Application of artificial intelligence techniques for the optimization of vehicular flow.

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Motivation

Some of the traffic jam problems of the big cities are generated by a lack of population and road planning, as well as a poor road infrastructure. The traffic flow in the cities can be modelated to find an optimal configuration which reduces the global travel times.
In this work, we propose a graph theory-based model to describe the global traffic flow. Also, we develop a Multiobjective Level Curves Algorithm (MOLCA), based on level curves, to solve the resulting nonlinear, multimodal, and multi-objective (NLMMO) traffic model.

Flow theory

For the macroscopic model, traffic is a continuous flow of particles, based on the average of the state variables. The variables of this model are: density ($k = n/L$), flow ($\phi = n/t$), and average velocity ($v_s = \phi/k$). The fundamental equation of traffic ($\phi = k * v_s$), explains the behavior as a continuous flow.

Basic Variables	Relations
$k = n/L.$	$v_s = v_l\left(1 - \frac{k}{k_e}\right)$
$\phi = n/t.$	$\phi = v_l\left(k - \frac{k^2}{k_e}\right)$
$v_s = \phi/k.$	$\rho = \sum k_e\left(1 - \frac{vi}{v_l}\right)$
$k_e = L/l*$	$v_s^2 + v_l + v_s + \left(\frac{v_l\phi}{k_e}\right) = 0$

L is the long of road. l is average length covered by a vehicle.

Proposal

Model. Diverse theoretical models of vehicular flow were analyzed to evaluate the factiblity of their implementation as a (MOOP). As a result, we propose the following optimization problem, with the fitness function as:

$$Max \quad z_0 = \left(\frac{1}{L}\right)\sum_i |v_i| * (l_i), \qquad Min \quad z_j = \sum_i (k_e)\left(1 - \frac{|v_{ij}|}{v_{l_{ij}}}\right)$$

Subjects to conservation constrictions. v_i and l_i are the velocities and the length associated with each edge. $v_{l_{ij}}$ is the free path speed of each edge for each objective function to be co-optimized with z_0.
Graph. Our network is represented as a graph where:

- The edges represent roads with an associated flow capacity $c(u,v) > 0$ and the intersection among the edges are the nodes.

$$0 < C_{(u,v)}^{min} \leq C_{(u,v)} + C*_{(u,v)} \leq C_{(u,v)}^{max} \quad (1)$$

- We select a finite number of roads, and we define a maximum C^{max} and minimum C^{min} limit capacity, associated with each edge.
- For each edge we define an edge in the opposite direction that represents the counter flow, given by the following equation:

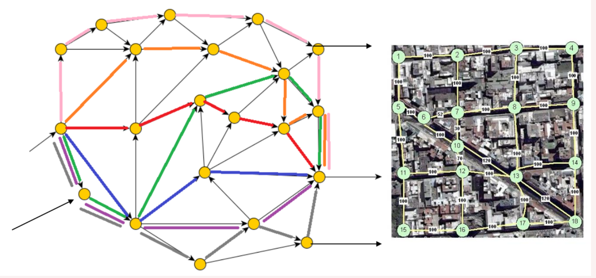


Fig.-1

Development of the MOLCA algorithm.

The whole process of the MOLCA algorithm is given as follows:

- Generation of the Pareto Front.
- Optimization of feasible solutions found on the Pareto front.
- Exploitation on the points to optimize on the Pareto front points.
- Solution of the graph by MOLCA with different percentages of counter flow.
- Parallel MOLCA algorithm (P-MOLCA) is implemented on OpenMPI and/or OpenMP.

MOLCA Algorithm

While not (end criteria)
- Generate a random $x_i \in \mathbb{R}\ \forall i \in [1, N]$.
- Establish a clearance for each constrain condition.
- For each constrain condition
  - $x^{(i+1)} = x^i + \Delta x$
- Until $\Delta x \approx 0$.
- Next individual.

Next Generation.
Use the x_i *that* meet the constrain conditions and initialize the optimization .

While not (end criteria)
- For each neighborhood where the restriction conditions do
  - $x^{(i+1)} = x^i + \Delta x$
  - While optimizing the objective function in search of a min or max.
  - Until $\Delta x \approx 0$.
- Next individuals.

Next Generation.

P-MOLCA

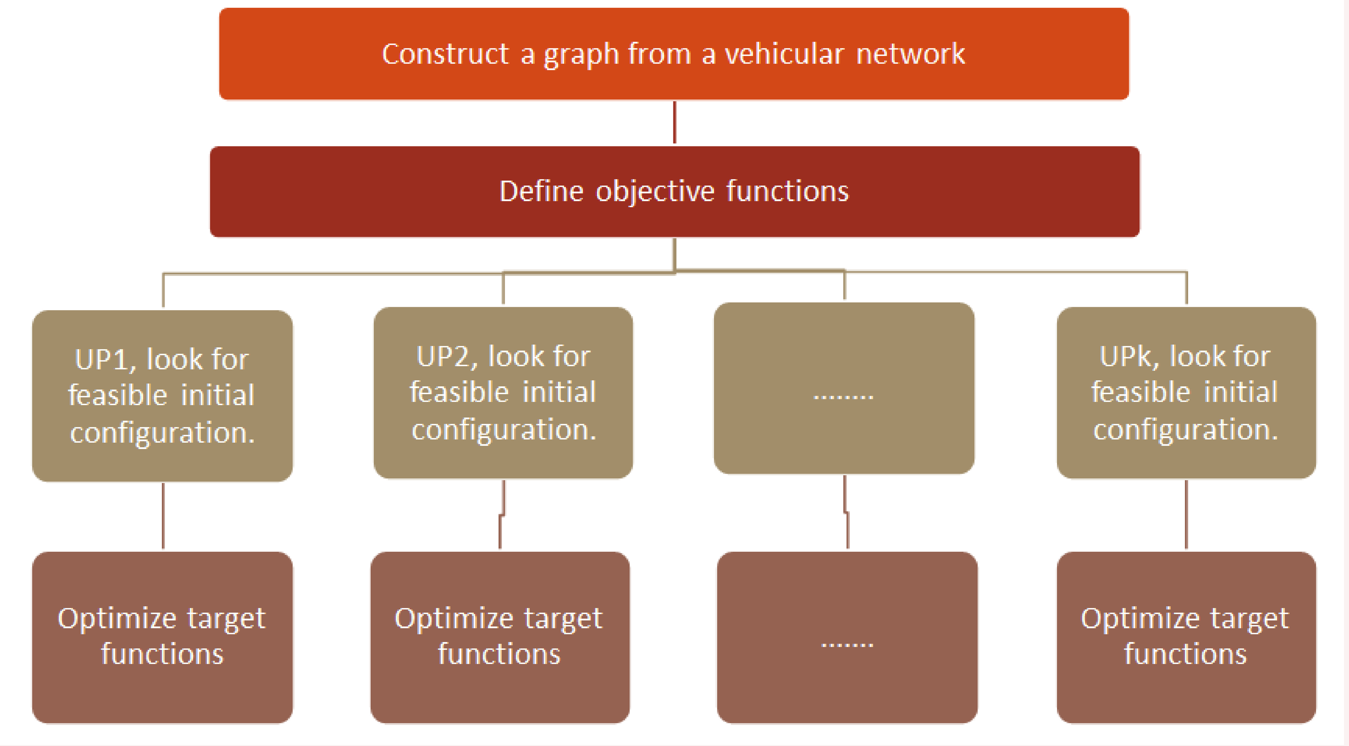


Fig.-2

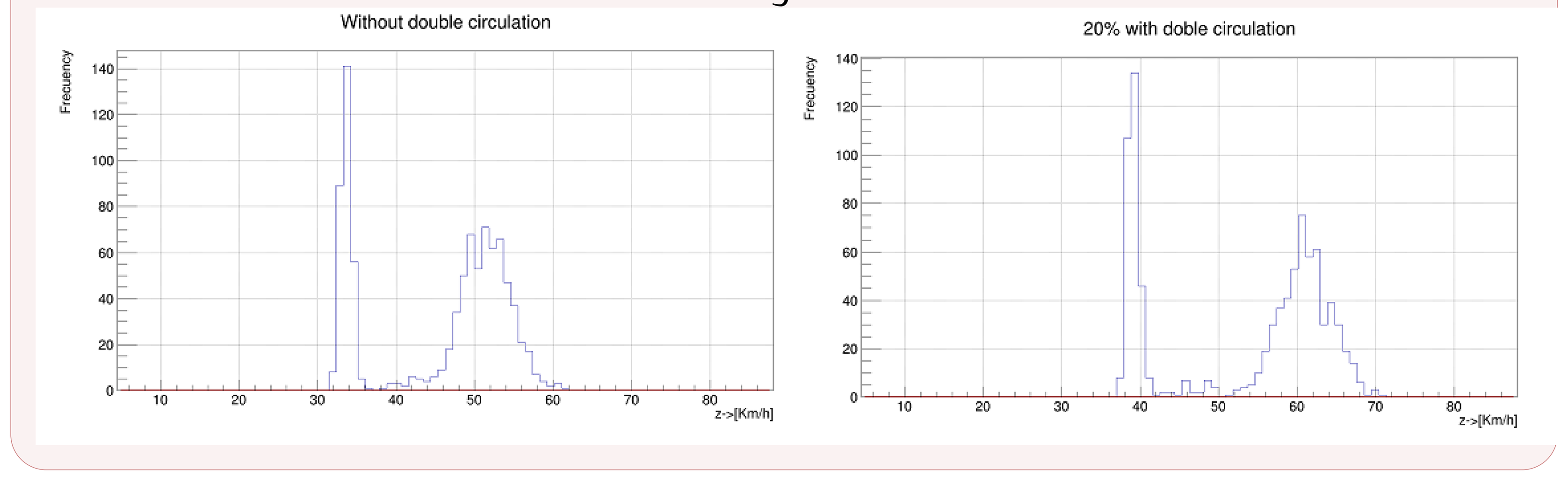
Experiments

Numerical simulation was done over a graph with 46 nodes and 75 edges, the minimum and maximum input speeds limits are 20 and 100 km/h.

For each iteration carried out in the optimization method, the evaluation of the objective functions, the velocity values in each direction per edge, and the verification of the conservation of velocity per node are obtained as results.

For the statistical analysis of the results obtained, it is necessary to generate a normalized histogram, for which the abscissa axis represents the amount of velocity in the graph (value of z) or in some road, and the ordinate axis is the frequency with which that amount of velocity was obtained from the total of experiments carried out

Fig.-3



Conclusions

The construction of the directed graph from a vehicular network allowed defining traffic directions, assigning flow capacities and weights to the roads. The use of the flow equations within the graph helped define the behavior of vehicular traffic between a pair of nodes. Based on the experiments carried out, it was found that the proposed model allows the optimization of the vehicular velocity by considering the existence of counter flows in certain roads.

References

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