Improving Waste Collection Procedures In Practical Smart City Implementations

Jan Dünnweber
Ostbayerische Technische
Hochschule Regensburg
jan.duennweber@othr.de

Amitrajit Sarkar
Ara Institute
of Canterbury
amit.sarkar@ara.ac.nz

Vimal Kumar Puthiyadath
KPIT Technologies Ltd
Vimal.Puthiyadath@kpit.com

Abstract

Computer-based Improvements to waste collection procedures are often a part of smart city initiatives. When we envision an ideal waste collection vehicle, it will arrive at every container exactly at the time when it is fully loaded. Beyond doubt, this will reduce traffic and support environmentally friendly intentions like an expansion of waste separation as it will make more containers manageable. An obvious difficulty of putting that vision into practice is that collection vehicles cannot always be where they are needed. Knowing the best time for emptying a container is insufficient for finding the optimal collection route. Therefore, we compare three different approaches to reducing the waste collection times by the use of networked fill-level sensors: Regensburg, Christchurch and Pune. Our analysis shows that the most efficient collection schedules result from adapting field-tested routes frequently on the basis of current sensor measurements and shortcuts resulting from route optimization computations.

1. Introduction

Even with the latest IoT technology like networked sensors and simulations forecasting the collection times of megacities, practical implementations of on-demand waste collection still have difficulties in keeping up with the prognosticated improvements. A collection vehicle that drives obstinately from the most heavily filled container to one with the fill-grade closest to that will obviously need more time in the majority of cases than a vehicle following a fixed plan, since heavily filled containers are probably positioned far apart from each other. Finding a smarter route leads us to the classic *vehicle routing problem* (VRP [1]), an instance of the *Travelling Salesman Problem (TSP)* with the added constraint that we need to return to the starting point after visiting a fixed number of points, since the collection vehicle has a limited capacity. Thus, we don't need to find the minimum Hamiltonian circle through all the points but multiple circles forming some kind of clover leaf. However, finding the best route to collect the waste containers does not only require to consider the distances between the single containers. Containers which are only filled to a certain level should be skipped, i. e. we are dealing with a instance of a dynamic route planning problem, which is also the subject of more recent research [2].

There are $\frac{n!}{2}$ different routes connecting n containers. For comparing all routes between only 10 containers, this means 3628800 routes must be analyzed. Modern waste collection vehicles can be loaded with ≈ 400 container of 120 liters [3]. $400!$ is a 882-digit number. Taken into account that skipping containers with little load, means the vehicle has to pickup an other one where it usually does not drive to, solving our dynamic VRP requires to solve a new problem of that size, every time when the fill-level measurements are updated. Nowadays, supercomputers can deal with such problem sizes [4]. However, the presented projects deal with approximate solutions, which can be found using a standard PC or an on-board computer in the garbage truck. Therefore, the presented work might be relevant for automating the navigation of future self-driving garbage trucks, like the one Volvo started testing in Brussels recently [5].

The approximate solutions presented in this paper are based on the *ant colony optimization* (ACO [6]). This approach has been proven suitable for dynamic VRP instances in a simulation, where the road network and the related traffic were taken into account [7]. ACO is a *swarm intelligence* procedure, i. e. not an individual (a simulated ant in the case of ACO) solves a problem but a group. For finding optimal routes, the simulation starts with letting the ants take random paths until they reach their destination. This random walk is optimized iteratively: each ant leaves a pheromone trail behind it which evaporates after a certain number of iterations. In every iteration the pheromone intensity of the shorter paths increases because whenever a simulated ant can choose among multiple paths, it takes the one with the highest pheromone intensity. This means, in higher iterations, the paths are no more randomly chosen but influenced by the most successful ants from preceding iterations, which are the ones whose pheromone trails did not evaporate until their followers reached them, since they were on the shortest paths.

The rest of this paper is structured as follows: Section 2 shows how the city of Regensburg benefits from using fill-level sensing and ACO-based route optimization for collecting their biological waste containers. Section 3 introduces *LevelSense* in Christchurch, an IoT-based approach to on-demand waste collection, which also uses ACO and is a part of a larger *Smart City* initiative in New Zealand, the *PiP-IOT project*. Section 4 introduces another route optimization algorithm, which is used by `kpit.com` for solving a related problem: Getting all the employees from various places in Pune to their their offices.

Section 5 looks back on the three projects, which were all put into practice, discusses the *lessons learned* from these projects, their benefits and points out some future perspectives.

2. Regensburg's Smart City Approach: Collecting Biological Waste more Efficiently

Our work in Regensburg focuses on improving the collection of biological waste. Figure 1 shows a container.

Figure 1. A Biological Waste Container equipped with a fill-level sensor

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

3. LevelSense and the PiP-IoT project

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

4. Collecting Employees at `kpit.com`

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

5. Conclusion and Future Perspectives

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

References

[1] G. B. Dantzig and J. H. Ramser, "The truck dispatching problem," *Management Sciences*, vol. 6, no. 1, 1959.

[2] J. Chen, R. Bai, H. Dong, R. Qu, and G. Kendall, "A dynamic truck dispatching problem in marine container terminal," *Symposium Series on Computational Intelligence (SSCI)*, pp. 1–8, Dec 2016.

[3] Hyundai Motor Company, "Garabge Truck Press Pack." Online e-Brochure `http://www.hyundai.com/gd/en/find-a-car/garbage-truck/press-pack.html`, 2018.

[4] V. V. Burkhovetskiy and B. Y. Steinberg, "Parallelizing an exact algorithm for the traveling salesman problem," *Procedia Computational Science*, vol. 119, no. C, 2017.

[5] Volvo Group, "Volvo pioneers autonomous, self-driving refuse truck in the urban environment." *Press release* `http://www.volvogroup.com/en-en/news/2017/may/news-2561936.html`, 2017.

[6] M. Dorigo and T. Stützle, *Ant Colony Optimization*. Scituate, MA, USA: Bradford Company, 2004.

[7] N. V. Karadimas, N. Doukas, M. Kolokathi, and G. Defteraiou, "Routing optimization heuristics algorithms for urban solid waste transportation management," *Transaction on Computing*, vol. 7, no. 12, pp. 2022–2031, 2008.