SOLUTION

Traffic Light Plan Optimisation: reducing travel time, number of stops for vehicles and tramway lines

Urban traffic congestion is a critical issue due to increasing city populations and economic activities, traditional methods of traffic management have proven inadequate, particularly in complex and heavily trafficked areas. The primary objective of the Snap4City proposed solution has been to reduce congestion, in areas where tramways need priority by providing innovative traffic light optimization strategies. Thus, a novel approach has been developed namely: Genetic Algorithm-based Multi-Objective Traffic Light Optimization (MaMoTLO). It takes into account multiple factors such as minimizing stops, reducing travel and waiting times (private and public), and ensures the synchronization of tramway schedules. This approach is particularly useful in urban area where multiple tramways intersect with regular traffic, creating potential bottlenecks for private flows. The solution proposed outperform and has been compared with existing state-of-the-art methods, including those based on Non-Dominated Sorting Genetic Algorithm II (NSGA-II), SUMO Actuated solutions, and Webster's formula for traffic light timing. MaMoTLO solutions have been tested using real traffic data from Florence, Italy, and simulated scenarios to measure their effectiveness in reducing congestion and improving traffic flow on Snap4City open platform.

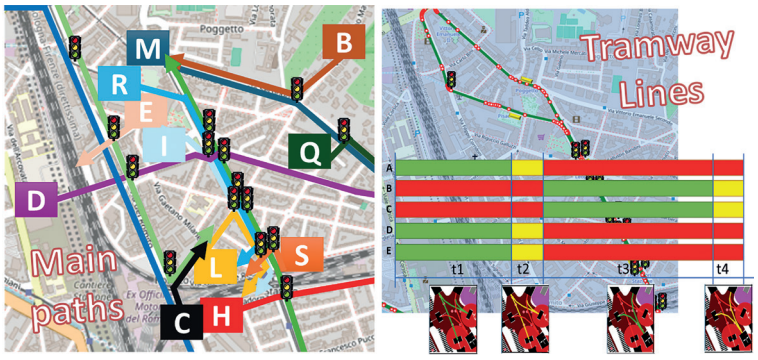

Figure: (left) Paths/directions in the study area of Florence, (right) paths of the tramways and corresponding traffic lights.

The findings indicate that selected MaMoTLO solutions outperform state of the art methods by providing a more balanced and efficient traffic light schedule, which is crucial for urban areas with high tramway traffic. The proposed optimization improves the flow of vehicular traffic and ensures that public transportation systems like tramways operate smoothly without unnecessary delays.

The traditional methods for traffic light management at crossroads can be essentially classified in:

- **Fixed-cycle** solutions follow a fixed cycle of green/yellow and red time durations (Traffic Light Plan, TLP) for each direction of traffic to prevent collisions and following normative.
- **Actuated solutions** adapt the cycles durations in real time according to local traffic density conditions of single junctions. This approach can be effective in certain traffic situations, while they are not usually capable to take into account the traffic status in the whole area, and of the arrival of the tramways with regular rates.

Both fixed-cycle and actuated methods may improve their performance by means of techniques such as:

- **Adjusted on Demand algorithms**: this add-on allows the traffic signal controller to receive requests about the presence of vehicles (ambulance, busses, police, etc.) or pedestrians and adjust the green duration (making it longer or red shorter) accordingly.
- **Traffic Prediction algorithms**: this add-on allows the traffic signal controller to use the previous traffic data to predict future traffic flows in the roads arriving at the junctions, as provided by Snap4City predictions tools.

MaMoTLO family of solutions is based on fixed-cycle approach to produce optimized TLPs of synchronized connected systems/groups of junctions with and without adjusting. They provide effective strategies to reduce traffic congestion:

- Combining Multiple-Objectives: to generate optimal TLPs considering multiple objectives and constraints, such as: high priority of public transport travel time, reduction of waiting time, reduction of number of stops, and take into account priority in multiple traffic directions (reduction of travel time), supporting green waves, and mitigating congestion at intersections, taking into account the lengths of the queues and of the tramway.
- Prioritizing public transportation and particularly tramway should be given the priority to guarantee the travel time to a higher number of people and for sustainability, and thus to avoid collapsing the transport systems since the rate on rides is high (tramway presents irregular velocity in segments due to the time needed at stops), and to minimize the number of stop for tramways at the traffic lights.
- Working at macroscale: the solution offers the ability to select a specific urban zone, as well as the entire city, to identify the real or simulated traffic flow workload and to optimize traffic light systems and produce all the TLPs for all the included junctions. This functionality allows for satisfying specific needs of the areas under consideration.
- Computing solution by using real traffic flow and/or typical values: the solution may use real traffic density and the related average vehicle speed as well as typical values to consider traffic density in the road network over time.

MaMoTLO approach incorporates innovative features (penalty, adjust, multiple constraints) and it has been demonstrated to produce traffic light plans which can be applied in areas in which the traffic light control does not monitor the traffic flows, and are not ready for the adjust, making the adoption of the solution cheaper and more sustainable. The Adjust on demand feature allows the control system to dynamically respond to real-time traffic conditions and the specific needs of tramway schedules. The solution ensures that tramways can cross intersections without unnecessary delays, while the Adjust on Demand rules allow for real-time adjustments to traffic light cycles to accommodate sudden changes in traffic flow. These capabilities make the MaMoTLO framework highly flexible, adaptive and robust, capable of handling the dynamic and often unpredictable nature of urban traffic in a large range of conditions.
The findings indicate that the MaMoTLO approach outperform traditional methods by providing a more balanced and efficient traffic light schedule, which is crucial for urban areas with high tramway traffic. By prioritizing tramways and optimizing traffic light schedules, it enhances the efficiency of public transportation and contributes to create a more sustainable and livable urban environment.

The solution has been capable to avoid stops for tramway lines (in the above described scenario), and to reduce the travel time, and waiting times of about the 7% with respect to the state of the art solutions.

The solution is based on Snap4City Scenario Editor which is accessible on all recent instances of the Snap4City platform. Read more on Scenario Editor on: https://www.snap4city.org/977

This result has been produced for the SASUAM scalability project, and for the OPTIFaaS Flagship project of CN MOST, the National Center on Sustainable Mobility in Italy (https://www.centronazionalemost.it/), and Snap4City as official infrastructure framework on which the experiments were conducted (https://www.snap4city.org). Snap4City is an open-source technology of DISIT lab.

This tool is accessible on Snap4City platform and some of its instances.

Extended version accessible from: https://www.snap4city.org/1015
SASUAM: Solutions for Safe, Sustainable and Accessible Urban Mobility, CN MOST, Spoke 8: https://www.snap4city.org/999
OPTIFaaS: Operation and Plan, Transport Infrastructure and Facilities Support as a Service, CN MOST Spoke 8 and 9: https://www.snap4city.org/1008
CN MOST: https://www.centronazionalemost.it/

SOLUTION