The Khepera Robot as a Teaching Tool

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Abstract

The Khepera robot is a small, commercially available, microprocessor driven robotic device that has been used at the United States Naval Academy for pre-college recruiting, college level engineering recruiting, course work and research purposes. It is a convenient platform for investigating each element of an autonomous system; namely data acquisition, signal conditioning and microprocessor control. This paper describes demonstrations used for pre-college recruiting and laboratory experiments used in a microprocessor based digital design course.

The Khepera robot is a versatile teaching tool. The robot itself is an excellent object lesson for a microprocessor based device. At the simplest level, students generate on-line commands that pass through a serial computer interface. The robot responds by moving as directed. Students may also investigate the operation of the proximity sensors by queuing the on-board analog to digital converter for the current state of the sensors. By adding the proper signal conditioning circuitry, other sensors may also be added to the robot. At the design project level, students may automate the robot and write code to generate desired behavior such as autonomous maze navigation.

I. Introduction

This paper describes how an automatable platform, the Khepera robot, has been integrated into parts of the curriculum at the United States Naval Academy (USNA). The Khepera robot is a small microprocessor driven device.[1] The device is shown in Figure 1. It is a convenient platform for investigating each element of an autonomous system; namely data acquisition, signal conditioning and microprocessor control. This device is flexible enough to be used for a full range of purposes, from pre-college recruiting to laboratory design projects.

This paper discusses how the Khepera robot is used in engineering recruiting and integrated into design projects. Code fragments are offered in this paper. The code is written primarily in Procomm script.[2] This enables the device to be controlled instantaneously with on-line commands as well as through short script programs. The choice of this particular programming language enables students with no programming background to participate in the exercises. This is often the case with the students encountered in the recruiting sessions. For the student with a more advanced programming background, the Khepera robot may be controlled with any language that is able to control a serial port.

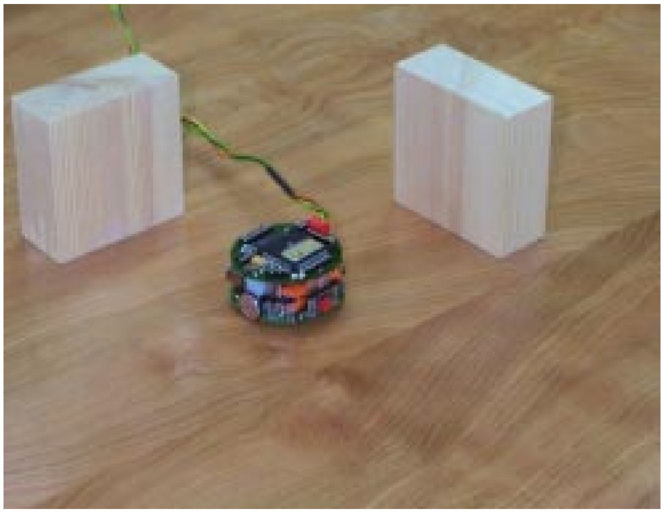

Figure 1: The Khepera robot negotiates obstacles.

The USNA is involved with a pre-college recruiting program called "Summer Seminar". High school students come to the USNA and take part in presentations from the departments. At this pre-college level, following a short tutorial, students learn to control the Khepera robot by using the on-board proximity sensors and writing short interactive programs. They begin with code fragments that move the robot and stop it when the sensors indicate that an obstacle is present. Very quickly these students are able to expand these code fragments into programs with more functional features. This exercise exposes the student to the very basics of serial port communication, programming, real-time sensing and robotics. Students respond quite favorably to the experience of being able to control a sophisticated robotic device.

Other institutions have been using the Khepera for competitive robotic contests[3] as well as student/faculty research[4]. The USNA has employed this microprocessor driven device in the digital design courses: EE242 Digital Systems and EE461 Microprocessor-Based Digital Design. The ability to add sensor devices to the Khepera's I/O turret[5] as well as the real-time controllability, also make this device applicable to the EE426 Instrumentation and Measurement course. USNA students also have made use of the Khepera in senior design projects EE12 Electrical Engineering Design. When students are questioned at the end of the semester regarding the use of the device in their course, the responses are overwhelmingly positive. As an instructor, for the digital and microprocessor courses, I have found that it gives students an appreciation for real-time control issues that are key to microprocessor devices.

II. Recruiting

As part of the Naval Academy's recruiting program, the Electrical Engineering department conducts a three week summer workshop designed to provide information about the electrical engineering program to high school students. As many as 300 students participate in this program. The groups are kept small for each of the individual one hour workshops. These workshops are designed to provide an introduction to the robots which results in a basic understanding and appreciation for the

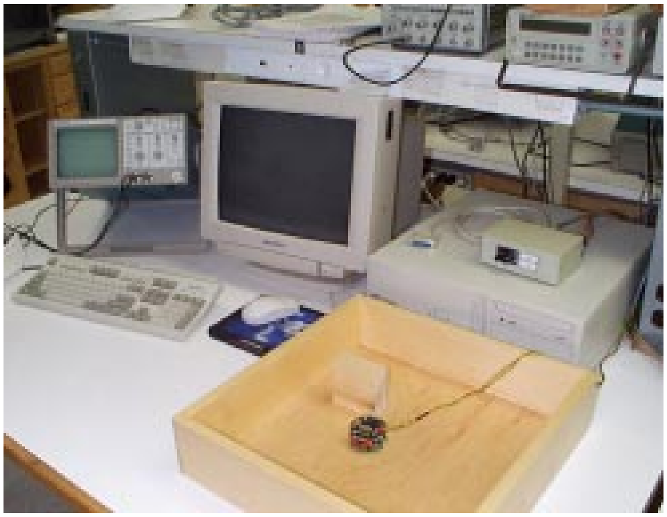

Figure 2: The Khepera robot shown in the microprocessor laboratory.

functions of sensors, motion control, computer interfacing and programming. The workstation is setup in a laboratory environment which consists of a personal computer, the Khepera robot, and a maze box, Figure 2. Each student is given a simple instruction booklet which contains background information on the Khepera robot, a description of its mechanical and electronic makeup, and a list of commands used to communicate. The instructor guides the students through the process in the following steps:

(1) Introduction to the Khepera, to include

a. Stepper motor assembly and proper handling during operation
b. Microprocessor and computer interface
c. Infrared sensors

(2) Students practice on-line commands to move the robot in any direction at different rates of motion. They also learn the commands for turning, rotating and stopping.

(3) Students run various programs that have built in functions that enable the robot to detect and avoid (move around) obstacles.

(4) Students edit programs, such as changing directions and speeds, then compile and run the programs to see how this affects the behavior of the robot as it encounters an obstacle.

The laboratory was only an hour long which presented some difficulty in designing a seminar that would be interactive, imaginative and exciting. Since we presented this class several times (24 times), we had the opportunity to make considerable improvements, and implement them immediately. This turned out to be an advantage on the part of the instructors. The seminar is progressive, starting with the most basic online commands, and then moving to the level of running programs that enable the robot to negotiate obstacles in a path, and finally to editing, compiling and running sophisticated programs, so it is well suited for all levels of abilities and backgrounds. The experiment is hands-on, which makes it dynamic and entertaining to high school students. It directly involves the students and presents them with the challenge of controlling a the movement and decision-making of the robot. This laboratory is very successful, however, it is important that students understand each step of the process before moving on to the next more difficult part. The instructors enjoy the seminar too, because it requires student participation which always enhances learning.

Students were canvassed during the summer seminar, with an overwhelming positive response to the robot laboratory. The seminar generated quite a few questions about robotics, computer interfacing, electronics and programming which was the primarily purpose of the seminar in the first place. This was our main objective: to capture the interest and imagination of pre-college students and get them to think about a career in engineering.

III. Microprocessor-Based Course Applications

USNA students taking a microprocessor course, use the Khepera in a laboratory experiment where they must choose a task and automate the robot. The experiments may include adding sensors and the associated signal conditioning circuitry. What the students take from this exercise is the experience of working with a high level microprocessor based device. It is meant to bring together the individual topics covered in the semester. Issues investigated include programming, timing the data samples taken from the sensors and real-time control. Two examples are given in this paper along with the algorithms. Code fragments for both of the applications are offered.

Tracking Speed Control

The goal of this project was to program the Khepera robot to follow a constantly moving object with varying speed. The motion of the object is limited to forward and backward. The attached block of code, shown in Figure 3, moves the robot forward and backward. This project is a good example of feedback in a control system, the robot adjusts it speed according to the speed of the moving object.

The basic movement command is the *D* command. See lines 1. through 5. in Figure 3. The command takes as arguments, the speed for the left and right motors. The format of the command is:

D,motor_speed_left,motor_speed_right

One of the forward-facing proximity sensor is used to sense the distance from the moving object. See lines 6. through 8. When the distance exceeds the desired range, the speed of the Khepera is appropriately increased as in lines 10. through 13. When the distance is less than the desired range, the speed of the Khepera is appropriately decreased as in lines 14. through 17. The next logical step to the algorithm development would be to include the full sensor suite and program the robot to respond to any movement. This is accomplished by reading the full suite of proximity sensors and adjusting the robot’s movement accordingly.

```
1.   ; Initial values for the motor speeds are defined.
2.           integer motor_speed_left = 3 ; initial values for motor speed
3.           integer motor_speed_right = 3
4.   ; Begin the robot moving.
5.   ; Transmit the command D,motor_speed_left,motor_speed_right.

6.   ; The constants tooFar and tooClose are used to determine the current distance of the robot from the
7.   ; moving object. One of the forward facing sensors, front_sen is used. This sensor must be sampled
8.   ; every time the loop executes.
9.           while 1    ; repeat always
10.                  if (front_sen < tooFar)             ; if the object is too far
11.                          inc motor_speed_left                ; speed up
12.                          inc motor_speed_right
13.                  endif
14.                  if (front_sen > tooClose)           ; if the object is too close
15.                          dec motor_speed_left                ; slow down
16.                          dec motor_speed_right
17.                  endif
18.                  ; Take a reading from the proximity sensor,  front_sen.
```

Figure 3: The code fragment used for tracking speed control.

```
1.   ; The program takes a reading from all of the passive light sensors by calling
2.   ; the procedure check_light( ). If any light sensor is being actuated, the variable
3.   ; light_level is set to TRUE.

4.   ; If light_level is set to TRUE then the procedure chase_light( ) is called where
5.   ; the direction of the light source is determined and the robot moves toward the light.
6.           while 1    ; repeat always
7.                   light_level = check_light( )    ; Check all light sensors.
8.                   if light_level                          ; If any light sensor is actuated, then
9.                           chase_light( )                  ; move toward the light
10.                  else
11.                          ; Transmit the command to stop the robot "D,0,0"
12.                  endif
```

Figure 4: The code fragment used for the Khepera moth.

The Khepera Moth

The purpose of this project was to create an automated program that enabled the Khepera robot to follow a light source. This is accomplished by the attached block of code, shown in Figure 4. The program utilizes the onboard passive light sensors to follow the light. The procedure *check_light*, line 7. in Figure 4 identifies the passive light sensors that are being actuated by the light source. Lines 8. through 12. move the robot toward the light or stop the robot if no light is detected. The next step in the algorithm development could be to incorporate this light following module with an obstacle avoidance program.

IV. Conclusions

This paper has presented examples of experiments and code fragments used with the Khepera robot at the USNA. The Khepera robot is a versatile platform that can be employed for engineering demonstrations or research work. At the USNA, this device has been used for pre-college recruiting and laboratory design experiments for microprocessor-based digital design and instrumentation courses.

V. Bibliography

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VI. Biographies

K.A. KORZENIOWSKI completed requirements for the Ph.D. at Brown University in 1993. Dr. Korzeniowski is currently an Assistant Professor of Electrical Engineering at the United States Naval Academy, Annapolis, MD. Current research work focuses on developing control, sensor fusion and motion planning algorithms for robotic systems.

J.L. RICE received her M.S. in Materials Science and Engineering at University of California, Davis. Commander Rice is currently a Master Instructor at the United States Naval Academy. Research interests include college level learning excellence development, biomedical signal processing, and rehabilitation engineering.