Exposing undergraduate students to fuzzy logic through robotics and mechatronics

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Abstract – The teaching of robotics and mechatronics has increased for the past few decades and has helped to expose particularly non-electrical engineering majors (in engineering and engineering technology) to electrical-mechanical devices. The material in this course can be helpful as many products like cameras become more digital. Throughout their major courses, engineering technology majors in particular will often take a co-requisite laboratory course along with a lecture course. Both courses can follow this pattern of having a lecture course coincide with a laboratory course or portion.

When robots and other motion devices are used in areas like space applications or unmanned aerial vehicles, soft computing paradigms come into play. The paradigms can also involve automotive applications. A couple of them are neural networks and fuzzy logic. While undergraduate students can be exposed to them, more often graduate students will learn how they work. Since these along with artificial intelligence are not generally required (if offered) for engineering technology students, the chance that they may take the course could be slim.

Keywords: Fuzzy Logic, artificial intelligence, soft computing paradigms, mechatronics, autonomous vehicles.

INTRODUCTION

For decades quite a few types of motion devices have been made intelligent, or intelligent systems have been created through artificial intelligence, neural networks and fuzzy logic, especially for non-engineering or unstructured environments [1-4]. Artificial intelligence, AI, was coined in 1956 at a conference though it roots go back centuries [1]. Fuzzy logic, which uses imprecision and uncertainty and also has roots that go back centuries, was developed in 1964 by Dr. Lofti Zadeh [3, 4].

Obstacle avoidance type of research on mobile robots has been in existence for over two decades. This technique as well as others was used on the Mars pathfinder in 1997 and on 2011 on the Curiosity Rover [5, 6]. These robots used fuzzy logic algorithms and other techniques to program and make them more autonomous so they can function in lunar environments and other non-engineered environments [5-8].

Fuzzy logic and autonomous behavior is not limited to robotics or space applications. It has been used in automobiles, aircraft, cameras and washer machines [3]. The term autopilot was coined in 1931, 25-years before AI was [9-12]. Qualified personnel will obviously be needed for the research and manufacturing of these types of products. Therefore, it will be necessary for colleges and universities to educate students who are capable of working in these fields. [3, 4].

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Especially on the graduate level, a research project can heavily involve the soft computing paradigms. With research in intelligent systems increasing, the need for students to learn about these areas will also increase [3, 4].

However, while an engineering student may be able to take classes in artificial intelligence or neural networks depending on the school, there is naturally a limit to the amount of technical electives (or electives period) that they may take. For engineering technology students the number of computer science classes that one may take may be even lower, but it depends on curriculum and policies of the school.

This paper is not simply a report on how robotics or mechatronics is simply taught. It puts attention on exposing the students to soft computing paradigms like artificial intelligence, fuzzy logic and others. It is possible for the students to gain exposure in the soft computing paradigms because of the types of robots they will build during the project. Parallax Boe-Bot and Gears Education System, both used in colleges and universities, can show examples of autonomous behavior [15, 16]. The Lego Mindstorms are very popular kits for instruction in robotics and mechatronics courses, and these motion devices can also be used in the learning of artificial intelligence or fuzzy logic [17].

The next section will discuss some of the curriculum relating to artificial intelligence, neural networks, fuzzy logic, robotics, mechatronics and control systems. It will discuss how students are exposed to or learn about these topics and subject matter at other universities. Then the work at Georgia Southern will be discussed. Later, the future plans for instruction will be discussed.

BACKGROUND

Artificial intelligence courses are not always required for computer science majors and are at times offered as electives. They are seldom if ever required for engineering majors. Fuzzy logic is not offered at every school on the undergraduate or graduate level. It is mostly offered at the graduate level if it is offered at all. Therefore a student may not have the opportunity to take the course-especially on the undergraduate level. Students also may not take courses in robotics, mechatronics, or control systems, especially if they are elective courses.

Engineering technology majors may be able to take artificial intelligence, neural networks and/or fuzzy logic as technical electives but may be less likely to take these courses than their engineering counterparts. However, some engineering technology majors do take courses in control systems and robotics (generally for technology majors). They often will work side by side with engineers and computer scientists after graduation. It is possible that they may work at a facility like NASA or the Sandia National Laboratories, where work on intelligent systems is performed [5-8].

Despite the lack of courses a student may take in the soft computing paradigms, they could get a little exposure through projects in courses like control systems, mechatronics and robotics. Here, students could work on projects using kits like the Lego Mindstorms [17]. The motion devices created from the Legos can possibly act in an autonomous or semi-autonomous manner.

In the engineering technology department at Prairie View A&M University, students taking robotics have as with many other major courses a laboratory course corresponding with the lecture course [13]. In the laboratory section students have worked on projects involving a stationary robot or the Lego Mindstorm 2.0 kit (2003-06) that were used to build mobile robots [18]. Some projects were of the pre-programmed variety, and others were semi-autonomous. The pre-programmed devices performed the same task each time they were run. The semi-autonomous devices backed away or avoided obstacles. It did not matter how or where the obstacles were placed. The device avoided a collision with them even when the obstacles were re-arranged.

The Lego Mindstorm NXT can show autonomous behavior and is an excellent tool to use for a mechatronics' class. The sensors and programming can allow for this behavior, and the parts can be created into assemblies and show the mechanical aspects that a robot can have. While mobile robots have been discussed in this paper, the robotic arm and walking robot are a couple of types of devices that can also be created from the Lego Mindstorm kit. One can learn from a practical standpoint about transformation operators, rotation matrices, projection, different coordinate systems, joints and degrees of freedom, and other items that are associated with stationary robots. They can also learn about grippers and end effectors. One can also get very creative in building devices (from the Lego parts) beyond what is shown in the mindstorm booklet.

The exposure to robotics at Prairie View A&M was not only in the classroom but also in competitions. Engineering and engineering technology students have participated in the NASA/ASCE Earth and Space Student Robotics Competitions in League City, Texas where the objective was to find a box (representing a lava tube) under at four to six inches of sand, drill a hole and seal it [19]. This robot however was tele-operated.

At Tuskegee University mechanical engineering students (and other non-electrical engineering students) take the mechatronics course, which is required for mechanical engineering majors [20, 21]. The lecture portion covered electrical circuits (Ohm's Law, Kirchoff's Current and Voltage Laws, direct current, alternating current, power, transformers, semiconductors, digital electronics, operational amplifiers, IC chips, control systems, sensors and other topics). Hands-on assignments were set so the students can get an understanding of the same topics from a practical point of view. The hands-on assignments are also set up to where students will understand how the robot is designed and constructed. After the hands-on assignments, the students will build the mobile robot that will perform the line tracking task. The task is where the robot follows a silver strip is on a dark carpet from beginning to end. The robot can perform this task no matter how the strip is shaped, and the program would not have to be modified for it to follow a different shaped strip.

COURSE

In the engineering technology classes at Georgia Southern, there was also a lecture and laboratory portion, which covered the same topics as was covered at other schools. For the engineering majors, the course is a laboratory course where students can actually do more hands-on and practical work.

The laboratory assignments in engineering technology were set-up to follow closely what the students receive in the lecture portion. They are designed to where the student can gain practical knowledge of the electrical components and theories. They also would gain some knowledge on how a mobile robot is constructed and its circuit would function.

This laboratory approach helps the students out greatly and is a similar to the one at Tuskegee. There, they would use the Gears Education System to build the mobile robot after completing the hands-on assignments [15, 16]. Circuits are assembled and then constructed with (or attached to) the mechanical components to create the mobile robot. However, if the Lego Mindstorms are used, the students will not be assembling a circuit. They would be building a mechanical assembly and creating a program for the device.

PROJECT

Right before the students begin working on the Lego sets, the class will cover briefly artificial intelligence and fuzzy logic. For artificial intelligence intelligent agents, simple reflex, goal-based, and utility based, are covered. For fuzzy logic uncertainty and imprecision, which play a significant part in fuzzy logic, along with linguistics terms, membership values, and membership functions, are discussed.

Examples relating to AI and fuzzy logic are covered. One relates to obstacle avoidance for a mobile robot. For example if an obstacle is at a very close distance to the right front of the robot, it probably is better for it to move or shift towards the left. If the path in front of the robot is clear, then it is likely that the robot can move straight ahead or forward. Here, the topic of IF-THEN statements out of fuzzy logic is discussed. The Mars Exploration Program rovers are covered so students can see devices that can use fuzzy logic in real life.

While programming is an important part of robotics (pre-programming or autonomous), the students will not go over lines of code as one would in Matlab, C,or C++ while using the Lego Mindstorms [17]. The Lego kit also comes with multiple sensors including an ultrasonic one. Ultrasonic sensors have been used in numerous fuzzy logic applications.

With the types of sensors that exist in the Lego kit, particularly the ultrasonic and light sensors, the robot is able to move in at least a semi-autonomous (not pre-programmed) manner. Tasks such as line tracking or obstacle avoidance can be performed. Even when the robot is approaching an object, it is able to slow down and stop no matter the distance. The robot can follow the different shaped lines without a change in the program.

At Georgia Southern students built mobile robots that followed a line of black tape. The line could be the shape of a square, a rounded off corner, or a lane or key in basketball with a semi-circle (analogous to the lane and top of the key). The objective was for the robot to find the line, move along that line, and then knock off the ball that is mounted. If the robot was off the line it would first use a search command to find the line. Once the line is found, it would carry out the task.

One robot had an ultrasonic sensor at the top. As it came into close range of the ball, it would slow down until it came to a complete stop when it is right up on the ball. Then it would knock the ball off of the stand. The other robot would pretty much perform the same task. However, it moved at a slower speed and used a touch sensor when it got to the mounted ball. In this case the touch sensor will cause the robot to stop when it touches the mount. Right after it stops, the robot (or an arm on it) will knock the ball off of its mount. In order to follow a line, the robot has a light sensor at the bottom like the other one does.

Regardless of the shape of the line, each mobile robot will perform the same function. It will look for the line if it is not already on it. Then it will follow the line until it gets to the mount and the ball. Lastly, it will knock the ball off of the mount.

If the robot had been pre-programmed to follow a line, it would have to follow a specified shaped line. It would move at a specified distance. It would slow down at a specified distance and stop, and then it may be able to knock off the ball. For these projects performed by the students, the robots could follow any shaped line without being re-programmed.

These projects are similar to the one that was performed at Tuskegee University.

FUTURE WORK

In some cases across the country, the Lego Mindstorms are also used on the K-12 level. Therefore, some college students may have exposure and experience with these devices. By using the Lego Minstorms alone for the project, the students will not be able to build on the knowledge gained from individual circuit laboratories (topics like KVL, KCL, semiconductors and electric power). In other words they would not be able to build a circuit for the robot if they used the Lego materials alone. This can be limiting if one is to obtain a complete knowledge of the workings of a robot [22].

There are kits like the Gears Education Systems or Parallax robots that can be used. In the past the Parallax Boe-Bot has been used. Now, the Robotics Shield Kit for Arduino is increasingly being used across the country and will eventually be used at this institution. If the Gears Education Systems or Parallax robots are used, then the student can build a circuit and the mechanical parts of the robot. Here, they can use the capacitors, resistors, LEDs (light emitting diodes), MOS-FETs (metal–oxide–semiconductor field-effect transistor), IC (integrated circuit) Chips and other electrical devices that come with the wheels, gears and other mechanical devices that are a part of the robot. It is possible that the student would gain a more complete knowledge of how a robot, mobile or stationary, is built and operates. Using these types of kits would be very beneficial for the students.

Yet, the Lego Mindstorms can be used with external devices and have been for years. Martin shows how Legos can be used with electrical and mechanical parts, external cables and printed circuit boards. The motion devices can be programmed with the C programming language [23]. Greenwald and Kopena discussed the building of mobile robot labs [24]. Examples of mobile robot instruction from the United States Naval Academy was discussed with examples of Legos combined with a Basic Stamp II [25]. In other cases MATLAB and C were used with the Lego system and a QuickCam camera [26]. These are just a few of the examples of where external parts and programming languages (languages other than the one provided by Lego) are used with a Lego system. Hence, students can use their knowledge gained from the electrical circuit labs and use the electrical parts in conjunction with the Lego Mindstorms. Recently, the Lego Mindstorm EV3 was released, and it comes with more advanced technology [27-29]. This apparatus eventually will be used in future courses.

For the exposing to artificial intelligence or fuzzy logic, the exposure will be mostly by way of the project since the course leans heavily on the students learning about the hardware (electrical and mechanical components). While the students will see practical applications of autonomous behavior, the course will not delve too deeply into the theory of AI and fuzzy logic as if they were taking one of those courses. However, in the future there will be more discussions about agents in AI and membership functions, IF-THEN statements, fuzzy logic control and uncertainty in fuzzy logic.

As this course is taught by the author more often, the projects will become more in depth than in past semesters (whether the Lego Mindstorms, Gears Education System or Parallax Boe-Bot are used). In other words the tasks completed by the students will become more complicated. It is not only desired that the students will gain more knowledge about the individual parts and theories of mechatronics. It is hoped that they will become better able to work on a project from beginning to end.

CONCLUSION

The Lego Mindstorm NXT was able to show autonomous behavior, and the behavior can be used as an example of fuzzy logic principles through by these demonstrations. It is felt that a student can learn a little about artificial intelligence and fuzzy logic by building and programming a Lego Mindstorm device. One does not have to extensively learn the theories, definitions and equations of a soft computing paradigm to gain a basic understanding.

Whether a student uses a Lego Mindstorm NXT, Gears Education System robot, or Parallax robot, the student can see examples of fuzzy logic in operation. They would be able to create and program motion devices that can behave in an autonomous manner. By working on a project like this, they can gain a practical understanding of the intelligent agents in AI and the uncertainty, imprecision, linguistic terms in fuzzy logic.

From the programming aspect, they can gain an understanding without having to use Matlab, C, or C++ to program a device. Here, one may be able to determine how far or how quickly the robot should move. These tasks (in how fast or far) can go along with the goals of fuzzy logic.

Another goal is to possibly increase the student's interest in studying in this field on the graduate level. By exposing a student to fuzzy logic and artificial intelligence for that matter, a student may have more interest in something like the Mars Exploration Program. They may have interest in working in the industries that produce the products that were mentioned earlier in this paper.

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