Genetic Algorithms for Multiple Objective Vehicle Routing

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1 Introduction

The talk describes a general approach of a genetic algorithm for multiple objective optimization problems. A particular dominance relation between the individuals of the population is used to define a fitness operator, enabling the genetic algorithm to address even problems with efficient, but convex-dominated alternatives. The algorithm is implemented in a multilingual computer program, solving vehicle routing problems with time windows under multiple objectives. The graphical user interface of the program shows the progress of the genetic algorithm and the main parameters of the approach can be easily modified. In addition to that, the program provides powerful decision support to the decision maker. The software has proved it´s excellence at the finals of the European Academic Software Award EASA, held at the Keble college/ University of Oxford/ Great Britain.

2 The Genetic Algorithm for multiple objective optimization problems

Based on a single objective genetic algorithm, different extensions for multiple objective optimization problems are proposed in literature [1, 4, 8, 10] All of them tackle the multiple objective elements by modifying the evaluation and selection operator of the genetic algorithm. Compared to a single objective problem, more than one evaluation functions are considered and the fitness of the individuals cannot be directly calculated from the (one) objective value.

Efficient but convex-dominated alternatives are difficult to obtain by integrating the considered objectives to a weighted sum (Figure 1). To overcome this problem, an approach of a selection-operator is presented, using only few information and providing a underlying self-adaption technique.

In this approach, we use dominance-information of the individuals of the population by calculating for each individual i the number of alternatives ξ_i from which this individual is dominated. For a population consisting of n_{pop} alternatives we get values of:

$$0 \leq \xi_i \leq n_{pop} - 1 \quad (1)$$

Individuals that are not being dominated by others should receive a higher fitness value than individuals that are being dominated, i.e.:

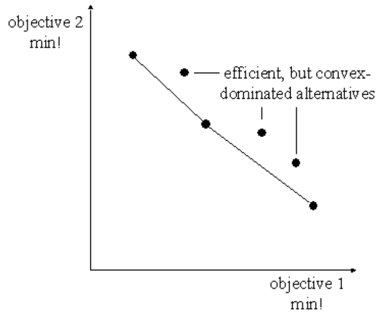

Figure 1: Efficient, convex-dominated alternatives

$$\text{if } \xi_i < \xi_j \rightarrow f(i) > f(j) \quad \forall i, j = 1, \ldots, n_{pop} \tag{2}$$
$$\text{if } \xi_i = \xi_j \rightarrow f(i) = f(j) \quad \forall i, j = 1, \ldots, n_{pop} \tag{3}$$

We calculate the fitness value for each individual i by a linear normalization. Individuals with the lowest values of $\xi_i (\xi_i = 0)$ receive the highest corresponding value of $f(i) = f_{max}$ and the individual with the highest value $\xi_{max} = \max[\xi_i] \quad \forall i = 1, \ldots, n_{pop}$ receive the lowest value of $f(i) = f_{min}$.

$$f_{max} \gg f_{min} \geq 0 \tag{4}$$

As a result we obtain:

$$f(i) = f_{max} - \left(\frac{f_{max} - f_{min}}{\xi_{max}} \right) * \xi_i \tag{5}$$

3 The implementation [7]

The approach of the genetic algorithm is implemented in a computer program which solves vehicle routing problems with time windows under multiple objectives [6].

The examined objectives are:

- Minimizing the total distances traveled by the vehicles.
- Minimizing the number of vehicles used.
- Minimizing the time window violation.
- Minimizing the number of violated time windows.

The program illustrates the progress of the genetic algorithm and the parameters of the approach of the can simply be controlled by the graphical user interface (Figure 2).

In addition to the necessary calculations, the obtained alternatives of the vehicle routing problem can easily be compared, as shown in Figure 3.

For example the alternative with the shortest routes is compared to the alternative having the lowest time window violations. The windows show the routes, travelled by the vehicles from the depot to the

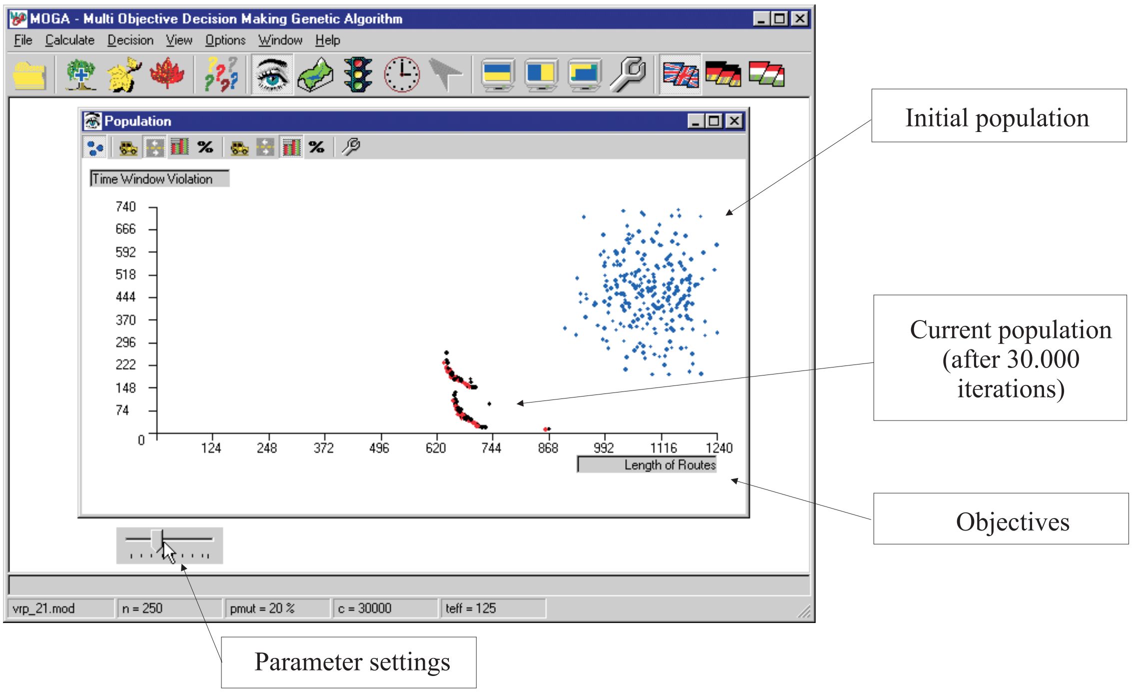

Figure 2: Progress of the genetic algorithm

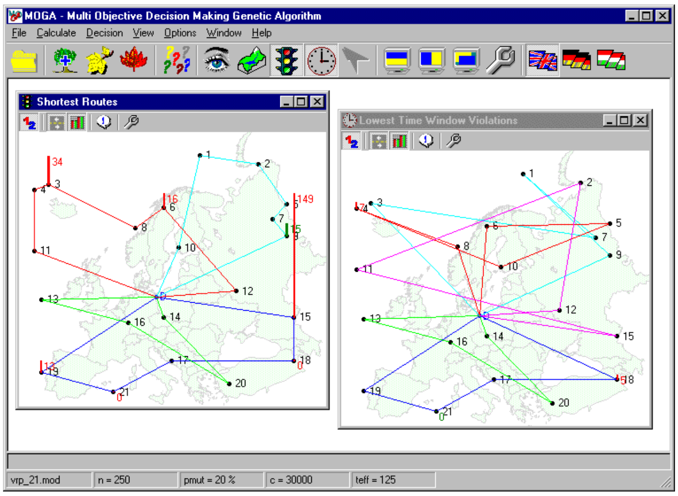

Figure 3: Comparison of obtained alternatives

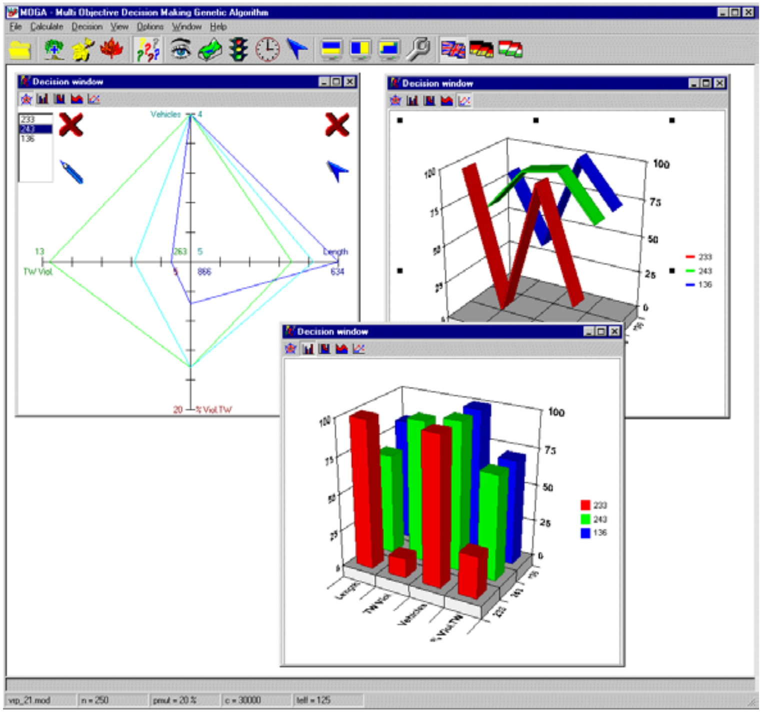

Figure 4: Decision support mode, showing trade-offs

customers. The time window violations are visualized with vertical bars at each customer. Red: The vehicle is too late, green: the truck arrives too early.

For a more detailed comparison, inverse radar charts and 3D-views are available, showing the trade-off between the objective values of the selected alternatives (Figure 4).

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