MOTIVATING AND ENVOLVING PROJECTS IN SIGNAL PROCESSING CLASS

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ABSTRACT

Several courses in engineering sciences can be highly theoretical with limited possibilities of practical application and therefore, for many students, these subjects are seen as a mandatory burden that they have to take, instead of an interesting topic that they really want to learn about. This is often the case of "Signals and Systems"*related subjects in Electronics and Electrical Engineering programs. These subjects are characterized by having dense mathematical contents and a wide variety of abstract concepts, requiring the students to deal with a lot of equations and properties seen in previous math courses. Due to this theoretical teaching approach, the learning process is further complicated as students have difficulties to recognize possible applications of these new concepts presented in class.

For this reason, we have introduced a series of practical projects in the Signals and Systems courses we teach, aiming to actively involve students in their learning process while motivating them by the practical application of the theoretical content seen in class.

Usually, these course projects are formulated as programming exercises using high-level computing languages such as Matlab, and its graphical environment Simulink, with good results. However, we go further with the design of these new projects, where this programming software are used as a tool and not as the main core of the project. To do that, these projects involve students working with hardware development, design, and testing, as they create and control the systems all by themselves. Note that hardware development is not limited to electronics or electrical issues; on the contrary, it is desirable that students expand their vision to other application areas closer to their regular life experiences, such as acoustics, visual arts, music and special effects.

The approach, implementation and evaluation of these projects have been done through cooperation between the University of Campinas, Brazil and Pontificia Universidad Javeriana, Bogota, Colombia, by professors teaching Signals and Systems related subjects, which enriches the project and serves as a foundation for future work in teaching and learning between the two universities.

KEYWORDS

Signals and systems, projects, hardware, cooperation, Standard 8, Standard 11.

BACKGROUND

Since some years, the Pontificia Universidad Javeriana, Bogota, Colombia, was linked to the CDIO initiative (Gonzalez et al., 2013).

For this reason, we have started several projects ranging from the reform of the curriculum to the implementation and monitoring of Active Learning more formally in some classes, with the support of several teachers and the Chair of the Electronics Engineering Program. With that, some innovations were made possible in different classes, one of these was Signals and

Systems, as it has some special characteristics that make it attractive for the new implementations.

Among the features of the course, which facilitate the implementation of these innovations, are first the availability of teachers motivated to face this challenge. Further motivations are the fact that the course is considered difficult, as it is highly theoretical. In addition, the course possesses a large amount of supporting material, which has been generated over time, and finally cooperation and acceptance of students, who have seen better results, in learning and motivation.

Several activities have taken place and have been implemented gradually, many of which are based on the premises of peer instruction proposed by Professor Eric Mazur (Fagen et al., 2002)., but adapted to our environment. The results of this activity were shown at the conference of CDIO in Chengdu, China, in 2015 (Cruz et al., 2015).

Exactly because such good results were obtained that the opportunity arose for cooperation with the University of Campinas in Brazil, exactly in the same class, Signals & Systems, sharing information and results, while respecting the independence and culture specific to each university.

Projects was one of the areas where improvements were made. They were previously concentrated on the use of software, so we wanted to make a change to include more interaction with real life and application of academic knowledge once they were acquired.

This paper will show the projects developed, its evolution and new implemented projects, then it will show the results obtained with the students in their learning process.

All the work related to the implementation and evaluation of these projects has been done through cooperation of Universidade Estadual de Campinas, Sao Paulo, Brazil and Pontificia Universidad Javeriana, Bogota, Colombia. This cooperation serves as a foundation for future work in teaching and learning between the two universities.

DESCRIPTION

Signals and systems is a course of third year of Electronics and Electrical Engineering programs. In this course, the students have to deal with very dense mathematical contents, a considerable amount of equations and concepts previously seen on the math courses. Unfortunately, it seems that these basic subjects negatively influence the student’s learning process and giving them an extra as they make it harder for students to recognize the possible applications of these new concepts presented in class (Cruz et al., 2015).

For this reason, we have introduced a series of new practical projects to the Signals and Systems courses we teach, aiming at involving the students in their learning process and also motivating the application of the theory just learned.

Usually, the projects have been based in programming with software as Simulink or Matlab, with good results.

Along with the development of these projects they have also been introduced some modifications to the traditional assessment methods (written tests) and added assessments include oral presentations, assessment with peers and creating posters, all based on the standard 11 CDIO . (Cruz et al., 2013) (Cruz et al., 2015).

EVOLUTION

Software projects

These projects are highly theoretical, they need programing skills, and the results are mathematical with low practical development, even though they might be useful to reinforce some particular concepts. On the other hand, they are cheap to develop and require very few resources.

In these projects, the students receive the files and the information about the process they should do, and then, they do the process and give us a result.

Some examples of these projects are shown below:

Project: DTMF (Dual Time Multi-Frequency)

When we used to dial numbers in our telephones, a way to recognize these numbers in destination is using the DTMF signaling. In this project the students must recognize the dialed numbers in a file (given by teacher), using time segmentation and FFT for tone recognition.

Activities

1. Students must generate in software the DTMF signaling.
2. Program must decode automatically the sequence of numbers with DTMF signaling.

Project: Filtering a noisy signal using Matlab.

Filtering is a good chance to hear a noisy signal before and after we apply a filter. In this way, a noisy signal is given to the students and they have to detect and to identify the bandwidth of the noise, to design the filter and finally apply it to the signal.

Activities

1. Hear the noisy signal and see its spectrum.
2. Define the noise bandwidth and design and adequate filter.
3. Apply the filter designed to the noisy signal.
4. Hear the signal before and after the filter.
5. Design and to apply different filters in order to choose subjectively the best result.

Project: Signals vector space

Vector space is a very challenging topic for students because of its highly mathematical contents, which requires from students a great capacity for abstraction in order to visualize and understand many concepts associated with vector spaces.

When we tell them, vector space is highly useful in cellular communication, they show their interest, so the project is to create a simple communication system, to send four symbols and the receiver has to understand what the transmitter is sending. So far, it sounds very basic and not very challenging for them. But, in addition to this, they have to add noise to the symbols transmitted and the receiver still should recognize them. They are challenged to determine how strong noise power can be before the receiver starts to make mistakes in detection.

Activities

1. Students must generate the four symbols as required.
2. The program should receive the symbols with no errors.

3. Power noise in transmission should increase as much as receiver does make less than one error in 40 symbols.
4. Group with higher power noise in transmission has a bonus.

With these projects, students must apply theoretical concepts to solve them. They find some theoretical problems when these are applied, given as a result an active leaning, then it has feedback made for students and teacher in the classroom. (Standard 8: Active Learning)

Software projects with practical results

We presented some different projects with more practical component, with very good results in motivation and learning.

Projects are useful to apply concepts related to the common life. They are still development in software, but their results are more than a mathematical equation (sounds or images) keeping them cheap to develop and require very few resources, using only the software and some basic recording equipment.

In these projects, the students have to create the files and with their concepts, should create the process to solve the problem and give us the result. The results are not unique and should vary from team to team.

Some examples of these projects are shown below:

Project: Voice characteristics modification

In this project, we show in a practical way the transformation of the signals in time domain (time reflection, time scaling and time shift). Usually, the examples are drawing signals on the blackboard; with this project, the students are able to hear the modifications of the signal, especially in human voice.

Activities

1. First, we will need a recording of some fragments of the human voice.
2. Time shift. They have to play in earphones a song by the left channel, and then the name of the singer by the right channel. File must play with at least five different songs and singers.
3. Time reflection. We will need a recording of a palindrome phrase (“Madam, I'm Adam” or “Satan oscillate my metallic sonatas”) and that phase must be play normally and in reverse.
4. Time scaling. The same previous phrase must be play with different speed (between 0,65 and 1,35 times the normal speed)

Project: Period and Power of signals coming from musical instruments

Power and energy of a signal are seen in class and some examples are solved on the blackboard, assuming the function is known. However, in real life, the function describing a signal is not always known and its energy should be measurement.

To deal with this concept, students have to measure three different kinds of instruments (same classification or similar characteristics), with the same recording conditions, try to guess the order of the results and finally compare them with the measurements.

Activities

1. Choose three different kinds of instruments (same classification or similar characteristics).
2. Recorder the sound of the instruments, keeping the same conditions.
3. Guess the order of power of the instruments.
4. Measure the period of the signals and calculate the mean power in a period.
5. Compare the results of the measurement with the guessing results

Results with these projects have been highly satisfactory, students recognize and can apply the concepts easily and they can have the results beyond software data and relate the concepts to the world around them.

However we want to go further, using the software as a tool and not as the main core of the project. So, more recently, we have prepared new projects, design by us, to provide students a new experience, where in addition to measuring signal characteristics, they can make their own designs, motivating them even more.

Practical projects

These projects involve students working with hardware development, design, and testing, as they create and control the systems all by themselves. Note that hardware development is not limited to electronics or electrical issues; on the contrary, it is desirable that the students expand to other application areas closer to their regular life experiences, such as acoustic, visual arts, music and special effects.

Some examples of these projects are shown next:

Project: Elephant in a Bottle

In this project we exemplify the importance and strength of the concepts of impulse response and convolution in a ludic way.

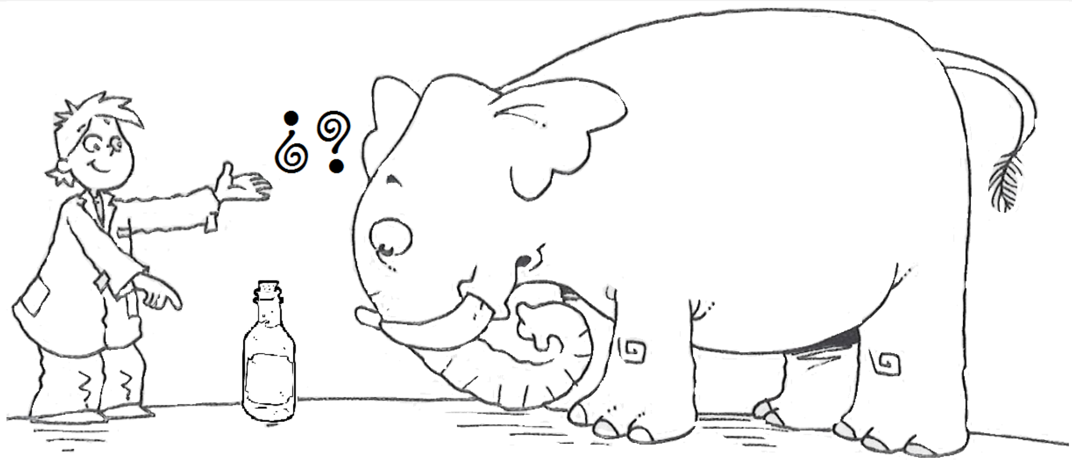
The objective of this project is to solve the famous riddle “how to fit an elephant into a bottle” using for that the tools so far learned in the course.

Note that it might be hard to deal with the elephant´s body using signals and systems, but we can easily work with the sounds it makes.

And we can place the sound of the elephant into the bottle by simply convolving the elephant´s sound with the bottle´s impulse response.

Activities

1. First, we will need a recording of the sound made by an elephant. It is easiest to look for it in the internet, but you can also go and chase an elephant into the wild to record it.
2. We then need to characterize the acoustic behavior of the bottle. To do so, you have a bottle, a microphone and a computer. Think how you can measure the impulse response of bottle. Make sure to check the quality of your measured response.
3. Now we need to “surgically” insert the elephant in the bottle
4. To conclude, write a report on what you learned from this experiment.



http://2.bp.blogspot.com/-SdkNV17a7uI/U2zW76ddgeI/AAAAAAAAAts/1O6f_9QPfEg/s1600/elefante.jpg

Figure 1. How do you put an elephant in a bottle?

Project: Manufacturing an unconventional musical instrument

In this project, we exemplify the importance and usefulness of concepts as frequency, time-frequency relationship, tone generator and spectral component in a practical way.

We are using the fact, that statistically 30% of the students play a musical instrument.

Previous to the project, some examples of unconventional musical instruments were shown. They may build a copy of these or create a new one.

The objective is that they use the frequency response to tune up their notes in each instrument.

Activities

1. Watch the videos given on the videography about different kind of unconventional musical instrument.
2. Manufacture an unconventional musical instrument with at least eight notes of the musical scale. It can be percussion, wind or string.
3. Tune up the musical instrument using a commercial software.
4. Students must play a song with the instrument, with at least 25 notes.
5. To conclude, students should present the instrument and print a poster about the process and the results.

Some examples of the musical instruments made are shown in Figure 2.

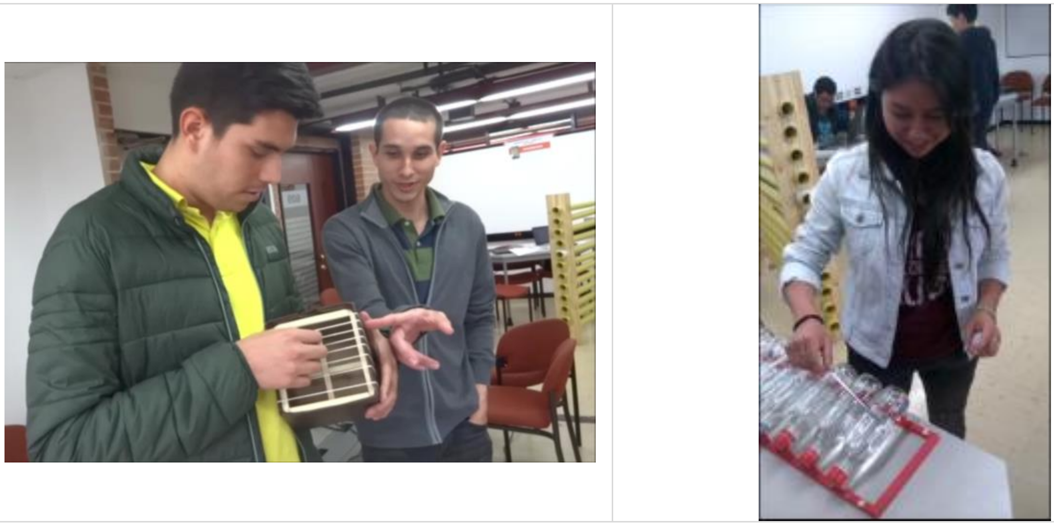


Figure 2. Examples of unconventional instruments made by the students

Project: Subsampling video

Sampling concept is widely used in signal processing and for this, there are many examples of how to use it, however the effects of subsampling usually do not interest the students, because they do not usually apply subsampling.

With this project, we want to give the students the opportunity to visualize the subsampling effect and the change of phase and to understand Nyquist sampling theorem.

Students have to choose a physical phenomenon, record it on a video with a fix sampling rate and to change the frequency of the phenomenon until it shows a different behavior. The best results were obtained when water falling down to different speed was recorded.

Activities

1. Understand Nyquist sampling theorem.
2. Choose a physical phenomenon to record.
3. Video must have the description of the phenomenon (text or audio).
4. The video should not be edited to show the physical phenomenon.
5. Students should present a poster about the process and the result of the experiment.

You can watch some videos with “water falling up”, in these links (they are in Spanish):

https://www.dropbox.com/s/ndjy1gd0fim33ew/se%C3%B1ales.mp4?dl=0
https://www.dropbox.com/s/4cjv88fbt6xapmu/poryectoMUESTREO.mp4?dl=0

We are very happy with the results and the product made by the students.

At first there was some opposition and resistance to this type of project, maybe they were afraid of the unknown, but at the end, some students of the last year asked why they did not have these kind of projects before.

Evaluation process is less stressful for the students, because they feel more confident to show their work and the acquired knowledge, after they are finished the projects. Sometime in class when they are showing their projects, the questions made for their peers are more difficult than teacher does. Standard 11

RESULTS

Results have been quite good in several aspects such as, Motivation (students are waiting for the next project), Participation (as the groups change each time, students are more involved in the project), Compliance (at the beginning, the projects had some of opposition –those implied more effort-, but after the students seen the results, they were glad), learning (students shown their projects and results, feel more confident and they are able to speak using better the concepts and explanations), linking theory and practice (projects can be done previuosly or after that theoretical topics subjects are taught), and even better grades.

In addition to the comments by both current students as some older students and the quality of the products presented, a measure based on the SSCI (Signals and Systems Concept Inventory) was conducted. The Signals and Systems Concept Inventory (SSCI) is a 25 question multiple-choice exam designed to assess students' understanding of core concepts taught in undergraduate linear signals and systems courses, which are an integral part of electrical and computer engineering curricula (Buck et al., 2005).

When applied as a preliminary test, still in the first week of school, and a final test in the last week of school, the SSCI measures the gain in understanding of these fundamental concepts resulting from participation in the course offered. It also allows the evaluation of the conceptual errors more often committed by students.

In the table below, we can observe the results obtained in one of our classes.

Table 1 using SSCI. Results obtained by a group

#	**First week (PRE)**	**Last week (POST)**	**Relative Gain**	**Gross Gain**
Student 1	80%	92%	60%	12%
Student 2	64%	68%	11%	4%
Student 3	36%	56%	31%	20%
Student 4	40%	48%	13%	8%
Student 5	52%	80%	58%	28%
Student 6	32%	68%	53%	36%
Student 7	52%	64%	25%	12%
Student 8	40%	72%	53%	32%
Student 9	52%	68%	33%	16%
Student 10	80%	92%	60%	12%
Student 11	32%	76%	65%	44%
Student 12	40%	60%	33%	20%
Student 13	52%	56%	8%	4%
Student 14	52%	80%	58%	28%
Student 15	48%	72%	46%	24%
Student 16	56%	76%	45%	20%
Student 17	32%	52%	29%	20%
Student 18	48%	64%	31%	16%
Student 19	40%	44%	7%	4%
Mean	**49%**	**68%**	**38%**	**19%**

The second column shows the mean score in the pretest (PRE), the third column shows the mean score in the final test (POST), the fourth column shows the relative gain, calculated as $<g>$ = (gross gain) / (100-Pre), and the last column shows the gross gain, calculated simply by gross gain = Post-Pre.

International comparison

From SSCI article (Buck et al., 2005), we can compare our performance with other 20 courses in Signals and Systems, 15 of these considered traditional methodology courses, and five considered as active methodology. In this article, the 15 traditional courses had an average relative gain $<g>$ = 0.20 ± 0.07 while the five active courses had an average relative gain $<g>$ = 0.37 ± 0.06. Our performance matches the average of the other evaluated active methodology courses.

CONCLUSIONS

Students usually ask for changes in methodologies, but when a chance of change is offered they initially present fear and resistance to change in and out of their comfort zone. So, We should not be afraid to try new teaching methods or assessment, considering that these will help in the learning process of students, although there is initial resistance from them.

The implementation of this type of methodology, requeiren a greater effort on the part of teachers, because like what happens with students, they go out of their comfort zone and should do more work, which involves more resources, including more dedication and preparation time, which is not necessarily valued from academic administration.

Developments and changes in the projects have proved effective with regard to student motivation and to engage beyond the lecture. They are committed to developing projects and are very proud to show their results. They feel more confident of learning obtained. This can be seen in them, the way in which made their presentations and how they speak

The average students' performance was very good when compared to other groups (schools abroad) who took the same test. Our results are on a par with other classes who worked with active learning methodology, and the result is significantly better than other groups who worked with passive methodology.

Working with partners in different Universities and in different countries is very useful to share experiences, ideas and knowledge, unfortunately, even knowing this advantage, it is not always easy to implement cooperation as there might be conflicts of interest or even administrative bureaucratic difficulties.

In our project, it was very gratifying to share experience and likewise be able to compare the results and see that what works for our institution or our particular course can also work in many other places.

Project implementation favors the use of different assessment methodologies, which gives students a greater opportunity to show their skills and knowledge acquired, and gives the teacher a greater range of being able to provide feedback to the student on aspects that could be improved.

Although it was not raised as an objective in the process, is evidence that students achieve better academic and results the same way, students feel their grades are rewarded for the effort and work done.

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BIOGRAPHICAL INFORMATION

Jairo A. Hurtado**,** Ph. D. is an Associate Professor at Pontificia Universidad Javeriana at Bogota, Colombia, at Electronics Department. He was Chair of Electronics Engineering Program and he has working in different projects to get a better process learning in his students.

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