

## **Autonomous Robotic Vehicle Design**

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### Introduction

The purpose of this paper is to demonstrate the use of hands-on educational methodology in multidisciplinary course. The work of this paper is similar in scope as the works of [1]-[6], wherein student team based project courses utilizing autonomous vehicles as the test bed have found success in the educational arena. A very comprehensive overview of how Mechatronic projects can be successfully implemented into the classroom is given in [7]. The current work was motivated by a desire to expose a wider range of students the excitement of team competition. Simultaneously, the robot kits used as the educational vehicle herein culminate a multidisciplinary embodying electromechanical design and fabrication principles and practices.

This paper describes a course developed to enhance the curriculum of Cal Poly Pomona's Mechanical Engineering program. The course entitled "Autonomous Robotic Vehicle Design" encompassed a three (3) hour lecture session and a three (3) hour lab session. Engineering principles stemming from Mechatronics and Electro-mechanical design coursework were applied to this course. The course required students to engineer and fabricate an autonomously controlled robot. Student teams were given the same box of robot parts which comprise the basic kit and starting point of the course. At the end of the quarter, the robots were required to perform a predetermined assigned task, i.e. walk a plank turn around and walk back. Course objectives included brainstorming and team design solutions, project and time management skill development, working in a real world open ended stifler problem environment. Outcomes of the course were measured by the successful completion of the assigned tasks, ability to work in team format, and the oral presentation of the white paper study.

### Course Outline

Students started with the same box of electro-mechanical hardware and were tasked to engineer, and fabricate a functional robot in 10 weeks. The robot kits used for this portion of the class were those based on the Insectronics kit of Karl Williams [8]. The selected course text dealing with autonomous robots was [9]. Hardware was purchased from Stampbuilder.com [10].

## Course Objectives

Students were expected to develop project management skills, team working interaction, and synergy of electro-mechanical engineering disciplines. Students each purchased a box of identical hardware at the beginning of the quarter. Weekly milestones were established prior to the start of the course. Each week, action items for the robot were checked from each team. This reinforced project management and time keeping skills development as part of the learning experience.

## Purpose of Class

The course objectives were to underline the importance of electro-mechanical design and integrate the following disciplines:

1. Mechanical design, fabrication, and assembly
2. Electronics understanding, design and fabrication
3. Vision sensor understanding and utilization
4. Programming knowledge and utilization
5. Coverage of robotics and artificial intelligence
6. Synergy of, Mechatronics, Electromechanical design, robotics, Artificial Intelligence and Machine vision.
7. Encompasses material from Mechanical Engineering, Electrical Engineering and Computer Science

## Mechanical Design

The mechanical lay-out of the robot kits used comprised of 4 main sub-areas:

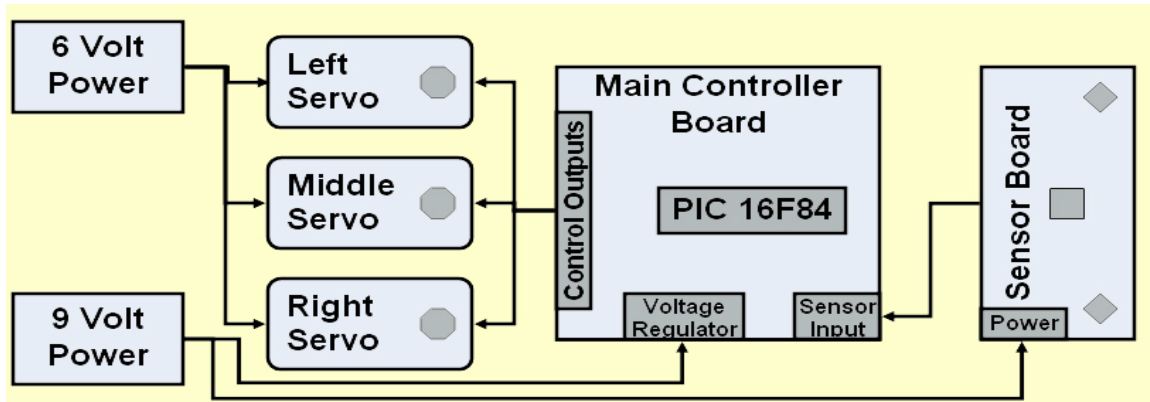
1. Basic mechanical design taken from Insectronics by Karl Williams
2. Hexapod robot designed to walk forward, turn, and walk reverse with six legs.
3. Two servos control sweep of side legs
4. Another servo controls the middle leg lifting the robot

## Electrical Design

The electrical design of the course project consisted of the following 4 sub-areas:

1. Designed around a PIC 16F84 microcontroller running at 4 MHz
2. Main control board is powered by a 9 volt battery through a 5 volt regulator
3. The servos use 4 AA 1.5 Volts batteries
4. The Basic Insectronics design employs a dual infrared L.E.D. sensor board

The electrical lay-out of the robot kit is shown schematically in Figure 1.



**Figure 1 – Electrical Schematic for ARVD Project**

### Program Tasks

The following were the main tasks of the programming portion of this project:

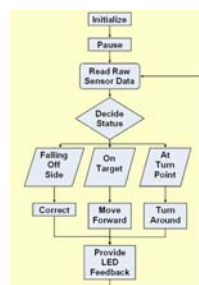
1. Control servo movement
2. Collect raw sensor data
3. Convert raw data to useful data
4. Based on sensor data determine current status
5. Based on current status decide on appropriate movement
6. Send status signal through LED's and Piezo buzzer

### Programming Steps

Details regarding the programming of the robot included:

1. Write code using PicBasic programming language and MicroCode Studio
2. Convert code to assembly language using MicroCode Studio
3. Convert assembly language to a Hex file using MicroCode Studio
4. Burn Hex file onto PIC microcontroller using a chip burner
5. Install PIC into robot

Figure 2 below illustrates the multi-steps used in programming the robot.



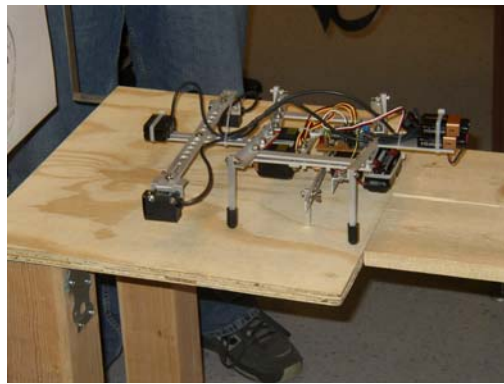
**Figure 2 – Programming Logic for ARVD Project**

## The Challenge

Students must modify and adapt the basic Insectronics robot design to autonomously complete 3 objectives:

1. Robots must be able to walk down a suspended 8 foot plank only slightly wider than itself.
2. They must then sense the end of the platform by either seeing the hanging flag or the edge of the 18 inch square rotation platform, and be able to turn 180° without falling.
3. The robots finish by walking 8 feet back to the starting point

Figure 3 illustrates a typical design solution.



**Figure 3 – ARVD Design Concept**

## Course Assessment

Tools used to assess the material learned by the students included weekly design reviews, which were structured after commercial industry design reviews. Each week, teams were required to provide a 5 minute status oral report to the other teams. This allowed each team to gage the development of the others. While keeping certain design items proprietary, common lessons learned were shared by each group. At the end of the course, individual student grades were based on team participation, attitude, attendance, team working skills/interaction and overall involvement in the course. Feedback forms were administered at the end of the course. Each student completed a review form for the course. Based upon the results of this survey, the methods used in this paper prove to be very effective. Students responded well to the assigned tasks and had a very enjoyable time while learning a great deal regarding electro-mechanical systems level engineering

## Biographical Information

KEVIN R. ANDERSON is an Associate Professor of Mechanical Engineering at California State Polytechnic University at Pomona. Dr. Anderson possesses over 15 years of practical experience in the aerospace sector of private industry. Currently, Dr. Anderson is employed as a Faculty Part Time member of the Jet Propulsion Laboratory (NASA-JPL). Dr. Anderson teaches courses in Mechatronics and Control

Systems. His research interests include instrumentation and control. Dr. Anderson holds the Ph.D. degree in Mechanical Engineering from the University of Colorado at Boulder.

CHRIS JONES is an Undergraduate Research Assistant and senior in the department of Mechanical Engineering at California State Polytechnic University at Pomona. Mr. Jones has been involved in a number of robot team projects over the last 5 years and continues to act as a mentor to high school solar race car teams. Mr. Jones is currently employed at the Jet Propulsion Laboratory as an engineering intern.

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