# Getting You Faster to Work – A Genetic Algorithm Approach to the Traffic Assignment Problem

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## ABSTRACT

Traffic assignment is a complex optimization problem. In case the road network has many links (thus a high number of alternative routes) and multiple origin-destination pairs, most existing solutions approximate the so-called user equilibrium (a variant of Nash equilibrium). Furthermore, the quality of these solutions (mostly, iterative algorithms) come at the expense of computational performance. In this study, we introduce a methodology to evaluate an approximation of an optimal traffic assignment from the global network's perspective based on genetic algorithms. This approach has been investigated in terms of both network performance (travel time) and convergence speed.

## Categories and Subject Descriptors

I.2.8 [**Computing Methodologies**]: Artificial Intelligence—*Problem Solving, Control Methods, and Search*; I.6.3 [**Computing Methodologies**]: Simulation and Modeling—*Applications*; J.4 [**Computer Applications**]: Social and Behavioral Sciences

## Keywords

traffic assignment; optimization; genetic algorithms

## 1. INTRODUCTION

The last decades saw a constant increase in road traffic demand. Trips tend to concentrate on a few central spots, like major roads or large intersections during the rush hour periods. This is very likely to cause congestion in the road network. Typically, solutions to this problem involve the adjustment of the load pattern in the particular road network. This in turn can be made by performing a better traffic assignment. Often, this can be done by computing approximations of the so-called user or Wardrop equilibrium [3, 2]; this is a variant of the Nash equilibrium and (in the context of road networks) means that a state is achieved in which no driver can individually benefit from changing to an alternative route. An equilibrium state, however, does not necessarily reflect the best possible solution. Our focus of research is to assess a road network's maximal optimization potential. In this study we aim to achieve a good approximation of an optimal distribution of cars to alternative routes between their origin and destination points (based on a global fitness function). Due to the complex co-dependencies, the optimization of individual cars' route choices with respect to a system optimum is very difficult. In this context we introduce a methodology to optimize the route assignments in a road network based on a genetic algorithm approach.


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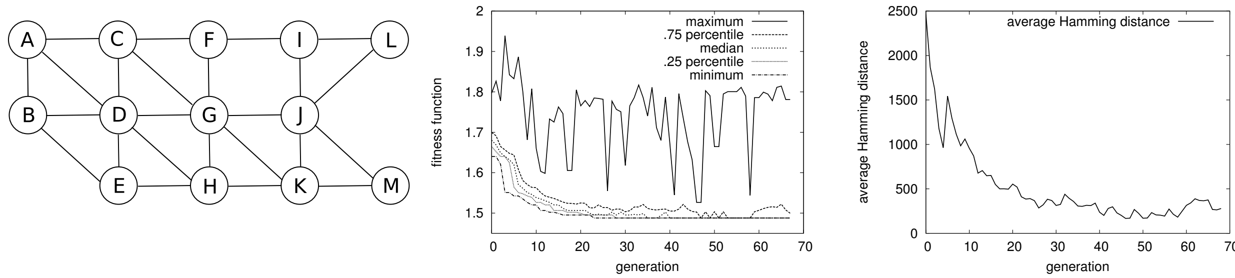
## 2. PROBLEM MODEL

Given a road network (which essentially is a graph where the nodes represent the intersections, and the edges correspond to the actual streets) and a number of cars, each assigned to an origin-destination pair (OD pair), the system optimal traffic assignment problem involves finding route assignments to cars that result in minimal travel costs from the global point of view. In this context, the travel costs can be defined by different metrics like the average travel time, the total travel time, or the mean of relative travel time increases. Note that such a system optimal traffic assignment potentially differs from a user equilibrium traffic assignment, where each user tries to optimize his own cost in a selfish manner.

In the introduced genetic algorithm approach an individual corresponds to a complete assignment of route choices, one for each car. These route choices are encoded in a bit field, which constitutes the individual's chromosome. As the size of the search space is crucial to the convergence speed of the algorithm, we limit the number of possible alternative routes for each OD pair to a constant value $k$. This value has to be evaluated empirically and depends on the scenario being investigated.

For all the individuals, the fitness function is evaluated, then genetic operators (roulette wheel selection, uniform crossover and random mutation) are applied. In this context we use the roulette wheel selection method along with the uniform crossover method for pairing and an additional random gene mutation. Further, we make use of elitism whereby we retain the best five individuals in a generation unchanged. The main intention is to preserve the beneficial properties of good individuals, while maintaining a sufficient diversity in the population in order to find yet better combinations of route choices in the search space.




(a) Structure of the road network. (b) Evolution of the fitness function. (c) Population diversity.

Figure 1: Experiments and results.

# 3. EXPERIMENTS

In order to evaluate the effectiveness of our global optimization algorithm, we performed experiments with the road network depicted in Fig. 1a. This road network was derived from the optimization setting on a macroscopic model as described in [1, chapter 10]. The authors define four OD pairs (AL, AM, BL, BM) for evaluation. They furthermore define the link costs as the travel time between two nodes in minutes. The demands for each OD pair are set to 400 cars for the OD pair A-M and B-M, 600 cars for A-L and 300 cars for B-L. Hence the total demand is 1700 cars.

In order to find the "best" routes for all cars, it is first necessary to define by which measure this decision is to be made. There are many possible choices for the fitness function. In this study we use the geometrical mean of the relative travel time changes. This fitness function minimizes the mean relative travel time change of all cars, when comparing their travel times in an optimized route assignment to the situation in which each car is traveling along the path with the lowest travel time at free-flow speed, that is

$$\sqrt[z]{\prod_{i=1}^{z} \frac{T_{c_i}}{\widehat{T}_{c_i}}} \tag{1}$$

where $c_i$, $i \in \{1, .., z\}$ are the cars, $\widehat{T}_{c_i}$ is $c_i$'s free flow travel time and $T_{c_i}$ is the $i$-th car's actual travel time in a particular simulation.

Fig. 1b illustrates the overall evolution of the genetic algorithm for $k = 8$. In the figure, the $x$ axis represents the evolution in generations and the $y$ axis shows the fitness values. The graph contains five plots, which depict the fitness functions of the best individual, the .25 percentile, the median, the .75 percentile and the worst individual, respectively.

As we are starting with a random initial population, we can observe that the fitness function value of the individuals in generation 0 are widely spread. Over the generations the fitness function improves. The plots indicate that not only the fitness function (which, we remind, is to be minimized) of the best individual decreases, but also that the homogeneity increases.

We also investigated how the population's diversity develops in the course of the optimization. Fig. 1c depicts the diversity of the population measured by the average Hamming distance between each pair of individuals in the population. More formally, the Hamming distance between two chromosomes $x$ and $y$ is defined as $d(x, y) = |\{1 \leq i \leq n \mid x_i \neq y_i\}|$, where $x_i$ refers to the $i$-th bit of $x$.

We have a total of 1700 cars in each simulation encoded on an individual. With $k = 8$ route alternatives (which can be coded on three bits) this results in a genotype with a length of 5100 bits. The random population (generation 0) has an average Hamming distance of 2463. This indicates that we start off with a population of high diversity. During the progress of generations, the diversity falls, which indicates an increasing homogeneity of the population itself. However, it can be seen that the diversity has not dropped too low before the fitness function converges (which occurs roughly after the 20th generation).

# 4. CONCLUSION

This paper has demonstrated that genetic algorithms are a feasible approach to the route assignment problem in road networks. We have shown a way to approximate the optimal assignment of routes to a number of vehicles in a given scenario. This optimization is performed with a global view of a microscopic traffic model. We could show that our approach finds a good approximation for the system optimal route assignment problem in a reasonable time.

# 5. ACKNOWLEDGEMENTS

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# 6. REFERENCES

[1] J. de Dios Ortúzar, L. G. Willumsen, et al. *Modelling transport*. Wiley Chichester, 2001.

[2] C. Gawron. *Simulation-Based Traffic Assignment – Computing User Equilibria in Large Street Networks*. PhD thesis, 1999.

[3] J. G. Wardrop. Road paper. some theoretical aspects of road traffic research. In *ICE Proceedings: Engineering Divisions*, volume 1, pages 325–362. Ice Virtual Library, 1952.