Multi-objective Traffic Signal Timing Optimization Using Non-dominated Sorting Genetic Algorithm II

Dazhi Sun, Rahim F. Benekohal, and S. Travis Waller

University of Illinois at Urbana-Champaign
Urbana, IL 61801, USA
{dazhisun,rbenekoh,stw}@uiuc.edu

Abstract. This paper presents the application of Non- dominated Sorting Genetic Algorithm II (NSGA II) in solving multiple-objective signal timing optimization problem (MOSTOP). Some recent researches on intersection signal timing design optimization and multi-objective evolutionary algorithms are summarized. NSGA II, which can find more of the Pareto Frontiers and maintain the diversity of the population, is applied to solve three signal timing optimization problems with 2-objective and 3-constraint, which account for both deterministic and stochastic traffic patterns. Mathematical approximation of the resulting Pareto Frontiers are developed to provide more insight into the trade-off between different objectives. GAs experimental design and result analysis are presented with some recommendations for prospective applications.

1 Multi-objective Traffic Signal Timing Optimization Problem

Minimizing the average delay and minimizing the number of stops per unit of time are important objectives for traffic signal timing design. However, none of feasible solutions could achieve the simultaneous optimality of these two objectives for an intersection with asymmetric traffic demand. A generic multi-objective traffic signal timing optimization problem at an isolated intersection with two-phase control strategy and permissive left turn can be formulated as:

$$\text{minimize } F(G) = [f_1(G), f_2(G)]$$

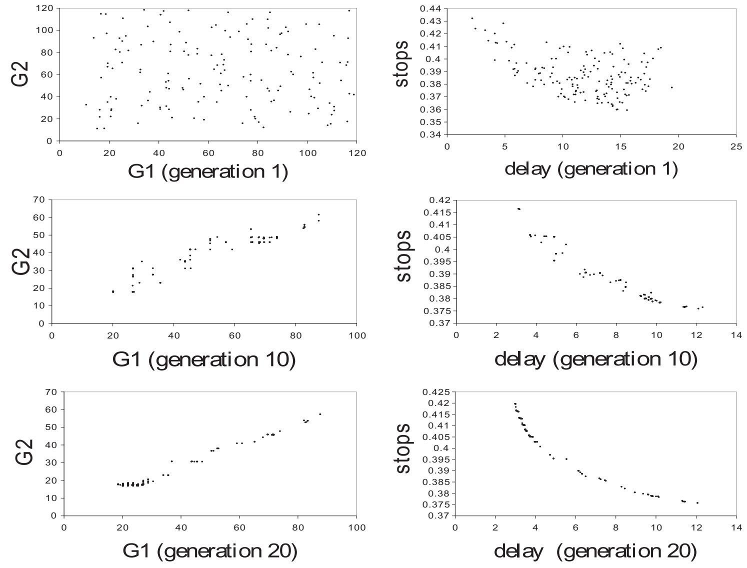
Where: G- vector of effective green time for each phase i; $f_1(G)$- the first objective function with respect to delay; $f_2(G)$- the second objective function with respect to stops.

Webster delay formulation and Akçelik stops function, which are widely used for calculating the corresponding performance index of delay and number of stops, are modified to be the objective functions mentioned in the above equation. Due to the impact of cycle length on the intersection overall effective capacity, an additional constraint on minimum cycle length was introduced to the above optimization problem.

E. Cantú-Paz et al. (Eds.): GECCO 2003, LNCS 2724, pp. 2420–2421, 2003.

2 GAs Experiment Design and Result Analysis

Three signal design problems are defined to minimize average delay and the average number of stops, using the effective green time at each signal phase as the design variable. NSGA II, first introduced by Deb et. al (2002), is modified to solve these problems. The used GA parameters are - maximum generation: 500; population size: 100; binary string length: 30; probability of crossover: 0.9; probability of mutation: 0.01; minimum green: 10; maximum green: 100. The designed scenario is a two-phase isolated intersection with permissive left turn. The critical flow ratios are 0.47 and 0.39 and saturation flow for each approach is 1800 pcphpl. It was observed that a clear frame of actual Pareto Frontiers can be located within 20 generations. As the generation number grows, more Pareto Frontiers were discovered and a well-fitted third degree polynomial function can be constructed to evaluate the tradeoff between the conflicting objectives. In the meanwhile, it was observed that the Pareto-optimal design variables locate along a certain straight line in the feasible space and the corresponding regression functions were developed in this study as well.
The following figures show the population and objective values at generation 1, 10 and 20 for the multi-objective signal optimization problem under stochastic traffic pattern with Webster cycle length constraint.



This study solved multi-objective traffic signal optimization problem by NSGA II and analyzed its effectiveness. Results showed that NSGA II can find a much better spread of optimal signal design plans on the true Pareto-optimal frontier at a high convergence speed.