EDUCATIONAL TOOL FOR CONTROLLING LEGO MINDSTORMS ROBOTS WITH CONTROL WEB

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Abstract: This paper presents software tools for using Lego Mindstorms NXT kit in programming courses. These tools consist of a simple library which allows programs written in C language and running on PC to directly control Mindstorms NXT robots and a driver for Control Web rapid development system, which allows the same for graphical programs created in Control Web. The implementation and use of these two tools are described.

Key words: Lego mindstorms, control web, education, programming

1. INTRODUCTION

The need for educated IT experts is increasing in the world and so does the demand for education efficiency and quality. Educational institutions strive to offer not only good knowledge but also to present it in an interesting way. This includes using real models and other tools in lessons. One of the interesting aids are model robots, which can be used not only for robotics courses but also for other IT subjects such as artificial intelligence, microcontroller programming or real-time operating systems. In recent years Lego Mindstorms robotic kit became very popular. Despite its primary intention for younger learners, it is quite often used with good results also on universities (Klassner, 2002). Lego Mindstorms is a set of components which allow building various robots equipped with touch, light, ultrasonic and sound sensors. The advantage is ready to use set of components matched together, which makes it easy to try various models (e.g. wheeled and walking robots), affordable price and many programming options besides the supplied environment with freely available tools such as operating systems and custom firmware. As a disadvantage for the use in programming lessons can be seen that the supplied programming environment with visual drag and drop interface is probably too simplified for the typical IT student (Schafer, 2004). For our lessons we developed software which can be used to control Lego robots with programs written in C/C++ and also with applications developed in rapid application development system Control Web.

2. TOOLS AND SOFTWARE USED IN COURSE

This section briefly introduces the components of the educational system. Lego Mindstorms NXT is a programmable robotics kit which represents next generation of popular Lego Mindstorms Robotic Invention System. The main component of this kit is called NXT brick. It is a computer which forms the brain of the robot. The main features include 32-bit ARM7 microcontroller with 256 KB FLASH and 64 KB RAM and 8-bit AVR microcontroller with 4 KB of FLASH and 512 B of RAM, 100 x 64 pixel LCD display and loudspeaker. To the brick sensors and motors are connected. We use the retail version of the kit which contains 3 motors, sound, touch, light and ultrasonic sensor. The brick is powered by 6 AA batteries or, in our case, by 6 rechargeable NiMH cells. The brick can be connected to personal computer using USB cable or Bluetooth interface. The kit contains software for PC, which provides visual programming language for writing programs for the NXT brick. Programs are then downloaded to the brick using USB port.

In our course of real-time programming we use Control Web besides programming in C/C++ with real-time operating system. Control Web is a Rapid Application Development (RAD) system which allows easy development of control systems running in real time with visualization. Main advantage of such a RAD system is that the application is developed by putting together existing components and setting their parameters instead of writing all the required code from scratch in lower-level programming language. This makes the development easy and quick. Another advantage is that the programs are platform-independent – they run in Control Web runtime and thus can be utilized on any computer platform which Control Web supports. Application design in Control Web 5 is very fast and comfortable thanks to integrated development environment. Required component is selected from instruments palette which organizes the instruments in subcategories, such as, for example, system instruments, control instruments, etc. The component can then be configured in property editor. Control Web supports many devices (PLC, I/Ocards, etc. by means of special drivers. The driver is a library of routines provided either by the manufacturer of the device or by Control Web manufacturer, and it allows the applications in Control Web to access any device in a uniform manner – via driver object which provides input and output channels. This way an application can, for example, set high digital output pin by writing 1 to the appropriate channel of a driver in the same way no matter if the pin is on an I/O card of different manufacturers or even on a PLC.

3. NEW TOOLS

In our lessons students learn to write real-time programs first in C/C++ language using school operating system RTMON and then also to create real-time applications in RAD tool Control Web. During the lessons they create various programs which usually just output messages to console window or to a graphical interface but also control simple heating plant model in real time. To make the lessons more interesting and beneficial for the students, we decided to add also the possibility to control Lego robots by student's programs. The proposed solution allows direct control of the robot from computer as opposed to the usual way in which program is written and compiled on PC and then downloaded into the microcontroller in the robot (NXT brick). This later option would be more suited for microcontroller programming lessons. It has the advantage of fully autonomous robot operation but also disadvantage of limited memory in the NXT brick. For our lessons we want to concentrate on the development of programs which concurrently perform several tasks, which is easier to do on PC. The program running on PC controls the robot via wireless interface, so the manoeuvrability

of the robot is not restricted while the memory available for program and data structures is virtually unlimited.

The requirement for our labs was that the solution allows: a) direct control of the robot by a program written in C/C++; b) direct control of the robot by Control Web application.

3.1 Control by C/C++ program

The option to write programs for NXT robots in different programming languages is often used. Lego provides documentation and tools for this, such as software development kit (SDK), hardware development kit, etc.

We used C++ class implementation (Berger, 2007) which allows controlling the robot online using serial port (in fact, a virtual port created by Bluetooth adapter). But because the primary language in our lessons is C and some students do not have enough experience in object oriented programming, we created a simple wrapper library of C functions which allows students to use this C++ implementation without object oriented techniques. The library is called NXTControl and consists of header file NXTControl.h and library file NXTControl.lib. The library contains the following functions:

- NXT_Open
- NXT_Close
- NXT_MotorStop
- NXT_MotorStart
- NXT_MotorSpeed
- NXT_SensorTouch
- NXT_SensorUltrasonic

The functions allow starting and stopping each of the three motors, setting its speed and reading the value from ultrasonic and touch sensors. Sound and light sensors are currently not implemented in the library.

To use the library, students simply copy those 2 files into their project and include the header into their code. The philosophy of use is as follows: open the library and obtain handle. Call library functions for controlling motors or reading sensors with this handle as needed; at the end of program close the handle. The PC must be equipped with Bluetooth interface, which is true for many laptop computers and for desktop computers cheap Bluetooth USB dongles can be used.

3.2 Control by Control Web

As mentioned earlier, Control Web is hardware independent system. It uses drivers to access external devices, such as technological cards or PLCs. It also contains drivers for standard communication such as text-based serial line or DDE client. The driver is independent component in the form of dynamically linked library with standardized interface. Control Web application communicates with driver using channels, which must be defined in the driver map file (text file with extension .dmf). Each channel is defined by a number, direction (input, output) and data type (real, boolean, string, etc.). Driver configuration is stored in parametric text file (extension .par) containing specific information for correct driver initialization. The architecture of Control Web drivers is open, so it is possible to write custom drivers for virtually any device. To make the robots controllable from Control Web, it was necessary to create such a driver. The driver is in fact DLL library for Windows which must export certain functions. We created the driver in C language, using the NXTControl library described above. The driver allows the same operations as the library but in Control Web specific manner. This means the driver provides set of channels and the application can write to certain channels to change the state of the robot (e.g. to start a motor) or it can read a channel to get the state of a sensor.

The channels provided by the driver are as follows:
- Channels 1, 2, 3 (Boolean output) – motor A, B, C start/stop.
- Channels 5, 6, 7 (Real output) – motor speed and direction (number in the range -100 to +100).
- Channel 10 (Boolean input) – touch sensor.
- Channel 11 (Real input) – ultrasonic sensor.

Test application in CW has been created to verify the driver. It can be seen in fig. 1. This application allows controlling the features available through the driver directly, by clicking a button and also reads the values from sensors periodically.
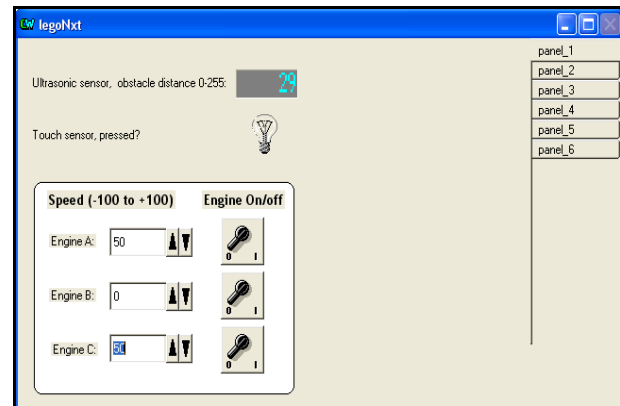

Fig. 1. Test application in Control Web

4. CONCLUSION

This paper presents two tools intended to improve the lessons of real-time programming by allowing students to program Lego Mindstorms NXT robots. The robots are directly controlled by program running on personal computer using Bluetooth interface. First tool is a library of C routines which allows writing programs in C/C++ for controlling the robot and the second tool is a driver for Control Web which allows controlling the robot by applications created in this development system. Both the C library and the driver were tested with the Spike robot with motorized tail with touch sensor and the ultrasonic sensor and proved to be working well. In the future support for other sensors will be added and laboratory exercises for students will be defined using these tools.

5. REFERENCES

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