AC 2009-1908: A KICKING MECHANISM FOR A SOCCER-PLAYING ROBOT: A MULTIDISCIPLINARY SENIOR DESIGN PROJECT

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A Kicking Mechanism for a Soccer Playing Robot – a Multidisciplinary Senior Design Project

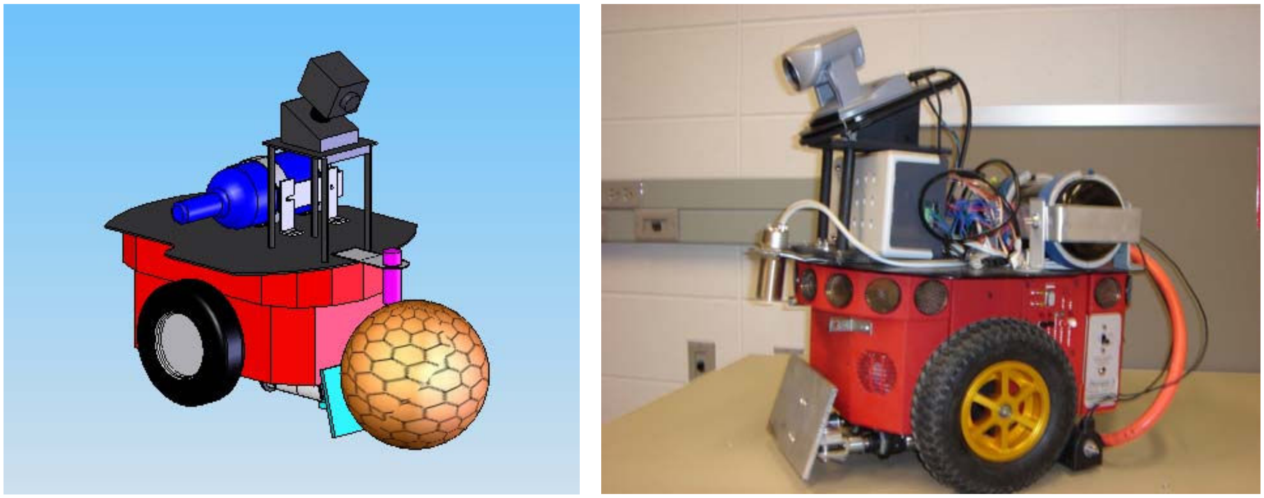
Abstract

This paper describes a multidisciplinary capstone senior design project that involves the design, build and test stages[1]. It is a two-semester project that was conducted by five senior students in the Department of Engineering at Indiana University - Purdue University Fort Wayne (IPFW). The objective of this project is to design and build a kicking mechanism that can be seamless attached to a Pioneer 3-DX mobile robot. The Pioneer 3-DX robot and kicker combination should be able to locate a soccer ball, approach and control it and finally kick it in a desired determined direction a minimum of five meters, through preprogrammed kicking strategies. This paper also describes several different assessment approaches used throughout the project. The faculty members from the Department of Engineering and the local sponsors conduct the assessment. The assessment results are provided. The impact on the engineering curriculum of this on-going Robocup project is also discussed at the end.

Introduction

In August 2007, the College of Engineering, Technology and Computer Science at IPFW and a local company initiated a 5-year project to promote robotics, artificial intelligence, and software engineering in the college curricula. The main goal of this project is to build a robot team to compete in the Robocup Middle Size League competition[2] by 2012. This project also aims at introducing robotics into a variety of computer science and engineering courses. As part of the first year plan, a Pioneer 3-DX robot was purchased. Using this robot as a development platform, the first task was to design and build a kicking mechanism that is seamlessly connected and interfaced with this robot. This task was carefully reviewed by the professors whose expertise are in Robotics and machine design, and determined to be an appropriate two-semester multidisciplinary capstone senior design project. Two of the professors, one in ECE and one in ME, became the faculty advisors for this project. It was also proposed that this project will require 2~3 EE/CmpE students and 2 ME students. In fall 2007, the students started from the formulation of the problem, generation of conceptual designs, evaluation of the conceptual designs, and finished with a detailed design of the final picked design. In spring 2008, the students built the system and conducted the experimental testing.

There were a total of four conceptual designs generated[3]. The team evaluated these four conceptual designs based on the following criteria: ease of implementation, reliability, size constraint, cost, and etc. Then the top rated design was chosen as the final design. The CAD drawing and a picture of the final built system are shown in Figure 1. The kicking system is composed of a pneumatically driven kicker, a PIC microcontroller based control and driving unit, and software design[3]. The Pioneer 3-DX robot and its attached kicking system had to be able to locate a soccer ball, approach the ball, and control it. It also had to be able to kick the ball in a particular direction for a minimum of 5 meters. RoboCup provides rules regarding the size and weight limitations of the robot for specific leagues. These restrictions together with the given dimensions and weight of the Pioneer robot determined the allowable size and weight of the kicking system. The PIC based control and driving unit were designed to provide enough power to drive the actuators of the kicker. The development software ARIA (Advanced Robotics Interface for Applications)[4], an object oriented toolkit, was provided with the Pioneer robot. High level visual tracking and robot movements were programmed using ARIA. Low level kicking motions were programmed using MPLAB. The two program modules communicated through a serial connection.



(a) CAD drawing of the final design (b) actual kicker attached to the robot

Figure 1: The final built kicking mechanism

Team Formation and task distribution

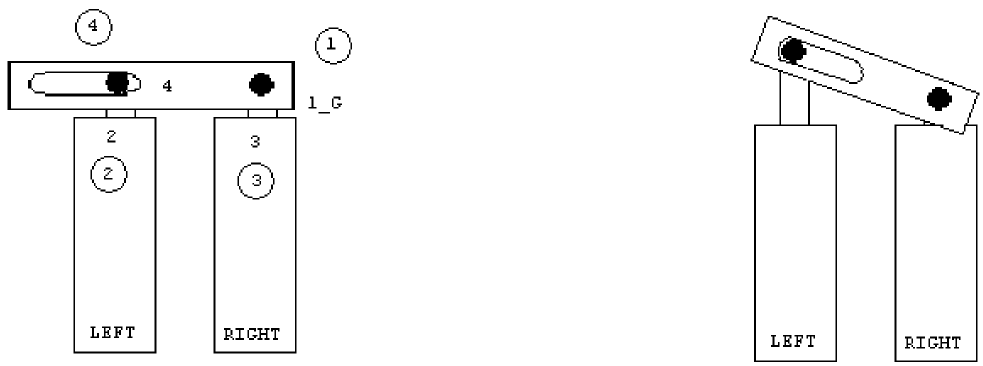
In the Department of Engineering at IPFW, student selection and project assignment for the capstone senior design project starts in the semester prior to when the project will start[3]. At first, a list of potential projects is posted on a website approximately three weeks before the end of the previous semester. All students are encouraged to apply for the project they are interested in by submitting a cover letter and resume. During the first week of the semester when the project starts, the senior design committee will meet with the project advisors to assign the final teams. For this Robocup project, the team members chosen were one CmpE/EE dual major student, two EE students, and two ME students. After the team was formed, the faculty advisors and students met weekly to ensure the progress. The whole project was divided into 4 individual tasks. The tasks and the student(s) who was in charge of each task is shown in Table 1. Students worked on their assigned tasks individually and met at least once a week to present their work to the whole team for discussions and suggestions.

Table 1: The task distribution

Task #	Task description	Student(s)
1	Microcontroller selection, interfacing, and software	1 CmpE/EE
2	Solenoid driving circuit	1 EE
3	Sensor interfacing	1 EE
4	Kicking mechanism and driving system	2 MEs

Mechanical System

The kicking mechanism was designed as a pneumatically driven dual cyclinder system[3]. The cylinders were controlled via 3/2 solenoid valves. The two pneumatic cylinders can be fired individually or as a synchronized pair. The kicking plate was attached via a pin to one of the cylinder and via a slider to the other cylinder. This simple linkage (shown in Figure 2) allows for kicks in three different directions. When both cylinders are actuated, the kicking plate will move straight forward. When only one of the cylinders is actuated, the kicking plate will kick either left or right. The kicking plate was fabricated with 6061 aluminum alloys and bonded to the aluminum bracket[5]. The kicking plate was secured to the dual cylinders. Before the kicking mechanism was attached to the robot, a wooden prototype was constructed that matched the critical dimensions of the robot base to conduct some testing. Once the prototype testing was finished and showed satisfactory results, the components were bolted to the Pioneer 3-DX robot. Figure 3 showed the final built kicking mechanism.



(a) Dual cyclinders and kicking plate (b) Side kick

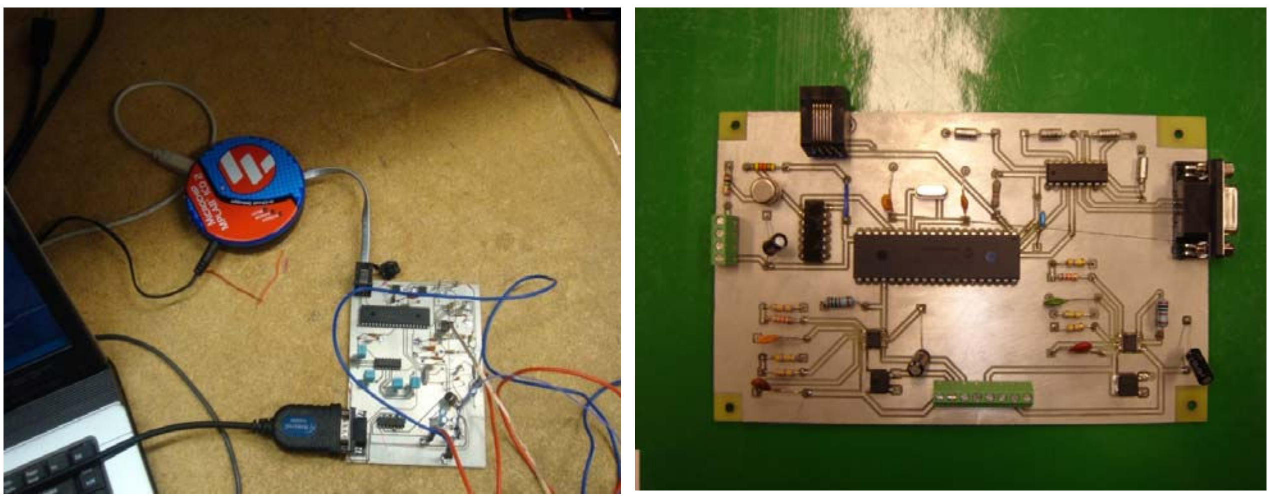
Figure 2: The kicking linkage

(a) Pneumatic system underneath the robot (b) The kicking plate

Figure 3: The pneumatically driven kicker

Electrical System

The electrical system[3, 5] was composed of a PIC microcontroller, two solenoid drivers, a proximity sensor and the interfacing circuitry. This unit could enable the main controller of the Pioneer 3-DX robot to drive the kicker as well as utilize possible sensors to determine short range robot motions. PIC18F458 was selected as the microcontroller to run the kicking mechanism. The solenoid driver was used to drive the solenoid valves for the pneumatic cylinders. The proximity sensor was implemented to detect the soccer ball when it is close enough to be kicked. All of the aforementioned components except the proximity sensor were embedded into a PCB (printed circuit board). The PCB layout was designed by the engineering team. The final PCB was fabricated in the Electrical Engineering Technology Department. Figure 4 shows this microprocessor-based control and driving unit.



(a) Downloading program (b) Final PCB

Figure 4: The PIC based control and driving unit

Testing Procedures and Results

The last phase of this senior design project was testing. During March – April of 2008 a variety of testing experiments were conducted to evaluate the system performance. Among the many requirements for the kicking mechanism, the most important one is how many kicks the system could perform before the tank pressure drops too low, and how far the ball can travel after the kick. Testing results showed that the ball was kicked around 181 times with an initial tank pressure of 2100 psi to a final pressure of 1000 psi. The robot stayed in operation for two hours. During that time the PCB board did not heat up and remained at room temperature. Another set of testing experiments were conducted to determine the relations between the ball travel distance and the regulator pressure. The regulator pressure started at 20 psi and was adjusted up to 130 psi. During the testing, the ball was stopped at a distance of 5m because 5m is the requirement set in the beginning of this project. Figure 5 illustrates the results. The results showed that the regulator pressure should be set to at least 90 psi for the kicker to consistently meet the requirement of kicking the ball at a minimum distance of 5m.

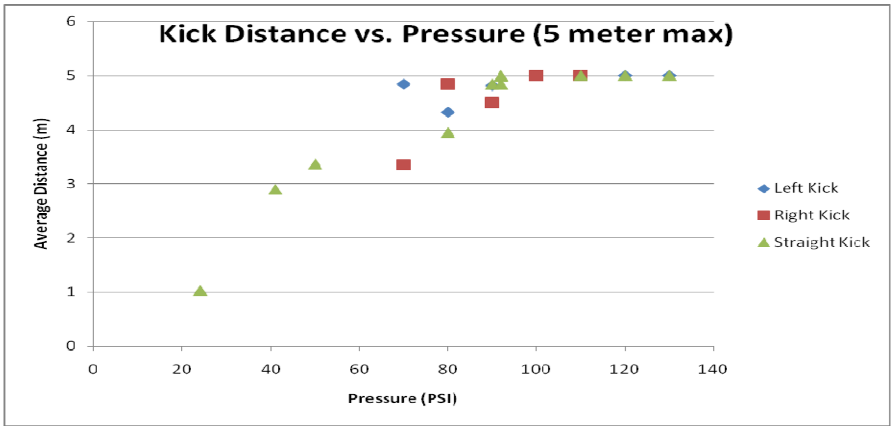


Figure 5: The ball travel distance vs. the regulator pressor

Some other requirements were also tested based on the specific components involved. The electrical system testing includes the proximity sensor interfacing circuitry, the solenoid driver unit, and the serial connection between the PIC 18F458 and the main controller of Pioneer 3-DX robot. The testing results[6] showed that the performance of the electrical system was consistent and reliable. The overall system performance testing involving the Pioneer 3-DX robot showed that the whole system could locate a ball, move towards it, and kick the ball into the goal.

Project assessment

As mentioned above, the senior design project in the Department of Engineering at IPFW is a two-semester project. In the first semester the students design the system. Then in the second semester the students build the system and conduct the testing. At the end of each semester, the students give an oral presentation about what they have accomplished throughout that semester. The presentation is open to the public. After the presentation, faculty members from the department and the industrial sponsors conduct an assessment of the course outcome for each individual project. Typical outcomes evaluated for the first semester capstone senior design course are as follows. The results were presented in the authors' other paper.[6]

1. The ability of the students to formulate a problem statement.
2. The ability of the students to generate solutions.
3. The ability of the students to evaluated the generated solutions.
4. The ability of the students to obtain a final design including safety, economic and ethical considerations.
5. The ability of the students to communicate effectively.

At the end of the second semester, a similar assessment is conducted by the faculty members and the industrial sponsors. The five outcomes evaluated for the project are listed below. The evaluators were asked to rate the outcomes from 1 to 4. The results presented in Table 2 shows that those outcomes are well achieved.

1. The ability of the students to build their design.
2. The ability of the students to test their design.
3. The ability of the students to evaluate their design.
4. The ability of the students to communicate effectively.

Table 2: The assessment results

Outcome	Evaluator								average
	1	2	3	4	5	6	7	8	
1	4	4	4	4	4	4	4	4	4.0
2	4	3	4	3	4	3	4	4	3.6
3	4	3	4	4	4	3	3	3	3.5
4	4	3	4	4	4	3	4	4	3.8

There are also other assessment activities related to the capstone senior design project. Throughout the first semester, the project advisor(s) assess the problem statement, the generated conceptual designs, the evaluation of the conceptual designs, and the detailed final design. The assessment is based on the written reports provided by the team. Throughout the second semester, the project advisor(s) assess the measured parameters statement, building prototype, testing and evaluation, and the final design report. The measured parameters statement and the final design report are assessed based on the written reports provided by the team. The building prototype, testing and evaluation are assessed through the demonstration given by the team. In the end of each semester, the senior design course coordinator assess the ABET course outcomes a, c, d, e, and g [7].

Impact on the Engineering Curriculum

The majority of capstone design projects in Department of Engineering at IPFW are currently multidisciplinary due to the fact that we have electrical engineering, computer engineering and mechanical engineering programs in the same department. The project presented in this paper is similar to other projects of multidisciplinary nature, but it also goes beyond that scope because robotics is a field that not only attracts people from engineering but also from computer science as well as from other areas. In addition to this capstone design project, there was another software engineering course that used this Pioneer 3-DX robot. The software engineering course, offered by the computer science department, requires a class group project. The students first learned how to use the APIs in the software development package ARIA provided with the Pioneer 3-DX robot. Then the students programmed the Pioneer 3-DX robot to accomplish certain interactive tasks utilizing the PTZ camera. One student in that software engineering project was also in this engineering capstone project. Therefore, the experience that he gained in the software engineering course could be used in the engineering capstone project. One computer science student is currently taking an independent study course using this Pioneer 3-DX robot. In fall 2008 the author and this student took the robot into one IEEE students' meeting and gave a demonstration to students who are interested in robotics from the whole campus.

As mentioned above the ongoing Robocup project is a long-term project. This project has brought an impact on the engineering curriculum. For the academic year of 2008-2009 one of the multidisciplinary capstone projects is to design and build our own omni-directional soccer playing mobile robot base. The team has already finished the design and is now in the phase of building the mobile robot platform. The advantages of designing and building our own robot are twofold. First, the robot could be customized exactly for our application, the Robocup competition. Second, it will be less expensive than buying a commercial robot. Robocup project has attracted a number of students' interested in robotics and therefore has produced a positive impact on the engineering education at IPFW.

Conclusion

In this paper, a multidisciplinary capstone senior design project to design and build a kicking mechanism interfaced with the Pioneer 3-DX robot is described. The whole system design consists of a kicker and a microprocessor based control and driving unit. The final delivered system and the testing procedures and results were presented. In addition the assessment methods used in this capstone design project as well as the impact on the engineering curriculum of the on-going Robocup project were discussed at the end.

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