Closed-Loop Optimization and Simulation for Rail Freight Yard

Paola Pellegrini, Pierre Hosteins, Samuel Deleplanque, Norbert Adamko, Miloš Zat'ko and Joaquin Rodriguez

February 7, 2020

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Paola Pellegrini[1], Pierre Hosteins[2], Samuel Deleplanque[3], Norbert Adamko[4], Miloš Zat'ko[4], Joaquin Rodriguez[2]

[1] Univ. Lille Nord de France, Ifsttar, COSYS, LEOST, 59666 Villeneuve d'Ascq, Lille, France
paola.pellegrini@ifsttar.fr

[2] Univ. Lille Nord de France, Ifsttar, COSYS, ESTAS, 59666 Villeneuve d'Ascq, Lille, France
{pierre.hosteins,joaquin.rodriguez}@ifsttar.fr

[3] Univ Lille, CNRS, Ecole Centrale, ISEN, Univ Valenciennes, IEMN, UMR 8520, Lille, France
samuel.deleplanque@yncrea.fr

[4] Simcon, s.r.o., 01008 Zilina, Slovak Republic
{norbert.adamko,milos.zatko}@simcon.sk

Mots-clés : *optimization ; simulation ; yard management ; rail freight*

1 Introduction

Managing a rail freight yard is a very complicated task that is currently performed mostly manually by yard operators. In the optimization literature, this management is typically decomposed in subproblems which are solved separately, considering only a subset of yard resources as constraining [1].

The Optimized Real-time Yard and Network Management (OptiYard) European project [2] aims to the optimization of the comprehensive yard management problem and to the production of a closed-loop optimization and simulation framework to show its applicability in reality. In this paper, we present the OptiYard closed-loop framework.

We consider the whole service operated on trains : trains are managed from their arrival at the yard up to their departure. All resources are modelled in detail : not only tracks, but also shunting locomotives and crews. The problem includes constraints on their number, their capacity and their time availability. Train and locomotive movements are modelled microscopically, to detect the occurrence of conflicts (situations in which an unplanned braking is necessary due to traffic) and take into account realistic running times. Finally, the problem is general in the sense that it can represent operations in virtually any yard, independently from its layout and from the type of operations which are carried out in it.

2 Closed-loop optimization and simulation framework

The aim of the closed-loop optimization and simulation framework is reproducing in laboratory a realistic situation in which a yard is automatically managed. Hence, in the framework, the simulator plays the role of a real yard and constantly communicates with the optimization module in charge of making decisions. These decisions concern all resource assignments and all wagon treatments necessary to effectively carry on yard operations.

We design an iterative algorithm which performs either a greedy or a randomized exploration of the search space, or a combination of the two. This randomized greedy heuristic makes all decisions, returning a solution describing the yard management plan considering all trains whose arrival is forecast when the optimization starts. The objective function measures the total delay of departing trains and the total time in yard of wagons. The two objectives are considered in a weighted sum in which a second of delay weighs 100 times more than a second of time in yard.

The Villon simulation software is used in OptiYard [3]. It is a tool which combines a discrete and a continuous simulation models and considers a detailed microscopic modelling of operations of various types of terminals. Operational procedures are represented through flowchart driven definition. Villon is based on state of the art methods and techniques of computer simulation (agent based simulation) and visualisation (3D accelerated utilising MS DirectX).

A two-way communication is established between optimization module and simulator. Specifically, the optimization module receives information by the simulator through XML files. Two types of XML files are produced : those including static data and those including dynamic ones. Furthermore, a continuous communication system is designed for decision sharing between the optimization module and the simulator. It is implemented through message exchange. It is based on a client-server architecture and it uses socket communication. There are two clients, one querying and one answering, both communicating only with the server. The communication server provides connectivity, security and data validation. All forwarded messages are in standard JSON format.

3 Case-studies

Two case-studies are considered : the Česká Třebová yard in the Czech Republic and the yard in the port of Trieste in Italy. The former is a hump yard with a marshalling capacity of up to $1,200$ wagons per day. The current average marshalling throughput is around 700 wagons per day, about 18% of which are intermodal wagons. The latter is a horizontal marshalling yard which handles around $8,000$ trains per year. Block trains are operated here : they arrive and depart with the same set of wagons, which are loaded or unloaded at the port.

4 Results and conclusions

The closed-loop framework was successfully applied to both case-studies. The time horizon that could be dealt with within the project in the two yards is not long enough to allow showing the superiority of optimization with respect to current practice.

The main contribution of the project is the ability to show that the optimized and automated management of rail freight yards is indeed possible. OptiYard provides a proof-of-concept demonstrating that the results of the optimization can be at least as good as those obtained in a real-world context.

5 Acknowledgements

The OptiYard project has received funding from the Shift2Rail Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 777594. The authors acknowledge the support provided by all the consortium partners, in particular Adriafer and CD Cargo for the data and information regarding the yards.

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