Simulation of Logistics in RoboCup Competition

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Abstract. This paper describes a proposal for a hardware simulation of a logistics scenario as a test platform of AI-methods for multi-agent systems to provide efficient and optimized logistics processes in flexible production systems. For demonstration a special case will be considered to use it as an exciting new competition in the framework of Robocup.

1 Introduction

In industry mobile robots are used as more or less intelligent autonomous transport systems to make logistics processes more flexible and efficient. However, it turns out that the mobile robot systems in this kind of applications are guided and controlled by supervisory systems and are still far away to act autonomously as intelligent mobile systems. The goal of this paper is to address this industrial problem to the research of AI-methods in mobile robotics. Our approach is to put it in the framework of an innovative new RoboCup competition in order to encourage young research teams to develop new creative implementations of artificial intelligence methods to solve autonomously logistic transportation problems.

We envisage a kind of hardware-in-the-loop simulation method, i.e. there is a flexible simulated production hall with integrated real mobile robot systems having the task to create an efficient material flow to provide a high rate of deliveries in due time. In order to keep the focus on the development of AI-methods for multi-agent systems the competition is based on a given standard robot platform.

2 The Logistics Competition

The competition arena consists of a field of 6 m x 6 m. The field represents a factory or production hall containing 10 production machines with certain specific process

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functions which can be easily adapted to rather arbitrary scenarios. The field is bounded by boards representing the walls of the production hall.

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Fig. 1. *Competition field - Simulation of a production hall.*

2.1 Factory

The factory consists of following system units.

- There are ten production machines distributed on the interior of the factory hall (competition field). Each of these production machine is simulated by a read/write RFID device equipped with an industrial 3-coloured (red, orange, green) LED light.

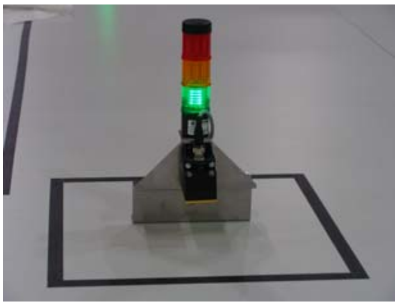

Fig.2 *Production Machine*

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The spaces of the machines are bounded by squares of black lines. These spaces are called the machine spaces of the factory.

- There is an **Input Store** which is marked by a “blue” area on the field. It is of size 0.4 m x 1 m.

- There is an **Outgoing Goods Store** which is marked by the “green” area on the field. It is also of size 0.4 m x 1.0 m.

- At two opposite edges there are **Test Stations** with a RFID reading device. The user can check the product type at these stations.

- At the other two edges there are RFID devices. These machines serve as a **Recycling Station** to receive raw material for the production process.

2.2 Product Definition

A pallet will be represented by a puck, see fig.3. Each pallet carries one product component. Each component is represented by a RFID mobile data carrier (short: tag) with a well defined part number. If the part number equals 0 then it will be said that the pallet is empty.

Fig.3: *Pallet with data carrier*

Clearly, it is easy to admit pallets with more than one tag. For simplicity, we limit ourselves to the case of pallets with one data carrier. To start with, we have defined a product – called – FLC with following sub-assembly structure:

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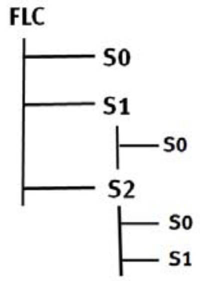

Fig.4 : *Subassembly structure of product FLC*

We can visualize the product structure as follows:

- The final product FLC is a wooden rack
- S0 is a wooden base plate
- S1 is a shelf
- S2 is the frame of the rack.

With other words: For production of FLC at least one machine is required which can produce the finished product FLC based on the components S0, S1 and S2. Since the input store only provides the basic components S0, additional machines to manufacture the subassemblies S1 and S2 are required. It is obvious that we can easily create any other subassembly structures.

2.3 Machine Definition

The RFID devices, see fig.2, will be controlled by a PLC which allows us to create an open and flexible machine configuration. We select following sample configuration:

- There are five machines producing the sub-assemblies S1 using the raw material S0. The processing time might be WT1, i.e. after WT1 seconds the part number of the tag is changed into the part number corresponding to S1.

- There are three machines producing the sub-assemblies **S2**. For setting up the production process two components S0 and S1 are required. More precisely, this means that at first the basic component S0 must be delivered the machine. After delivery the pallet will be marked empty. The empty pallet may be moved to the Market Place in order to receive a further basic component S0. Next the sub-assembly S1 must be delivered to start finally the production process. The processing time takes WT2 seconds, i.e. after WT2 seconds the part number of one of the RFID data carriers is changed to the part number corresponding to S2.

- There are two machines producing the main product **FLC**. Similarly as above, for setting up the production process now three components S0, S1 and S2 are required. After delivery of S0 and S1 both associated pallets will be marked

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empty and can be loaded with S0 at the Market Place. To start finally the production process the sub-assembly S2 must be delivered to the machine. The processing time takes WT3 seconds of playing time, i.e. after WT3 seconds the part number of one of the RFID data carriers is changed to the part number corresponding to FLC.

- There is a random generator to cause a downtime of machines.

- The production machines indicate their different operating modes:
    - Operation mode **ready:** green LED light is on
    - Operation mode **processing:** green and orange LED lights are on.
    - Operation mode **setup finished:** only the orange LED light is on
    - Operation mode **work order finished:** green LED light is on
    - Operation mode **wrong material:** orange light is flashing (2 Hz).
    - Operation mode **out of order:** red LED light is on

2.4 Mobile Robots Platform

The logistics of the production shall be realized by autonomously acting mobile robot systems. As a common platform we suggest to select the mobile robot system Robotino® of the company Festo, see [2].

Robotino® is a holonomic mobile robot platform driven by three independent, omnidirectional drive units. The drive units are integrated in a sturdy, laser welded steel chassis. The chassis is protected by a rubber bumper with integrated switching sensor.

Fig.5: *Robotino of Festo Didactic GmbH &Co.KG*

Robot dimensions:
Diameter: 370 mm
Height including housing: 210 mm
Overall weight: approx. 11 kg
Maximal payload of about 6 kg

2.4.1 Drive Unit

Each of the 3 drive units consists of the following components:

- DC Dunker motor with nominal speed of 3600 rpm and nominal torque of 3.8 Ncm.
- Integrated planetary gear unit with a gear ratio of 4:1. Additionally there is toothed belt with gear wheels providing a transmission ratio of 4:1.
  Altogether this provides a gear transmission ratio of 16:1.
- Omnidirectional wheels of diameter of 80 mm.
- Incremental encoder with a resolution of 2048 increments per motor rotation.

2.4.2 Sensors

Robotino® is equipped with 9 infrared distance measuring sensors which are mounted in the chassis at an angle of 40° to one another. Robotino® can scrutinise all surrounding areas for objects with these sensors. Each of the sensors can be queried individually via the controller board. Obstacles can thus be avoided, clearances can be maintained and bearings can be taken on a selected target.

The sensors are capable of accurate or relative distance measurements to objects at distances of 4 to 30 cm. Sensor connection is especially simple including just one analogue output signal and supply power. The sensors' evaluation electronics determines distance and read it out as an analogue signal.

The anti-collision sensor is comprised of a switching strip which is secured around the entire circumference of the chassis.

The inductive proximity sensor is supplied as an additional component. It serves to detect metallic objects on the floor. The output voltage of the sensor is 0 to 10 [V]. The sensing range is 0 to 6 mm.

Path tracking can also be implemented with the two included diffuse sensors.
Flexible fibre-optic cables are connected to a fibre-optics unit which works with visible red light. Reflected light is detected. Different surfaces and colours produce different degrees of reflection. However, gradual differences in reflected light cannot

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be detected. The sensors must be attached to the mountings furnished for this purpose, and must be connected to the I/O interface.

Robotino® is equipped with a colour webcam. The webcam is equipped with a USB interface and provides an integrated jpeg compression. It supports a colour depth of 24 bit true colour and a VGA resolution with 15fps.

2.4.3 Controller Board

The controller housing is connected to the wiring in the chassis via one plug-in. Thus you can easily take off the controller housing and you have direct access to the mechanical system.
The controller system of Robotino® is divided into two parts – an embedded PC and a microcontroller interface card.

Fig. 6.: *Controller of Robotino®*

The main controller is an embedded PC 104 plus controller with the 800 MHz processor AMD LX800. There are numerous communication interfaces on board:

- SDRAM 128 MB
- 2 x Ethernet
- 2 x USB
- 2 x RS232
- Parallel port and VGA port
- Wireless LAN Access Point following the standards 802.11.g and 802.11.b. The access point can be switched into server and client mode. As an option you may also have a 5Ghz access point following the 802.11 a standard..

The microcontroller interface card communicates via a serial interface with the embedded PC. The 32 Bit NXP microprocessor provides the PWM signals and the PID controller for the motors. Further following components are available:

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- JTAG interface for programming the microprocessor.
- 4 Ethernet interfaces, one of them is directly accessible for the user at the controller housing.
- FPGA for fast evaluation of the sensor signals.
- External I/O interface consisting of 10 analogous inputs, 8 digital short-circuit-proved in- and outputs and 2 relays for additional actuators.

For example, localization and mapping methods need an additional range sensor – laser scanner – as described in the paper [4], see also [9] where you can order such additional package.

2.4.4 Software

There is a Linux-Ubuntu operating system with real time kernel running on a 1 GB flash card. As an option it will be also offered a 4 GB or 16 GB flash card. There is an API with libraries which allows you to create applications for Robotino® in numerous programming languages:

- C++ und C
- C#
- .net and JAVA
- MatLab and Simulink
- Labview

You may find a lot of examples concerning using the different API's in the public forum "openrobotino", see [5]. JAVA requires at least a 4GB flash card. Recently, there is also an API for the new standard robotics software platform ROS available [8]. As a free download, Festo offers a proprietary graphic programming language Robotino®View following the international standard IEC 61131. It provides the possibility to create autonomous applications for several robots including direct communication via UDP between the robots.

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3 The Logistics Competition

The described concept of a factory allows us to build up arbitrary complex test scenarios for mobile robots systems to verify AI methods in terms of efficient logistics processes. We would like to demonstrate it for the special case of the product structure FLC as shown in Fig.4. The idea is to define a competition scenario for this special factory to initiate and promote AI development for logistics processes.

3.1 General Strategy

A match is played by two teams, each consisting of not more than 3 players.
Robots of the same team will be marked by a colored shirt above the controller housing. The shirts have three equal stripes of color either green – white – green or blue – white – blue depending on the color of their goal.

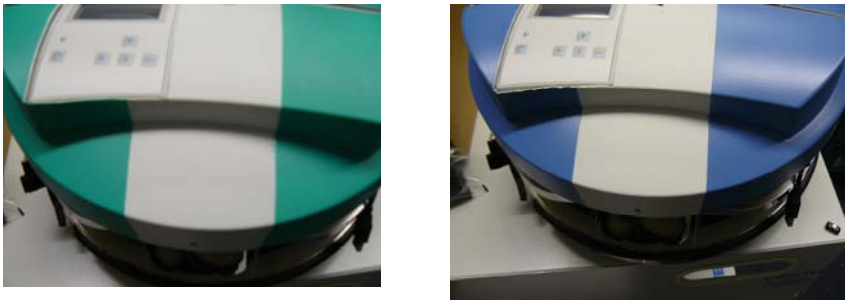

Fig.7: *Shirts can be easily put on*

Main goal of the game:
Deliver products of type FLC as much as possible in Outgoing Goods area. Winner of a match is the team with most delivered finished products.

The first key challenge is to identify the type of machines. The locations of the machines are well known but not the function type of the machines. For identification of the type the robots must test the behaviour of the machines depending on delivered components. Here it must be taken into account that at the beginning only basic components are available. Thus the strategy must be to identify first the machines producing S1 components in order to be able to identify the machines producing S2 components, etc. To be time efficient, the challenge is to communicate the identification results to all team members.

If all team members finally know the positions of the machines with associated function type then the structure of material flow for production of the FLC product is rather simple. First the basic component S0 must be taken out of the input stock area and must be delivered to one of the machines producing FLC. Parallel a production process of a component S1 respectively S2 must be started in order to deliver them afterwards to the former machine in order to start the production process of the main product FLC. The autonomous coordination of these processes requires a very efficient communication between all team members. The big challenge is to find methods how to improve autonomously such processes.

In an industrial situation two typical problems may cause interruptions of the planned schedule:

- Production machines may have downtimes.
- There are other devices moving through the production hall which might block the direct access to the machines and the delivery store area.

The first case will be handled by an external PLC which will cause downtimes of the RFID devices by random. The second scenario will be represented in the competition by the opponent team. They can try to block the access to important machines. Thus the production team has to overcome a further challenging problem:

- Change dynamically the path planning for placing the pallets at the machines.

At the end the delivery of the main product FLC requires additional abilities of the robots. The robots of production team must hit the pallets into the Outgoing Goods Store area. One of the opposite team can act as a goal keeper in order to prevent the delivery of the finished products.

3.2 Common Platform

One important rule is that teams have to work with the same platform. There are several important reasons for this decision:

- Focus on the original task to develop intelligent behavior.
- Standard equipment reduces costs and saves developing time of well known equipment. Do not reinvent the wheel for hundred of times.
- Restriction to standard platforms is an important requirement from the industrial viewpoint in order to be able to provide support and maintenance.
- Thus the restrictions to standard platforms often initiate innovative and much more efficient solutions of well problems.
- Standard platforms provide fair chances to new teams to join the competition.
- Changes of the standard are only allowed in one direction. Intelligent behavior is strongly related to sensors. Thus teams have full freedom to integrate any kind of sensors

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3.3 First Experiences

This concept was introduced as a demonstration competition at the RoboCup 2010 in Singapore. The results were still rather poor and have shown that this competition puts extremely high challenges to the participants. However, it must be taken into account that the teams had in general only three months preparation time. This short time made it nearly impossible to do following main steps in detail:

- Developing of a powerful software framework to select an appropriate strategy how to proceed and to communicate autonomously in the team,
- realization of an efficient dynamical path planning method and
- to provide the robots with abilities to place the pallets under the RFID write/read devices with required accuracy and to hit in a clever way the pallets into the Outgoing Goods Store area.

3.4 Conclusion and Outlook

Discussions with the participants have shown that at the present stage it will be important to reduce the requirements for the next competition in 2011. One possibility is to dispense on the “defender” team and to focus on production. A solution could be to provide two competition fields and competing teams have to start production at the same time. An visualization will show the actual status of the added value of competing production processes such that spectators can immediately follow which team has a better added value.

On the other hand the delivery process can be made more realistic in the way that various gates of delivery can be introduced but by random only one gate is active for delivery. Further an input area for express goods can be introduced in the following sense. If an express good is available then the team has only a limited time to take care that corresponding component will be produced and delivered.

For the future there are two essential approaches to increase the challenging of this competition:

- Again, introduce the concept of dynamical obstacles.
- Introduce order processing in the sense that teams have to follow production plans and have to minimize deviations.
- Further, the complexity of the product structure may be increased.

At present the power of the PC 104 in the controller of Robotino is rather limited. Thus it is not possible to use standard software platforms as ROS, see [8]. It is planned that already in 2012 there will be a new controller version of Robotino with an ETX-Board which allows to integrate any high level Intel processor.

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