculated until alignments are finally determined). Furthermore, since highway alignment optimization problem includes infinite number of alternatives to be evaluated, an efficient algorithm that can quickly generate alternatives, evaluate them and find an optimal solution is essential.

Different GA application scenarios to the highway alignment optimization problem can be found in our previous works. For example, Jong & Schonfeld (2003) developed specialized GA operators for efficient optimal search. Jha & Schonfeld (2000) integrated a Geographic Information System (GIS) database to the GAs for enhanced real-world application. Kim, Jha, & Son (2005) developed a stepwise GA method for improving computational efficiency when dealing with a large problem size. In recent years, Kang, Schonfeld, & Yang (2009) developed a prescreening and repairing method for further improving the efficiency of the GA search process. In our most recent work (Kang, Jha, & Schonfeld, 2012) a sensitivity analysis dealing with problem specific parameters (such as design speed, radius of curvature, different cost sets) has been explored for enhanced practical application.

Despite extensive research undertaken in dealing with various key aspects of the highway alignment optimization problem, the sensitivity analysis of critical GA parameters has not been fully examined in the previous studies. It is widely acknowledged that critical parameters, such as the number of genetic operators, the number of encoded decision variables, the parameter for selective pressure, and the parameter for non-uniform mutation play an important role in the search process and may affect the quality of optimal solution (Goldberg, 1989; Lovell & Jha 2005; Jha, Lovell, & Kim, 2004; Jha, 2012). Moreover, since GAs use probabilistic transition rules (Goldberg, 1989), it is very important to check how the critical parameters affect the search process and solutions.

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