Flexible Intralogistic Processes Through Service Robot System Composition

Matthias Rollenhagen[1], Nayabrasul Shaik[1], Matthias Lutz[1], Christian Schlegel[1]

I. INTRODUCTION

Shrinking product life cycles and logistics contract durations force companies to comply with short payback periods for their logistics automation systems. It is not possible to meet this goal with conventional static automation machinery, since they can only be used for a specific process, not providing the required flexibility. Seasonal or spontaneously temporal fluctuations also pose a problem for static automation machinery, as these kinds of market behaviors cause frequent under- or over-utilization. For these reasons many intralogistic processes today are carried out manually in large part, which is flexible but also expensive.[1]

In contrast to conventional automation machinery, service robots can be used flexibly according to location and task. Exploiting this flexibility to full capacity and in an economically efficient way, it is required to easily adapt intralogistics robotic systems to new requirements (changed environments, processes and products). Logistics companies and departments have to be enabled to easily configure service robots on their own, without becoming robotic experts.

To tackle this problem, we propose flexibilization of robotic intralogistics automation systems by constructing them from composable building blocks with unified interfaces and left open variations points using Model-Driven Software Development. In the following sections the approach is illustrated by a commissioning application and conclusions are drawn about the effect of using this approach in intralogistics.

II. A COLLABORATIVE COMMISSIONING APPLICATION

A. Scenario Description

The application (Fig. 1) consists of a fleet with two different robots collaboratively executing commissioning orders: Robotino 3 for transportation and a UR5 manipulator equipped robot for order picking. The commissioned items are stored in two different kind of shelfs: The first one is an inclined shelf storing the items in an unstructured way inside cardboard boxes and the second one is an a-frame, providing the items in a structured way. Additionally, ungraspable objects are stored in regular shelfs.

The fleet receives orders from a mocked warehouse management system and autonomously performs the commissioning. The robots collaborate during the execution of the commissioning, splitting the task into order picking and transportation of the picked items, within small load carriers. Where needed, e.g. item handover, the two collaborating robots directly interact on behavior model level. Items which cannot be grasped by the robot, are commissioned using human robot collaboration, exploiting the human's grasping capability. The robot relieves the human worker from performing the transportation. Videos of the execution of the complete application is available in YouTube [3].

[1]Matthias Rollenhagen, Nayabrasul Shaik and Matthias Lutz are members of the Service Robotics Research Center at Ulm University of Applied Sciences headed by Prof. Dr. Christian Schlegel {rollenhagen,shaik,lutz,schlegel}@hs-ulm.de

Fig. 1. Collaborative robotic commissioning, picking pharmaceutical packages from cardboard boxes in industrial environment.

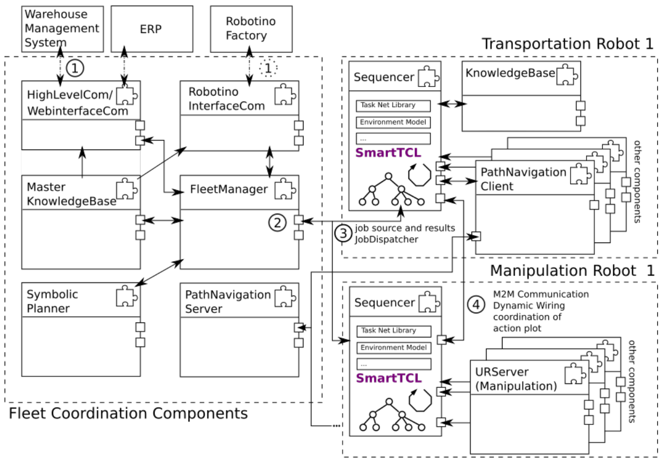

Fig. 2. Heterogeneous robot fleet system architecture.

B. System Architecture

The software system is composed out of components modeled and developed using the SmartMDSD Toolchain

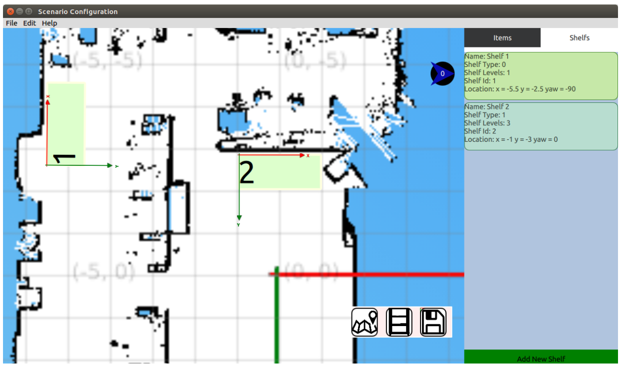

Fig. 3. Domain-specific software tool for modeling intralogistic environments. The GUI shows a map with two placed shelfs.

[5]. The robot fleet's architecture (Fig. 2) is driven by the idea of autonomous, loosely coupled, individual service robots [6]. Each robot consists of a set of again loosely coupled SmartSoft components, orchestrated by a Sequencer component (3T Architecture). The components required for fleet coordination (Fig. 2 left) can either run on a dedicated infrastructure computer or on one of the robots in the fleet.

Received orders (1) are assigned (2) to idle and matching robots (3). The individual robots coordinate their interactions using dynamically established Machine-2-Machine communication. The coordination between collaborating robots on the robotics behavior level is performed between the Sequencer (4) components of the robots.

C. *Domain-Specific Tool Support*

Before deploying the fleet to a new environment, the system needs to be adapted to its specific characteristics like items and storage infrastructure. To enable adaptability to these characteristics, the components are developed leaving open explicated variation points. A software tool (Fig. 3) is used, to provide a graphical modeling interface for creating new system configurations. The tool enables workers without deep robotic knowledge to perform robot system adaption, by binding the left open variation points (e.g. shelf orientation, item grasping properties, etc.).

III. CONCLUSION AND FUTURE WORK

Evaluations in an industrial environment showed, that the approach provides the required flexibility. The different robotic systems were composed of available building blocks, being adapted to the application's and environment's needs.

The adaption of the system to new environments and processes by composing dedicated software components and by using the explicated variation points, exploiting domain knowledge has been exemplarily evaluated by a set of object recognition components: The development of a recognition component for a small group of well defined items is feasible in a much shorter period of time, than a complex, generic recognition system. This approach made it easy to extend the robot's recognition abilities to new products by developing additional, relatively small and composable components, thereby increasing the robot's versatility. Additionally, domain-specific software tools enable the users to easily adapt their robots to environment and process changes. These straightforward ways of adapting service robots to new requirements assures the reuse of systems in large parts, which enables contract logistics companies to spread their payback periods over multiple contracts.

The same applies to temporal fluctuation: During times of under-utilization, service robots can perform different tasks inside the company (e.g. supporting the production line). The requirement changes compared to the logistics tasks are too fundamental for simple reconfiguration. But the component based approach allows to adapt to these requirements by development and substitution of single components. The other way around, service robots regularly used in the production line can be adapted to intralogistic processes in times of high commissioning demands. This way, robots can be used in different processes, without redeveloping the whole system.

In intralogistics there is a limited number of primitive operations [2], that could be carried out by configurable components. Therefore, it seems obvious to promote a robotics business ecosystem [4] for the intralogistics domain. This ecosystem should enable the collaboration of the various stakeholders to benefit from their dedicated expertise, as well as the distribution of components via a virtual market place. One of the questions arising in this context, is how fine-granular components need to implement these logistics operations, and how to deal with nonfunctional properties of the building blocks. The building blocks need to be generic enough, to allow a flourishing building block market, but also concrete enough, for using them without deep robotic expertise to offer financial benefits.

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