

A MATLAB-Based Speech Recognition Module for First Year Engineering Students

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Abstract

An instructional module is presented which introduces first year engineering students to electrical engineering, signals and systems and the basics of speech recognition. The Coast Guard Academy's context for this module, the inter-disciplinary *Introduction to Engineering and Design* course, is described. Next, brief overviews of the module's learning objectives and key concepts are provided. Details of the module are explained—how the students learn the basics of time and frequency, programming in MATLAB[®], time domain speech processing and operation of multi-media devices on a Windows[®] computer. How student teams then complete a MATLAB script file implementing a speaker-independent speech recognition system for a two-word vocabulary is also described. Two exciting demonstrations are outlined, one which displays the signals from an electronic keyboard in time and frequency domains and another which demonstrates state of the art commercial speech-to-text software using the Gettysburg Address. The module wraps up with a contest pitting each team's recognition accuracy against the others. Finally, assessment tools and lessons learned are discussed. The module is seen to be an interesting and positive way to introduce first-year students to electrical engineering in a way that draws on their intuition, captures their imagination and rewards their efforts.

I. Introduction

How do you get students interested in engineering, and particularly Electrical Engineering, as a major? How do you expose students, including those who have no intention of becoming engineers, to some meaningful aspect of Electrical Engineering? At the U.S. Coast Guard Academy, you use a portion of the *Introduction to Engineering and Design* course that is required for all freshman students. More than that, you try to make the Electrical Engineering segment of the course as interesting and enjoyable, while still realistic and representative of Electrical Engineering at the Academy, as you can.

Two years ago we decided that the EE module had to be changed. The former material was technically accurate but not particularly interesting to the students. It also did not support course objectives in the area of design, and it was not very representative of the Electrical Engineering section at the Academy. With the assistance of LT Martin Roberts, on loan to the Coast Guard Academy from the U.S. Navy, we developed a new module featuring digital signal processing and speech recognition. It involves technology demonstrations with a high “wow” factor and a hands-on design project. This paper discusses that module.

II. The Introduction to Engineering and Design Course

The U.S. Coast Guard Academy is, like the other Federal service academies, historically an engineering school. Four of the eight majors currently offered are in engineering fields: Electrical, Civil, and Mechanical Engineering, and Naval Architecture and Marine Engineering. Although majors such as Government and Management are also offered, a substantial portion of the core curriculum is focused on the technical education of future Coast Guard officers. Thus, all cadets are required during their fourth class (freshman) year to take a one-semester course titled Introduction to Engineering and Design (IED).

A. Environment

Cadets at the Coast Guard Academy are in many respects similar to students at most American colleges. Because the Academy has, in a typical year, about thirteen applications for every space in the incoming class, the admissions procedure is highly selective. There is also a substantial effort on the part of Admissions to ensure that the Corps of Cadets is diverse in gender, ethnic background, and home location. Indeed, cadets come from every state in the country and from several foreign nations. The typical fourth class cadet, if there is such a person, is intelligent, physically and emotionally fit, and motivated to become a commissioned officer in the Coast Guard.

Cadets receive financial support, so they do not hold outside jobs. However, they have many other activities to engage their time. Military obligations, mandatory athletics, and ongoing Coast Guard training add to their academic load and leave them busy, tired, and, in the opinion of many of them, overworked. As in an increasing number of civilian colleges, class attendance is required. There is a heavy emphasis at the Academy on personal honor and honesty, regardless of consequences to self.

There are, of course, some significant differences. Cadets are required to live in the dormitory throughout their years at the Academy. They wear military uniforms throughout the day, and stand at attention when a faculty member enters the room at the start of class and again when he or she leaves at the end of the period. Thus, the cadet's day is rather more highly structured than that of his or her counterpart at a typical civilian college.

B. IED Course Objectives

This, then, is the environment in which we present IED. The course has several objectives, among which are to:

- teach cadets a formal, systematic method for problem solving and design.
- introduce cadets to the four engineering majors offered at the Academy, as part of a larger program to assist them in making an informed choice of major.
- familiarize cadets, including those who will not themselves become engineers, with the various roles which engineering and engineers perform in the Coast Guard at large.

The course concept diagram (Figure 1) shows the key elements of the course graphically. At the center are the principal academic goals: problem solving and design. We want cadets to come out of this course with both knowledge and practical experience in the application of a systematic problem solving methodology. We also want them to have experience with designing specific solutions to problems.

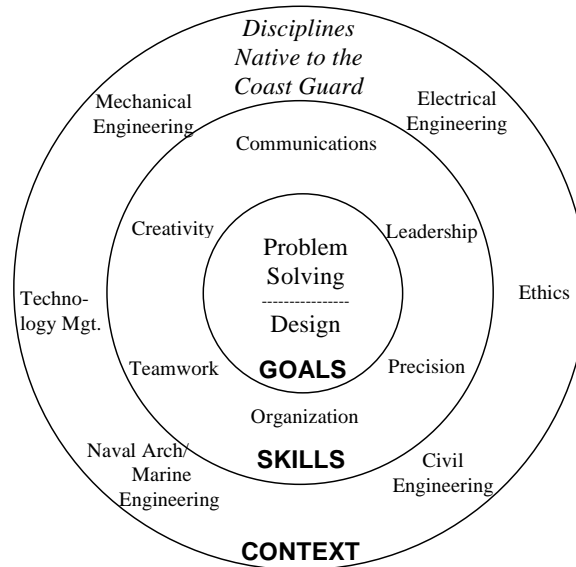


Figure 1: IED Concept Diagram

Surrounding the course goals are some specific skills which we hope to teach and reinforce in IED. These are not so much academic subjects as the general tools which Coast Guard officers need to apply their education in practical situations. Teamwork, organization, communication, and leadership are critically important to Coast Guard officers, and thus are repeated in many courses throughout the Academy’s curriculum. We want to give cadets a sense of creativity, since the solution to real-world problems can seldom be found in a manual. We also seek to instill precision in thinking, writing, and speaking as well as in working scientific and mathematical problems. Virtually everything we do in the course relates, at least indirectly, to several of these core skills.

The outer circle represents the academic context within which we seek to meet our objectives. This includes the four engineering disciplines represented by majors at the Academy as well as basic problem solving, design, project management, and communication skills and ethics as it applies to practicing engineers. These topics become the vehicles through which we develop and exercise the cadets in the core goals and skills that we want them to acquire.

C. IED Course Structure

In keeping with the concept of IED, the course is structured in several modules. Some are not specific to any particular engineering discipline. These include the discussion of the problem solving and design process which starts the course, instruction on technical writing and presentations, and a discussion of ethics from an engineering perspective.

The majority of the class and lab sessions, however, are devoted to four modules which correspond to the four engineering majors at the Academy. Each of these segments seeks to familiarize cadets with opportunities in that field of engineering, both within and outside the Coast Guard, and with the major. Each also conveys a small body of knowledge and provides an opportunity for a group design project:

- In the Civil Engineering module, cadets are introduced to some basic concepts of strength of materials and structures. Using a computer program developed at the U.S. Military Academy, they design and test virtual bridges. In small groups they then design, construct, and load test a spaghetti bridge, with the goal of achieving the highest strength to weight ratio.
- The Mechanical Engineering module includes instruction on kinetic and potential energy, conservation of energy, and springs. Assisted by a computer simulation, they determine the length of elastic cord which will allow an egg (in a plastic bag attached to the cord) dropped from a known height to come as close as possible to the floor without breaking.
- During the Naval Architecture and Marine Engineering segment of IED, cadets learn about buoyancy and various factors which effect the stability and performance of ships. The design project consists of using the computer to design and evaluate a boat hull design, which they then build from foam. The goal is to maximize the boat's transport efficiency, a metric which includes factors for cost, stability, performance, and safety. The boats are tested in a circulating water channel (the hydraulic equivalent of a wind tunnel).
- The Electrical Engineering portion of IED is devoted to a study of the basics of signal processing and a design project in speech recognition. Cadets learn some basics of using and programming in MATLAB. They then complete a program which reads a digitized sound file containing a recording of one of two specified words and characterizes it according to the word it contains. The goal here is to maximize their program's recognition accuracy when presented with words spoken by several different persons.

As can be seen from this summary, each of these modules includes a design project and a competition. Every module involves teamwork in a small group, with leadership of the group rotating among the cadets. Each module exercises communication through a written project report, and some of them additionally with formal oral presentations. Cadets practice organizational skills in order to accomplish the goals of their projects along with their other activities, and often demonstrate creativity in their designs. As faculty we always stress precision in design and communication.

A discussion of the Electrical Engineering module is the focus of the remainder of this paper.

III. Electrical Engineering Module Overview

A. Design Criteria

Naturally, the Electrical Engineering module must support the overall objectives of IED. In addition, however, we have some specific criteria for this module, as shown in Figure 2.

Since one of the objectives of IED is to familiarize cadets with the various engineering majors, we want the EE module to present Electrical Engineering in a positive light. Thus, it is important that the module be enjoyable for the cadets. We also want the module to present a realistic Electrical Engineering problem, so that cadets get an idea of some of the things which Electrical Engineers do. That problem must, however, be of sufficiently limited scope that it is practical for freshmen with as yet limited technical background to solve the problem successfully. This ensures a positive experience with the material.

- | |
|---|
| <p style="text-align: center;">Electrical Engineering Module Design Criteria</p> <ul style="list-style-type: none">• Realistic EE Problem• Positive Experience• Hands-on Project• Competition• Allow for Additional Effort• <i>Fun!</i> |
|---|

Figure 2: EE Module Design Criteria

In order to get the cadets' interest, it is important for the project to be hands-on. That is, it must involve doing in addition to learning. The competitive aspect also adds to the interest, as groups vie to have the most accurate speech recognition system. Some cadets, of course, want to be able to take off on their own and put in extra effort. We therefore wanted the project to be expandable, in the sense that cadets who wish to do so can do some additional learning and work to enhance their project.

To motivate the speech recognition lab project, it is presented in the context of a Coast Guard Cutter improvement initiative. The cadets are told that the Coast Guard is developing a semi-automated control system for Cutters, which will allow the bridge crew to operate the ship by voice command. Their part of the project is to develop a speech recognition module to distinguish between the words "port" and "starboard" or "ahead" and "astern." The specific pair of words varies from one semester to the next but always consists of two words which

- have opposite meanings in the context of the ship's operation.
- are possible to distinguish using the relatively unsophisticated signal analysis techniques the cadets will have available to them.

The goal of each group is to design a program in MATLAB that performs speaker-independent speech recognition on the specified limited vocabulary with the best possible accuracy.

B. Learning Objectives

While the above design criteria guided us in designing the module, there also had to be specific learning objectives which support the department's goals for the course. These are summarized in Figure 3.

The first six learning objectives relate to the discipline-specific knowledge base that is part of the module. They are concerned with signals, signal processing, and the use of MATLAB on the computer. These are all representative of the Electrical Engineering program at the Academy. The remaining objectives are related to the non-discipline-specific goals of IED.

- | Electrical Engineering Module Learning Objectives | |
|--|--|
| 1. | Understand what a signal is |
| 2. | Understand the difference between the time domain and frequency domain |
| 3. | Understand how the sampling process can represent an analog signal with just a sequence of numbers |
| 4. | Use simple MATLAB commands correctly |
| 5. | Write simple MATLAB script files correctly |
| 6. | Understand how parameters can be used to represent spoken words |
| 7. | Understand the kinds of work that Electrical Engineers generally do |
| 8. | Understand what EE majors do at the Coast Guard Academy |
| 9. | Work together with classmates as a successful project team |
| 10. | Present results in a well-organized, well-documented and well-written format |
| 11. | Implement the 10-step design process to solve an engineering problem |

Figure 3: EE Module Learning Objectives

C. Structure

The Electrical Engineering module is taught as a series of six class sessions, as shown in Figure 4. Two of these, shaded in gray in the figure, are conducted in the classroom, while the other four are held in the computer laboratory.

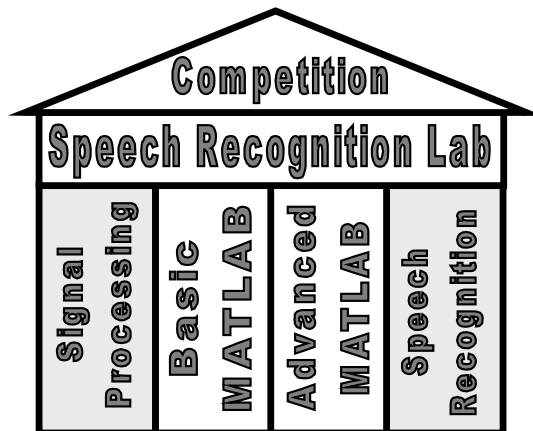


Figure 4: EE Module Structure

The structure diagram illustrates the three layers of concepts that the cadets learn in sequence. Each of these building blocks is described in detail in the next section.

IV. Electrical Engineering Module Details

A. Text

While many introductory level texts exist for freshmen engineering courses, and some of those even include the same general topics, we found none that could readily be adapted for use in a two-week module. Consequently, we wrote our own.

The text's chapters parallel the class sequence, with chapter titles as shown in Figure 5.

Electrical Engineering Text—Table of Contents	
<i>Chapter</i>	<i>Title</i>
1	Basics of Time and Frequency: An Intuitive Approach
2	Tutorial: MATLAB Basics
3	Tutorial: More MATLAB
4	Basics of Time-Domain Speech Processing: An Intuitive Approach
5	Additional Tool for Speech Recognition: Distance Between Vectors

Figure 5: EE Text—Table of Contents

Chapters 1 and 4 are assigned as reading prior to the lectures on those topics, while chapters 2 and 3 contain the MATLAB tutorials that the students complete in class. Chapter 5 contains additional material that may be used for extra credit or for a more in-depth look at speech recognition techniques. As the chapter titles indicate, the text takes an intuitive, rather than a rigorous, approach to the fundamental technical concepts. The goal is to tie these concepts to something that the student can readily grasp. The text is about 65 pages in length and is included as an appendix to the course text published by McGraw-Hill.

B. In-Class Preparatory Activities

A 30-minute lecture on the basics of time and frequency kicks off the first class session. Three fundamental theoretical concepts are presented—the idea of a signal, and the two dualities used in all of signal processing: time domain versus frequency domain, and continuous time versus discrete time. The simplest of all time varying signals, the sine wave, is shown first in a plot of amplitude versus time. The definitions of time and frequency are illustrated using this plot, and then the single frequency present in the sinusoid is shown in an amplitude versus frequency plot. As more sine waves of varying amplitudes and frequencies are added, the time and frequency domain plots are updated together to include them. In this way, the student should be able to grasp that the recorded voice signal is the sum of thousands of individual sine waves of varying amplitudes and frequencies. The concept of phase is mentioned but not developed.

The 30-minute lecture concludes with a brief discussion of sampling. The sine wave previously examined is sampled and the resulting sequence of numbers is shown. Using only the number

sequence and the knowledge that the reconstructed signal is constrained to vary predictably between the points, as required by the Sampling Theorem, the signal is reconstructed and compared with the original sine wave.

A 20-minute demonstration reinforces the concepts of signals in time and frequency. A sine wave generator, a synthesizer keyboard and a microphone are connected to different input channels of an audio amplifier. The monaural output of the amplifier is connected to speakers, a digital oscilloscope and a digital signal analyzer. We used a model 54501A digital oscilloscope and a model 89410 Vector Signal Analyzer, both from Hewlett-Packard, but any equipment that displays amplitude versus time and amplitude versus frequency in real time over a bandwidth of 0 Hz to 4 kHz will do.

Beginning with a sine wave, the progression from simple to complex signals is repeated. The demonstration includes playing pre-recorded musical selections from the synthesizer's memory and illustrating the different frequency contents of musical instruments such as vibes, bells, harpsichord and pipe organ. If time permits, having students participate on the synthesizer and microphone adds to student interest and enjoyment.

The second set of in-class preparatory activities consists of the two individual MATLAB tutorials. MATLAB seemed a natural choice for the computer programming portion of this module because of its gentle learning curve and its native abilities to process and display vectors of sampled data. We have used alternately the professional version on our lab computers and the student version on student-owned notebook computers. Conveniently, all freshmen at the Coast Guard Academy are required to purchase the same model PC. However, we prefer the lab computers because this avoids the hassles of helping to ensure MATLAB is loaded properly on each student machine. Although both versions of MATLAB contain excellent tutorials, we chose to narrow the focus of our tutorials to include only those aspects of MATLAB we used in this module.

The first 50-minute MATLAB tutorial focuses on syntax. The written tutorial leads the student from simple to more complex commands that may be executed one at a time at the MATLAB command line. This ability of MATLAB to interpret single commands as self-contained units avoids the overhead involved with compiled languages such as C++. The MATLAB uses of basic arithmetic, algebraic rules, variables, simple functions such as square roots, arrays, and punctuation are covered here.

In the second 50-minute MATLAB tutorial, the student learns to combine individual commands in a sequential script. File naming and saving operations, the decision programming structure (if-then-else) and the commands required to display results in the MATLAB command window are introduced and exercised.

The third and final set of in-class preparatory activities begins with the 30-minute lecture on the basics of time domain speech processing. Although many powerful frequency domain approaches are documented in the literature, the simplicity and effectiveness of the time domain techniques make them more suitable for this short module.

Several key elements are covered in this lecture. The first is matching individual speech sounds, or phonemes, to the amplitude versus time waveform plots. For example, Figure 6 shows the component sounds in the words “yes” and “no.”

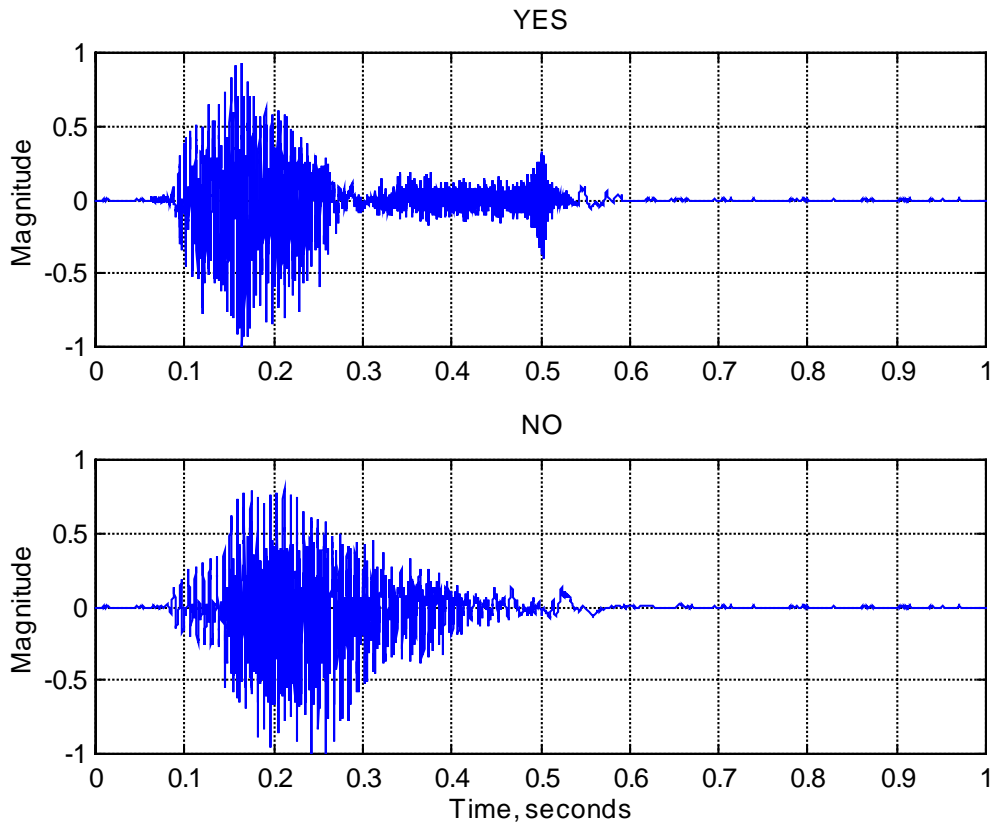


Figure 6: "Yes" and "No" Waveforms

The waveform portions are enlarged in more detailed plots, and the differences between voiced sounds (vowels) and unvoiced sounds (consonants) are illustrated. This knowledge enables the student to analyze speech waveforms not only in terms of sinusoids of varying amplitudes and frequencies, but also in terms of phonemes. This prepares the students to learn the next set of concepts.

The concept of parameterization, the process of selecting and representing the most distinctive elements of the speech waveform, is foundational to time domain speech processing. Parameterization reduces the amount of data used to make decisions. Just as a tailor can use a handful of key measurements such as girth, length and inseam to make an expertly custom fitted garment, so a few key measurements can uniquely characterize a speech waveform. Here we use two parameters: the short-time average magnitude, and the short-time zero-crossing rate.¹

By “short-time” we mean that these measures are computed using short, sequential segments of the speech waveform, short enough that each one contains no more than one phoneme. The average magnitude is simply the mean of the absolute values of the data in a segment. The zero-

crossing rate is the number of times within a segment that the speech waveform crosses the x-axis, where amplitude is zero by definition. The vowels have more sustained amplitude than do consonants, since they are produced with a more open mouth and a more sustained airflow. Consequently, the average magnitude can be used to distinguish between consonants and vowels. Consonants, on the other hand, often have higher frequencies associated with them. The hissing sound inherent in the “s” phoneme is an example. These two parameters provide a wealth of information about speech waveforms.

Computing a parameter for the segments in a word results in a short sequence of scalars, one scalar per segment, which uniquely characterizes a particular word. Whereas a one-second waveform sampled at 8000 times per second contains 8000 data points, a parameter vector may be as short as ten or twenty elements. This data reduction is a crucial part of time domain speech processing.

In addition to recognizing the phonemes in a waveform and understanding parameterization, the student needs to understand how to apply a decision using a threshold. By further reducing the short parameter vector to a scalar, the relational operators learned in the MATLAB tutorial (which operate on scalars but not on vectors) may be applied. In this way, MATLAB scripts may be written to distinguish between speech waveforms representing two words. The threshold is the value of the scalar that marks the point of separation between the two words. If the value of the scalar is greater than the threshold, the word is ‘A’; if it is less, the word is ‘B’.

Three operations that reduce a parameter vector to a scalar are introduced: the MATLAB functions SUM, MEAN and MAX. Of course the sum and the mean are not linearly independent measures; this wrinkle requires the students to sort out duplicate information on their own. The maximum value can be used to identify specific phonemes present in one word but not another.

The final in-class preparatory activity is motivational. A commercial speech-to-text software package such as IBM's ViaVoice™ or Dragon Systems' NaturallySpeaking™ is demonstrated. We chose to read Lincoln's Gettysburg Address because of its brevity, common vocabulary and well-known rhetorical and inspirational qualities. Typically, these programs correctly recognize 97-98 percent of the speech's 267 words. As the students see the concepts they have been learning spelled out on the computer projection screen in the words of the Gettysburg Address, they start to see the big picture of speech recognition and are ready to begin work on the class project. If time permits, students can try dictating too. This can be quite fun for the class, particularly with students having strong regional accents.

C. Out-of-Class Preparatory Activities

In parallel with the in-class activities described above, the students perform a series of activities outside of class to help complete their preparation for the project. These are the daily quizzes, an Internet survey of commercial speech recognition products, and a word recording session.

Time pressures on first-year cadets at the Coast Guard academy are intense. Three short take-home quizzes encourage them to complete the assigned reading and tutorials outside of class.

Each has 10 multiple choice/short answer questions that may be easily and quickly completed from the reading and MATLAB tutorials. To reduce grading load on the instructors, the cadets grade their quizzes at the beginning of the class periods.

Introducing students to an application of technology comes with the hope that they will be able to use it. A five-question Internet survey on commercial speech recognition products helps them gain an appreciation for what is available for their use, and at what price. Another emphasis of this exercise is proper citation of Internet sources. Half credit is awarded for the quality of the answers, and half for the quality of the citations.

Finally, the students need to know how to record words to use in the project. A short handout tailored to the model of computer they will be using leads them through the process of recording, trimming and saving sound files in the proper format for use in MATLAB. The Windows Sound Recorder application is used to record the words at 8000 samples per second, 8 bits per sample, pulse code modulation (PCM), and monaural recording, which is one of the available standard settings. The Sound Recorder allows cadets to trim leading and trailing silence to obtain a recording of 1.0 seconds or less (which is required when using the student edition of MATLAB) and save it as a standard Windows sound wave (.WAV) file. MATLAB's "wavread" function then provides a convenient means to input the sound data into the recognition program.

Two points of caution are in order here. First, the recording should be done in a quiet environment. We had the cadets record their words in their own rooms, on their own Windows computers, instead of in the relatively noisy computer lab. Secondly, the computers' sound cards must be of sufficient quality to accurately record the higher frequency phonemes such as the 's' sound. Some computers we tested had an effective bandwidth of only 2 kHz, making the 's' sound like 'f' in replay. This limitation would have significantly hampered the project. During the class period, we used two workstations having good sound cards and located in a nearby quiet room for last-minute recording, and used the lab computers only for MATLAB.

D. Class Project: MATLAB-Based Speech Recognition System for a Two-Word Vocabulary

The project is a capstone activity that serves to join together the "blocks" of knowledge just obtained. Here the students work in teams, exercise the engineering design cycle, grapple with the messiness of a real-world implementation, and have some fun. It requires each group to produce a limited-vocabulary, speaker-independent, post-processed speech recognition software system. That is, the program may assume that the input word is one selected from a strictly limited vocabulary, in this case just two words. It must, however, be able to cope with words spoken by a variety of individuals. It does not need to recognize words in real time, but works on recorded sound files.

The scenario is delivered to the students as a Coast Guard memorandum from "Chief, Engineering Branch" to "Cadet EE Design Team," titled "Shipboard Speech Processing System." Their mission is to produce a computer program to distinguish between the words "port" and "starboard" for later use in a voice controlled ship maneuvering system. In alternate semesters we

used the words “ahead” and “astern.” The memo also lists the deliverables expected from each team—a working MATLAB script file, lab report, etc.

The team’s score is the percentage of 20 words, 10 “port” and 10 “starboard,” recognized correctly. The instructor provides two pre-recorded word pairs when the project is assigned; the team members record four pairs (ideally one pair per team member); and four more pairs are added on contest day for the final evaluation.

The students are set up for success. An example MATLAB script file “decide1.m,” which works correctly for the words “yes” and “no,” is provided. It incorporates MATLAB functions to perform the necessary signal processing tasks, including dividing the recording into 15 time slices or “bins” and determining the average magnitude and number of zero crossings in each bin. For each word it analyzes, the script displays graphically both the zero-crossing rate and the average magnitude for the word by bin. Typical plots for “yes” and “no” are shown in Figure 7.

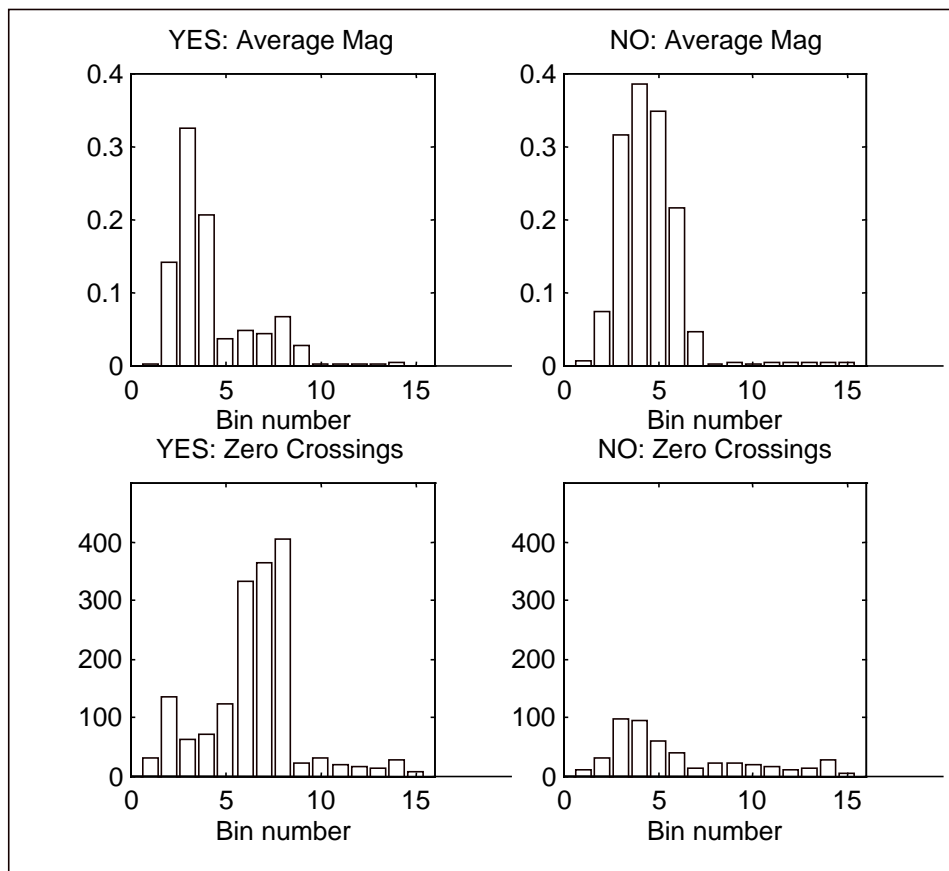


Figure 7: "Yes" and "No" Parameters

The script also computes six scalar values: the MAX, MEAN and SUM for both parameters, as shown in Table 1. For comparison purposes, the six scalars computed for a typical “yes” and “no” are shown in the table. Finally, the script implements a decision block with an appropriate threshold to distinguish between “yes” and “no.”

Table 1: "Yes" and "No" Parameters as Scalars

	"Yes"	"No"
Average Magnitude		
Sum	0.916	1.426
Mean	0.061	0.095
Maximum	0.325	0.385
Zero Crossings		
Sum	1675	499
Mean	111.6	33.2
Maximum	404	99

A script file shell "decide2.m" is also provided to each group of cadets. It contains most of the code in "decide1.m," but not the decision block. The team's task is to run the "decide2.m" script for enough recordings of "port" and "starboard" that they see a pattern. They must then select one of the two parameters, one of the three functions, and a threshold that consistently separates "port" from "starboard" words recorded by any person. They then complete the script with a decision block implementing their design.

The typical successful solution hinges on the presence or absence of the 's' sound, as reflected by the maximum number of zero crossings found in any segment of the word. If this parameter exceeds about 250 the 's' is present and the word is "starboard" (or "astern"). If not, there is no 's' sound and the word is "port" (or "ahead"). Cadet design groups typically achieve speaker-independent recognition rates of 70 to 100%. When they are allowed to adjust their threshold, most teams not initially at 100% are able to improve their accuracy another 5 to 10%.

The final requirement in the module is a written laboratory report incorporating an abstract, a description of the design procedure used, results, conclusions, and appendices. The students are encouraged to reflect on "what it all means" and to synthesize their thoughts, rather than merely regurgitating concepts and results.

V. Assessment and Conclusions

Two crucial questions must now be answered. First, how well did the module fulfill its design criteria? Second, how well did the students perform? In this section, we discuss these two questions in order. The primary assessment tools used were the graded exercises, an end-of-course survey of students, and a formal end-of-course review by the six instructors. From these measures, a fairly clear picture emerges of the effectiveness of this module.

The module fulfilled several of its design criteria as shown in Figure 2. The class project is a realistic representation of the laboratory exercises that EE students do at the Coast Guard Academy, and allows the groups to compete against each other. A handful of groups put in additional effort as suggested in the text; these were usually the "A" students and/or those interested enough in the subject that they enjoyed putting in the extra time. For the large majority of students this was indeed a positive experience.

The module could be improved with respect to two of the design criteria, that it be a hands-on project and that it be fun. While the students very much enjoyed the EE class demonstrations, and enjoyed the EE lectures as well as any of the lectures in the course, the EE class project received lower scores on the student survey than the other three class projects. These survey scores are summarized in Table 2:

Table 2: Student Response to IED Modules

Class Project/Contest	Score (0.0 to 4.0 scale)	
	Mean	Std Dev
Pasta Bridge	3.5	0.8
Foam Boat	3.5	0.8
Egg Bungee Jump	2.9	1.0
Speech Processing System	2.1	0.9

Several factors appear to be responsible for this lower score:

1. The EE module was definitely the most abstract of the four, and as such accurately represents the abstract nature of much of electrical engineering. As a result, however, many of these freshmen that could readily comprehend the stresses on a bridge truss had difficulty with the multiple stages of mathematical manipulations involved in computer based speech processing. Students who did not understand why their group's program worked did not enjoy the project as much as those who did understand.
2. The students did not build anything with their hands in this module, but instead had to be content with the screen printout of a computer program. In the eyes of many of these students, this was a singular deficiency. Perhaps the real issue is that too little creativity was allowed in the class project.
3. The module was too rushed for some of the students. Another one or two 50-minute class periods would have allowed these students to comprehend the material more fully.
4. Three of the six instructors were not sufficiently prepared to teach the module with maximum effectiveness. This was due primarily to the relative complexity of the module and the lack of time for sufficient briefing of the instructors. Those instructors who were able to work through an entire lesson or project beforehand had far fewer problems.

Student performance in achieving the learning objectives was satisfactory, as shown in Table 3. Two assessment summaries are provided, the first from the student survey and the second from the various exercises graded by the instructor. The student survey asked the students to rate their achievement by choosing from a sliding scale with five possible answers: Not at all, Not well, Somewhat, Fairly Well and Very Well. These were converted to a 0.0 to 4.0 scale. The EE grades provided by the six instructors for the hourly exam questions, quizzes, lab report and project results were converted directly from a percent scale to a 0.0 to 4.0 scale and weighted appropriately. The different way each of these two summary measures was computed accounts for some of the difference between them.

Table 3: EE Module Assessment Results

Objective	Number of Students Responding	Student Mean	Student Std Dev	Instructor Evaluation	Instructor Measures
I understand what a signal is.	87	2.3	0.9	2.8	Exam, lab, quizzes
I understand the difference between the time domain and frequency domain.	88	2.3	0.9	3.1	Exam, lab, quizzes
I understand how the sampling process can represent an analog signal with just a sequence of numbers.	89	2.3	1.0	3.1	Exam, lab, quizzes
I can use simple MATLAB commands correctly.	87	2.5	1.0	3.1	Exam, lab, quizzes
I can write simple MATLAB script files correctly.	88	2.4	1.0	3.1	Exam, lab, quizzes
I understand how parameters can be used to represent spoken words.	91	2.3	1.0	2.8	Exam, lab, quizzes
I generally understand the kinds of work that Electrical Engineers do.	88	2.5	1.0	---	
I understand what EE majors do here at USCGA.	83	2.3	1.1	---	
I can work together with classmates as a successful project team.	90	3.2	0.7	3.5	Contest results, lab writeup
I can present results in a well-organized, well-documented and well-written format.	89	3.1	0.7	3.5	Contest results, lab writeup
I can implement the 10-step design process to solve an engineering problem.	88	3.1	0.8	3.5	Contest results, lab writeup

The average student response for the first 8 objectives lies between “Somewhat” (2.0) and “Fairly Well” (3.0). This, of course, measures the students’ own assessment and suggests that they, on average, think that they assimilated the material reasonably well. The graded exercises for these 8 objectives show a “B” average, indicating that by some objective measure they actually did learn the material. In other words, the students did a satisfactory job of learning the material and were able to apply it effectively. They did more than the bare minimum. The last three objectives, which were the same for all four modules in the course, show a markedly higher score in both survey and graded exercise. This is to be expected, since group work often represents the understanding and achievement of the best students in the group, and since by the time the survey was taken, the students had exercised these objectives not once but four times.

In conclusion, the module effectively introduces fourth class cadets to the Electrical Engineering program at the Coast Guard Academy. It accurately represents the abstract nature of much of

electrical engineering and, as implemented, trades some hands-on fun to achieve this. The students learned the material and in their teams achieved success in the class project. Reducing the pace of the module slightly and increasing the preparation of the instructors will improve the delivery of the module. Finally, adding more creative elements to the project may help compensate for its lack of physical, hands-on work.

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