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FLIP: Prototyping multi-robot systems

Lars Kock Jensen [a], Bent Bruun Kristensen [a,*], Yves Demazeau [a,b,1]

[a] The Maersk Mc-Kinney Moller Institute for Production Technology, University of Southern Denmark, Campusvej 55, 5230 Odense M, Denmark
[b] Laboratoire LEIBNIZ, Institut IMAG 46, Avenue Felix Viallet, 38031 Grenoble Cx, France

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Abstract

The main objective of this article is to promote the use of inexpensive and realistic prototypes to verify the applicability of state-of-the-art technologies in the area of mobile robotics and intelligent manufacturing systems. We propose a toy prototype based on a LEGO® Mindstorms™ RCX brick extended with a PDA and wireless LAN. We describe and evaluate the application of an agent-oriented approach for a prototype of an autonomous transportation system. This transportation system is an integral part of the FLIP project in which intelligent collaboration during transportation and processing of LEGO® bricks is investigated.

Keywords: Multi-agent systems; Intelligent manufacturing; Agent architecture; Autonomous robots

1. Introduction

In general, a major focus of attention in manufacturing is optimization. So far centralized planning and control of the work processes has been the general approach to achieve an optimization of the overall performance of the production system. There has been less focus on issues concerning robustness in terms of fault tolerance and flexibility with respect to product variety and changing demands, which may have significant impact on long-term performance. The holonic concept [9,16], proposed by the Hungarian author and philosopher Arthur Koestler, could be a source of inspiration for another view on the design of production systems. Based on biological and social observations, he argues that entirely self-organized and non-interactive entities do not exist. In other words—every entity is made up by smaller entities and is itself part of larger whole. An equivalent theory is proposed by Marvin Minsky in [12]. He states that the mind is a complicated network of semi-autonomous non-intelligent processes (agents) and that intelligence emerges from the interaction between these agents. Applying these views for manufacturing systems suggests that control should be

* Corresponding author. Fax: +45 66 15 76 97.
E-mail addresses: lkj@mip.sdu.dk (L.K. Jensen), bbk@mip.sdu.dk (B.B. Kristensen), yves@mip.sdu.dk, Yves.Demazeau@imag.fr (Y. Demazeau).
[1] Fax: +33 4 76 57 50 81.

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distributed to each entity (e.g. a production unit) if we wish to manage the complexity and evolution of large production systems.

The multi-agent system paradigm enables us to design manufacturing systems that govern the key properties of the holonic concept—autonomy, cooperation, self-organization, and re-configurability. The fields of artificial intelligence, autonomous agents, and multi-agent systems have evolved dramatically over the past couple of years but the number of industrial applications is much lower than one would expect. We have not yet come to a point where integration of intelligent agents is prevalent among manufacturing system designers, even though the inherent properties of intelligent agents could yield more flexible, adaptable, and possibly more efficient systems in a long term perspective. The lack of a unified agent-oriented methodology for production control and the high risks imposed by expensive industrial prototypes makes it less attractive for industry to make a shift of paradigm. Recent work [5] is addressing the issue of methodology and promising industrial projects have been presented in [4,9,16] but still major investments have been put into prototype development in order to evaluate the results.

LEGO® Company is an important provider of toys for countries worldwide. The huge factory in Billund is highly streamlined and efficient and has a high degree of automation. However, improvements could be made with respect to the flexibility of the production system. The efficiency of reconfiguring the production lines to support the huge range of different products could be improved considerably. Adaptation to changes in the workload on the production lines is another issue that needs attention. Intelligent and adaptable manufacturing systems that go beyond simple automation are required in order to improve on the current situation.

The transportation of final and intermediate products between different manufacturing units seems to bring up many of the issues concerning flexible and adaptable production and thus provides a rich scenario for the development of an intelligent prototype. Different types of transportation appear during the production of LEGO® bricks. Conveyor belts, ceiling rails, and robotic manipulators are installed in almost every production hall at the factory. They provide a means of transportation during molding, assembling, decoration, pre-packing, and final packing of LEGO® bricks. Autonomous Guided Vehicles (AGVs) transport boxes of bricks between different production units and they load pallets onto trucks for external transportation. However, there are certain constraints on the AGVs. They are only capable of following a magnetic wire in the floor and therefore restricted to stay on the given path even if an obstacle or another AGV is blocking.

We propose an inexpensive toy prototype, the Flexible Inter Processing (FLIP) prototype [10,11], that bridges the gap between simulation and real physical applications. A toy prototype should fulfill certain criteria in order to challenge the mere use of simulations and in order to justify its existence as an intermediate step between simulation and industrial prototyping. A set of essential criteria for the FLIP prototype is listed below:

- Flexible technology that supports a variety of domains, such as transportation (FLIP) and games (robot soccer).
- Distribution of control and intelligence.
- Generality of the underlying software architecture and design.
- Accurate and reliable localization of mobile robots.
- No constraints on movement (*open path method*).
- Intelligent and adaptable behavior in dynamic environments.
- Functionality to support transportation tasks.
- Intelligent collaboration and appearance around transportation tasks.
- Efficiency with respect to transportation tasks.

Similar projects to which to compare our prototype with are very few. The closest we can find is the eM-Plant project [7] that provides application object libraries – like the AGVS one – for simulation of production, but the object-based approach this project adopts does not enable to simulate intelligence in behavior nor its distribution.

We see the software-based system as being composed of two layers with distinct objectives (see Fig. 1). The top layer, the FLIP prototype, is developed for experimentation with intelligent collaboration among autonomous units in a transportation scenario. The FLIP prototype is seen as a generalization over the various concrete transportation cases but is also a specific application of an underlying more general platform, the LEGOBot platform. The units of the LEGOBot platform are at the FLIP prototype dedicated to transportation and include a number of stationary and