

Signal Processing Within an Integrated Teaching Laboratory

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Abstract - An Integrated Teaching Laboratory (ITL) is being built at the University of Colorado to provide interdisciplinary design and development experiences for engineering students beginning at the freshman level. The ITL will be fully operation in 1997 and will consist primarily of open space with portable lab stations that can be reconfigured to accomodate various types of experiments. Students from every discipline in the engineering college will work next to one another in the lab. The close proximity will foster interdisciplinary curiosity and cooperation, and encourage teamwork and creative problem-solving. The building is being designed with many sensors so that it can itself be part of experimentation that can range from environmental air analysis to water flow to electrical usage. This paper will specifically address the results of the pilot sections of the ITL First-Year Engineering Projects Course in which one section is focusing on speech processing in the design of systems that are controlled by speech.

I. Integrated Teaching Laboratory

The vision statement for ITL is to "pioneer a multidisciplinary learning environment that integrates theory with practice and promotes creative, team-oriented, problem-solving skills." This vision supports "learning by doing," in recognition of the following statements:

I hear - I forget
I see - I remember
I do - I understand

Figure 1 contains a chart of the concepts of ITL.

ITL is a thirteen million dollar project that is funded by the State of Colorado, alumni, corporations and foundations. It will be fully operation in 1997 and will consist primarily of open space with portable lab stations that can be reconfigured to accomodate various types of experiments. Students from every discipline in the engineering college will work next to one another in the lab. The close proximity will foster interdisciplinary curiosity and cooperation, and encourage teamwork and creative problem-solving [1]. The building is being designed with many sensors so that it can itself be part of experimentation that can range from environmental air analysis to water flow to electrical usage.

II. First-Year Curriculum Development

In addition to providing the building and laboratory structure, a new curriculum focus must also be integrated into the coursework. Eventually the ITL curriculum focus will be incorporated into courses at all levels, in all departments. Some departments, such as the Aerospace Department, are already working on this integration. Most of the curriculum work at the moment is focused on the first-year projects course. This course is now being taught for the second semester - two sections were taught the first semester and three sections are being taught this semester. A sample syllabus is shown in Figure 2.

The course components are designed around the following:

- introduction to engineering design projects via guest lectures from different disciplines
- interdisciplinary teamwork
- open-ended, hands-on design experiences
- communication skills (oral and written)
- introduction to engineering methodology (CAD, spreadsheets, modeling software, graphics tools)
- mentoring by upper class teaching assistants.

We now discuss each of these components in more detail.

The students in the course have selected engineering as a major, but nearly one-third of them have not yet selected a specific major within engineering. Therefore, we want to introduce the students to the six different engineering majors within the College, and we do this with six guest lectures. The guest lectures are centered on a design project that the presenting Professor has completed in his/her research area, and thus are not the typical introduction to a specific discipline.

Several team building exercises are completed by the students in the class before the teams are selected. A number of factors are used in selecting teams, with an interdisciplinary group as one of the goals.

Several open-ended, hands-on design experiences are incorporated in the semester. A simple bodiometer is designed with Legos, and it is used to measure wrist circumference and arm length. After designing the bodiometer, a careful drawing is prepared. This drawing is passed to another group of students who then build and test it; they also then write the documentation for it.

Another project presents the students with a group of Mystery Artifacts. These objects are left in the lab, with a minimal amount of information. The students then have two weeks to analyze the artifacts and to perform experiments with them in order to develop a reasonable suggestion of the use of the objects.

In a Reverse Engineering project, each team selects something that they can "reverse engineer." By dissecting the object, and analyzing the function of its components, they then learn the basic principles behind the object's performance. One group last semester "reverse engineered" a lawnmower; this year's groups are just now in the process of selecting their project.

The largest design project for the semester is a six-week project, and it is discussed further in the next section of this paper.

Communication skills are stressed throughout the course. Students write individual one-page summaries of all the guest design lectures. They also write group reports on the Mystery Artifact Project, the Reverse Engineering Project, and the Design Project. Weekly group status reports are required during the Design Project. Group presentations are also made on each of the three projects. An English Professor gives two informal lectures to the class and provides feedback on several of the writing assignments.

The students lab room contains three PC computers with software that includes Microsoft Office (word processor, spreadsheet, power point), MATLAB, Turbo C compiler, and some additional CAD software. The students use this software to prepare their reports and analyze the data they have collected.

Two senior teaching assistants (TA) are available during the lab periods to answer questions and provide assistance. We specifically selected seniors as opposed to graduate students so that the TAs would be perhaps more approachable by the first-year students to answer not only course questions but also more general questions. This mentoring has been very successful.

III. Learning about Speech Processing

One of the open-ended design projects that is used this semester is a voice recognition project. This project involves designing a voice control system and then testing and evaluating its performance with a microphone/voice-controlled model car. The design of the vocabulary involves learning about speech signals and voice recognition techniques, and then developing a set of words that can be distinguished using prewritten computer

software. Figure 3 contains a diagram of the system that the students use in this project.

One of the objectives of the voice recognition project is to introduce first-year students to signal processing through the specific example of speech processing. As an initial introduction, speech processing is presented from four different views - a physiological view, a linguistic view, an acoustic view, and a perceptual view [2,3].

Physiological View

To understand speech signals, it is important to understand how speech is generated. This involves looking at the principal organs of speech. The generation of a speech signal begins in the lungs as the diaphragm forces air into the trachea. The air then flows through the vocal cords and their supporting cartilages. If the sound that we are generating is a voiced sound, the vocal cords will vibrate with a frequency that is called the pitch; if the sound that we are generating is an unvoiced sound, the vocal cords do not vibrate. The air, which may or may not include the vocal cord vibration, now flows through the vocal tract. In the vocal tract, the speech signal is modified in many ways. The position of the tongue, the lips, and the teeth affect the sound generated. Some sounds are forced through the nasal tract as the uvula and velum close the path through the mouth.

Students can determine which sounds use the vibration of the vocal cords by touching the front of their larynx as they speak. They are also asked to describe the specific articulation points for generating sounds. For example, to generate the vowel sound in the word "beat", the tongue is in a high front tense position, while the vowel sound for the word "bet" requires a mid front lax position for the tongue.

Linguistic View

There are over forty basic sounds, or phonemes, in the American English language. These sounds are divided into eleven vowel sounds, four semivowel sounds, six diphthongs, and twenty consonants. The vowel sounds are voiced sounds that are articulated by various positions of the tongue. Semivowels are similar to vowels. Diphthongs are sounds that are generated by sliding from one vowel to another, as in the word "bite", in which the tongue moves from low back to high front. The consonants are subdivided into other categories, including nasals, stops (voiced and unvoiced), fricatives (voiced and unvoiced), whisper, affricates. These consonants use the palate, the lips, and the teeth as articulation points for the sounds.

After discussing the phonemes of American English, the students perform some research on other languages. The number of sounds in languages can vary from languages with very few sounds, such as Hawaiian with thirteen phonemes, to Chippewyan with 45 phonemes.

Some languages have very unique sounds, such as the click consonants in Zulu, which are implosive, injective or suction sounds produced by the formation of a partial vacuum between the tip and the back of the tongue. Tonal languages such as Chinese and Navajo use the same articulation but varying pitch frequencies to represent different phonemes.

Acoustical View

From viewing a time domain plot of a speech signal, students can identify voiced and unvoiced sounds and periods of silence. In the voiced sounds students can identify and measure the pitch period, and then it is an easy calculation to determine the pitch frequency.

Students collect their own speech sounds on a diskette, and then use the data files in assignments in which they compute simple time-domain metrics used in speech analysis. These measurements include average energy, average magnitude, and the number of zero crossings in moving frames of data from the data file. Figure 4 contains examples of speech signals collected by the students.

Perception View

The interaction of the vocal track, the ear and the brain in the speech-production/speech-perception process is a very complicated process. We are only beginning to understand parts of this interaction which involves message formulation, language coding, neuro-muscular actions, basilar membrane motion, neural transduction, language decoding, and message comprehension.

V. Voice-Recognition Project

The design of the voice-controlled model car has been divided into three subsystems. The first subsystem uses a microphone and an Ariel board in a PC to collect speech signals and store them in an ASCII file. The second subsystem is a C program that reads the speech file and computes average magnitude and the number of zero crossings for an utterance, and using predetermined tolerances, identifies the word. An example of a decision function for a group of English words is shown in Figure 5; this system controls the model car using the words BACK, HALT, LEFT, MOVE, and PROCEED RIGHT. Once the word is identified, a corresponding signal is sent to the computer's serial port. The third subsystem is the hardware that converts a signal from the serial port on the computer to a signal that is transmitted to the remote-controlled car.

First-year students do not have the backgrounds to design these components, but they can experiment with and understand the function of the subsystems and participate in combining the subsystems into a functioning project. In addition, the students can develop

a small vocabulary that can be distinguished using the metrics of average magnitude and zero-crossings, using tolerances that they determine. They can then evaluate the performance of the system in terms of controlling the car and in terms of speaker independence. To make the project more interesting, each team uses a different language to control the car; the languages being used this semester are Russian, Japanese, Arabic, Gaelic, American Indian, and Pig Latin! In the final demonstrations at the end of the semester, each voice recognition system will be demonstrated using the model car which can be disguised as another object, such as a robot. (Guess what the car becomes for the Pig Latin group!) The system can also be used to validate the potential design of a voice-controlled wheelchair.

V. Conclusions

Signal processing has interesting applications that can be used to introduce students to engineering design and engineering projects, even in first-year courses. Students are motivated by real-world applications, and through simple example in signal processing, they can apply the mathematics and computing skills that they have learned to do simple designs.

References

- [1] Etter, Delores M. and Joseph Bordogna, "Engineering Education for the 21st Century," IEEE International Conference on Acoustics, Speech, and Signal Processing, Apr 1994.
- [2] Etter, Delores M., "Using Speech Processing to Illustrate the Multidisciplinary Nature of Engineering," American Society of Engineering Education Conference, Jun 1994.
- [3] Etter, Delores M., "An Introduction to Engineering with Signal Processing," IEEE DSP Workshop, October 1994.

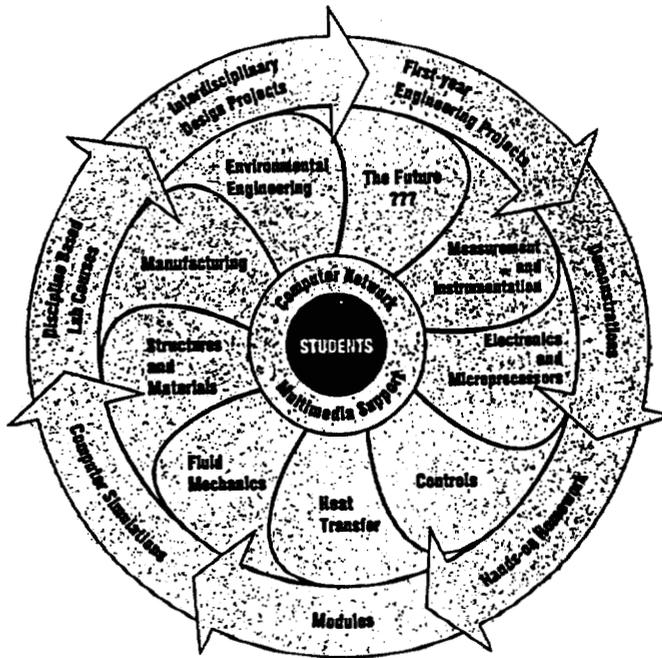


Figure 1 Integrated Teaching Laboratory Concept.

Week	Lecture Period (1 hour)	Lab Period 1 (3 hours)	Lab Period 2 (3 hours)
1	Introduction Biographical sketches	Team dynamics exercises	Form teams Communications styles exercises
2	Introduction to reverse engineering	Mysterious artifact challenge	Mysterious artifact challenge
3	Technical writing Journaling	Challenge inspection/ analysis	Group report: Artifact challenge
4	Intro. to design process	Bodimeter exercise	Design project
5	Guest design lecture I	Design project	Design project
6	tbd*	Design project	Design project review
7	Guest design lecture II	Design project	Design project
8	tbd	Design project	Design project
9	Guest design lecture III	Design project	Design project
10	Guest design lecture IV	Design project	Group report: Design project
11	Intro. to mechanical dissection	Reverse engr. project	Reverse engr. project
12	tbd	Reverse engr. project	Reverse engr. project
13	Guest design lecture V	Reverse engr. project	Reverse engr. project
14	Guest design lecture VI	Reverse engr. project	Reverse engr. project
15	tbd	Reverse engr. project	Group report: Reverse engr. project

Figure 2 First-Year Course Syllabus.

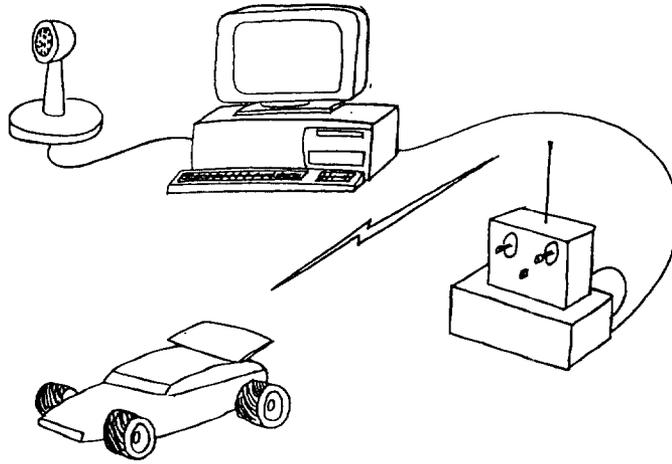


Figure 3 Voice Recognition Project.

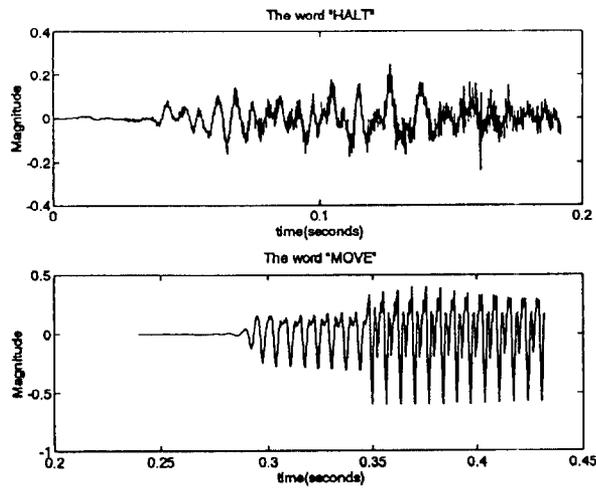


Figure 4 Sample Voice Signals.

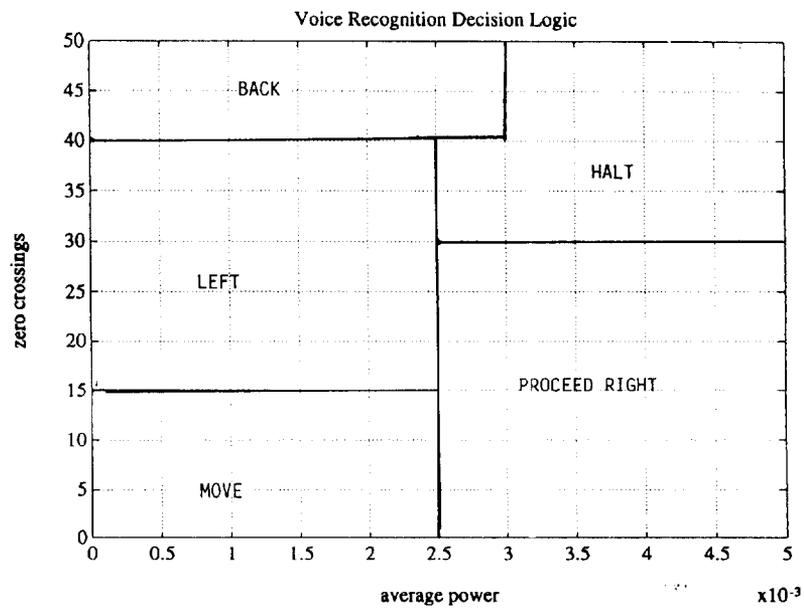


Figure 5 Sample Decision Logic.