Multidisciplinary Instrumentation Student Projects

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Abstract

During the fall 2012 semester, electrical engineering and chemistry students at Trine University collaborated on design projects to build instrumentation systems. These multidisciplinary design projects are discussed in this paper. In the beginning of the semester, electrical engineering students in the class entitled Instrumentation were introduced to the software languages MATLAB and Labview, and they were introduced to how to write data acquisition (DAQ) software using these languages. For the last month of the semester, teams of students were responsible for designing computer controlled data acquisition systems. There were seven teams each working on a different instrumentation system including a filter fluorometer, a system to measure thermal conductivity, and a syringe pump system.

These projects were very open ended and involved significant design by the student teams. Electrical engineering students were responsible for design of both the hardware and software of their systems. Students were responsible for selecting the hardware to use and determining how to interface it to the computer. Some groups used USB DAQ boxes to get data from sensors to a computer while other groups used serial cables. Electrical engineering students selected whether to use MATLAB or Labview, and they were responsible for determining the specifications and writing the software needed. Students also were responsible for determining how to calibrate their systems. Chemistry students acted as advisors during the projects. They provided technical advice and helped write users guides for the systems. The resulting projects varied quite a bit because of the many decisions made by the students.

Introduction

During the fall 2012 semester, electrical engineering and chemistry students at Trine University collaborated on design projects to build instrumentation systems. In these projects, students designed computer controlled data acquisition systems intended to be used by chemists.

Engineering classes are often successful at conveying technical knowledge. However, engineering requires a range of skills beyond purely technical skills including problem solving, teamwork, and communication skills. According to [1], “Most engineering is done cooperatively, not individually, and technical skill is often less important than interpersonal skill in getting the job done. In survey after survey, representatives of industry place communication and teamwork at the top of their lists of desirable skills for new engineering graduates.” Multidisciplinary team projects have been shown to impart these skills to students. Continuing from [1], “Studies have shown that relative to students taught traditionally (that is, primarily with lectures and individual homework), cooperatively taught students tend to have better and longer information retention, higher grades, more highly developed critical thinking and problem-solving skills, more positive attitudes toward the subject and greater motivation to learn it, better interpersonal and communication skills, higher self esteem, lower levels of anxiety about academics and, if groups are truly heterogeneous, improved race and gender relations.” Furthermore, according to [2], “People acquire skills most effectively through practice and feedback.

No matter how many times students see a skill demonstrated, they rarely master it until they have attempted it repeatedly and received guidance in how to improve their performance after each attempt." Through these projects, students had an opportunity to practice both technical and teamwork skills through an open-ended multidisciplinary team project.

Project Requirements and Goals

Electrical engineering students, in groups of three or four, were required to build or improve an instrumentation system that could be useful in the chemistry labs on campus. This assignment was part of the junior/senior level electrical engineering course entitled Instrumentation. Students had approximately a month to complete their projects. The systems needed to involve some type of data acquisition system, and they were required to use either Labview or Matlab. Furthermore, the students were required keep a journal documenting their work, they were required to write a final report, and they were required to write a user's guide for the project.

Each group of electrical engineering students was paired with two chemistry students. The junior or senior level chemistry students were all in the class Instrumental Analysis. Chemistry students acted as technical advisors on the project. Each group of electrical engineering students asked the chemistry students questions about their instrumentation system, and the chemistry students also edited the users guides written by the electrical engineering students.

Students were presented with a list of possible projects to choose from mostly based on the equipment available in the chemistry lab. The project choices were: A titration system, a pH measurement system, a system to automatically read from a balance, a system to measure thermal conductivity, a system for developing holograms, a spectrometer or fluorometer, and a system to deliver precise amounts of deionized water. Students were paired into groups, and then each group listed their top three preferences for projects. Based on that input, groups were assigned instrumentation systems to build. Students were not given any formal introduction to the equipment. They were just told, for example, to build a titration system or to build a thermal conductivity system. In many cases students had not used such instruments before. With help from the chemistry students in their groups, it was their responsibility both to determine what the system could be used for and what to build.

These projects had a few different goals. Too often, students see the computer environment and the real world as two separate entities. It is the job of the engineer to integrate these two worlds. Specifically, data acquisition and control are central to many of the automation and modernization tasks needed to compete in a global workforce. The primary goal of these projects was to prepare undergraduate students to not only use the scientific instruments available today but also to build the scientific instruments of tomorrow. A second goal of these projects was to improve the equipment available in the chemistry lab. Some equipment, such as the filter fluorometer and pH probe, was not often used because there was no convenient way to display and store the resulting data. After the projects, these devices became more useful because the equipment was integrated with a computer data acquisition system.

Project Examples

These projects were quite open-ended and involved significant design by the student teams. Students were responsible for both hardware and software design decisions. They had to select hardware, determine how to connect the hardware to the computer, and write the software of a user interface. Some groups worked with pre-existing instruments while other groups used thermocouples, pH probes, or other discrete components. Some groups used USB data acquisition boxes while other groups used serial cables to interface their hardware with the computer. Students had the choice of using either Labview or Matlab, and earlier in the semester, the students were given introductions to both software environments. However, all teams elected to use Labview.

The figures below illustrate projects completed by students and show some of the range of projects completed. Figure 1 illustrates the thermal conductivity project. This instrument is capable of measuring the thermal conductivity of metal bars, and the figure below shows the instrument measuring the thermal conductivity of an aluminum bar. The hardware used in this project is relatively simple compared to most other projects. As seen in the figure, the hardware primarily involves a hot plate and a ring stand with clamps. Thermocouples inside a piece of foam measure the temperature of the bar and are connected to the computer via a USB data acquisition box. The students wrote Labview software to control the system and calculate thermal conductivity from the cross sectional area of the bar and the readings of the thermocouples.

Figure 2 illustrates the titration project. The students began with a functioning titration system. They were not able to find any documentation or manual for the hardware likely due to its age, so first, the students had to figure out how to operate the system. The students made a number of improvements. They added a servo motor and USB servo controller to turn the valve used to pour the liquid. Also, they added a thermocouple under the beaker to measure temperature in the beaker. While the thermocouple reading is affected because it is outside the beaker, it is accurate enough to determine whether a reaction is exothermic or endothermic. Labview software was written to control the valve, monitor the temperature as a function of time, and store data in Excel format.

Figure 3 illustrates an instrumentation system which can submerge a sample in a liquid for a fixed amount of time. This system could be useful in processing holograms or photographs which must be submerged in a developer or a rinse solution for a fixed amount of time. Students designed and constructed the motor controlled lever arm. They also wrote software in Labview to control the servo motor and coordinate the timing.

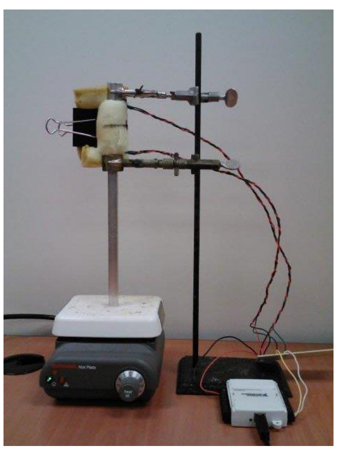

Figure 1: Thermal conductivity system

Figure 2: Titration system

Figure 3: Hologram development system

Lessons Learned

Based on the experiences of these projects, multiple improvements can be made if this assignment is run in future semesters. The first lesson learned is that structure is needed to encourage students to practice communication skills. In this project, electrical engineering students were required to contact their chemistry team members at least twice. They were required to ask questions early in the project, and they were required to get feedback on a draft users guide. Only one group went beyond these requirements. The team that built the thermal conductivity system, shown in Figure 1 above, met with their chemistry teammates later in the project and had the chemists work through their users guide to test out their system. With the required communication, all groups interacted, and saw the challenges of communicating, with teammates in a different discipline. Without the structured assignments involving multidisciplinary communication, it is less likely that communication would have occurred. Also, students practiced their communication skills by writing final reports, users guides, and regular journal entries. Again if there were no specific requirements to document projects in these ways, it is quite unlikely that students would have practiced their writing skills in these projects.

A second lesson learned is that structure is needed to encourage students to apply mathematical concepts too. In building an instrumentation system, many tasks may involve mathematics. For example, mathematics is involved in designing and implementing filters to reduce electrical noise, and mathematics is needed to calibrate an instrument. The assignment for these projects spelled out the required communication, but it did not spell out the required use of mathematics. A couple of groups made rough attempts at calibrating their systems, and the group designing the pH probe system built an opamp based amplifier. However, most groups used hardly any mathematics in their projects. If this project is run again in the future, the assignment should clearly require instrument calibration, filter design and implementation, or the use of other mathematical techniques.

The third lesson learned is that a more structured assessment process is needed with this project. The electrical engineering students were graded equally on completing the work, the quality of their work, their journal entries, and their final report. A rubric was used to determine the grades. The rubric was useful, but could use improvement so that quality of work is weighted more heavily than completing required tasks. Also, there was no formal assessment done on the assignment to compare the amount students learned through their projects to the amount learned in other types of courses. If this assignment is run in the future with a larger class, a more formal assessment of the assignment should be implemented to determine whether this type of project work is superior to a traditional lecture type class.

The fourth lesson learned is that these type of projects work best in a lab filled with miscellaneous equipment, spare parts, and old instruments. This project received funding from a grant by the Indiana Space Grant Consortium. Due to the funding, students were given the opportunity to buy new equipment for their projects. One team bought a new instrument. With the exception of small miscellaneous items like motors and valves, all other teams used equipment available on hand. The team that ordered the new instrument had the task of building a system to deliver fixed amounts of deionized water, and they bought a new syringe pump. It took a couple of weeks for the pump to arrive. Once it arrived, they realized that they needed a specialized serial cable, and the cable took another week to arrive. Due to the delay with ordering parts, they were barely able to get their system working by the end of the semester. Using available equipment is not without problems. Manuals were not available for all pieces of hardware. Also some groups had to be flexible with their aims for the project. For example, the group working on the titration system, shown in Figure 2 above, initially intended to include a pH probe in their system. However, they had trouble finding a working pH probe, so they decided to include a thermocouple instead. Also, the group that built the fluorometer system evaluated two partially-working spectrometers before electing to use the fluorometer system. Overall, the projects using available equipment had less severe problems and were more successful.

The fifth lesson learned is that projects must be selected carefully to balance the amount of software and hardware development involved. These projects were intended to require both hardware and software design. However, some projects involved more of one type of design. Students found Labview VIs available online for the pH probe system and the syringe pump system. Because of the available Labview drivers, not much software development was needed. In both cases, the groups used the available VIs and found plenty of hardware related work to do for their projects. If this assignment is run again in the future, instrument systems should be selected carefully to encourage both hardware and software development.

Conclusion

In these projects, students designed and built instrumentation systems, and they worked in an unstructured environment on multidisciplinary teams. Compared to a lecture class, this project-based environment is closer to what students will find once they enter industry. Students also practiced their ability to share information with and collaborate with teammates in another discipline. According to [3], “Effective information sharing and decision coordination are vital to collaborative product development and integrated manufacturing.” Communication and teamwork skills are necessary for engineers, and these skills are rarely practiced in lecture based classes. Also after these projects additional or updated equipment was available to chemistry students and researchers using the chemistry labs on campus. Some systems which previously outputted data to a chart recorder, such as the fluorometer, now interface with a computer. Overall, these projects were quite successful.

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Bibliography

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