Building the first steps into SP Research

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ABSTRACT

When young students begin to wonder about their career's future, research spirit is not always awake. Some of them will choose a path that is away from their vocations without even knowing. As undergraduate SP course's professors, we found a way to widen their options, with a research assignment.

This paper explains what the objectives of such a task are, reports our experience during the last three years, shows a student's paper example, points out how to asses the outcome and shares promising results.

We believe that this small contribution may increase the number of doctorate candidates; which will serve, indeed, to build our nation's future.

1. INTRODUCTION

An undergraduate course on Signal Processing is seldom a good environment for research production. Students have many challenges ahead at the beginning of such a subject, so they lack time and knowledge to endure a research assignment. Priorities include theoretical concepts about discrete time systems, problem-solving skills and, at least, a glimpse of signal processing applications.

We are no exception in Argentina. In a five-years engineering program, SP has only one semester, located at the beginning of the fourth year. Although students have a solid background in mathematics, particularly in signal and systems, a six-hours-per-week course doesn't leave much time for syllabus expansion. As professors in such a course at the Buenos Aires Institute of Technology (ITBA), we have been trying to overcome these constraints in order to promote new SP engineers [1].

One of the instruments that gave us best results has been laboratory training. We could acknowledge that learning is a complex process, firmly sustained by hands-on experiences. Details about hardware and software assignments can be found at [2-4].

In spite of that work, there were some issues that remained unattended. Research was among them. Slowly, the idea of blending it into our course, started to grow.

2. IDEA'S ORIGIN

It is maybe against common sense to share advanced concepts of signal processing in an introductory course. But the key word here is "share".

It took us many years of teaching experience to realize what the most important part of learning is. No matter how many concepts you teach, no matter how deep you go, no matter how tough your exams are, the only lessons that will remain in their minds are those that touch them.

By no means we are trying to say that building a strong curriculum is worthless. We are expressing that, in a particular sense, it is not enough. A good student, firmly concentrated in solving difficult problems and skilful with simulating tools, doesn't have much time to think about his future. He responds well to the challenges we confront them with today, but what about tomorrow? Is he prepared to choose "the right job" if he doesn't know what the alternatives are? Has he even a clue of the implications of his future social role in his country?

Those questions are very hard to answer. We will address our attempt of response in this paper, leaving the social implications out of the scope of the present work.

In Argentina, a junior electrical engineer has diverse job opportunities. Assuming that he is perseverative and lucky enough to follow his vocation, he may become an entrepreneur, find an industry position or begin a teaching career. Although it seems quite similar to other countries, there are some important differences. The chances that a young professional works in a research team or developing project are extremely low. There are many reasons to understand that, but none to justify them.

A new company manager will spend much of his time trying to start his business, and learning how to deal with our always-changing regulations. Research won't be in his priorities at the beginning, but it won't be so later on, because many other business opportunities will be easier and more profitable in the short term.

A junior engineer in an industry position will be learning how to buy and maintain expensive electronic equipment, but he won't be any of its creators. This is so for the same market reasons explained above, or in case of a foreign company, research will be performed overseas.

Becoming a professor is not always an alternative. Despite the strong vocation, many young engineers leave the university in search of better jobs. The environment is friendly, the assignments are interesting but the earnings are tiny. That is why we have many part-time professors. That is why university deans cannot demand a PhD degree from every professor.

We should point out that there are many exceptions to the facts that we mentioned. The country's dilatory exit from the economic depression of the beginning of millennium help people see beyond their noses. There are some national companies that have realized the importance of research and are working on that. Several multinational enterprises saw a potential market for developing teams, as the salary of our professionals decreased because of devaluation. Universities are aware that they are the seed of research advances and encourage professors to enhance their curriculums.

This changing panorama is not clear for electrical engineering students. They are focused on earning a degree. An oral survey we made on what they would expect from a professional job, besides a good pay, showed us that many of them leave it to fate!

That is the origin of our idea. In spite of lacking time and resources, we decided we could make a difference. We had seen many cases were an undergraduate course was based in a developing project, but it was very unusual to find research assignments. Thus we carried out the change.

Research appreciation grows slowly. It must be developed without high stress; every assessment should be evaluated carefully. Large expectations for quick results have to be avoided. In short, creating a research assignment is a completely different task compared to a laboratory experiment.

3. OBJECTIVES

In order to have enough time to perform the investigation, we leave some material, which includes DSP hardware, for graduate studies.

At the beginning of the semester we start the induction game. We teach them the difference between a book and paper; we talk about the many applications that are created day after day thanks to serious investigation. We also draw a line between introductory material and research subjects, showing ways of solving each situation.

As in any SP syllabus we teach discrete time systems, DFTs and digital filters, employing simulating tools such as MATLAB [5]. When they realize that SP is much wider than the initial topics they are learning, we open the door to our research assignment.

There are some tips to take into account if we want not to scare them away.

First, there should be many projects to choose from. Students are more willing to work hard when they feel they are doing what they have selected.

Second, assignments must be introduced as real application problems, where students are able to understand the implications of their hypothetic results. At this point we never overestimate what they can accomplish. It turns out to be better to achieve more than what they have expected. It also encourages a competing impulse to reach further.

Third, project objectives have to be detailed clearly. We summarize them in the following paragraphs:

- Procedure: we emphasize that a methodology to get job done is mandatory. Before they start, they have to know where they stand. Research is not about reading a book and following author's instructions. They have to understand the problem. They have to know what models are available and which theory is behind them. They are supposed to find out the actual state of the art in that matter. They must organize the material according to different categories or research lines. Only after that come the ideas, the creative part. And all are welcome. But in order to rank them, some simulations should be carried out. In case a result seems to be promising, the implementation stage takes place. The procedure is the path to go, but each research team reaches as far as it can, skipping any step it need to. We evaluate how the group evolves through these points.
- Volume of information: One of the biggest challenges of research is to find what is worth for each project. Digging into hundred of papers, managing references and classifying what they need are the core of this objective.
- Line of work: each research problem has many ways to be faced. We certainly choose subjects that have partial solutions in different approaches. Students have to study them, and make a choice according to their background, their skills, their sources of information and their ability to contribute with new ideas.
- Simulations: this job is mandatory. Even if they were unable to produce something new, they have to simulate other people's ideas. When they are creating a MATLAB tool to prove a point, they are exploring their own capabilities and they are grasping researcher's spirit.
- Implementation: when they finally reach into something, they are eager to see it working. This is not a goal in the assignment, but we realized that is important to let this door open. Sometimes, when students get very excited about a subject, they want to keep going. They have to know that they can go as far as the resources let them, even beyond the course.

Forth, the assignment is team-work oriented. Each member has a role to play that is clearly identified. His contribution to reach the final goal will be evaluated. There is a leader, who is in charge of the organization (including proper timing), researchers, reporters and simulators. Roles depend on the subject chosen and the number of students in the group (four to six).

4. PROJECTS IN PERSPECTIVE

We have been working with research projects for three years. The first time we did it was a voluntary work. Students have to do it in their spare time. Although we thought we would have no echo, two teams accepted the challenge. We tutored them along the semester and got interesting results. One of the teams was admitted in an internal Research & Development contest and got a mention (third prize).

In 2003 we started the second "research" year. But this time we did some program adjustments in order to include the assignment in our regular syllabus. No basic exercises were excluded, the time was traded with a digital filter implementation in a PC [2]. This year we had four new projects, as we had four teams of five to six students each.

Students followed the procedure we had traced and got into the simulation stage very well. We could check that they learned how to deal with large amounts of information easily. Some of them even enjoyed the job, as they continued into the implementation level with relative success.

2004 was not exception. We also had four new projects that gave us interesting results.

We include a list of each project name in order to illustrate the idea that subjects may be very diverse, and somewhat deep.

2002

- Physical Synthesis of String Musical Instruments
- 3D Sound Simulation using spatial localization technologies

2003

- Speaker separation through microphone arrays
- Noise reduction in pipes using adaptative filtering
- Pitch shifting approaches
- Automatic guitar notes detector

2004

- HRTF's interpolation for sound direction detection in an azimuthal plane
- Signal Processing applications in QPSK modulation
- Electrocardiogram's base noise reduction through adaptative filtering
- Wide band active earphone that eliminates external noise.

Students are very productive when they get motivated. We will describe a particular report example to clarify our point. Team members have been very successful reaching the objectives we had instructed. Their work was named "Speaker separation through microphone arrays" and was the winner of 2003 R&D Contest.

After a fine tuning, the table of contents was:

Abstract
1. Introduction
2. Sound waves and voice tutorial
3. Microphone arrays
   3.1 Principles
   3.2 Array spacing
   3.3 Near field sources
4. Reception lobe simulation
   4.1 Delay & Sum Technique
   4.2 Frost's Algorithm [6]
   4.3 Generalized side lobe canceller
5. System Design
   5.1 General
   5.2 Design Criteria
   5.3 Microphone distribution
   5.4 Digital Filter Design
   5.5 Delay quantization
   5.6 Direction continuity
   5.7 Block Diagram
   5.8 Complete Scheme
6. Simulations
   6.1 Radiation lobes
   6.2 Simulation specifications
   6.3 Simulation results
   6.4 Simulation files
7. Implementation
   7.1 Passband filters
   7.2 Delay designs
   7.3 Hardware implementation
   7.4 DSP Program
   7.5 Material availability and adaptability
   7.6 I/O interface implementation
8. Results and Conclusions
9. Future upgrades
10. Acknowledgements
11. References

We could see that the students were able to address many steps of a research job without a previous formal background. Human voice production, array beamforming [7] and adaptative filters were subjects that they could understand by themselves. As tutors, our task was to filter material, to show alternatives, to accept or reject their ideas and to encourage them all the time.

Figure 1 is one of the pages of this report, at section 6.3 where they show some simulation results.

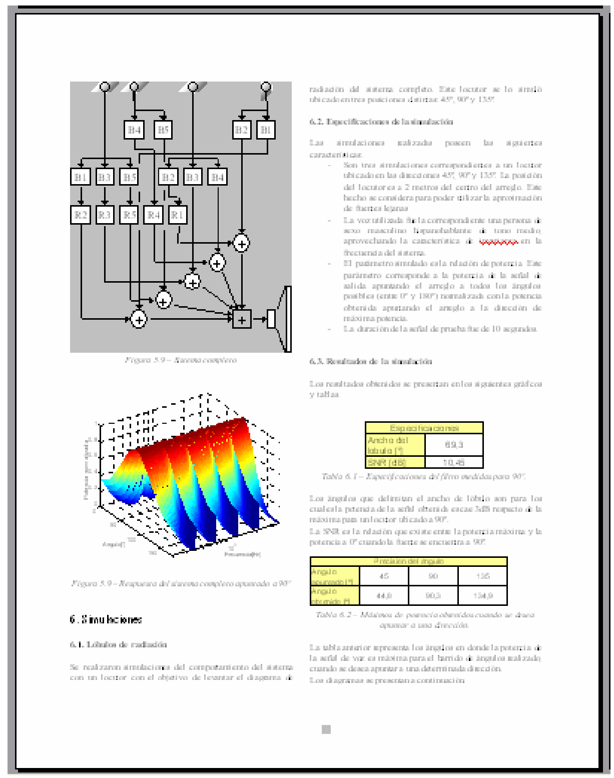

Figure 1: Report example page

As their confidence improved, students got into the implementation stage. It was carried out after the course had finished, and they were very proud of their accomplishment.

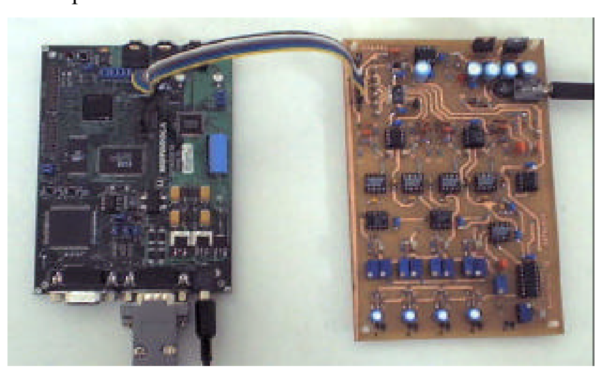

Figure 2: Hardware Implementation

Figure 2 shows the hardware used, Motorola DSP 56303 Evaluation board [8] at left and the I/O interface with microphones they have designed at right.

5. How to Evaluate

Being the first research experience of an undergraduate student, the assessment of such a job should be evaluated very carefully.

The first question is how to do it. We think that it should be done in steps. At the end of each month of the course we perform an oral examination where we asses:

1. Understanding of the problem. Theoretical background required and books available for that purpose. Papers related to subject that could show the way.
2. Further reading of research material. Classification. Resolution of line of work. Justification. Reference filtering.
3. Development of ideas. Simulation results. Possible implementation criteria.
4. Final report evaluation. Performance (in case of implementation)

The second question to address is what to evaluate. We have been discussing this matter in a national engineering forum [9] reaching consensus in assessing the following parameters, in order of importance:

- Report quality
- Project simulation achievements
- Oral presentations
- Selection of information resources
- Theoretical concepts manipulation
- References chosen
- Summarizing capabilities
- Advance level of the implementation stage (optional)

6. It is Working!

One way of knowing how it went, is to request feedback. Students get very interested in the project because they keep working with it after the course is over. Although the number of teams is small, the percentage of groups that went on is relevant:

2002: **50%**; 2003: **50%**; 2004: **75%**.

Another good sign is student's grade. If we compare these results to other assignment grades obtained in the same course, they are higher. The average grade increases almost 10%.

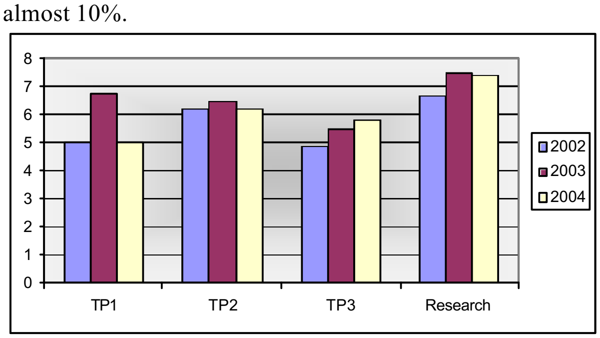

Figure 3: Student's grades

The grade load of the assignment was 15% of the total grade. It is not high because we wanted to be sure that they keep considering basic training as mandatory.

We also found that students develop other skills. They become aware of how huge the gap between what they know and what's known is. But at the same time, they feel comfortable because they are able to shorten it. They are no longer intimidated by tons of papers. They are even confident in writing a one.

7. Conclusions

We introduced a new assignment in an undergraduate course: Research. Students have to deal with complex material, mostly unknown, and return results at the end of the semester.

We have shown our experience, pointing out goals that students have achieved successfully. We also summarized how to asses these reports and which is the feedback received.

Exploring limits is a way of growing. Young people are always eager to see further. We let them a hand.

At the same time, we could be awakening vocations that can contribute to enhance technology development. Maybe better opportunities for our global tomorrow.

Yes, teaching is a nice job.

Acknowledgements

To our students

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