Building and Understanding Robotics-a Practical Course for Different Levels Education

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1. Introduction

Robotics is one of the best ways to connect students with motivation to learn technology. The project deals with a kind of edutainment robotics system whose objective is to offer a chance to students of different levels to acquire knowledge about robotics. At the same time, this learning process will involve the students, as they can design and build their own mobile robot. Our efforts will concentrate on developing our own cheap educational robotic system in order to meet the requirements of flexibility, functionality, extensibility, easy handling, and low cost.

In our implementation, the "Mobile Robot" system for the course consists of the mechanical parts, the hardware and the software. The mechanical parts are based on the LEGO bricks and our own designed input and output bricks as the platform of the project. New designed hardware includes 4 driving DC motors and 9 sensor channels. Students can program using a graphical interface, simple C and Java language according to their knowledge. This new system is more flexible and suitable for students to understand all aspects of robotics technology.

This project is based on the cooperation between TAMS group of the Department of Informatics in University of Hamburg (UHH) and ARMS group at Robotics Institute in Beihang University (BUAA). The course will be used at the computer science department of University of Hamburg and at the Mechanical and Electrical Engineering department of Beihang University in parallel. It is also suitable for professional schools or for further education. Based on their own ideas students can build different mobile robotic prototypes. Using the software environments, they can program the robots and carry out simulations offline. Then they can download soft codes to the controller and test on-site. During this process, they have to deal with the sensor information and realize the various movement functions by controlling the motors. They will learn the sensorial technology and motor-control methods. At the same time, students can overview the process using a web-camera and can interrupt in case of malfunctions. The most important aspect is that students will get a thorough knowledge of the principles of mobile robotics.

2. Overview of the system

The whole system consists of three parts: the mechanical, the hardware and the software parts. The mechanical parts are the physical background of the project. The hardware including the driving motors and sensors is the bridge between the mechanical parts and the software.

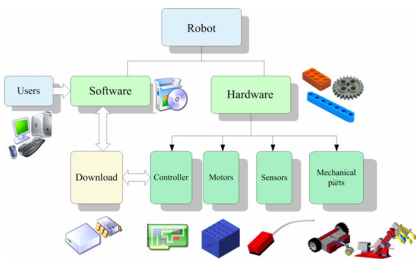

Figure 1: Block diagram of our new tutoring system for the practical course

Scenario design

The scenario of this project is built in wood, as shown in Fig. 2. The dimension is 122cm wide and 183cm long. It contains 4-6 "L" Walls, whose positions are unfixed. The floor of the platform is in white, and the normal walls and "L" walls are in Black. The obstacles can be rebuilt using "L" walls due to the standard shape. For example, a "T" obstacle can be built by two "L" s.

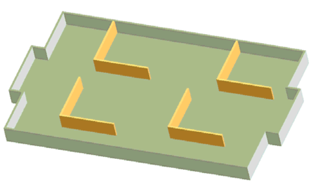

Figure 2: Scenario design for the practical course

Mechanical part

The best choice for the mechanical part is using normal LEGO bricks which can meet all requirements of functionality, extensibility and easy handling. Various types of block and gears can be added and connected together to turn out into a unique robot. On the other hand, almost all of the students have some experiences on Lego bricks when they are young.

The series of LEGO Bricks 9649 is used in the project. The motor output and sensor input of LEGO Mindstorms are not only limited and simple but also expensive so that we have to find other cheap alternative. We should add other cheap bricks for sensors and DC motors to the system ourselves. Based on the cooperation with the group of ARMS at Beihang University (BUAA), we have redesigned two new kinds of DC-Motor Bricks and five kinds of Sensor Bricks since there is no input and output brick at all in 9649. All of the new sensor bricks and DC motor bricks have been double-checked and fit original LEGO bricks well. Fig. 3 shows the mechanical system which can be used to achieve different kinds of mobile robots.

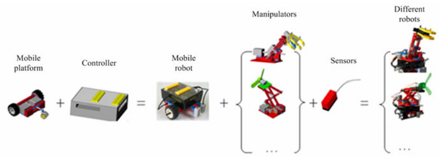

Figure 3: Draft of the mechanical system

Control hardware

The hardware, as shown in Fig.4, includes the controller, sensor inputs and DC motor outputs. As mentioned above, the original RCX Controller of the LEGO system is not efficient enough for our project since only three sensor inputs and two DC motor outputs are included. Here the focus is on the controller. We do not insist on using the original controller from LEGO, while design a new control system which will be in charge of collecting the sensor information, actuating all DC motors, and sending all working information back to GUI using wireless communication. The students can program soft codes on their own laptop at home; then send them to the client terminal to simulate. They can download all soft codes to the mobile robot using RS232 interface.

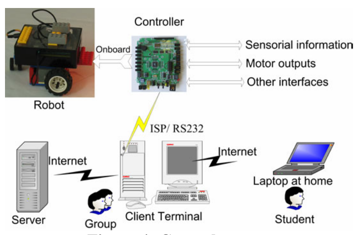

Figure 4: Control system

Software requirements

First of all the software must provide a flexible, robust and stable programming interface to the robot hardware. Secondly the system should be easy to use by students. The senior middle school students can program using iconic interface environment like RCX programming. Meanwhile, the special graphic programming environment of the Mindstorms system is not convenient for university students who prefer to program in normal C language. Among many program languages, C is chosen for this project because it has general characteristic of a lower-level language. The third point is security. Students are allowed to use features of the hardware. It should make no difference for the students whether working directly in the laboratory with the robot or programming it from their homes. Nobody, except the designer of the robot, is permitted to program the sensor or the PID-motor controller of a robot. This requires the hardware to be hidden from the user by means of a hardware abstraction layer (HAL). Moreover the system should not be bound to any specific operating system.

3. Implementation

Tasks description

Using the LEGO bricks, some suitable sensors and simple DC motors, the students can realize several task functions step by step, from the easy ones to the much more complicated ones.

Following a line: The mobile robot should follow this black line and move forward from one end to the other end.

Looking for an object: The second task is to hunt for a special object in the scenario. There is a burning candle on the floor whose position is uncertain. The mobile robot should find it automatically, move forward and stop in front of it.

Following a moving object: Task three consists of following a moving object, for example a human hand, inside the scenario. The robot will only move forward if it detects something in front. It will follow till the object disappears.

Mapping the scenario and path planning: The scenario contains obstacles and looks like a maze. The mobile robot should map the work space and draw a sketch map. Then the robot will find the shortest path to return to the starting point.

Cooperation between two mobile robots: This task is the combination of all the functions above. That means it is a maze with obstacles, but the positions of the obstacles are different from those in task 4. A group consists of two mobile robots, robot A and robot B which own different working abilities due to the different sensors and output functions.

Furthermore, special competition can be developed, such as a 2 to 2 battle or Robocup. Other possibilities are still open.

4. An example—following a line

-Building a robot

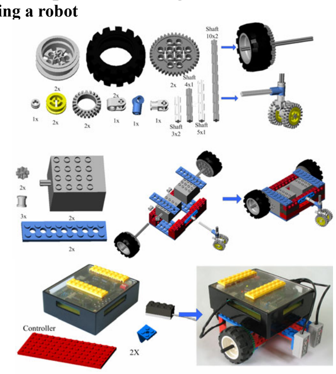

Figure 5: Building a robot

-Programming

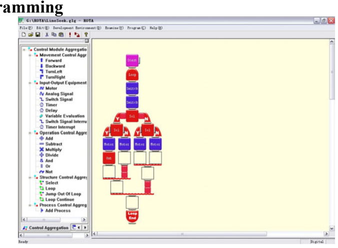

Figure 6: The iconic programming environment

--Testing and improving

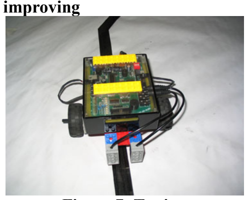

Figure 7: Testing

Open topics

In future, the tele-access capability will be met. The Bluetooth will be used as a wireless communication device according to the velocity and the data transfers. The CCD image input will be added to the system. But it will not be used for image processing but overview; the onboard controller only sends the images to a GUI at first step. In order to meet these new requirements, another higher level controller will be needed, which will manage the USB camera, the wireless interface between the onboard hardware, and the information exchange between the two layers of controllers on the robot.