Integrating sensors data in optimization methods for sustainable urban logistic

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This is a summary of the author's PhD thesis supervised by Guido Perboli and defended on the 20th March 2018 at the Politecnico di Torino (Corso Castelfidardo, 34/A, 10138 Torino TO). The thesis is written in english and is available from the author upon request at edoardo.fadda@polito.it. This work deals with the develop new optimization methods and algorithms that use IoT new opportunities and solves new problems.

In particular, we focus on the exploitation of the sensor data in optimization method for sustainable urban logistics by considering two case studies: the optimization of waste management and social engagement for e-grocery and IoT data collection. In both of them, the use of new technologies modifies the way by which information is gathered and communicated, hence it changes how the studied problems can be formulated and solved.

The first case study considers the optimization of waste collection. We choose it because of the lack of information usually associated with the sector waste collection operations. To our knowledge, the project Optimization for Networked Data in Environmental Urban Waste Collection (ONDE-UWC) is the first one that exploits IoT data for smart-city applications (see Fadda, E. and Gobbato, L. and Perboli, G. and Rosano, M. and Tadei, R., Waste Collection in Urban Areas: A Case Study, Interfaces, 48, 307-322, 2018). In this project, the data related to the evolution of the quantity of waste are collected by the vehicles used for the collection. By using these data, it is possible to develop an optimization model, able to consider the evolution of the waste and to plan in an optimal way the routing and scheduling of the waste collection. This is a very important example of how IoT data change the nature of the optimization problem and the associated business model.

The goal of this approach is to minimize the number of time shifts and the corresponding routing of the waste collection operations of a company operating near the city of Torino.

The study is innovative because it does not enforce the periodicity of the routes. Nevertheless, due to this additional degree of freedom, the mathematical model rises in complexity and it is not solvable with commercial solvers. For this purpose, we develop a math-heuristic able to compute a solution of the problem in a time compatible with the operations of the company. This solution method allows the heuristic to be used in the real field and, with the IoT architecture implemented in the project represent a breakthrough for the sector of municipal waste collection.

In the second case study, we consider social engagement for e-grocery and IoT data collection because collecting data from the sensors and delivering packages are actions that do not require any specialization and that can be performed by every person. Furthermore, while the standard workforce has to travel on purpose to go to the location of the task, it is possible that some person passes in that area for doing other stuff. Then, it is possible to ask common people to perform tasks that otherwise would have required the standard workforce. This principle generates two positive effects: the first one is that the company can use its workforce for doing tasks that require more skilled people, the second is that the tasks are done by using travels that would have occurred in any case (this decreases the total number of travels, hence it decreases traffic and pollution).

The underline optimization problem is to minimize the amount of rewards while performing all the tasks. The importance of this project relies on the fact that it applies the users' engagement paradigm to activities of importance to the community.

To our knowledge, this is the first time that the optimization problem derived from crowd-sourcing is considered. The optimization model has been reported in Fadda, E. and Perboli, G. and Tadei, R., Customized Multi-period Stochastic Assignment Problem for Social Engagement and Opportunistic IoT, Computers & Operation Research, 93, 41–50 (2018).

We formulate the deterministic and the stochastic mathematical model of the problem and we propose heuristic methods able to find a good solution in a reasonable amount of time for both types of problems. It is important to remark that, since this problem has not been found in the literature, our results define the present best performance. In order to make a complete analysis of the proposed solution methods, to assess the efficiency of the meta-heuristics and to evaluate the robustness of the solutions we ran several numerical experiments by mean of a generator of instances of different sizes. These experiments conclude the analysis of the optimization of social engagement. In conclusion, it is possible to claim that the crowd-sourcing business models represent a new way to perform last mile logistics, furthermore the advantages provided by the sensors data in the optimization framework have huge potential.