Teaching Robotic to High School Students

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Abstract

At Queensborough Community College robotics is taught to inner city high school students to motivate and introduce them to the fields of engineering and technology. Robotics are used to improve learning and motivate all levels of students interested in STEM careers. Studies suggest that students who are introduced to robotics are more likely to major in some field of engineering than those who have not. In past few years, robotics and robotics competitions have been increasing worldwide contributing to student excitement in the engineering fields.

Robotics presents mechanical, electrical and software engineering experience to students. This introductory robotics course covers the construction, programming and operation of robots. The topics to be presented include power, ohms law, electronic components, analog and digital signals, binary and hexadecimal number systems, microcontrollers, input/output ports, motors, sensors, encoders and embedded programing.

This paper will describe the methods, resources and the topics used to teach robotics to high school students. To understand how robots operate it must begin with the basics. Students must identify electrical circuits, voltage, current, resistance and power. Components such as batteries, DC motors, sensors, gears and microcontrollers function must be demonstrated. Students also need to understand the concepts of speed, load, acceleration, friction and torque. This paper will also introduce the hardware and software used for robots. The microcontrollers used in this course are the Lego Mindstroms EV3 and the VEX IQ controllers. The programming language used for the operation of these robots is ROBOTC programming which covers input/output operation, data types, functions, control structures and components control.

Keywords

High School, Microcontrollers, ROBOTC, Robotics, Teaching

Introduction

The summer course Introduction to Robotics at QCC (Queensborough Community College) enrolls 22 students from high schools around the Queens County in New York City. This four credits course is covered in 90 hours of lectures/labs and 30 hours of math workshop, this course is an elective for the Electrical and Computer Technology students at QCC. This course is geared to high school students who are struggling with various aspects of mathematics and takes a hands on approach in presenting the fundamentals of college algebra and trigonometry with

engineering applications. A robotic course should provide the opportunity for high school students to learn a programming language and exploit concepts which are used in college computer programming, physics and math courses as well as in industry applications.

A course in robotics should be designed to introduce robot construction, programming, operation and basic theory of analog and digital electronics to the students. Topics covered in this course are voltage, current, power, analog and digital signals, electronic and digital components, motors, sensors, microcontrollers, binary and hexadecimal numbers, rotation, speed, torque, encoders and C-like programming. The robotics course give the high school students the opportunity to work in teams to build EV3 and VEX robots from scratch using the microcontrollers, motors, sensors and the many construction building parts.

Objectives

The goals for a course in robotics for high school students should be for them to describe the concepts of Ohm's law, Watt's law, electronic components and circuits, binary and hexadecimal numbers, analog and digital signals for robots. Describe the functions and purpose of robotics components like microcontroller, input/output ports, memory, sensors, motors and the use of software to program a robot for autonomous maneuvers. Students should use varying structures and components to build, program and test a robot. Furthermore students should learn to work effectively as a team, practice project leadership, interpersonal skills and conflict resolution in a classroom environment. Other objectives for students include are problem solving via the planning, organization and delivery of projects in robotics.

Topics

A robotics course should start by introducing to the high school students the concept of electrical circuits. Students must learn about what is voltage, current, resistance, Ohm's law (V = I*R) and the Watt's law (P = V * I). They should be familiar with series, parallel and series-parallel circuit in order to comprehend how robot motors and sensors receive or transmit power and signals for its operation. Electrical components like battery, inductors, capacitors, diodes, LED's, and transistors should be introduced, likewise digital signal and digital circuit with gates should be part of this course for the purpose of controlling and programming a robot. In laboratory students would construct electronic circuits using the above components and measure resistance, voltages and currents using a digital multi-meter. Students should also know the color code to determine the resistors value. At QCC we use Multisim circuit simulation program to teach the operation of many electronic components in electronic circuits. An example would be a LED-resistor series circuit shown in figure 1. In this exercise students build the circuit on a breadboard and measure the voltages and currents of each components to decide if Ohm's law and Kirchhoff's voltage law is fulfilled.

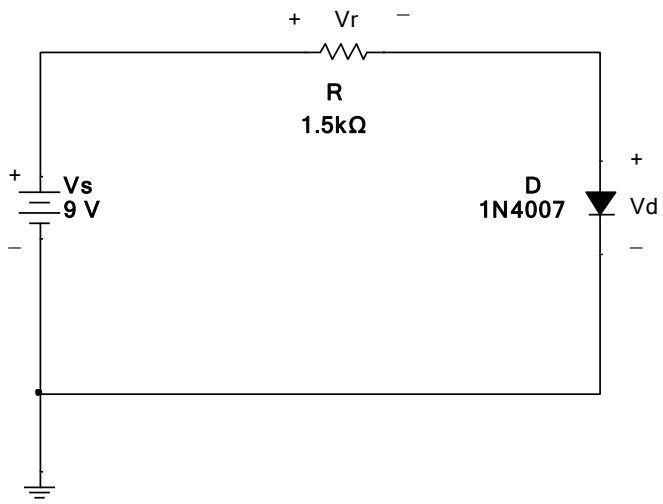

Figure 1- LED-Resistor Series Circuit

Other topics included in the robotic course are the series RC circuit containing a resistor and a capacitor, characteristics of transistors and SPDT switches, bipolar junction transistor inverting switching circuit (figure 2) and transistor active region biasing circuit. Students need to know how transistors function in order to learn how some of the sensors for robots work. Function generator and oscilloscope are test equipment students should learn to use in the lab to run experiments on the switching circuit below.

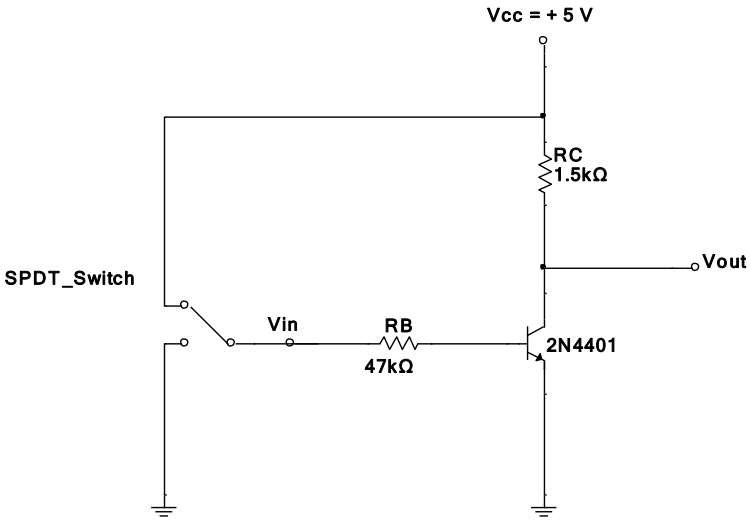

Figure 2-Bipolar Junction Transistor Inverting Switching Circuit

Students should know about binary and hexadecimal number systems, memory, address bus and data bus, input/output ports and microcontroller the main part of a robotics system. These topics will help students understand and code programs for the operation of a robot.

When teaching about motors like continuous rotation motors and servomotors, you should include speed and torque relationship, no loud speed, stall torque, rotational inertia, gears, motor encoders, motor driver circuits like unidirectional and bidirectional H-bridge circuit and motor speed control using PWM (pulse width modulation). Additional topics included in this course are varies sensors like touch, infrared, color, ultrasonic range finding sensor or sonar sensor, gyro, bumper switch and limit switch sensor. These sensors are used in robots for different purposes, for example the sonar sensor is used for a robot to avoid obstacle, the color sensor is used by the robot for color detection or line following and the touch or bumper switch is used evade walls or other objects when the robot gets close to it.

Lego EV3

The Lego EV3 robot set comes with a controller with eight ports, four ports used for motors and the other four used for sensors which can be coded using ROBOTC programming language. This brick like computer is used to control motors and collect data from sensors to accomplish a task. This set includes many Lego parts to build, program and test different forms of robotics system. Other components included in this set are three servomotors, ultrasonic sensor, gyro, color and two touch sensors.

VEX IQ

The VEX IQ set comes with a robot brain with twelve smart ports for either motors or sensors and a remote controller. VEX IQ parts are plastic snap together robotics system which comes with many structure and motion components including wheels, beams, plates, gears, connectors, pens and shafts. This set also has four smart motors, gyro, distance, color sensors and two of touch LED and bumper switch plus cables for all the devices. VEX IQ brain can also be programmed using ROBOTC programming language.

ROBOTC

A program is a set of instruction**s** loaded into the memory of a computer or a robot to accomplish a task or solve a problem. The task could be as simple as adding two numbers or as complex as having a robot move safely through a field of obstacles. A programmer is responsible for identifying the task, design a solution and write the code of the program. Programs can be written in many languages. Today most programs are written in high-level languages like C++, JavaScript, Visual Basic or HTML. For each program language you need an application program or a complier to convert the high-level code into a machine code (binary 0 and 1) so the CPU (microprocessor) could process the program. The CPU's job is to fetch, decode and execute the instructions from the memory until the end of the program.

Note that a robot only follows the program you load on its memory, it does not think for itself. The robot can be no smarter than the program that the human programmer gave it. You, as

programmer, will be responsible for planning and describing to the robot exactly what it needs to do to accomplish its task.

In this paper you will be introduce to a programming language called ROBOTC. Writing codes to maneuver a robot is an important part of robotic course. ROBOTC is written for different platforms like Lego, VEX, and Arduino microcontrollers. ROBOTC is a powerful C-based programming language for a Windows environment for writing and debugging programs, and the only programming language at this level that offers a comprehensive, real-time debugger. ROBOTC is a cross-platform solution that allows you to learn the type of C-based programming used in advanced education and professional applications.

Rules of programming in ROBOTC

ROBOTC is a text-based programming language based on the standard C programming language. Commands to the robot are written as text on the screen, processed by the ROBOTC compiler into a machine language file, and then loaded onto the robot, where they can be execute. Capitalization is important to the computer. Replacing a lowercase letter with an uppercase letter or an uppercase letter with lowercase will cause an error. The most basic kind of statement in ROBOTC simply gives a command to the robot.

For example motor [motorA] = 50; // run motorA at 50% power

Statements in ROBOTC are executed in order, as quickly as the CPU of the robot is able to reach them. Spaces, tabs, and line breaks are generally unimportant in ROBOTC. Every statement ends with a semicolon. It's like the period at the end of a sentence. Punctuation pairs, like the parentheses and square bracket are used to mark off special areas of code. Every punctuation pair consists of an "opening" punctuation mark and a "closing" punctuation mark. Simple statements can only run one after another in order, but control statements allow the program to choose the order that statements are run. For instance, they may choose between two different groups of statements and only run one of them, or sometimes they might repeat a group of statements over and over.

Program 1 is an example of a display routine in ROBOTC.

```
//program 1- hello world

task main ( )
{
displayTextLine(0, " Hello World  ");          // Display the text on line 0 of 8 on the LCD
wait1Msec(10000);                              // Wait for 10 second
}
```

Program 2 as an example of adding two numbers and display the result.

```
//program 2- add 2 numbers
task main( )
{
        int x = 5;
        int y =10;
        int sum;
        sum = x + y;

  displayTextLine (1, "x = %d", x);
  displayTextLine (2, "y =%d ", y);
  displayTextLine (3, "sum =  %d", sum);        //Display the sum on the screen.

while(true)                    // An infinite loop to keep the program running until you terminate it
  {
        sleep(10);
  }
}
```

Program 3-uses the sonar sensor to move the robot while avoiding obstacles

```
task main()
{
                                        //While distance sensor is more than 100mm (10cm) away

        while(getDistanceValue(distanceSensor) > 100)
        {
                setMotorSpeed(leftMotor, 50);      //Move left motor at 50% speed
                setMotorSpeed(rightMotor, 50);     //Move right motor at 50% speed
        }
        setMotorSpeed(leftMotor, 0);         //Move left motor at  0% speed
        setMotorSpeed(rightMotor, 50);     //Move right motor at 50% speed
        wait1Msec(1000);

}
```

Since teaching the robotics course to high school students in past four summers, we have noticed some of the students from the robotics class are attending QCC and majoring in the field of engineering or technology. The ambition of offering this course was to get students interested in the STEM curriculum. We attempt to give the students the opportunity to observe what engineering and technology is all about. Most of the class time was spend on building,

programming, testing and learning about robots by assigning good amount of projects both individually and in groups. You must keep the students occupied and attentive in the classroom by introducing fundamental, fresh and stimulating projects. Every lab introduced a new performance for the robot using either Lago EV3 or Vax IQ. We had students write programs to move the robot in a triangle or figure eight path. Other programming projects included were obstacle avoidance, maze, random roaming, wall following, color detection, multicolor line follower and object manipulation and transportation. As the course progresses we try to introduce the latest robot technology and improve the subjects in the course.

References

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