Living Systems/Adaptive Transportation Networks

Whitestein Technologies A Case Study

1. *Introduction*

This article presents a case study of an agent based system for dynamic transport optimisation. LS/ATN (Living Systems – Adaptive Transportation Networks) was developed by Whitestein Technologies Inc. for a European logistics company, to help reduce the cost of transportation. The main benefits brought by agent technology over traditional Transport Management Systems (TMS) are the abilities to adapt transport plans and schedules in response to unforeseen events, and to reduce overall transport costs by improving the coordination between regional dispatchers and the utilisation of trucks. This document gives an overview of the system, the optimisation approach, the development process, and the main experiences and lessons learned.

2. *The transportation problem*

Optimal utilisation of capacity is one of the most important factors in the transportation business. To this end, logistics companies implement computer-based tools for planning of the transportation network both at a strategic level and for short-term route optimisation. Traditional off-the-self software solutions are able to automatically create dispatching plans, but cannot adequately handle unexpected events and produce the necessary plan deviations in real-time. In cases of last minute changes of orders or unexpected unavailability of trucks due to traffic jams, breakdowns or accidents, static planning systems cannot be used, and human effort is needed to adapt the dispatch plans and control their execution. This is because these planning systems are designed for relatively stable and not overly complex transportation networks, where transportation processes are mostly repetitive and therefore analytical optimisation methods are applicable [1].

Planning systems need to find optimal routes in response to transportation requests arriving simultaneously from many customers. Transportation orders contain information about the location where the product must be delivered, the product quantity, and the time window allowed for pickup and delivery. The challenge lies in allocating a limited number of trucks of varying capacity and available at different locations, so that transportation time and costs are minimal, while the number of on-time pickups and deliveries, and therefore customer satisfaction, are maximised.

3. Whitestein Technologies

Whitestein Technologies is a Switzerland-based software company, founded in 1999, which specialises in agent-based solutions for the production and logistics domains. Today, Whitestein has a team of more than 80 people at four European locations. The core logistics product offered by Whitestein is LS/ATN. It is based on LARS (Living Agents Runtime System), a development toolkit for agent-based optimisation. LARS was initially developed by Living Systems GmbH, Germany, a pioneer of industry-grade software agent technologies, which was acquired by Whitestein Technologies in 2003. The successor of LARS is named LS/TS and is now being offered by Whitestein as a new agent development platform. A set of advanced solutions for complex telecommunications problems, as well as professional services are also part of the company portfolio.

4. The LS/ATN system

LS/ATN (Living Systems – Adaptive Transportation Networks was initially developed for a German subsidiary of a major European logistics company, and later contracted and customised for another smaller logistics customer. LS/ATN supports, optimises and, to a large extent, automates the dispatching process of logistics companies.

The complexity of the truck allocation problem is due to the dynamic nature of transportation:

1. transportation requests are not all known in advance, in that new orders can arrive at any time during the execution of optimisation;
2. old orders can change during optimisation; and
3. the size of the order may be correctly known only when the driver arrives at the pickup location.

The optimisation problem consists in finding a delivery plan, which is a set of routes and the associated transportation schedule for each route. A schedule must specify the locations and the times at which trucks must arrive and depart from each of these locations. Other input parameters that characterise the transportation problem are related to the product to be transported (e.g. order type, volume, weight, loading time, etc.) and the trucks available for transport (e.g. truck type, volume, loading and unloading equipment available, and staff and tariff).

4.1 Agent-based optimisation

The design of the agent-based system takes into account the geographically dispersed nature of transportation and the way that European logistics companies approach the transportation problem. The agents therefore represent geographical regions, while cargo load is modelled as information (objects) flowing between agents. Thus, transportation operations are allocated to different dispatching regions, with each region controlled by an *AgentRegionManager,* while a broker agent (the *AgentDistributor*) deals with incoming transportation requests.

Optimisation is implemented as a two-step process and aims to achieve the lowest transportation cost:

1. In the first step, a local optimisation is performed. Every incoming transportation request is received by the *AgentDistributor* and allocated to the *AgentRegionManager* of the region containing the pickup location. The *AgentRegionManager* then searches for an optimal solution within that region, using a hill-climbing algorithm.

2. In the second step, global optimisation is performed. The solution found at Step 1 is changed by bilateral negotiation between the *AgentRegionManagers*, in order to find improvements to the current solution. In this negotiation, agents ask each other questions in order to determine the availability of trucks for a certain load, or the availability of load for a certain number of trucks. Communication is restricted to the agents of the starting region and the end region, and is designed for the exchange of a minimum amount of information, in order to keep the overhead time and memory at minimum. For example, for a route which begins in Germany and ends in France, the negotiation and information exchange is only between the Germany agent and the France agent, and not with any other agent. Other negotiation solutions were also implemented and tested (e.g. between three and four agents), but they were found to significantly increase the solution space and therefore the search time, while the quality of the final solution was less than 0.1% higher than the bilateral negotiation.

While the optimisation function is mainly based on cost, other objectives include reducing the number of trucks by utilising them more efficiently, and reducing the length of the routes. In addition, the optimised solution must satisfy a set of constraints, which the algorithm calculating the routes must consider. Some of these constraints are compulsory (*hard constraints*), such as capacity and weight limitations of the truck, opening hours of customers, that pickup date is before delivery date, and that pickup and delivery are performed by the same truck, etc. Other constraints (*soft constraints*) can be violated against a cost penalty, such as finding the earliest possible pickup time or the earliest delivery time.

Optimisation is dynamic, being performed every time a new transportation request is entered in the system. This allows the system to dynamically adapt transport plans and schedules to possible deviations and unforeseen events. Distributing the optimisation task among the agents ensures scalability with increases in the number of requests, and improves robustness by avoiding a single point of failure. The negotiation and coordination between agents have the potential to reduce overall transport costs and to improve resource consumption.

4.2 System integration

The system can be used both standalone for simulations purposes, supporting planning decisions, and also to automate the optimisation task, when running as an integrated tool with telematics systems and transportation management systems (TMS). As an operational production environment, the agent-based system must be linked to several back-end systems:

- the back end is integrated with an order acquisition system;
- the final results are automatically sent to the specific billing and reporting TMS subsystems; and
- geographical data necessary to calculate distances and time between locations is gathered and displayed in real-time from geographic systems.

In addition, the dispatcher also has the ability to trace the execution of plans and routes of trucks, so that a decision can be taken whenever a delay occurs. Information on times at which a pickup or delivery occurred is usually fed back automatically to LS/ATN via a telematics system. The link with the telematics system is implemented through an agent that proactively informs the dispatcher whether loading or unloading were according to plan, but information about plan changes can also be entered manually by the dispatcher when it is obtained, for example, through a phone call from the truck driver. Real-time tracking of pickup and delivery times is used by LS/ATN to react to plan changes and update current plans. For example, when an order is modified or is cancelled, if the corresponding route is still being planned, the agent re-optimises the plan and informs the dispatcher. If the route is being executed, the agent only suggests a change to the transport plan but leaves the final decision to the dispatcher.

5. Business case and project management framework

The development of LS/ATN was a major project, involving more than 20 people over a period of three years. The project started with a one year investigation phase, aimed at analysing the business and technical requirements, to evaluate different solutions and to establish the value of agent technology in comparison with existing transportation management systems (TMS). In this stage, it was also important to the customer to ensure that Whitestein could deliver both standard large IT projects, successfully addressing complexity and scalability requirements, as well as providing dynamic optimisation in real-time.

From a business perspective, Whitestein proposed a detailed business case containing projections of cost and Return On Investment, for a subset of the business operations of the customer, over a period of 10 to 12 months. In technical terms, the LS/ATN system was compared with traditional TMS technology. In such traditional TMS systems, order information is collected, transportation routes are determined by an automatic management module, route information is then manually dispatched to the truck drivers, and finally payment is calculated and truck companies are invoiced. The advantage of LS/ATN is that it provides automatic and optimised dispatching support and an automatic link to truck's telematics systems. While some TMS systems also address the optimisation problem, they use either linear programming or standard industry software packages for logistics (e.g. iLog). Moreover, traditional TMS systems are designed for medium size logistics companies and therefore optimisation addresses only the regional and not the European level. In addition, some of them are only single user applications.

A six-month period followed in which the system specification was developed, through collaboration between Whitestein and the customer, involving frequent face-to-face meetings (up to two or three times weekly) with local business and technical representatives. During the specification process, one key aspect addressed was system usability. To ensure easy adoption and operationalisation of the final system, LS/ATN user interfaces had to share functionality and design features with the user interfaces of traditional TMS systems, both in terms of static features and features that allow the user to design and change the interface elements (e.g. windows, columns, etc). In addition, the system needed to have only an assisting role, with the dispatcher retaining full control over the dispatch information, given the experimental nature of the project. The dispatcher thus needed to be able to override, at any time, system decisions and have the visual and functional facility to move all the trucks into manual dispatcher mode, thus falling back on the electronic switchboard.

6. *Lessons and experiences*

From Whitestein's experience, the successful adoption of agent technology depends on several factors, as follows.

1. It was important to help people understand the business value of an agent-based system, to explain to them how agent technology works and how the optimisation problem is approached. However, it was also essential that optimisation was not over-emphasised in relation to other technical features necessary for the system to compete on the TMS market. It was thus necessary to ensure that innovation was introduced only where needed and was balanced by standard features and functionality provided by TMS tools.

2. In the process of selling agent technology, the agent metaphor was useful in attracting customer interest, as it was found to be an intuitive way of modelling the business domain, through the one-to-one mapping between agent roles and business roles (e.g. the dispatcher).

3. Building a good customer relationship was crucial and required significant effort and cooperation from both sides. For example, more than three years were needed for the developers to completely dig into the domain and understand its special challenges in detail.

4. The challenge throughout the project was to deliver software of industry-standard quality, and generally to compete with vendors of existing TMS tools. It was thus important that development and deployment were approached with traditional software engineering methods and standards, and traditional project and risk management techniques used for IT implementations.

5. A major challenge in operationalisation was getting users to accept and trust the results of the optimisation, and thus to start using the system on a daily basis.

7. Summary

This case study has presented the implementation of a dynamic transport optimisation system using agent technology. LS/ATN is a system built by Whitestein Technologies for a major logistics customer to make transport operations more efficient, and to reduce running costs. A combination of heuristic-based and inter-agent negotiation mechanisms are used to determine transportation routes that minimise cost while maximising truck utilisation and reducing the amount of driven kilometres. The system was used both as a simulation environment to support planning, and as a production system to provide dispatch information in real time. Experimentation with LS/ATN as a simulation environment gave rise to significant benefits compared to traditional packages for transportation management, leading to a potential 5% to 10% cost reduction when used as a production system.

References

[1] K. Dorer and M. Calisti, An adaptive solution to dynamic transport optimisation. In M. Pechoucek, D. Steiner, and S. Thompson, editors, *Proceedings of the Fourth International Joint Conference on Autonomous Agents and Multi-Agent Systems: Industry Track*, 45–51, ACM Press, 2005.

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