学位論文の審査結果の要旨

Transportation and mobility systems have become large-scale and complex in many cities with broad social impacts and strong implications for the economy and the environment. Experts use simulators to study the mobility and transportation in search of solutions to the problems observed in current systems. However, designing a sustainable transport system is a difficult task. The dimensionality of the problem and the number of possible solutions is overwhelmingly high for an expert. Thus, the expert usually can only focus on reduced parts of the system and analyze few alternatives that try to solve the problem partially.

This work focuses on a framework implementation that joins evolutionary computing, mobility and transportation simulators, and data mining techniques. The aim is to provide a sound method and tools that allow the exploration of a large number of potential solutions and the trajectory of the evolution to improve a system. The framework starts with the formulation and modeling of a mobility problem according to a specific case of study. After that, evolutionary computing with single and multi-many objective optimization evolutionary algorithms is used to explore the tentative solutions according to the model. The outcome of optimization is analyzed in variable and objective space to identify patterns, understand better the model, and extract knowledge useful to the decision maker. The framework is iterative, where the knowledge extracted can be used as feedback to fine tune the model or to study more complex formulations of the problem.

In this work, Quito city's business center is used as real world case study which covers approximately 5x8 km2. This work implements a mobility model for Quito, including mobility plans and the transportation network.

A first problem tackled in in this work is traffic signal optimization formulating the problem from a single and multi-objective optimization perspective.

A first study optimizes 70 traffic signals, modelling the mobility of 20.000 agents that use private transportation. A set of genetic operators combined with a deterministic varying mutation schedule is proposed to accelerate the convergence of the algorithm and promote a better solution's configuration to induce continuous traffic flow among neighboring intersections. Several experiments are performed using a single objective approach to minimize travel time. A detailed analysis of solutions is provided. In the variable space, the analysis verifies that the neighborhood operators induce coordination between signals and find some patterns using clustering methods. The identified groups are geolocated, verifying that they are positioned in neighborhoods as expected. Such clusters of coordinated signals favor the continuous traffic flows. In the objective space, analysis verifies that the groups of coordinated signals reduce travel time and emissions. Analyzing the difference in CO2 emissions between optimized and non-optimized solutions, emissions reductions are found across the area of study when signals are optimized is found.

A second study formulates the problem as a bi-objective optimization approach to minimize travel time

and fuel consumption simultaneously. The study shows that the inclusion of fuel consumption helps to achieve a robust optimization with better convergence, although both objectives are correlated.

Another problem tackled in this research examines traffic density levels in urban transportation. The study contemplates the urban transportation system under various proportions of private and public transportation users. The purpose is to explain the conditions to achieve different levels of service and their relationships with the optimal configuration of the public transportation, traffic density, travel time, fuel consumption and emissions. The level of service (LoS) refers to quality measures in a traffic stream. In this work, LoS is defined based on traffic density. The scenario is based in Quito's business centre, modelling the mobility of 27.000 agents that use private and public transportation, and modeling five main Bus Rapid Transit (BRT) corridors which are the most demanded and congested routes.

A first study focuses on a three-objective formulation of the problem, minimizing travel time, fuel consumption and traffic density. The Adaptive epsilon-Sampling and epsilon-Hood (AeSeH) algorithm is adopted to search the optimal configuration of public transportation system, in terms of capacities of the buses and departure times between buses, for various proportions of the population that uses public and private transportation. The results show that in general solutions with the best LoS have low values of fuel consumption, but high travel times. Similarly, solutions with worst levels of service show best travel time (most agents use their own car) but the worst fuel consumption. Sustainable public transportation implies a low environmental impact. In general, the results prove that best levels of service and low levels of fuel consumption can be achieved simultaneously. An analysis in Particulate Matter (PM) emission and its geo-location is conducted between two optimal solutions from the Pareto optimal set. The analysis pointed that a reduction in PM depends on BRT headways and technology (fuel type).

A second study concerns the same scenario using a bi-objective formulation of the problem, focusing only on travel time and traffic density as optimization objectives. Comparable results show a confirmation that better LoS (low density) corresponds to a high proportion of public transportation users. Also, a new set of solutions with the same LoS is chosen to make a complete analysis of the variable, objective and geographical space. This complementary analysis revealed that even if the solutions share the same LoS with different configurations in capacities and headways, effects in pollution must be taken into consideration by the decision makers when they decide to improve the transportation system.

The results of this investigation have been published in 1 journal paper and 5 international conference papers.

公表主要論文名

論文発表（１）（レフェリー制のある学術雑誌）

1. Rolando Armas, Hernan Aguirre, Fabio Daolio, Kiyoshi Tanaka, “Evolutionary Design Optimization of Traffic Signals Applied to Quito City”, PLoS ONE, vol.12, no.12, (37 pages), 2017.

論文発表（２）（レフェリー制のある国際会議議事録）

1. Rolando Armas, Hernan Aguirre, Kiyoshi Tanaka, “Multi-Objective Optimization of Level of Service in Urban Transportation”, Proc. of Genetic and Evolutionary Computation Conference (GECCO 2017), pp.1057-1064, 2017.
2. Rolando Armas, Hernan Aguirre, Fabio Daolio, Kiyoshi Tanaka, “An effective EA for short term evolution with small population for traffic signal optimization”, Proc. of 2016 IEEE Symposium Series on Computational Intelligence (SSCI 2016), pp. 1-8, 2016
3. Rolando Armas, Hernan Aguirre, Fabio Daolio, Kiyoshi Tanaka, “Traffic Signal Optimization and Coordination using Neighborhood Mutation”, Proc. of 2016 IEEE Congress on Evolutionary Computation (CEC 2016), pp. 395-402, 2016.
4. Rolando Armas, Hernan Aguirre, Saul Zapotecas-Martinez, Kiyoshi Tanaka, “Traffic Signal Optimization: Minimizing Travel Time and Fuel Consumption”, Proc. of Artificial Evolution (EA 2015), LNCS, vol. 9554, pp.29-43, 2015.
5. Rolando Armas, Hernan Aguirre, Kiyoshi Tanaka, “Effects of Mutation and Crossover Operators in the Optimization of Traffic Signal Parameters”, Proc. of 10th International Conference on Simulated Evolution and Learning (SEAL 2014), LNCS, vol. 8886, pp 167-179, 2014.