Simulation Tool for Cooperative Mobile Robots

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ABSTRACT

This paper reports on the first attempts to create a simulation program for cooperative mobile robots. The organization of the robot family is borrowed – at least to some degree – from nature. A bee-hive was chosen as the organizational basis of the robot family. The queen of the hive is represented by a PC, the workers are mobile robots. Mobile robots can only communicate with the queen via an RF link. The task for the robots is to patrol an area and check the state of lights (operational, emergency, or darkness). The position of the robots are given by ceiling-mounted cameras directly to the queen. The queen can modify the route of the robots with directions via RF. The simulation system is developed in LabVIEW. Based on the results of simulation experiments robots are being constructed and used in a test environment similar to the simulated one.

INTRODUCTION

Intelligent electronic systems penetrate everyday life as it stands. The advent of this era began, when transistors first appeared in the 1950s. The miniaturization of transistor-based systems, especially of digital computing devices opened up a totally new world in electronics. Microprocessors, personal computers and microcontrollers are common nowadays not just in industrial applications, but in customer electronic products, too. Self-contained devices with onboard processors and controllers are to be found almost everywhere: in cars, cameras and mobile phones, just to mention a few everyday gadgets. Household appliances, like washing machines, refrigerators, and vacuum cleaners are also beginning to be equipped with such a brain. An even faster growing area in applying intelligent electronics is the toy-market.
The word robot comes from Karel Capek and is now applied to machines that accomplish certain tasks without getting tired or bored, always with the same precision and quality. Industrial robots are widely used for assembly, welding, painting, transporting heavy objects and other tough tasks, often in environments not suitable for humans. Industrial robots are characteristically fixed in arrangement; they can not change their location, just move one or more "limbs". Mobile robots on the other hand are autonomous machines, and are able to do locomotion.

Mobile Robots

A mobile robot could very well be defined as a mobile machine that interacts with its environment through sensors, and attempts to achieve some objective. The objective could be relatively simple e.g. following a line drawn on the floor, or it could be quite difficult e.g. operating as a member of a team of robots playing soccer. Mobile robots are to be found in toy boxes of today's children in an exponentially increasing number, they even seem to be a must. Robot pets, like Sony's Aibo dog (Fig. 1) are equipped with a special purpose computer, that makes the robot understand and fulfill commands, process sensory data and handle accordingly.

Fig. 1. Sony's Aibo

Robotic Kits from Toy Manufacturers

Popular construction toys like LEGO or fischertechnik have robotic kits (Figures 2 and 3). These kits inherit the building-block approach from their predecessors and contain at least the few most important elements for robot construction. Programming the robots in both toys is done – among other freely available tools – with a block- and function-oriented graphical language.

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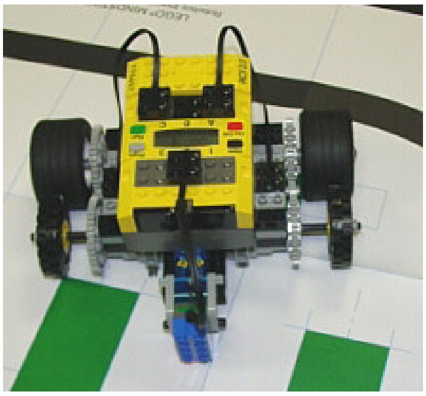

Fig. 2. A LEGO robot

Fig. 3. fischertechnik robots

MOBILE ROBOTICS IS INTRODUCED IN THE DEPARTMENT OF INFORMATICS, BUTE

Staff and students of the Department of Informatics (Faculty of Mechanical Engineering, Budapest University of Technology and Economics) started designing and building mobile robots from LEGO and fischertechnik kits in the end of 2003. These kits were chosen because they offer a cheap and flexible alternative to robotics kits and ready-made mobile robots.

Stand-alone Robots vs. Robot-families

Robot-building started quite naturally with the sample designs from the manuals, however individual designs appeared very soon afterwards. Stand-alone mobile robots were the first construction tasks, nevertheless such self-contained robots require a very complicated brain and they are prone to errors more, than a team of similar, but a bit dumber robots organized in a "family". The organizational structure for the cooperative robot family is borrowed from nature; ants and bees were chosen as the basis, although the analogy is far from thorough. The Robot Queen represents the central intelligence, being the organizer in the family, and coordinating the workers. Workers can communicate only with the Queen as of now, however communication among workers is also under consideration.

Let Us Simulate

An MSc thesis dealing with the development of a robot-family has been written and successfully defended at the Department of Informatics in June 2004. This thesis, and all the preparations turned the attention to simulate robot-families.

From the first development efforts it very soon occurred, that a simulation system for such robot families helps a great deal to create the hierarchical, organizational and control structure of the family. As it is very well known the power of simulation is in reducing risks, time and expenses by operating the system model instead of the actual system. The above-mentioned advantages of simulation are especially emphasized, when the system model is implemented as a computer program.

That is why a simulation system for studying the behavior of robot-families was envisioned, and is now under development and testing.

SIMULATING A ROBOT-FAMILY

The First Project

First of all a suitable assignment had to be defined with the details clearly worked out. The first project is set to deal with a building services application. Mobile robots move around in a building to check the operation of certain devices, like light, heating and air conditioning.

Robots check for example, whether lights are working properly or lights are working unnecessarily (no one is in the room). As this task is a rather complex one, only the operation of lights is examined first.

There is an area specified (Fig. 4), where certain parts have to be lighted always, such as corridors leading from offices to staircases and lifts. Lights can have three states: normal operation, emergency and no lights at all. Robots have to patrol the area in regular time intervals and report the state of lights. Robots have to communicate their position to each other, so that they can cover the whole area optimally.

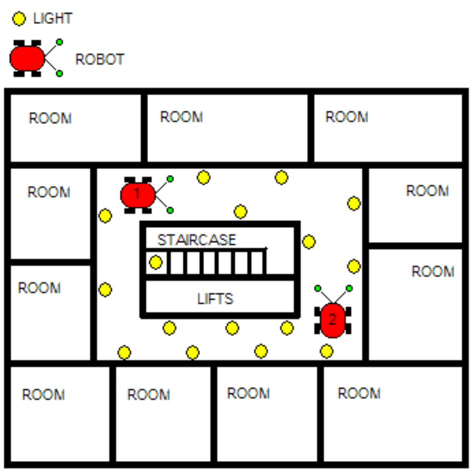

Fig. 4: Environment Layout

Each robot is equipped with an RF transmitter, but they can only communicate with their superior, the Queen. The position of each robot is detected with the help of ceiling-mounted cameras, just like in robotic soccer, however robots can detect their position from special markings on the ground, too and then transmit it to the Queen. The information from the cameras goes also into the Queen. The Queen in this case is PC equipped with the appropriate RF devices to communicate with the robots. In the simulated environment the Queen is a different program task running on the same PC as the simulation. Cameras are substituted by the continuously computed trajectory of the robots projected on the layout. In certain positions of the layout markings are placed and when a robot moves over such a marking, its detection is simulated.
The speed of the robots can either be zero or a slow fixed speed. Acceleration to and decceleration from this speed is almost instanteneous, that makes simulation a lot more easier. A robot's speed is also zero, when it has to align its orientation according to the commands from the Queen.
The lights can be switched by a preprogrammed algorithm, or by the user. As of now, there are no external obstacles allowed in the area.

Implementation

National Instruments' LabVIEW was chosen as a development tool. LabVIEW stands for Laboratory Virtual Instrumentation Engineering Workbench, and is available in various computer platforms, such as Linux, MacOS, Windows, Solaris, HP-Unix. LabVIEW applications are called virtual instruments or VIs for short. VIs have a user interface as shown in Fig. 5 (front panel in LabVIEW terminology) and a block diagram (Fig. 6), where the actual program is built with LabVIEW's graphical components.
The ease of use and programming, together with LabVIEW's excellent connection to the outside world through data-acquisition, I/O and network protocols makes it the ideal tool for scientists and engineers.

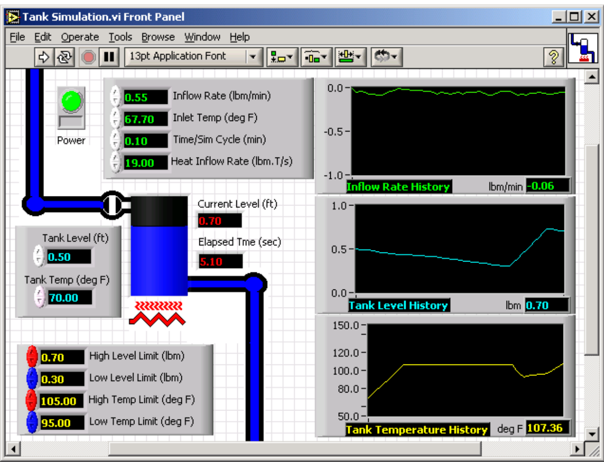

Fig. 5: Front Panel in LabVIEW

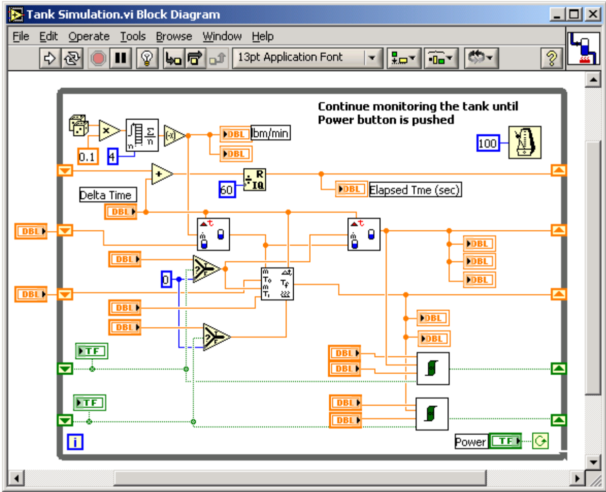

Fig. 6: Block Diagram in LabVIEW

The above mentioned properties of LabVIEW make it an ideal environment for rapid application development, that is one of the major reasons for the authors' choice.
Fig. 7 shows the main screen of the mobile robot simulator program.

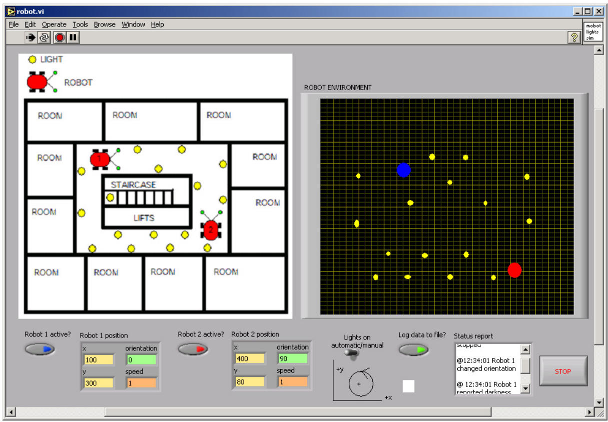

Fig. 7: Mobile Robot Simulator Front Panel

The mobile robot simulation program has the following functionality:

- maximum two robots can be simulated simultaneously
- the operation of lights can be set to a predefined time-sequence or
- lights can be operated manually
- the ceiling-mounted cameras' information is simulated by the calculated position of robots
- robots' reports on the state of lights is written to the screen and optionally to a log file

FURTHER PROJECT IDEAS

To check the operation of heaters and air conditioners, temperature and humidity sensors have to be mounted on the robots. Further on an intelligent control can be developed, which uses the number of people in the certain room, not just temperature and humidity values. To accomplish this task either a passive door-mounted

people-counter has to be used or wall-mounted cameras are necessary or even robots can count people.
Besides it is important to develop the necessary communication among robots, something similar to the queen-robot RF links.
Such intelligent robotic wardens are a good alternative in older building, where there is no building intelligence installed. To build and intelligent building costs less, when new premises are build, however upgrading an existing structure could cause problems, not just the financial art, but the noise and inconvenience of construction work, too.

CONCLUSION

The very early development stage of a cooperative mobile robot family was presented. During the work quite a number of aspects came up. These aspects are important for both the actual construction and programming of the robots, as well as the development of the simulation system.
The results show, that when the actual robot control and communication is developed, previous simulation experiments provide considerable help.

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