Scalable Robotic Intra-Logistics with Answer Set Programming: Abstract Report

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Answer Set Programming (ASP; [6]) has come a long way, starting as a semantics for logic programming, over having increasingly performant systems, to a growing number of significant applications in academia and industry. However, this development is threatened by a lack of commonly accepted design patterns and techniques for ASP to address dynamic application on a real-world scale. In addition, many industrial applications require the integration of multiple types of knowledge and forms of reasoning, a feature commonly neglected by existing approaches. As a first step to overcome these problems, we have identified *robotic intra-logistics* as representative scenario for our investigation. This domain is a major subject of interest in the context of the fourth industrial revolution, as witnessed by Amazon's Kiva [1], GreyOrange's Butler [2], and Swisslog's CarryPick systems [3]. All of them aim at automatizing warehouse operations by using robot vehicles that drive underneath mobile shelves and deliver them to picking stations. From there, workers pick and place the requested items in shipping boxes. For this setting, we aim to provide scalable and efficient ASP-based solutions by (1) stipulating a standardized test and benchmark framework; (2) leveraging existing ASP techniques through new design patterns; and (3) extending ASP with new functionalities.

What distinguishes robotic intra-logistics from other combinatorial problems is its multidimensional nature that necessitates the integration of a great many of aspects, most notably path finding and order fulfillment. So far, we introduced a scalable approach for a generalized variant of *Task assignment and path finding* (TAPF; [7]), laid out the conceptual problem domain accompanied by a benchmarking suite, and conducted a real-life case study for car assembly:

We introduced the *asprilo*[5] framework [4] to facilitate experimental studies of approaches addressing complex dynamic applications. Although *asprilo* relies on Answer Set Programming and Python, it is readily usable by any system complying with its fact-oriented interface format. This makes it attractive for benchmarking and teaching well beyond logic programming. More precisely, *asprilo* consists of a versatile benchmark generator, solution checker and visualizer (see Figure 1) as well as a bunch of reference encodings featuring various ASP

[5] *asprilo* stands for *Answer Set Programming for robotic intra-logistics*, its software tools are freely available at `https://potassco.org/asprilo`.

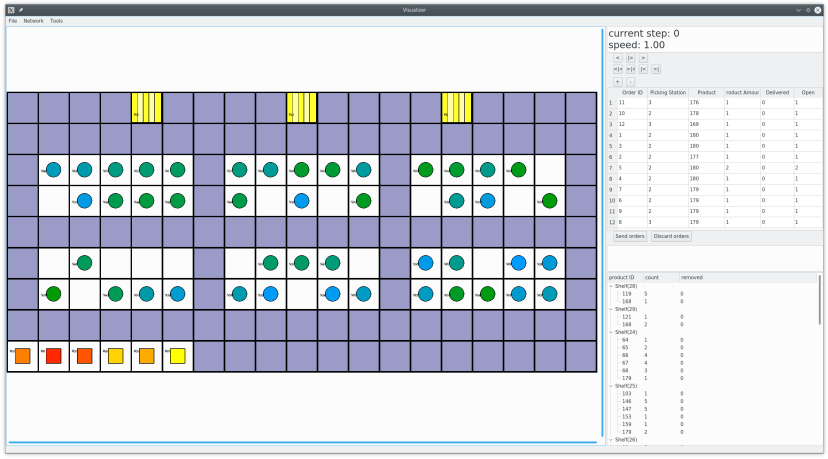

Fig. 1. Screenshot of *asprilo*'s visualizer: The main window gives a warehouse layout.Picking stations are represented by striped yellow squares, shelves by solid circles, and robots by solid squares. Highways are brought out in purple.

techniques. Importantly, the visualizer's animation capabilities are indispensable for complex scenarios like intra-logistics in order to inspect valid as well as invalid solution candidates.

TAPF models suffer from their limiting assumption that the number of agents and targets are equal. We proposed the *Generalized TAPF* (*G-TAPF*) [8] formulation that allows for (1) unequal number of agents and tasks; (2) tasks to have deadlines by which they must be completed; (3) ordering of groups of tasks to be completed; and (4) tasks that are composed of a sequence of checkpoints that must be visited in a specific order. As different G-TAPF variants may be applicable in different domains, we model them using ASP, which allows one to easily customize the desired variant by choosing appropriate combinations of rules to enforce. Our experimental results show that the popular CBM (conflict-based min-flow) algorithm is better in simple TAPF problems with few conflicts, but worse in difficult problems with more conflicts. We also show that ASP technologies can easily exploit domain-specific information to improve its scalability and efficiency. With these contributions, we made a notable jump towards deploying TAPF algorithms in practical applications.

Automated storage and retrieval systems are principal components of modern production and warehouse facilities. We addressed this prevalent problem in the context of car assembly at Mercedes-Benz Ludwigsfelde GmbH [5], a large-scale producer of commercial vehicles, where routes for automated guided vehicles used in the production process have traditionally been hand-coded by human engineers. Unlike this, we propose a declarative approach based on Answer Set Programming to optimize the routes taken by automated guided vehicles for accomplishing transport tasks.

References

1. Amazon Robotics. URL: http://www.amazonrobotics.com/.
2. GreyOrange Butler. URL: http://www.greyorange.com/products/butler.
3. Swisslog CarryPick. URL: http://www.swisslog.com/carrypick.
4. M. Gebser, P. Obermeier, T. Otto, T. Schaub, O. Sabuncu, V. Nguyen, and T. Son. Experimenting with robotic intra-logistics domains. *Theory and Practice of Logic Programming*, 2018. To appear. URL: http://arxiv.org/abs/1804.10247.
5. M. Gebser, P. Obermeier, M. Rasch-Heitmann, and T. Schaub. Routing driverless transport vehicles in car assembly with answer set programming. *Theory and Practice of Logic Programming*, 2018. To appear. URL: http://arxiv.org/abs/1804.10437.
6. V. Lifschitz. Answer set planning. In D. de Schreye, editor, *Proceedings of the International Conference on Logic Programming (ICLP'99)*, pages 23–37. MIT Press, 1999.
7. H. Ma and S. Koenig. Optimal target assignment and path finding for teams of agents. In C. Jonker, S. Marsella, J. Thangarajah, and K. Tuyls, editors, *Proceedings of the Fifteenth International Conference on Autonomous Agents and Multiagent Systems (AAMAS'16)*, pages 1144–1152. ACM Press, 2016.
8. V. Nguyen, P. Obermeier, T. Son, T. Schaub, and W. Yeoh. Generalized target assignment and path finding using answer set programming. In C. Sierra, editor, *Proceedings of the Twenty-sixth International Joint Conference on Artificial Intelligence (IJCAI'17)*, pages 1216–1223. IJCAI/AAAI Press, 2017.