Multi-agent Train Driver Rescheduling: Simulating Environment Dynamics

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1. Introduction to MAS@NS

This demonstration presents recent developments in the MAS@NS project: a collaboration between Netherlands Railways and the D-CIS Lab to explore the effectiveness and suitability of a decentralized multi-agent approach to crew rescheduling. The project (launched in 2007) was reported on earlier at BNAIC'08 [1] and other conferences ([2], [3]). These publications describe the problem domain and present the rationale behind the MAS-based approach as well as details concerning the architecture and performance results. The project has resulted in a full scale prototype at the end of 2008, which is capable of solving large disruptions based on actual timetable and driver duty data. This demonstration focuses on recent advances in the ongoing pursuit of the goal of evaluating the system in an operational setting.

In the Netherlands Railways (NS) operations, each day ~1000 duties are carried out by drivers operating from 29 crew depots. The number of trains per day is ~ 5000, resulting in ~12000 train driver tasks. The NS planning process consists of three phases: timetable planning, rolling stock scheduling, and crew scheduling. The crew scheduling process supplies each train with a train driver and with sufficient conductors. During the operational phase, plans are continuously adjusted to cope with delays and disruptions (incidents, blockages, breakdowns, etc.). Our challenge is the rescheduling of train drivers.

The MAS@NS approach involves several agent types, representing the stakeholders in the environment: Train drivers' agents and Dispatcher agents. Furthermore, agents that encapsulate knowledge regarding the rail network and timetable are part of the system: Route Analyzer agent and Network agents. These provide up-to-date information about the environment to train driver agents. The main principle underlying MAS@NS is task exchange: train driver agents redistribute infeasible train driving tasks across the train driver agent population by exchanging tasks with other train driver agents.

2. Simulating Environment Dynamics

At the end of 2008, the MAS@NS full scale prototype was able to find solutions for *individual* scenarios. The environment in which these scenarios took place was fairly static: except for the disruption events defined in the scenarios no additional changes in the overall plans during the operational phase were modelled. In reality, however, plans are updated continuously to reflect the state of rolling stock and infrastructure. To simulate the environment dynamics of a real operational setting for MAS@NS, a number of concepts are added, as indicated below.

First, in the real world small disruptions are very common. Approximately one in every eight trains has a delay of more than three minutes. Other trains have small delays between zero and three minutes. To model this in MAS@NS we introduce delays for every train by randomly generating a disruption from an exponential distribution function for every train. The parameters of the distribution function were chosen in such a way that the resulting punctuality within our system is on average equal to the punctuality in the real world. In the current implementation of this simulation model, it is assumed that small delays can only occur at the final station of each train route. In future versions this will be improved by allowing delays to occur at intermediate stations and by modelling the possibility that delays might also decrease during the trip of a specific train.

Second, in an operational environment, information about disruptions contains predictions of the duration of the disruption based on information available at the time of the disruption report. In previous MAS@NS versions, these predictions are excluded from the scenario definitions (i.e., the duration of a disruption is fully known at the start of the disruption). Currently, scenario definitions are extended to include predictions of disruption durations. In turn, these predictions are used to ensure that solutions found by the task-exchanging train-driver agents do not rely heavily on parts of the timetable that have a high probability to change as more information about disruptions becomes available.

Finally, in the event of complex disruptions, finding at least one solution that covers all infeasible train driver tasks may not always be possible. In the real world this triggers dispatchers to re-examine the timetable and possibly cancel trains for which no drivers can be found. In the current version of MAS@NS – when no complete solution is found – so-called *partial solutions* are returned to the dispatcher, indicating the tasks which cannot be reallocated to available train driver agents. The dispatcher may then decide the best course of action based on the partial solution.

The current version of the simulator in MAS@NS is capable of simulating the events of a complete day. The large agent population and large amounts of inter-agent communication taking place in the system make MAS@NS a challenging system to develop, debug, and maintain. To this end, several visualization and analysis tools have been developed which hide unnecessary system level details and provide MAS@NS users/developers with higher level views on the solution finding process. Additionally, these tools are suitable for demonstration purposes: Visualizations can be generated for the (team-formation based) solution process (both abstract and situated in a representation of the Dutch rail-network environment) as well as the detailed duty modifications in the rescheduling solutions found by the system.

Acknowledgments

The authors express their gratitude to NS Reizigers and Cor Baars (DNV/Cibit) for starting this project. The following D-CIS Lab colleagues provided valuable contributions: Hilbrandt van Boven, Pascal Hoetmer, Michel Oey, Reinier Timmer, Louis Oudhuis, Martijn Broos, Sorin Iacob, Thomas Hood, and Kees Nieuwenhuis. The research reported here is part of the Interactive Collaborative Information Systems (ICIS) project (http://www.icis.decis.nl/), supported by the Dutch Ministry of Economic Affairs, grant nr: BSIK03024. The ICIS project is hosted by the D-CIS Lab (http://www.decis.nl/), the open research partnership of Thales Nederland, the Delft University of Technology, the University of Amsterdam and the Netherlands Organisation for Applied Scientific Research (TNO).

References

[1] Abbink, E.J.W., Mobach, D.G.A., Fioole, P.J., Kroon, L.G., Wijngaards, N.J.E., v.d. Heijden, E.H.T. *Actor-Agent Based Approach to Train Driver Rescheduling*, Proceedings of the 20th Belgian-Dutch Conference on Artificial Intelligence (BNAIC 2008), Bad Boekelo, 2008.

[2] Abbink, E.J.W., Mobach, D.G.A., Fioole, P.J., Kroon, L.G., van der Heijden, E.H.T., Wijngaards, N.J.E. *Actor-Agent Application for Train Driver Rescheduling*. Proceedings of AAMAS09, 2009.

[3] Mobach, D.G.A., Abbink, E.J.W., Fioole, P.J., Lentink, R.M., Kroon, L.G., v.d. Heijden, E.H.T.,Wijngaards, N.J.E. *Train Driver Rescheduling using Task-Exchange Teams*, in: Proceedings of the 2nd Int. Workshop on Optimisation in Multi-Agent Systems (OPTMAS) at AAMAS09, 2009.