Self-Organizing Railway Operations

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1 Introduction

As the implementation of the European Union's transport policy after the introduction of the third railway package opened up rail passengers' services to competition, new stakeholders entered the railway market introducing new objectives of operations. In this new landscape, rail Infrastructure Managers (IMs) were assigned to manage the available network capacity to the Railway Undertakings(RUs), and also ensuring "that infrastructure capacity is allocated in a fair and non-discriminatory manner". The latter obligation arises from the fact that conflicts between RUs demands are anticipated and need to be solved fairly. However, Timetable Design is a highly complex task which determines directly or indirectly the overall efficiency of the railway network, including the quality of transport service, passenger satisfaction, and schedules of rolling stock and railway personnel. Moreover, timetables are vulnerable to disruptions, namely small delays, or disturbances at the operational level. In this case, alternative decisions are taken to ensure a smooth and quick recovery from the disruption back to the timetable.

The traffic management of railways is conducted centrally by rail dispatchers who are responsible for sequencing the trains and setting the routes to solve any potential conflict between trains. Since the available time for computing a solution is limited, many IMs have developed systems that provide decision support to dispatchers which are built for centralized decision making. However, many researchers have suggested an alternative approach to solving real-time traffic problems by applying a decentralized organization of control. Having subsystems that control smaller areas of the network, optimized local solutions can be easily reached and then aggregate to a global solution. Yet, nature has managed to implement a more delicate approach, self-organization.

Self-organization, a special form of decentralized control, is adopted in the majority of biological systems, including cells, social insects, multi-cellular organisms, and social groups. It is the result of an evolutionary process which allowed a large number of entities (insects, cells etc.) to benefit from their organization in a synergistic scheme but they lack the communication or computational capabilities to adopt a centralized organization. In contrast to the centralized systems, control in self-organized schemes is not only distributed across many independent subsystems of entities but these systems are dynamic, namely, the entities they consist of can move freely across these subsystems. Since entities have a local view of the environment then input, processing and memory requirements are much lower.

In this work, we aim to model trains as entities of a self-organized system similar to the biological systems seen in nature. This agent-based model will implement a bottom-up decentralized process, aiming to produce results comparable to centralized traffic management systems.