The Intelligent Container - Toward Autonomous Logistic Processes

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Abstract. In this demonstration a research prototype for autonomous local control of logistic processes in the transportation domain is presented. The aim of autonomy in logistics is to gain flexibility and robustness in process execution as well as increasing promptness and reducing human efforts in the coordination of a logistic process. This is enabled by state-of-the-art technologies from computer science and electrical engineering. The intelligent container and associated stationary systems form a demonstration platform that provides a distributed infrastructure for autonomous process monitoring, control, and coordination systems.

1 Introduction

A change to dynamic demand-oriented markets and mass customisation with the associated increase in part-load traffic and need for custom-tailored logistics services require new control and coordination strategies for logistic processes. Conventional centralised planning and control methods cannot cope with these challenges regarding robustness, flexibility, and pro-activity. The upcoming paradigm shift of autonomous cooperating logistic processes aims at facing these challenges by decentralisation of decision-making to the logistic objects and application of state-of-the-art technologies [1].

Logistic objects are, e.g. in transportation, freight items, means of transport, transport containers, or warehouses belonging to different organisations. These logistic objects have the ability to interact with other logistic objects of the considered system. Furthermore they are able to act independently according to their goals and abilities. The autonomy of logistic objects is made possible by recent developments in information and communication technologies, for example RFID technology for identification, GPS for locating logistic objects, wireless communication and sensor networks, as well as intelligent software agents deciding on behalf of logistic entities.

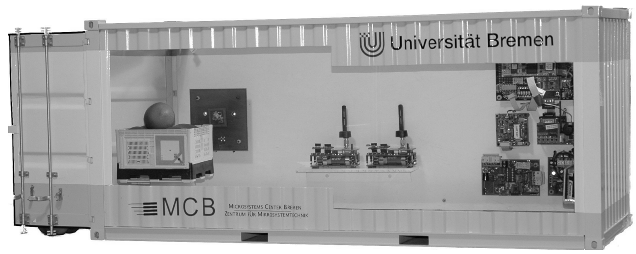

Fig. 1. The intelligent container as a 1:8 scale model.

This is the research focus of the Collaborative Research Centre (CRC) 637 that has been established as an interdisciplinary long-term project by the German Research Foundation (DFG) in the beginning of 2004 with researchers from industrial engineering, economics, computer and information science, electrical engineering and mathematics. The intelligent container presented in this article is a demonstration prototype for decentralised decision-making and autonomous coordination of logistic objects in transportation processes including on-line freight quality assessment and robust management of process disturbances.

2 Design of the Intelligent Container

The intelligent container depicted in Fig. 1 and associated stationary systems provide a distributed infrastructure that hosts the process monitoring, control, and coordination systems based on interacting FIPA-compliant software agents deciding on behalf of logistic entities, RFID-based detection of loaded and unloaded goods, as well as wireless sensor networks enabling on-line quality assessment inside the container [2].

2.1 Distributed Agent Platform

Logistic entities as well as secondary logistics services (e.g., traffic information, route planning, and service brokerage) are represented by a system of software agents [3] that interact as defined by FIPA standards [4]. The agents are distributed within the logistics network. Some agents run on an embedded system inside the intelligent container for quality supervision [5], others run on external stationary PC platforms of companies participating in the logistic process, e.g., the manufacturer/sender or providers of logistics services. In our set-up these external platforms are pooled on a single notebook computer that hosts agents of logistic objects for process coordination and planning. This PC platform also provides a simulation environment for autonomous logistic processes. Both agent platforms are based on the Java Agent Development Toolkit JADE[5] or its embedded system branch LEAP, respectively.

[5] `http://jade.tilab.com/`

2.2 RFID-based Tracking and Mobility

Transport packing and labels are usually disposed after arrival. Expensive sensor or processor equipment would be lost after the transport ends. Thus, we use low cost passive RFID tags that provide only very small computation and data storage facilities. The freight supervision process runs on an embedded platform provided by the means of transport or transportation container. The quality supervision agent accompanies the freight along its way through the supply chain. It is transferred in parallel to the physical object by migrating from warehouses to means of transport and vice versa.

RFID tags control the transfer of the agent by providing information on the network address of the last platform or server that hosted the freight supervision agent. When the freight object enters the domain of a new platform the platform manager reads the information from the RFID tag and requests the corresponding agent under the given address. When it is transferred to a new platform it connects itself to the local sensor facilities and continues the supervision task in the new freight hold.

2.3 Wireless Sensor Network

The freight hold environment is monitored by a wireless sensor network (WSN). The sensors may cover temperature, humidity, acceleration, concentration of certain gases or simply switches for supervision of the doors of freight compartment. We use a WSN system that is based on IEEE 802.15.4-compliant low-power RF interfaces and follows a component-based design scheme used in the well-known and widely-used TinyOS (as shown in e.g. [6]). Each of the WSN node may either be deployed during the loading of the freight items or directly attached to a freight item. After being loaded into the container all deployed sensor nodes autonomously form ad hoc networks. The agent platform/gateway system inside the container acts as a base station to the sensor network.

3 Demonstration Scenario

A demonstration scenario shows the application of the intelligent container in a road transportation scenario with a full truck load of a highly perishable good that needs steady cooling. After the specification of a transfer order no human interaction is needed besides transhipping the load. A simulated truck virtually transports the intelligent container within the German motorway network. During the scenario disturbances like traffic congestions and rising temperature inside the container are triggered. These events need on-line assessment and replanning that is autonomously handled by the respective agents. The scenario and the status of selected agents are visualised in a GUI (cf. Fig. 2).

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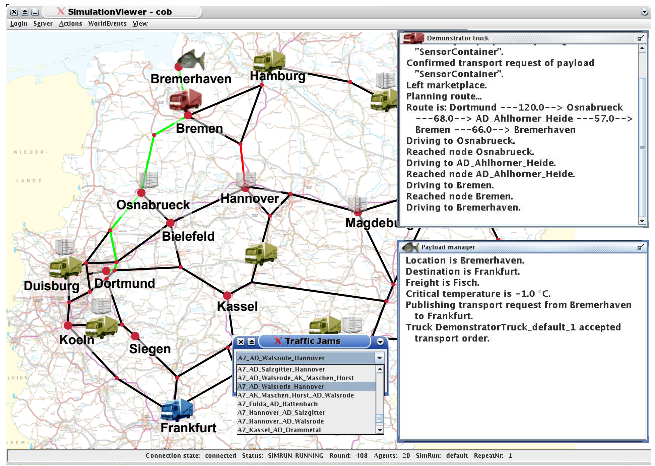

Fig. 2. Scenario monitoring GUI showing the traffic network, trucks and loads with their respective positions as well as status information of selected agents.

Processes". The intelligent container was developed by the cooperation of several people within the CRC 637. For their valuable contributions we express our gratitude to Markus Becker, Farideh Ganji, Adam Sklorz, Detmar Westphal, Bernd-Ludwig Wenning, Martin Lorenz, Ingo J. Timm, Andreas Timm-Giel, Luis Javier Antûnez Congil, and Christian Ober-Blöbaum.

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