Session 2525

# Multidisciplinary Design of Computer Controlled Systems

**Hugh Jack, Padnos School of Engineering, Grand Valley State University**

## Abstract

When we teach design we quite often focus on a single area or problem. Senior design projects are often seen as a way to broaden the subject area of the design. But, quite often we experience difficulty when crossing disciplinary boundaries.

Two successful projects that include electrical, mechanical and computer elements will be described. These projects were conducted by mixed groups of senior students from mechanical and electrical programs. In one of the projects, a mobile robot was interfaced to the Internet, in the second the project was design to be interfaced to a PLC. All of the projects are now in use supporting undergraduate laboratories and outreach programs.

## 1. Introduction

The school of engineering at Grand Valley State University (GVSU) had it's first graduates in 1988. Since then, the school has continued to grow and now has students in electrical, computer, mechanical and manufacturing engineering. The faculty and curriculum are not departmentalized by program as is found in most programs. As a result, it is quite easy to offer courses and projects that have multidisciplinary content.

The engineering program at GVSU is practical in nature. This includes mandatory co-op employment and a two semester capstone project. The first semester of the project is winter, and it involves planning and design. The second semester is summer and involves construction, debugging and testing. Typically the projects are conducted for local companies and eventually are used by the companies. The academic expectations for the projects are a professional quality design and build. By necessity most projects are multidisciplinary, involving both mechanical and electrical work. Quite often these devices use controls, such as PLCs. Examples of these projects are automated test stands, production equipment and product design/redesign. Budgets for these projects are rarely below $10,000.

This environment creates an expectation of high quality work that the students assume is normal. Occasionally a senior project will be run internally, with the school of engineering as the sponsor. These projects are funded and used to develop needed equipment. To date I have supervised three of these project teams to develop equipment for three different needs. Two of these projects used multidisciplinary teams. They are,

- keytag maker - a four station keytag production machine that is controlled by PLC to support a controls course.
- internet controlled mobile robot - for a K-12 outreach program a mobile robot was developed to allow remote manipulation and video feedback over the web.

Both projects were completed successfully and are currently in use.

## 2. The Keytag Maker

EGR450 (Manufacturing Controls) is a course that teaches logic based process control using PLCs. The course includes extensive lab work that applies PLCs in a variety of applications. The first labs effectively teach the student to program and interface the controllers, but for the pedagogy some of the unpredictably of real implementations is hidden. An advanced lab was needed to expose the more difficult problems such as integration of multi-module systems, process startup, process integration, alignment, etc. [1]. This need was met by having a senior project student team develop a small production machine.

Initially the objectives for the project were left somewhat open, they were,
- make keytags,
- develop it to have four stations,
- allow PLC control, and TTL voltage level control where possible,
- allow the stations to work independently or together,
- keep the budget in the $5,000 range.

The team selected was comprised of four electrical and two mechanical students. And, two of the electricals had some machining experience. The team developed a design that in sequence used,

i) a drill to put holes in the keytags (these are also used for aligning the other stations),
ii) a feeder station,
iii) an embossing press, and,
iv) a shearing press.

At the beginning of the project it was determined that each station would have stand-alone hardware with control boxes. When operated together the control boxes could be ganged to share E-stop control. The overall layout is seen in Figure 1.

The drill press station was the most elaborate of the four, it was based on a bench drill press with hand feed. It was retrofitted with a motor and timing belt set to drive the feed, and various other enhancements such as spindle power control and sensors. The control box was designed and build from discrete components and included two control modes. First was with TTL binary values for setting the spindle advance/retract rate and reading the position. The second was with a simple advance/retract command that altered the setpoints for a PID control loop, it also contained a motor amplifier. The feeder station was based on a stepper motor and used a commercial translator unit. Both the embossing and shearing presses used hydraulic power. The control cabinets allowed switching of the valves to advance and retract the cylinders. All stations (except the feeder) use a hole sensor that would watch for the drilled hole and a pneumatically actuated clamp to hold the work. The final machine worked well and is now used to support four lab experiments in the course. The final system can be seen in Figure 2, it cost about $6000.

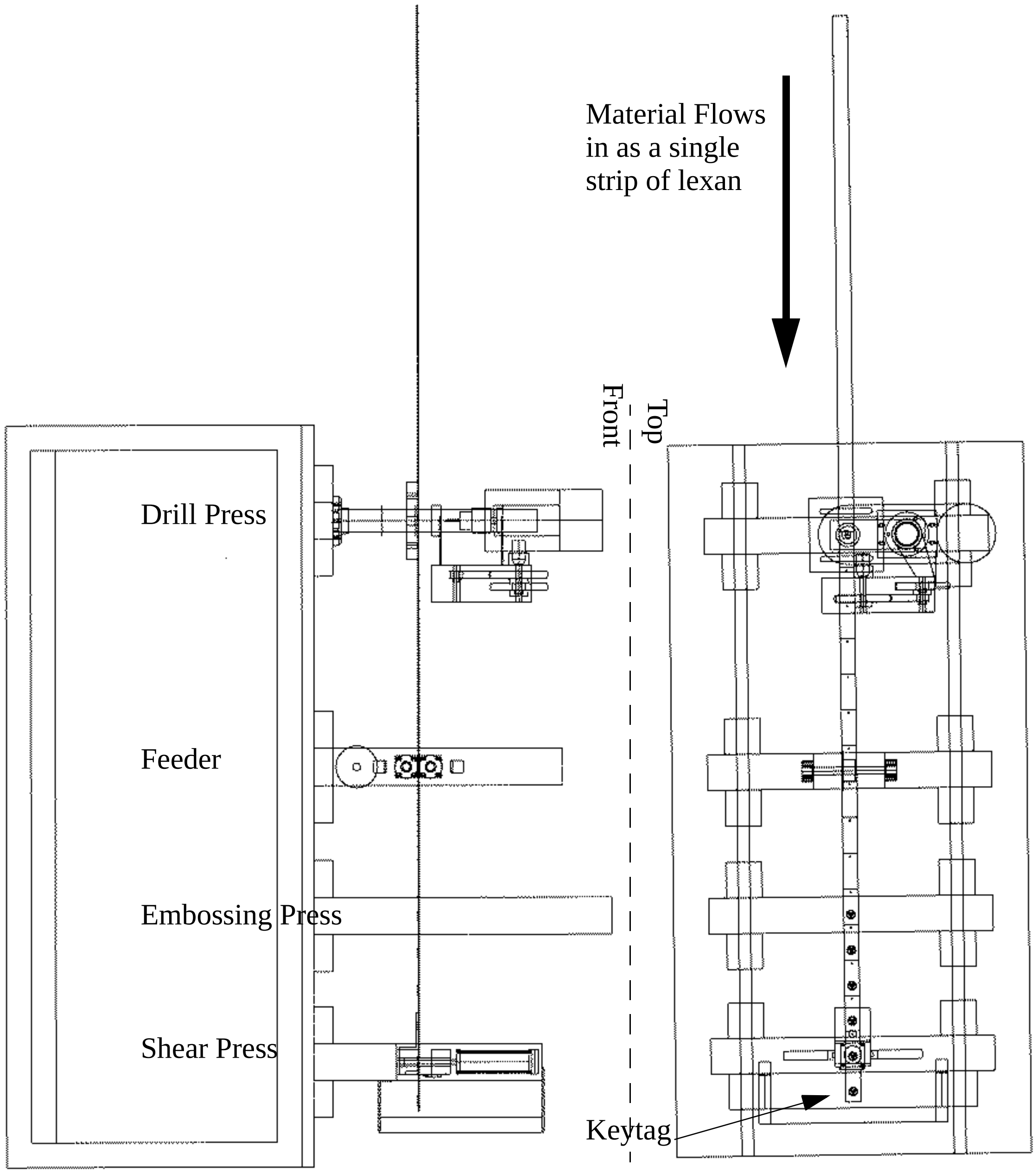


Figure 1 - The physical layout of the keytag maker

Figure 2 - Photographs of the keytag maker

## 3. Mobile Robot

Recently funding was obtained from NASA to fund a K-12 outreach program focusing on space exploration. The main thrust of the project was the science, but a portion focussed on the robotics in the project. As a result a remotely controlled mobile robot with video feedback was designed and built. The final robot is controlled and video viewed through a web browser (rover.engineer.gvsu.edu).

Initially the objectives for the project team were,

- develop a robot based around an old IBM PC with new parts to cost less than $500
- allow it to operate using batteries and be mobile
- allow control via a web browser

The team selected was comprised of four electricals and one mechanical. After some planning the team divided themselves into interest areas based on components in the system. Figure 3 shows the component layout of the system.

- chassis / shroud design - 1 mechanical
- motor controllers - 1 electrical
- interfacing and power systems - 1 electrical
- web based programming - 1 electrical
- operating system and software - 1 electrical

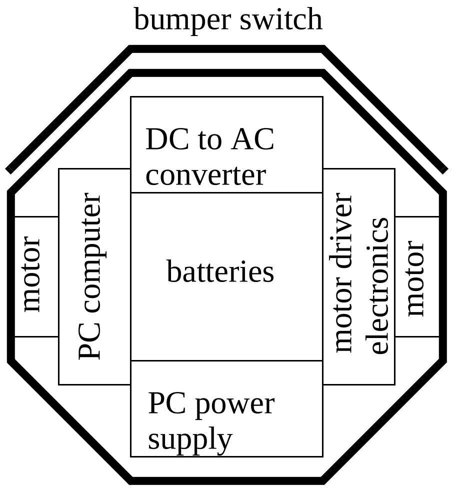


Figure 3 - The physical layout of the robot

The robot was build using many available materials and equipment. The chassis was made from welded aluminum and this was covered with plexiglas to make the outer shell. The motors were purchased and mounted. Custom electronics were designed and build to drive the motors (using PWM). The robot is build around a reclaimed 486 PC. The mother board and essential parts were mounted in the robot chassis. The operating system chosen was Linux for its power and networking abilities. The PC was powered with a normal power supply, but this required a power converted (bought at WalMart) to convert the battery power to AC. Software drivers were written to control the robot, and interface with the Internet.

The project was successful and can be seen in Figure 4, it cost approximately $300.

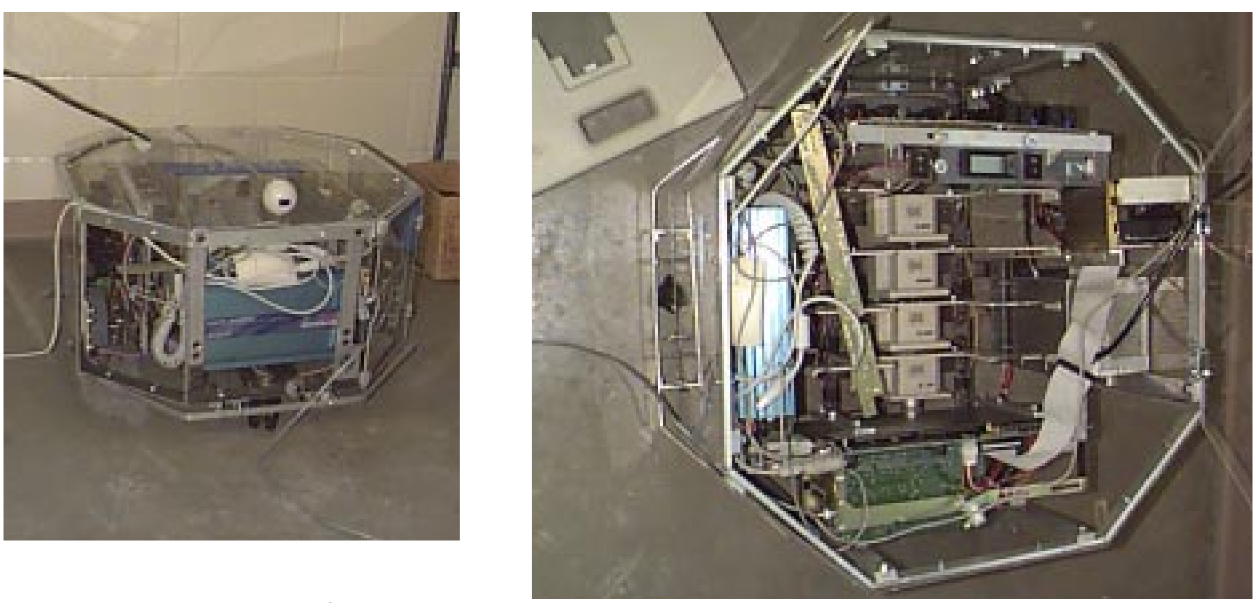

Figure 4 - Photographs of the robot

## 4. Lessons Learned

These projects faced some challenges that required special attention. Some of the main issues that faced the multidisciplinary student teams were,

- none of the team members were experienced leaders,
- they were not sure what the other disciplines offered and had been educated to solve problems within a single discipline, and,
- they were not acquainted with individual designs that must fit together. This led to confidence and motivation problems.

In response to these challenges there were some steps that were taken to increase the chances of success. The leadership problem was minimized by planning the composition of the project team. The team discipline, skill and interest composition was chosen to match the work required. After the teams were organized, they elected leaders. This gave a main contact person, a single voice, an organizer for the team, and somebody to push when times became difficult.

The issue of understanding other disciplines and learning how to mix their talents was something that had to be learned during the project, but this was encouraged by giving guidance and then letting the students discuss the design. Over time they began to see how their knowledge fit into the larger design. In both cases the teams were given the guidelines and some direction in the form of review sessions, and then asked to formulated the design. This self direction of the design allowed them to design within their own areas of competence and avoid weak areas. This also gave more team ownership.

Easy access was provided to a number of technical resources such as equipment, people and information. This reduced many of the trivial barriers. This was especially important for the multidisciplinary teams because no one team member understood all the project details, and some amount of backtracking was required. Easy access was given to financial resources after the basic design concept was set. This cut down anxiety about purchasing small components.

The issue of preparing to start doing independent design was a very large psychological barrier involving a leap of faith. This was overcome by having a design review to ensure the design was understood by all before preceding. This involved the production of a single document that detailed all of the system components and how they interact. This reduced the expertise barrier between students by making them aware of how they fit into the larger project. At that point approval was given to help convince students that the design was feasible.

In summary, guidelines for success are:

1. Match the team disciplines to the skills required, but let the team select the leader.
2. Provide the team with guidelines and allow them to explore these as a group.
3. Allow the team to select the design within guidelines.
4. Establish and agree to the design early before preceding to implementation.
5. When the design is acceptable, transmit your satisfaction to increase student confidence.
6. Ease access to technical and financial resources. Expect some waste from backtraking.

## 5. Conclusion

The paper described two projects that were conducted by senior students. Both of these projects had multidisciplinary aspects that make them more challenging. An abstract discussion of the issues was used to develop a set of suggestions for others planning to do similar projects.

## References:

[1] Jack, H., “Teaching PLCs With A Production Line”, ASEE North Central Section Conference Proceedings, Detroit, April, 1998.