A New Interactive Evolutionary Algorithm for the Vehicle Routing Problem

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ABSTRACT

This paper presents a new interactive evolutionary approach for the vehicle routing problem. After a short review of main interactive optimization systems, we describe an evolutionary algorithm based on a set of human-computer interaction techniques. With a graphical display of the current population of solutions, a human can visually identify interesting route segments and tag them accordingly. Human annotations are taken into consideration in the evolutionary operators during the optimization process. Our interactive optimization approach is under experimental validation and user tests on benchmark problems are carried out to investigate the human-algorithm interaction.

Categories and Subject Descriptors

I.2.8 [**Problem Solving, Control Methods, and Search**]: Heuristic methods; G.2.1 [**Combinatorics**]: Combinatorial algorithms; H.5.2 [**User Interfaces**]: Graphical user interfaces (GUI)

General Terms

Algorithms, Human Factors

Keywords

Human-machine interaction, Genetic algorithm, Vehicle routing problem

1. INTRODUCTION

The Vehicle Routing Problem (VRP) is a main combinatorial optimization problem. Since its first formulation in 1959, the VRP has been extensively investigated by the operations research community interested in its NP-completeness and the variety of its real life applications in transportation and logistics. With the rise of metaheuristics such as tabu search and genetic algorithms, many benchmark problems have been solved effectively, even optimally.

Metaheuristics are often evaluated only according to two criteria: speed (computing time) and efficiency (solutions quality). Hansen *et al.* [1] claim that *interactivity* is also a desirable property of metaheuristics and define it as the ability to "*allow the user to incorporate his knowledge to improve the resolution process*".

However, most solving techniques are fully automatic and do not involve humans in the solving process. Thereby, a great part of human knowledge and expertise remains unexploited. In addition, metaheuristics are generally applied as follows: they take a model of the optimization problem as an input, perform more or less complicated computations, then give back a solution. Such a black-box paradigm makes it difficult for a human to understand the origin of the given solution.

2. HUMAN-IN-THE-LOOP OPTIMIZATION

Recent work have been carried out to break with such an "oracle" paradigm (the human submits a question to the system, which provides an answer) and go towards an interactive optimization process instead: the human and the machine work together.

In the Human-Guided Search approach [2] human user can assign *mobility* values (low, medium or high) to each VRP customer in order to constraint a local search method to a sub-region of the current solution neighbourhood.

In the family of population-based optimization methods, genetic algorithms have also been adapted to an interactive solving process: the machine generates solutions and user evaluates them [4]. This approach, called *Interactive Evolutionary Computation*, is suitable for problems whose objective function can not be formulated mathematically (in artistic applications for example) and has a major drawback related to the user fatigue.

3. THE PROPOSED INTERACTIVE GENETIC ALGORITHM FOR THE VRP

We propose an interactive genetic algorithm for the VRP in which tasks are clearly divided among human and machine during the optimization process. The system displays graphically the current population of solutions. The human inspects them visually and can express two kinds of preferences, "I like" (👍) or "I don't like" (👎), by specifying the parts he deems interesting or not. Before generating the next population, human annotations (*tags*) on the *phenotypes* are transmitted into *genotypes* in order to be considered by the genetic algorithm.

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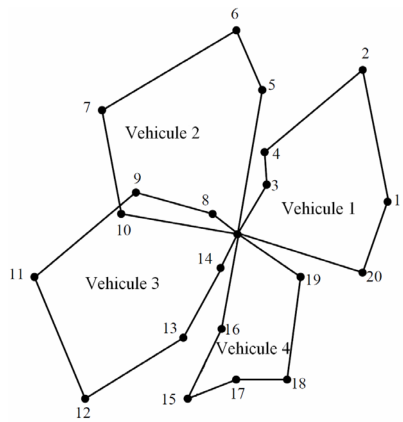

Figure 1: A VRP solution S.

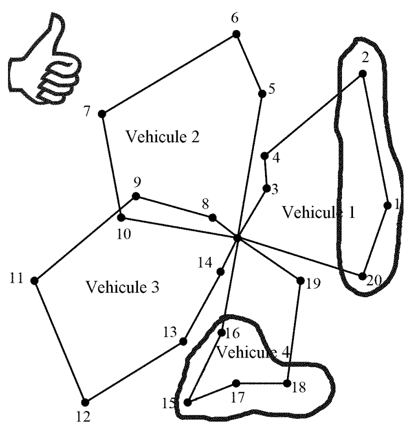

Figure 2: User "I like" tags on the solution S.

Figure 1 shows an example of VRP with $n = 20$ customers solved with $m = 4$ vehicles, and figure 2 shows the same solution with an example of human tags. Using a customers permutation encoding without trip delimiters [3], the two previous solutions are respectively represented by the following two chromosomes:

20	1	2	4	3	5	6	7	10	8	9	11	12	13	14	16	15	17	18	19
20	1	2	4	3	5	6	7	10	8	9	11	12	13	14	16	15	17	18	19

Shaded boxes in the second chromosome correspond to the two parts of the solution judged as interesting by the user. These tag affects the three key steps of the genetic algorithm: selection, crossovers and mutations.Indeed, this interesting solution will get a higher selection probability. If it is selected as a parent in a crossover, the two crossover indices (*Order Crossover* (*OX*) operator) will be randomly selected outside the shaded intervals. Similarly, the mutation operator is not allowed to modify tagged boxes in order not to broke the corresponding customers sequences. Similarly, the algorithm attempts to break a route after a "I don't like" annotation.

4. OVERVIEW OF HUMAN ACTIONS

In order to let the user play a central role in the optimization loop, the developed graphical user interface (GUI) has two main 2D views: the *solution view*, the *population view*.

In the *solution view*, one single VRP solution is displayed. This view lets the user perform actions at two different interaction levels: the *sub-solution level*, and the *solution level*. Visual tags detailed in the previous section correspond to the sub-solution level handling a vehicle route or sub-route. At the solution level, apart from standard actions like zoom and translation, user can filter the solution elements (customers details, fitness ...) and ask the algorithm to perform a crossover with another solution. He can also force the elitism of a solution or remove it.

The *population view* displays the current population in a 2-dimensional grid and corresponds to the population interaction level. User can sort the population and ask the algorithm to generate a new one. This view looks like a classical image preview pane in usual operating systems. User can switch between the population and solution views by double-clicking the solution.

We found it useful to add an additional view, called *evolution view*. The successive populations handled by the optimization process are summarized in a scatterplot chart: each solution is displayed as a point whose x-y coordinates are respectively its generation number and its fitness value. This view is updated after each population generation and lets thus visualize the convergence of the algorithm. Besides, tagged solutions are highlighted and genetic operators (crossovers and mutation) are represented as links between points.

5. CONCLUSION AND FUTURE WORK

With a graphical display system and a set of simple and intuitive interactions, a human can express preferences about the solutions generated by a genetic algorithm and control its convergence. We are currently driving user experiments to validate our approach and to identify challenging issues in the interaction techniques.

We plan to extend it to other richer VRP variants (with time windows (VRPTW) or in dynamic environment (DVRP)) and test it on large-scale instances. It seems also interesting to consider other *visual* optimization problems such as *bin packing* or *scheduling* whose solutions can be graphically understood and handled by a human user.

6. REFERENCES

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