The UPJ EET MicroMouse: This New Addition Impacts Learning In Embedded Microcontrollers

Stanley J. Pisarski
University of Pittsburgh at Johnstown

Abstract

The University of Pittsburgh at Johnstown (UPJ) offers the Bachelor of Science degree in Civil, Electrical, and Mechanical Engineering Technology. Many of the courses offered in UPJ's Engineering Technology Program rely on laboratory experiments to supplement the lectures. The Embedded Microcontroller course offered by the Electrical Engineering Technology (EET) department at UPJ is no exception. Students enrolled in this course are required to design interface circuitry, write and debug microcontroller programs, perform simulations, and field test the final product.

Since 1992, the Electrical Engineering Technology Department (EET) at UPJ has utilized Motorola's 68HC05 series microcontroller to control many different peripheral devices including personal computers, liquid crystal displays, keypads, analog to digital converters, digital to analog converters, temperature controllers, motor speed controllers, X-Y recorders, and stepper motors. This microcontroller is one of the easiest devices to program and has many individually programmed bi-directional I/O port pins combined with a serial peripheral and a serial communications interface in addition to input capture and output compare functions. This year a new member was born and has been added to the ever-expanding list of experiments utilizing the microcontroller as the main control unit. The UPJ EET MicroMouse is the combination of a miniature land rover vehicle with sonar-type sensors that scurries around on the floor mapping out its surroundings while avoiding obstacles in its path.

This paper focuses on the evolution of this course, the newest member of the group (UPJ EET MicroMouse), and links student learning to the use of exciting projects compared with more traditional mundane cookbook experiments. It will examine the fundamental reasons for learning while comparing and contrasting different types of learning styles and how we, as educators, can increase morale and motivate our students to do their best.

I. Introduction

The Electrical Engineering Technology department at the University of Pittsburgh at Johnstown has offered a basic course in microprocessors since the fall term of 1985. The core course was focused around the popular 8-bit Intel series 8085 microprocessor. The laboratory, offered to supplement the lectures, centered on the SDK-85 trainer. It featured a hexadecimal keypad for user input, a six character LED display for output, and a prototyping area for assembling custom circuitry to interconnect to the I/O ports to learn port interfacing and I/O programming techniques. Memory allocation was 256 bytes with an additional 4 Kbytes extension. Programs were manually cross-assembled and they were eventually entered through the keypad to be executed, but saving programs was initially non-existent. Several years passed and along came computer generated cross-assembly of the source code. Computer downloading capabilities soon followed and the ability to easily modify the file and retest it abounded. Programming assignments were written in assembly language and the ability to write fairly complicated programs progressed over the years. Since this was the EET students first introduction to assembly programming, the microprocessors course was focused on modular programming techniques and many assembly language programs were written and tested using this basic philosophy. Simply show the students how to write programs in assembly language using a simple 8-bit processor while making extensive use of the monitor routines to communicate with the keypad, display and ports and learning will occur. While this method allowed the students to try out sophisticated programs, it did not teach port interfacing and the strategies required to write the driver routines necessary to communicate with external hardware devices. This critical link in the learning process to control external hardware with microprocessors was not being covered and it was impossible to accomplish everything in a single course.

II. Evolution

In the fall term of 1992, an additional course in embedded microcontrollers was added to the EET curriculum as a technical elective and this course has seen continual improvements each year. It is based around the 8-bit Motorola 68HC05 series microcontrollers and contains all the hardware necessary to operate a basic microcontroller system with just the addition of a power supply and an external oscillator. It features a maximum internal clock speed of 2 megahertz with an external 4 megahertz oscillator, 24 individually programmed bi-directional I/O ports, a serial communications and serial peripheral interface, 16 bit free-running timer, with timer input capture, and timer output compare capabilities. All this, coupled with 4 Kbytes of on-chip EEPROM, made this integrated circuit easy to work with and a dream to program. An erase/reprogram cycle takes approximately two minutes. These features made this microcontroller invaluable to the student who needs quick reprogramming cycles to try out different ideas. The addition of several Motorola Evaluation Development Modules allowed the students to write programs (still in assembly language because of instructors preference), simulate the program, and interface to custom made external hardware devices producing an interesting learning experience.

After a formal introduction to the microcontroller basics, instruction set, cross-assembler and simulator, the students begin by writing subroutines to interface and communicate with 1) serial and parallel bus liquid crystal display modules, 2) matrix hexadecimal keypads, 3) digital to analog converters, and 4) analog to digital converters. These topics require approximately eight to nine weeks of the term leaving the rest of the laboratory periods for nontraditional laboratory experiments. Laboratory exercises for this course are far from cookbook style experiments. The students are only supplied with the functional specifications for the resulting operational system and they provide the creativity to make it happen and meet or exceed the design specifications.

Over the course of the past seven years, the students have completed projects such as: “A Real Time Countdown Timer”, “An X-Y Plotter”, “A Digital Thermometer”, “A Digital Tachometer”, “A Digital Temperature Controller”, “A Stepper Motor Driver”, “A DC Motor Speed Controller”, “A Message Display Board” and several others. In some cases, the hardware already existed in the engineering technology department’s inventory and in other cases the hardware was custom designed and constructed just for this course. Over the years, the electronics shop and machine shop located on campus have worked on several projects that involved creating, drilling, and assembling custom printed circuit boards and special machined fixtures, so this year is no exception. In the beginning of the fall term of 1999, the author of this paper was inspired to create something new for the students to use in their experiments in the microcontroller class. A decision was made to fabricate some type of robotic device that was inexpensive (due to a limited budget) and small in size (making it easy to store), but fun to program, which would create excitement within the student body.

Initial design work for this project commenced on September 15, 1999 and on November 10, 1999 at 11 AM the UPJ EET MicroMouse was born. It is approximately 15 inches long, 6 inches wide, and 8 inches high, weighing a mere 4 pounds. It has black ultrasonic eyes, and a light gray coat. It scurries around on the floor mapping out its surroundings and moving in directions that allow it to avoid obstacles in its path. In essence, it mimics a live mouse by using stepper motors to control all motion allowing for forward, reverse, directional control, as well as clockwise and counter-clockwise rotation. An additional stepper motor sweeps the ultrasonic transducers from side to side and they generate sound waves which reflect off objects in its path giving it a sense of sight just like the bats have done for hundreds of years. Its tiny brain is the Motorola MC68HC705C8 microcontroller that controls each motor while sending and receiving signals from the ultrasonic sensors. The food that it consumes is electrical energy from a 16.8 volt nickel-cadmium battery pack neatly tucked inside its outer shell. Its nervous system consists of over one hundred feet of ribbon cable that carries the electrical signals to all parts of its body. It is truly a sight to see (Photo 1 and Photo 2).

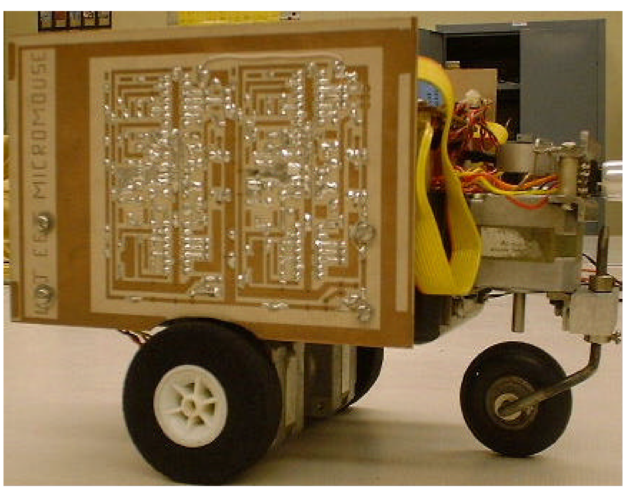

Photo 1

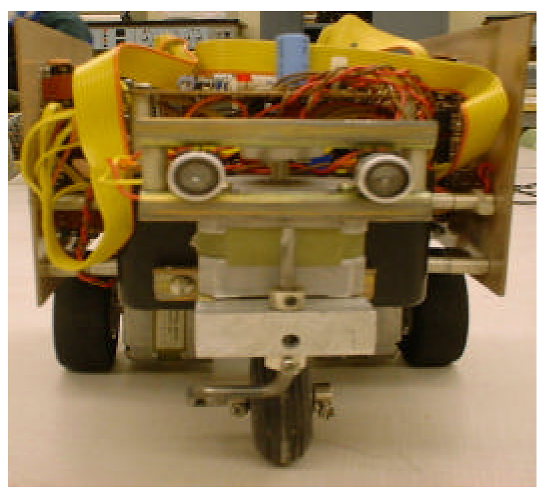

Photo 2

III. Student Involvement

At the beginning of the fall term 1999, the students enrolled in the microcontroller course were advised that by the end of the term they would play an important part in the MicroMouse project. During the term, the students in the course became familiar with all the features of microcontroller and were given in-class and laboratory assignments leading up to the programming work required to control the MicroMouse. Initially, the students worked in groups consisting of two team members. No team leader was selected for each group, but one eventually developed out of the need to organize and divide up the work. The equipment and facilities were made available to the students to work any time they desired even in the evenings and weekends. The instructor's expectations were made very clear about the quality and quantity of work that was necessary to accomplish the job to make the MicroMouse operational.

The students divided into two teams (Photo 3 and Photo 4) and began working on this project by writing subroutine modules to control the acceleration rate of the stepper motors for forward and reverse directions. Varying the time each stator coil is energized during its sequence controls acceleration. Once the program was written to control the motor's shaft speed and rotational direction, the next phase was to produce clockwise and counter-clockwise rotation of the MicroMouse. This required interleaved motor sequences to turn one wheel clockwise while the other wheel rotated counter-clockwise. This action allows the MicroMouse to spin about its center similar to a tank in a hard cornering turn. Phase three was completed to enable the MicroMouse to sense objects in its path. This was accomplished by exciting the ultrasonic transmitter with a high frequency square wave voltage while the stepper motor moved the sensors through a 150 degree arc. The ultrasonic receiver looked for the reflected sound wave signal. The absence of a signal means no object is present and the MicroMouse can continue to move in that direction. A reflected signal means that an object is present in front of the MicroMouse and a decision is made to change direction. This enables the MicroMouse to avoid bumping into objects in its path.

Photo 3
Team 1 Left to Right
(Ryan Eash, Terry McClemens, Scott Blum and David Penrose)

Photo 4
Team 2 Left to Right
(Kelly Thompson, Shawn Springer, and Bryan Wilhelm)

IV. Learning Experiences

Learning is defined in Webster's Dictionary as "obtaining knowledge of something or of how to do something. Paul Chance, in his book "Learning and Behavior" defines learning as "a change in behavior due to experience." He goes on to state that "Although learning is a result of experience, not all experience produces learning." "If learning is a change in behavior due to experience, then a scientific analysis of learning means identifying the lawful relation between behavior, on one hand, and experience on the other.[1] How do I know if my students learned from their experience with the MicroMouse? Although no scientific research was carried out to answer this question, you may form you own conclusion as to whether true learning occurred in this group of students from the outcomes that were observed over the course of this experiment.

The student's first reaction to the MicroMouse project is that this will be a cookbook type experiment. They believed that they had all the information they needed to control the MicroMouse and allow it to move without direct operator control. Once the teams started to write their subroutines, they soon realized they didn't have all the answers to their questions and neither did the instructor. Questions such as: "How many times do I pulse the stepper motor to obtain one complete wheel revolution?" "How far will the MicroMouse move with one wheel revolution?" "How fast can I accelerate the wheels without losing torque or losing rotor synchronism?" "How quick can I stop the MicroMouse without skidding?" How many wheel rotations cause one complete rotation of the MicroMouse, "How long will it take for the sound wave to return from an object 2 feet away?" were pondered and studied. Physical measurements such as MicroMouse weight, wheel diameter, distance between wheels, motor speed/ torque relationship, and others needed to be obtained in order to answer the questions in a search for the solution to the problems. Students measured, calculated, experimented, and performed many trials before becoming successful in achieving the project goals. The electrical engineering technology students had to draw on information from other courses they had such as physics, mathematics, statics, dynamics and machines as well as their experience in circuits and assembly programming for the microcontrollers. This one project forced them to apply their knowledge and experiences in areas other than electrical engineering technology. It made them think and question themselves in their search for the solutions to the many problems that provided a roadblock to their success. The students were successful in their efforts and completed their assignment. Team morale was high as the students encouraged each other to not give up and to try out different ideas. Many students spent extra hours before and after normally scheduled laboratory hours to achieve success and indicated that this was fun and that this perception helped motivate them to succeed. I applaud their efforts.

Did my students learn during this experience and how does this compare with their other experiences with cookbook style laboratory assignments? The students perceived that they learned from this experience and they had fun doing it even if it meant spending their own free time to get done. Their average test scores on this topic increased approximately 15% compared with their scores on tests that covered material involving cookbook style experimentation. The oral responses to the questions I asked the students about topics in this area provided me with the feedback I needed to answer the question in my mind. Did my students learn from this experience? Yes, I believe they did. Did their behavior change during this process? It sure did because they were not accustomed to thinking outside the box and it forced them to comply, otherwise failure would have been evident. Were the students stimulated by the events that occurred? They told other students what they were doing and were proud to show them what they did. This change in their attitude affected them in a positive way and I hope it made a difference in the way they view experimentation and inspired their curiosity. It was curiosity that killed the cat, but curiosity is one behavioral trait that drives an engineer to search for the answers to all problems in their lives.

V. Conclusion

Students have many different types of learning styles. David A. Kolb suggests that humans have four different learning cycles. They are Concrete Experience ("Feeling"), Reflective Observations ("Watching"), Abstract Conceptualization ("Thinking") and Active Experimentation ("Doing").[2] It has been stated that people retain 10% of what they read, 20% of what they hear, 30% of what they see, 50% of what they see and hear, 70% of what they say, and 90% of what they say and do. If your students are not doers, then put them into a position where this occurs naturally such as in the laboratory environment. Provide the students with the information they need or provide them with the resources to find the information themselves. Encourage them to do their best and mentor them when they are confused and frustrated. Remember that it takes a team effort to be successful and the instructor is part of the team even if he is only an outside observer. Compliment the students for a job well done and reward them for their efforts. The students will then look forward to their next experience because of the positive reinforcement they have received in the past. Work can be fun!

VI. Acknowledgements

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Biography

STANLEY J. PISARSKI
Stanley J. Pisarski has been an instructor of EET at the University of Pittsburgh at Johnstown for 20 years. He received a BSEET in 1977 and has worked as a project engineer for Robicon Corporation in Pittsburgh, PA, consulting engineer for Ocenco Inc., in Blairsville, PA, and a research and design engineer for K. H. Controls Inc., in Blairsville, PA. He is a Licensed Professional Engineer in Pennsylvania.