Coordinating Maintenance Planning under Uncertainty (Demonstration)

Joris Scharpff Matthijs T.J. Spaan Leentje Volker Mathijs de Weerdt
Delft University of Technology, Delft, The Netherlands
{j.c.d.scharpff, m.t.j.spaan, l.volker, m.m.deweerdt}@tudelft.nl

ABSTRACT

In maintenance of (public) infrastructures, such as the national highway network, an asset manager is responsible for high network quality and throughput, while limiting expenses to a minimum. The maintenance activities, however, are often performed by commercial contractors, mainly driven by profit. Using a network-based payment mechanism we align the objectives of both stakeholders. Nonetheless, this greatly increases the complexity of planning maintenance activities, rendering it very difficult for human planners to develop (near-)optimal maintenance plans.

We demonstrate a support tool that facilitates multiagent planning for contractors so that they can coordinate their activities with other contractors in the network. This tool is initially intended as a serious game to create awareness and support amongst practitioners concerning this novel network-based coordination. In later stages we foresee great potential in the use of our tool as part of future dynamic contracting procedures.

Categories and Subject Descriptors

I.2.11 [**Distributed Artificial Intelligence**]: Multiagent systems

General Terms

Economics, Human Factors, Experimentation

Keywords

Multiagent systems, Planning and Scheduling, Coordination

1. INTRODUCTION

The planning and scheduling of maintenance activities on infrastructural networks, such as the highway network example of Figure 1 used in our gaming sessions, is a challenging real-world problem. While improving the quality of the infrastructure, maintenance causes temporary capacity reductions throughout the network. Given the huge impact of time lost in traffic on the economic output of a society, planning maintenance activities in a way that minimises the disruption of traffic flows poses an important challenge.

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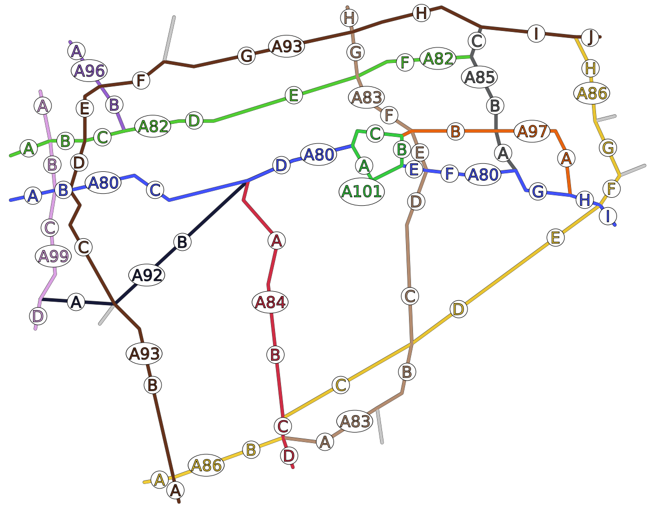

Figure 1: Example of a road network we use in the demonstration.

A powerful real-world example is the Summer 2012 closure of the A40 highway in Essen, Germany [1]. Instead of restricting traffic to fewer lanes for 2 years (the usual approach), authorities fully closed a road segment for 3 months, diverting traffic to parallel highways. Traffic conditions on the other highways hardly worsened, while €3.5M in social costs due to traffic jams were avoided (besides lowering construction costs).

Such convincing examples have motivated research into more innovative contracting procedures for infrastructural maintenance. In previous work [3], we presented a two-phase, dynamic contracting procedure as a solution for these problems. In the first phase, known as the procurement phase, maintenance activities are identified and assigned to the contractors through tendering. These activities are planned and performed in the second phase such that the inconvenience for the users of the network is limited to a minimum. The work we present here is a first step towards integration of our tool in the execution phase of this dynamic contracting procedure.

2. PROBLEM DOMAIN

We identified the need for a network-based approach towards maintenance planning. However, there are several complicating factors in this domain.

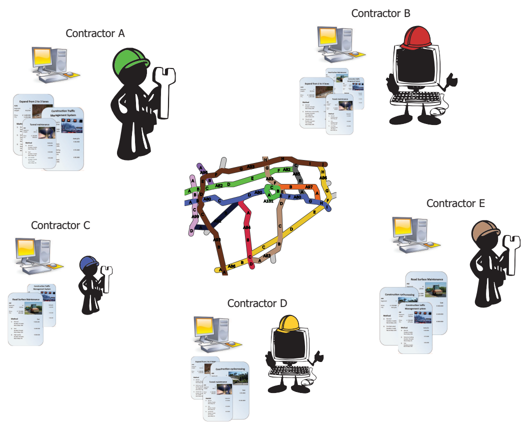

Figure 2: In the game, contractors (played by humans or computer agents) need to plan their given portfolio of activities on the network in the most profitable way. Their portfolios are represented by task cards, that specify the details of each activity. Note that each contractor is responsible for a different part of the network detailed in Figure 1.

Firstly, while a (public) asset manager is commonly responsible for the quality and throughput of the network, the actual maintenance has to be performed by commercial and autonomous third-party contractors, mainly focused on maximising profits. These two objectives have to be aligned through rewards/penalties in order to steer towards socially favourable maintenance plans.

Secondly, contractors performing the maintenance are interdependent through their activities on the network. A contractor servicing one part of the network influences other contractors in other parts, as his work has a negative impact on the traffic flow. Therefore, the use of congestion payments might result in high penalties for all contractors and hence the need for contractors to coordinate their maintenance plans on a network level is apparent.

Finally, execution of maintenance is inherently contingent. Apart from the possible difficulty of ascertaining an asset's actual maintenance state there are various causes for possible delays (e.g., weather, breakdowns, etc.).

Recently, we have proposed a novel combination of *dynamic mechanism design* with *stochastic planning* to tackle these challenges [2]. Agents are rewarded or fined, according to the quality they deliver and the additional congestion caused by their activities on the network, such that in expectation their profit is maximal exactly when these global objectives are optimised. Here we study the application of that research with human players in a real-world setting.

3. SERIOUS PLANNING GAME

We have implemented the problem of maintenance planning and the solution we proposed in [2] in a serious simulation game, that we dub the serious planning game. Players, either humans or computer agents, take on the role of contractor and have to plan their maintenance activities such that their profits are maximised. They are supported by an automated planner that provides insight into payments and costs, and is able to provide plan suggestions, see Figure 2.

The major goals of our serious game are:

1. Studying whether our novel contracting method can be used in practical scenarios, and whether practitioners are likely to accept and adopt our method.
2. Creating awareness and support amongst practitioners regarding the impact of (coordinating) maintenance activities on a network level. Using this tool we want practitioners to get a feel for our novel and progressive concept, increasing the likelihood of acceptance.
3. Validation of the payment mechanism. Human players will most likely not be perfectly rational, therefore we study the strategies played by human planners and the resulting outcomes.
4. Closing the gap between theoretical concept and realistic contracting. This will increase the likelihood of practical implications.

In order to evaluate our serious planning game, we have developed questionnaires and observation protocols, allowing for a systematic analysis of the different problem factors.

4. DEMONSTRATION

We demonstrate the complexities faced in planning maintenance activities on a network and the need for a support tool through playing the game. Conference attendees will be given the possibility to participate in the game and experience the difficulty of finding (near-)optimal maintenance plans, while having to deal with other human or computer players. Games will be played through the use of our game interface, played on tablets, and participants will be asked to fill in short (simplified) questionnaires at the beginning and end of the game.

The main goal for a player is to plan his activities in the most profitable way. Activities can be performed in different (pre-determined) ways, varying in cost, duration, risk, quality effect and traffic disruption, and interfere with other player's maintenance. For instance, closing both the A97b and A101 of the network of Figure 1 concurrently causes major congestion while separate maintenance might introduce only little additional traffic hindrance. These situations are challenging and must be coordinated, either using the automated planner or by means of agreements through player-to-player communication. Eventually, players with unfinished tasks will be fined and the players that score best in each of the objectives (considering the portfolio it was given) are declared a winner.

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