Dancing Humanoid Robots Lab Demonstration for the First Year Engineering Students

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Abstract

This work addresses an exciting humanoid robots laboratory demonstration developed by students (one senior and two master's students) for the first year engineering students. The goals of the demonstration are to entice the first year mechatronics engineering and industrial engineering students, and to motivate them to continue with their engineering studies. For this task, three robotic kits, Robotis Premium, from Robotis, Inc. are acquired; three humanoid robots (18 Degrees of Freedom each) are assembled, and a three-minute robotic dance choreography is created, programmed, and delivered. The demonstration of the robot dance group is included in the regularly scheduled lab sessions of an introduction to engineering course. Student survey results show that this experience was exciting and that it increased students' motivation for studying engineering.

Introduction

First year engineering students face many academic challenges. Some of the students find it difficult to study the language of the profession (mathematics), basic physical laws and facts, as well as general education topics without additional extrinsic motivation. Due to the fast pace of technological advances, faculty are often challenged when trying to find new and exciting engineering examples to motivate their students.

Many educational institutions, both formal and informal, have implemented some type of robotic kits to support science and engineering education. The great popularity of these kits (like LEGO NXT/EV3) stems from their affordability and flexibility. However, some engineering students feel overexposed to this product. Also, NXT Mindstorms kits are often incapable of performing more complex robotic tasks. To step up from NXT Mindstorms robots, universities are selecting more advanced robotic platforms. At our institution, NI LabVIEW Robotics Starter Kit for Education 2.0 (DaNI) is selected as one of the robotics platforms for upper level undergraduate engineering courses. However, DaNI robots are also wheeled robots that resemble a larger version of LEGO EV3s. Thus, other robotic configurations are investigated.

Humanoid robots are often viewed as "mechanical little people." The acceptance of humanoid robots as pets, friends, teachers, students, and coworkers is based on their physical similarity with humans and the similarity of their range of motions and actions with those of humans. To encourage freshmen to stay in an engineering program upperclassmen engineering students built three humanoid robots and programmed them to dance together. The robotic dance group performed for the first-year students.

This work includes sections on previous work, curricular context, description of the robotic hardware with associated integrated development environment (IDE), and educational experiences for the robot builders as well as the first-year students. The results of a short questionnaire are provided and analyzed and appropriate conclusions drawn.

Previous Work

The importance of laboratory experiences and projects in engineering education can be justified by various learning theories, e.g., "Kolb's Experiential Learning Cycle." According to Kolb[1], regardless of the learning style, people learn best if they follow a cycle consisting of four steps (axes): experiencing (concrete experience), watching (reflective observation), thinking/modeling (abstract conceptualization), and applying/doing (active experimentation). Thus, both reflective observation and active experimentation are essential parts of the learning process. Kolb's learning cycle has been used in various engineering education programs such as civil[2-4], mechanical[4], chemical[2, 3, 5], industrial[6], aeronautical[4], and manufacturing[2, 3, 7] engineering.

The success of robotics activities in engineering education has been well reported in literature[8 – 12] but mostly activities using mobile wheeled robots. The use of humanoid robots is rarely reported. Zalewski and Gonzalez use NAO humanoid robot from Aldebaran Robotics[13] while Thai, Kuo, and Yen[14] use Robotis Bioloids in undergraduate student projects. The advanced humanoid robots described in this work are based on the newest hardware and software humanoid robotics platforms. Robotis Premium Bioloid kit with CM-530 controller was offered in 2014[15] while the RoboPlus Robotis software suite received a critical upgrade in 2015[16].

Curricular Context

The humanoid robotic dance project described in this work is implemented in a required introduction to engineering course at our university in the two ABET accredited engineering programs: Bachelor of Science in Engineering with Specialization in Mechatronics (BSE-Mechatronics) program and Industrial Engineering program. Introduction to Engineering is a two credit hours, one semester long course. It meets for three hours a week, where one hour is dedicated to lectures and two hours are dedicated to labs. During the lab sessions, guest faculty perform laboratory demonstrations for students. One of the lab modules deals with robotics. There, students use LEGO NXTs and LEGO EV3s kits to build mobile wheeled robots to perform simple mobile robot tasks. This hands-on module runs for three weeks since students need to build their robots, learn the software and program their robots to perform various tasks (move back and forth, move in a square, and follow a person keeping their distance). The robotics dance demonstration is implemented as a part of the robotics laboratory module. All first-year engineering students were exposed to the Robotic Dance Demonstration (38 students in two sessions) in EN 101 Introduction to Engineering course. Also, all of the first-year students filled the survey on robotic dance demonstration.

To aid others in the implementation of this lab, a detailed description of the robot hardware and software is provided next. The description with some specific challenges illustrates the complexity of this exercise exemplifying what engineers often encounter in a workplace.

Robotis Premium Humanoid Robot Hardware

Robotis Premium Bioloid is a robotic kit manufactured by Robotis, Co., Inc. in 2007. The kit consists of 18 Dynamixel AX-12A servo motors, a CM-530 robotic controller, a number of sensors, an infrared (IR) remote controller, a wireless communication module (optional), and an assortment of assembly parts like frames, cables, wheels, nuts, and bolts. The kit allows assembly of many robotic devices. Twenty six such devices are presented as examples in the Robotis Premium Quick Start Manual[16]. An 18 degrees of freedom (DOF) humanoid robot is the most complicated and interesting robot that can be built with this kit. One of such robots built by engineering students is shown in Figure 1.

Figure 1. Robotis Premium Type A Humanoid Robot having 18 DOF

The eighteen Dynamixel AX-12A smart servomotors are individually addressable and can be connected in series with the controller. In addition, each servomotor has a temperature sensor and an overload sensor. These sensors are used to protect the motors. The motors have two software-selectable modes of operation; the wheel (continuous) mode and the joint mode. In the wheel mode, servos can move continuously with specified speed from 0 to 1023 in the counter clockwise (CCW) direction and with speeds from 1024 to 2047 in the clockwise (CW) direction. In the joint mode, angles are specified from 0 to 1023 corresponding to angles from 0 to 300° thus having angular resolution of 0.29°. Stall torque for the motors is about 1.5 N-m. Albeit, the motors use plastic gears producing gear reduction ratio of 254:1. After stripping a few plastic gears during normal robot use, the company was contacted and asked to consider offering metal gears for this motor.

Robot sensors include two IR sensors placed in robot feet (optional), a distance measuring sensor (DMS) that can measure distances in the range of 10 cm to 80 cm placed in the robot's chest, and a gyro sensor (one x-axis and one y-axis accelerometer) placed in the robot's waist. Also, there is an IR sensor in the robot's head used for communication with an included IR gamepad.

The CM-530 controller based on ARM Cortex microcontroller (depicted in Figure 2) is capable of controlling 26 Dynamixel servomotors. The controller is shipped with the type A humanoid configuration preloaded. Even though the other two configurations, B and C, are described in the Quick Start manual their configurations must be downloaded. The controller includes the power switch, START, MODE, L, R, U, and D pushbuttons. By using the MODE pushbutton the user can choose one of the three modes: manage, program, and play. CM-530 supports blue tooth wireless controllers and ZigBee wireless controllers. Also, it has a built-in microphone, a buzzer, and a number of I/O ports. The controller can communicate with a PC via a USB interface.

Figure 2. CM-530 Control Module Mounted on the Back of a Robot

Robotis IDE

An integrated development Environment (IDE) RoboPlus is bundled with the robotic kit. After the installation of the software an upgrade was required immediately. Students downloaded the newest IDE, RoboPlus 2.0 which is not fully functional. The software installation of version 2.0 creates four desktop icons: RoboPlus Launcher, RoboPlus Motion, RoboPlus Task, and RoboPlus Manager. However RoboPlus Manager 2.0 does not support Dynamixel AX-12A servomotors. One must use RoboPlus Manager 1.0. RoboPlus Launcher shown in Figure 3 is a graphical user interface (GUI) that allows easy access to the other three robotic suites.

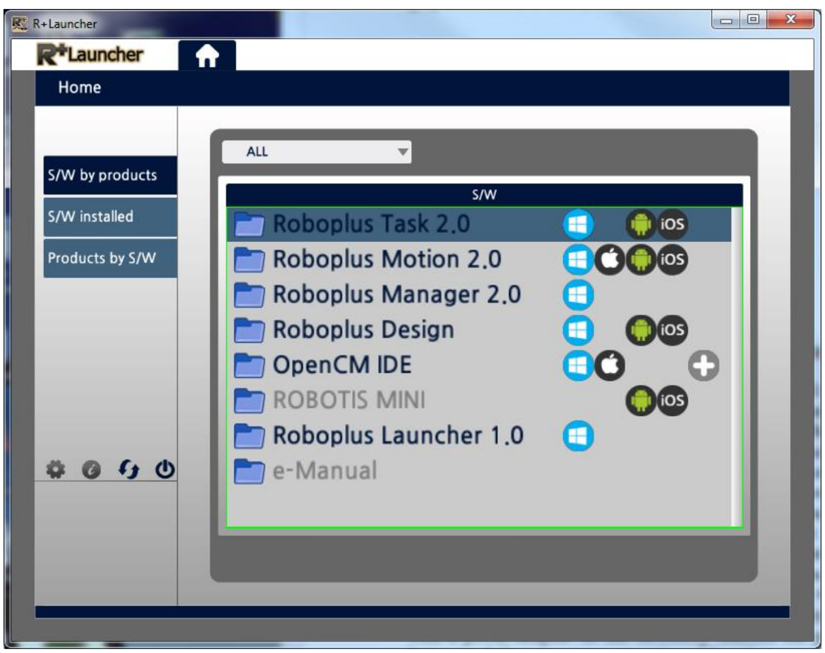

Figure 3. Screenshot of RoboPlus Launcher 2.0

Figure 4 shows RoboPlus Task 2.0 GUI, the software that allows the creation and downloading of behavioral algorithms into the robot[9]. While this GUI/editor minimizes errors through forced program structure it is somewhat slow for experienced programmers. One can, relatively quickly, create robot programs if the existing motion library is used. RoboPlus Task creates .tskx files that can be downloaded into the robot.

Figure 4. Screenshot of RoboPlus Task 2.0 Software

Figure 5 shows RoboPlus Motion 2.0 GUI. This software creates complex robotic movements that can be called in RoboPlus Task. The movements are stored in .mtnx files. The bottom left corner of Figure 5 indicates that the robot is not connected to the computer. That is the reason that two light red columns “Real Robot” have question marks for all 18 servomotor values. Figure 6 is a screenshot of the Motion GUI when the robot is connected and all joints powered.

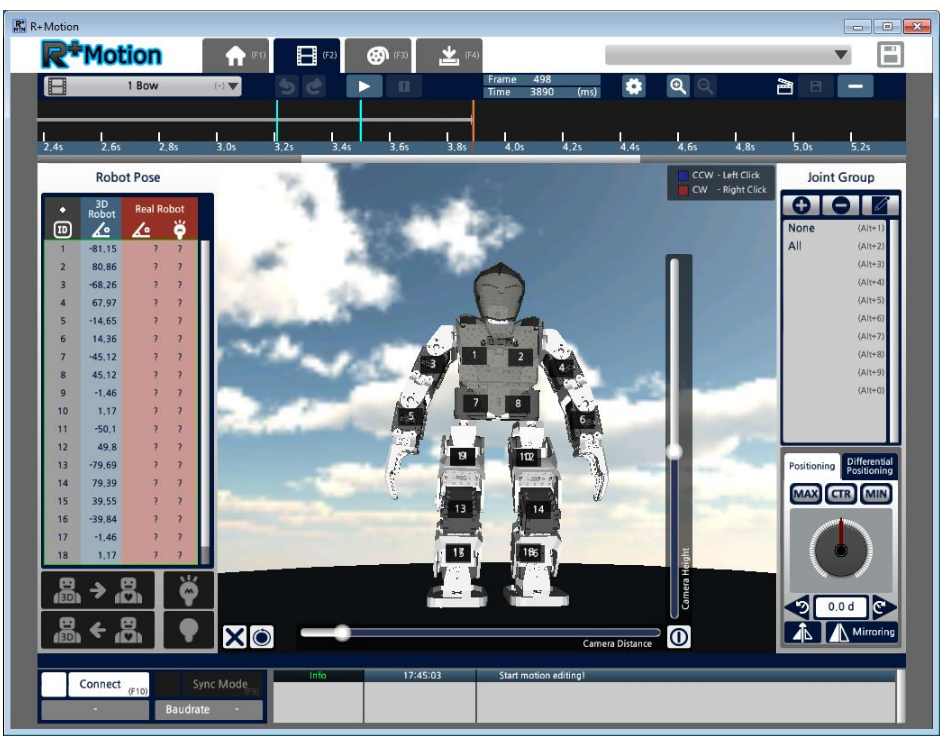

Figure 5. Screenshot of RoboPlus Motion 2.0 GUI – Robot not Connected

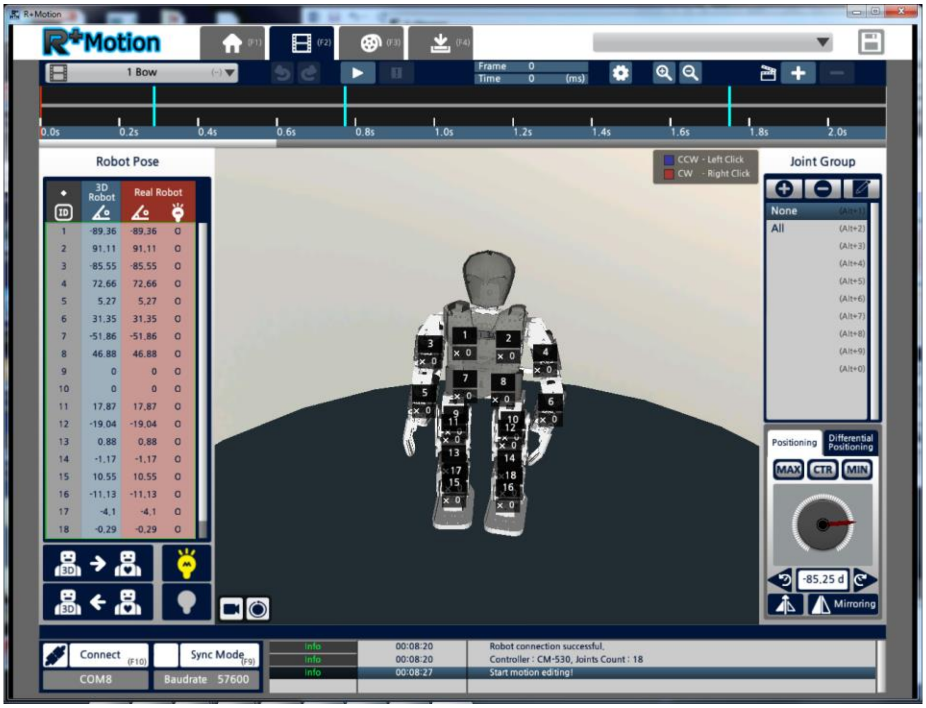

Figure 6. Screenshot of RoboPlus Motion 2.0 GUI – Robot Connected

Finally, RoboPlus Manager 2.0 software manages the devices (sensors and motors) that are included in the robot. Figure 7 shows the screenshot of the Manager GUI.

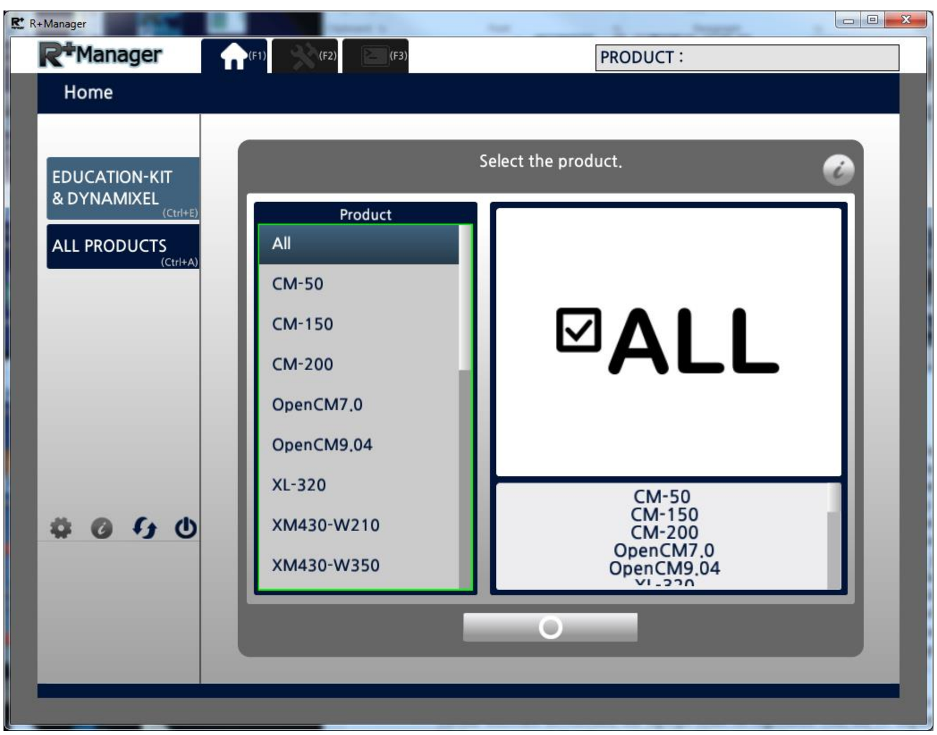

Figure 7. RoboPlus Manager 2.0 GUI

Robotic Task – Dancing Robots

The robot builders, three engineering students were asked to assemble three humanoid type A robots and make them dance to a popular tune. The robots were to dance in accordance to a choreography of students' own design. When done, the students were to use the robots and perform in front of the first year engineering students. No other instructions were given.

Educational Experience for the Builders

The robot dance student team consisted of one undergraduate senior student and two MS graduate engineering students. The undergraduate engineering student was the only one with a number of years of choreography experience. The team chose a popular and appropriate music piece "One Foot Boy" since the Robotis humanoid robots are about 15″ tall. The team was able to build three humanoid robots. They learned how to program humanoid robots using RoboPlus IDE. They used the newest software version, 2.0. For some dance moves they used an existing motion library from RoboPlus Motion module, while for others they developed their own. Their program in RoboPlus Motion module required a substantial effort.

The team had to deal with a hardware failure. During testing, one of the servomotor's gears was stripped. Unfortunately, the newest IDE did not support AX-12A Dynamixel servomotors, so they couldn't just replace the failed servomotor since they could not assign an ID to that new servomotor. They overcame the problem by replacing just the stripped gears using a spare servomotor. In the process of assembling, programming, and operating humanoid robots students improved their programming and troubleshooting skills, and while demonstrating the robot dance with three robots they improved their communications skills. All these are in accordance with the ABET criterion 3, (a) – (k) student outcomes[17].

Educational Experience for the First Year Students

Before the presentation, the students are asked to comment on their level of excitement with respect to their engineering studies. Then, one of the student authors shows one of the robots; identifies the servo-motors, various sensors, joints/links, and details the functions of the robot controller. After this, another student describes the robotic programming environment (R+ Manager, R+ Task, and R+ Motion) and demonstrates programming of a simple robot motion. Finally, the three robots are placed on a table or on the floor; their program starts are synchronized by a single clap; and the dancing music is started. While dancing, the robots demonstrate various motions, often emphasizing the ones that many humans can't perform. Figure 8 is a photograph showing the three humanoid robots dancing on the lab floor. After the demonstration, the first year students are asked to rate how much they liked the robotic dance demonstration, and to again comment on their level of excitement for being in an engineering program. An overall lab knowledge assessment tool was developed and administered for the entire first-year robotics experience (the dancing humanoid robots and building and programming of LEGO Mindstorms EV3 robots).

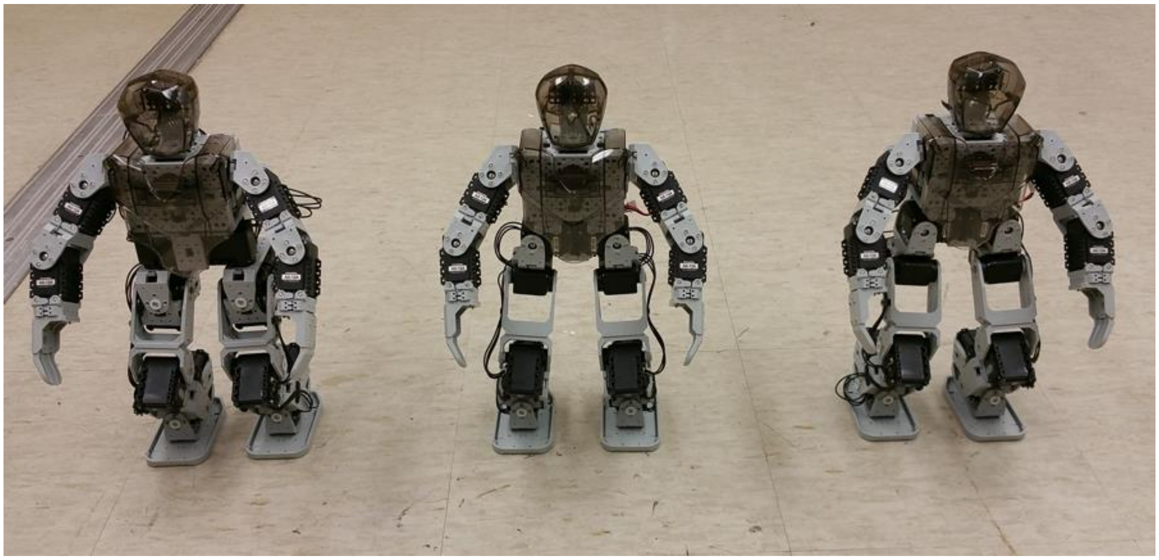

Figure 8. Dancing Robots

Assessment and Evaluation of Student Perceptions and Knowledge Gains

A simple instrument was developed to measure how much the first-year students appreciated the humanoid robotic dance demonstration. The instrument, a questionnaire, was administered and the results evaluated for two groups of first-year students. Group 1 had 18 and Group 2 had 20 students. The instrument consists of three questions rated on the Likert scale from 1 to 5, where 1 means “not at all,” and 5 means “very.” Also, there were three additional open-ended questions. Surveys were administered immediately after the dancing robots experience. The survey results for the two groups, as well as the survey questions are shown in Table 1. The table includes score averages and standard deviations.

Table 1. Survey Results for two Groups of First-Year Students

Num.	Question	Group 1	Group2	Total	St. dev.
1	How exciting was the robotic dance demonstration?	3.89	4.24	4.11	0.73
2	Because of the robotic dance I am more excited to study engineering	4.17	3.95	4.03	0.91
3	The robotic dance helped me understand robotics concepts.	3.56	3.38	3.42	0.95
4	What could you do with humanoid robots?				
5	What kind of an app dealing with humanoid robots would you like to see?				
6	How exactly would you like to communicate with humanoid robots?				

Figures 9 – 11 show the distribution of student responses for the first three questions. Since the two groups did not have the same number of students, Group 1 responses were normalized. It can be concluded from Figure 9 that the robotic dance demonstration was exciting for the majority of students. However, there is a large difference between the two groups showing 7 students in Group 1 being indifferent while showing only 2 such students in Group 2. Figure 10 shows the influence of the robotic dance demonstration on students' motivation to study engineering. Since there is only one negative response, it can be claimed that the main objective of the robotic dance experience for the first-year students is confirmed. Finally, Figure 11shows that the perception of students' gain in knowledge of robotics concepts was not as expected. For this reason, the humanoid dance demonstration will be modified to include a longer explanation of all robotic actuators, sensors, and the RoboPlus software suite.

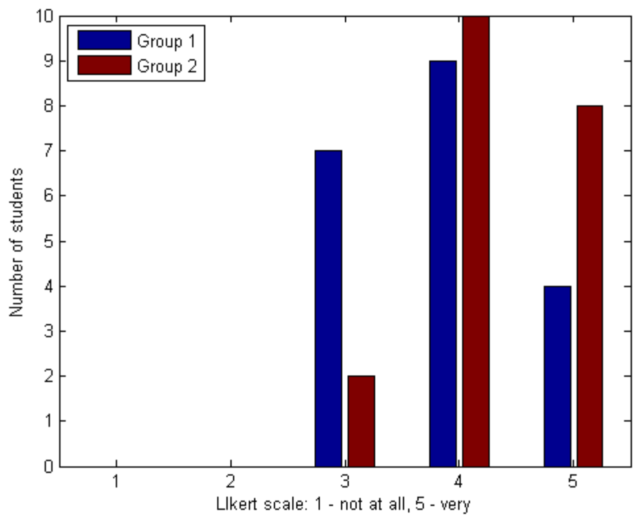

Figure 9. Responses to Question 1: How exciting was the robotic dance demonstration?

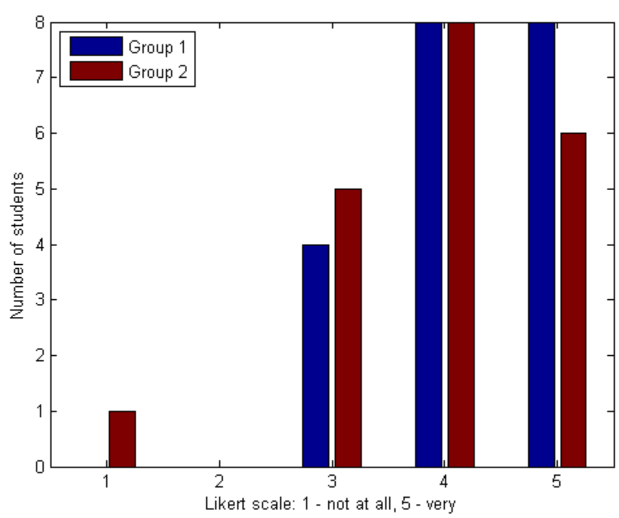

Figure10. Responses to Question 2: Because of the robotic dance I am more excited to study engineering

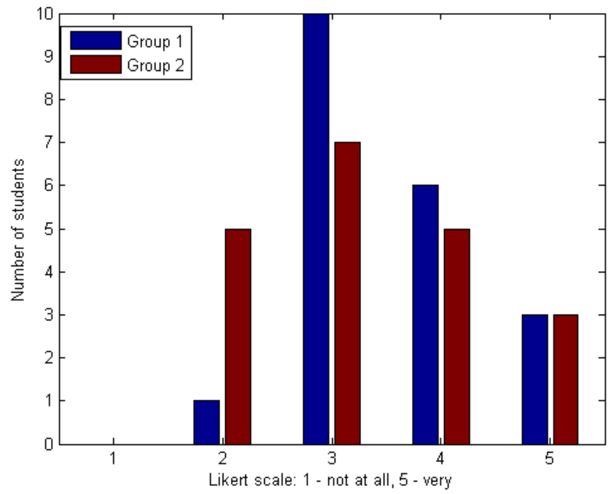

Figure 11. Responses to Question 3: The robotic dance helped me understand robotics concepts.

Questions 4 - 6 are open-ended questions that were designed to allow students to think about humanoid robots possible applications. Question 4, “What could you do with humanoid robots?” was rather general question trying to elicit some unique responses. Students responses show that they want humanoid robots to help with everyday activities and household chores, be solders, be like “Data from Star Trek,” work as surgeons, or work in hazardous environments. Question 5, “What kind of an app dealing with humanoid robots would you like to see?” was somewhat misleading. Some students thought of smart-phone apps only. Others had interesting suggestions, from including GPS tracking and robot-view cameras to game-mimicking, helping with workouts, and virtual reality applications. Question 6, “How exactly would you like to communicate with humanoid robots?” was relatively simple. Students’ responses included voice commands, natural language understanding, texting, sign language, hand gestures, and telepathy.

The overall lab knowledge assessment survey included questions like “What are robots? Why are we studying robotics? Why do we use sensors with robots? Can you name three typical robotic sensors? What is the main difference between servo- and stepper-motors as actuators?” However, since the exact impact of the dancing robots demonstration on students’ knowledge gain could not be differentiated from the second part of the lab dealing with LEGO Mindstorms EV3 experience the results of this survey are not reported in detail. According to the results of the survey, all students defined robots as smart devices, but some did not emphasize their mechanical nature. While the reasons students gave for studying robotics varied, most of them clustered on mobile and humanoid robots with few mentioning automation and industrial uses of robots. Most of the students were able to describe well the need for sensors in robotics and to name few typical sensors (infra-red, touch, ultrasound, light). The question comparing servo- vs. stepper-motors was a bit difficult. Most students emphasized cost and precision while only few of them mentioned open-loop vs. closed-loop operation. This is understandable, since these are higher-level concepts that students most likely didn’t encounter before.

Conclusions

In this paper, a novel laboratory experience using three humanoid robots is described. One group of students assembled the robots, chose music, created a choreography, programmed the robots to dance together, and demonstrated the robot dance to the first-year engineering students. Both groups gained valuable knowledge of humanoid robotics. While the robot builders learned much about humanoids hardware and programming, the first-year students learned what is possible with such robots. By watching actual humanoid robots dance together to music, the first-year students received an extrinsic motivational boost to study engineering.

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