The Use of Scilab-Cloud for Teaching Digital Signal Processing Concepts in Electrical Engineering Curricula

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Abstract

The digital signal processing (DSP) is a relevant area in the electrical/computer engineering field, since several applications have been observed during the past decades. On the other hand, students have demonstrated difficulties to understand not only the eventual applications, but also its mathematical concepts and theory. Actually, open source packages are available and increasing, but the use of these tools are not very widespread in electrical engineering curriculum. This paper presents the use of Scilab-Cloud software platform for teaching some fundamentals of digital signal processing in undergraduate level, particularly for electrical engineering curriculum. Therefore, some experiments have carried out with undergraduate electrical engineering students and a questionnaire answered by them evidenced the potential of Scilab-Cloud as an interesting alternative tool to foster and motivate students for learning DSP skills.

Keywords: Digital Signal Processing; Scilab Cloud; Engineering Education.

1. Introduction

Usually, the study of digital signal processing (DSP) concepts is a huge challenge for many students, since it requires a good background on advanced calculus and abstract reasoning. In many cases, engineering, computer science and technological engineering students lack the required background, and they have difficulties to learn these subjects [1]. Even for graduate level, the understanding about basic skills of DSP concepts are not easy for many students.

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In other work [2], for example, a new approach to undergraduate digital signal processing education was based on a simple strategy, i.e., by emphasizing applications. In this research, some cases of speech processing and image processing, as well as the application of traditional digital signal processing topics, such as digital filter design and discrete Fourier transform (DFT) have been investigated, using Matlab-based homework assignments to enhance the understanding of some DSP concepts. In another research [3], a web-based educational tool has been presented for digital signal processing teaching in an undergraduate course with modern microprocessors architectures and applications. The other work published by authors [4] presented a web-based educational tool as a teaching methodology in an undergraduate course involved with advanced microprocessors architectures and their applications. The potential use of virtual laboratories in engineering education was discussed by some works [5,6], particularly the use of online and remote labs to perform experiments on real equipment's via Internet. However, it should be noted that remote labs usually require a higher cost for equipment acquisition and allocation of physical space for the laboratory. Other strategies to enhance teaching digital signal processing was proposed, essentially based on project-based learning [7,8]. The software Matlab, for example, has been applied in many cases [9-11], but its license cost and installation requirements do not allows the use by several students during the classes. On the other hand, new open source platforms have been introduced and improved in the last years, such as the Scilab environment, among others [12,13]. Recently, many works have addressed the use of virtual laboratories and web-based solutions, especially for the availability of new online tools [14-18]. However, the use of these tools are not very widespread in electrical engineering curriculum and particularly for learning DSP issues. Based on the aforementioned, the present work describes the use of the Scilab-Cloud tool for teaching digital signal processing concepts in electrical engineering curricula for 34 electrical engineering students, at the Nove de Julho University, located in Brazil. The Scilab-Cloud tool has been used to enhance the DSP learning skills and a questionnaire was analyzed to assess learning. The aim of this manuscript is to disclose that a simple Cloud Plataform, as the Scilab-Cloud, has been able to address important signal processing concepts, using only one Chrome Book computer as a terminal, or even the student's mobile phone, connected to the Institution Wi-Fi network. The results have shown that more than 70% of the students have stated that Scilab-Cloud was useful; particularly considering no prior installation, besides the fact that this kind of platform is easy to learn new instructions and edit new commands. Moreover, as shown in the results (Table 2), the students have further commented that this platform is very interesting due to the possibility of graphical visualization after the code processing.

1.1. Cloud Computing and Scilab – Related Works

The use of virtual laboratories in engineering education has been growing a lot in recent years, due to possibility to perform several experiments via Internet. More particularly, cloud computing allows students and teachers more flexibility and mobility in the use of resources, considering different service models such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) [19]. As cited by other works [19,20], the establishing of the cloud computing is helping online education or e-learning using, for example, the devices owned by the students, such as the mobile phone, since most technical implementations do not have enough resources to use laboratories shared by different students and courses. Therefore, the students and instructors can access distinct virtualizes resources on the cloud data from devices such as Laptops, PDA,

mobile phone and Tables, from anywhere and anytime [21]. As mentioned by King [21], students at remote locations can use mathematical and statistical tools, such as R and Scilab, from Amazon Elastic Cloud (EC2), for example, as well as other virtual applications. The Scilab is an open technology and it offers similar functionality when compared to Matllab, being originally oriented to local installations, but a cloud platform allows users a possibility to use the software without a need to install it on own computer [22]. Moreover, as cited by other work [23], the use of all cloud computing services is capable of creating a model called "social cloud", especially for university without computing labs or complex physical systems. This kind of social cloud, as disclosed by Encalada and Sequera [23], has "striking benefits such as centrality, ease of use, scalability, and ubiquity, providing a superior learning environment when compared to that of a simple physical lab".It is important to highlight that cloud computing usually needs less processor capacity, as a software and applications, for an Institution; hence, the investments are only oriented towards the purchase of terminals [24], such as the case of the present research, since the students and teacher have used a simple Chrome book computer, connected to University WiFi network. The use of Scilab-Cloud, for instance, is a fast and easily solution for running Scilab codes, since the tool available in the web-based environment allows user to access examples from Textbook Companion Project´s [25], besides the fact that it is possible to easy visualize graphical examples in a simple way, by using a computer or the student´s mobile phone. The Scilab-Cloud tool, such as used in the present study, is offered as a Web 2.0 service with a public application-programming interface (API), which can be used freely to execute codes on the cloud as a SaaS. In addition, some recent studies [26-28] have performed a systematic review about the use of cloud computing in higher education institutions (HEIs), m-learning services (mobile learning) and the benefits and/or risks related to its implementation. In these works, it has been noted that cloud computing technology can change the way teachers, students and Institutions deal with teaching and learning process. Since the cloud computing is a clear trend in the next years, the students should be familiar with this technology, including thinking about future job opportunities or even starting their own cloud-based business [29].

2. Materials and Methods

In this section, we describe the web-based environment of the Scilab-Cloud used for DSP issues learning purposes. This tool has been developed by FOSSEE group at India and is available in https://cloud.scilab.in/. Fig. 1 shows its interface and main resources. In code area (space labeled as "1"), the students write a new code or select an existing code from the tool (Fig. 2) [4]. When you click the "Execute" button, the code written in the code area is executed and its result is shown on the right side of the screen (space labeled as "2").

2.1. Educational use of the Scilab-Cloud: learning cases

This section provides the educational use of the Scilab-Cloud tool for learning some DSP issues. Each student used a Chromebook computer, or even his cell phone, connected to a WiFi network. A teacher, also connected to the Institution's WiFi network, was responsible for conducting each experiment and the final evaluation of the student´s performance. The DSP exercises have been tested during one semester, according to the topics foreseen for the digital signal processing issues in the Electrical Engineering Degree. In this subsection, the learning cases, or experiments, defined during the classes for DSP issues, using Scilab-Cloud tool are presented.
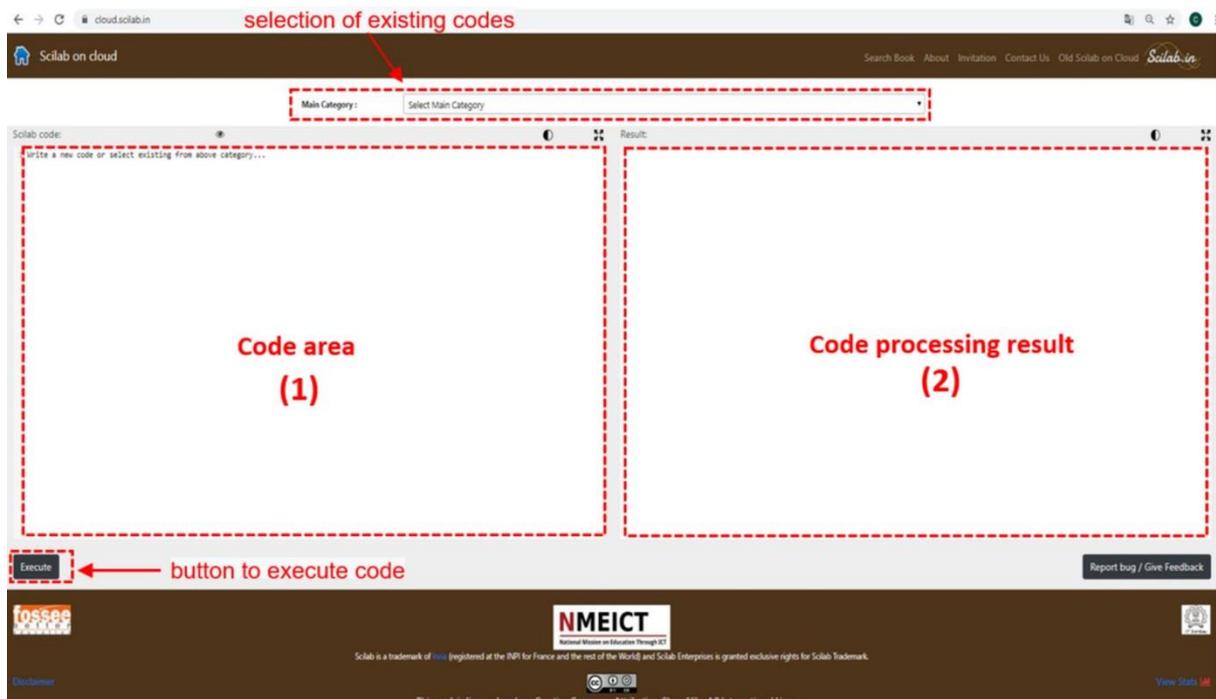
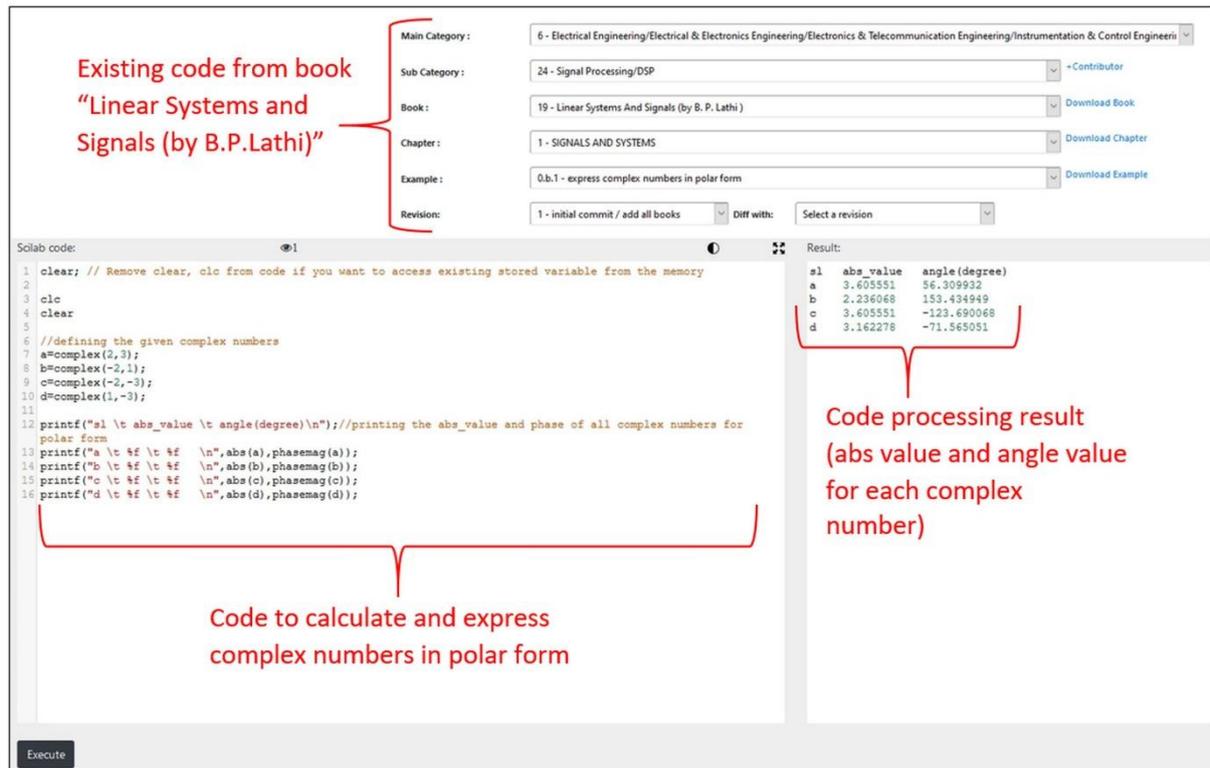**Figure 1:** Interface of the Scilab-Cloud web-based environment

Figure 2: Existing code from "Linear Systems and Signals" book (by B.P.Lathi), executed in Scilab-Cloud environment to express complex numbers in polar form

2.1.1. Exercise for signals sampling

As a first experiment, the students have evaluated the discrete-time signals come from sampling a continuous-time signals. As described by some works [30, 31], a sampler converts the continuous-time signal $x_a(t)$ into a discrete-time sequence $x(n)$ by extracting the values of $x_a(t)$ at integer multiples of the sampling period T_s, as defined by Equation 1:

$$x(n) = x_a(nTs) \tag{1}$$

For an exercise, the students have noted a discrete-time signal at sampling frequency of 10kHz. The following expression has been used for a sampling signal case (Figure 3):

$x_a(t) = \cos(100 * 2 * \pi * t)$, for a continuous-time signal;

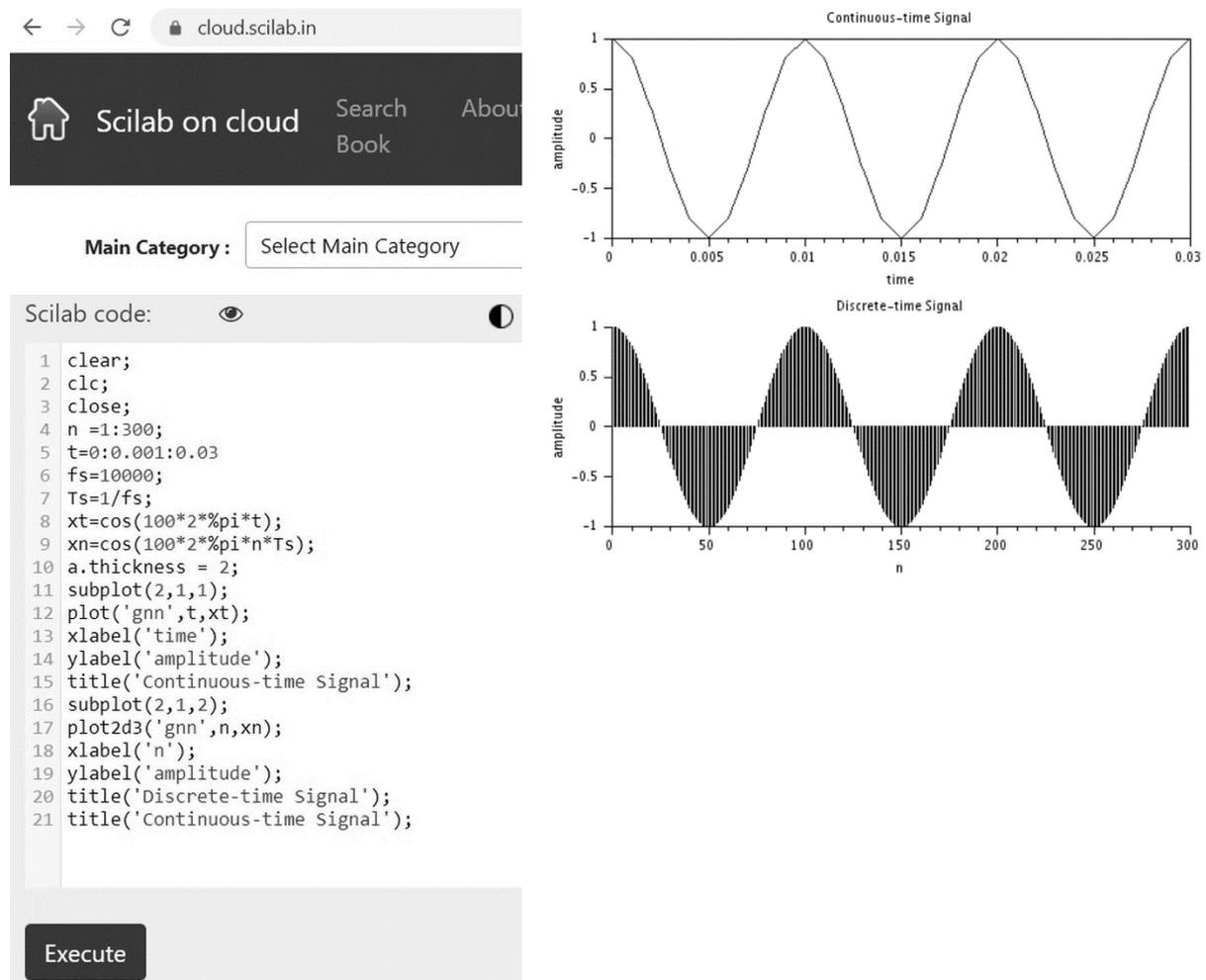$x(n) = \cos(100 * 2 * \pi * n * Ts)$, for a discrete-time signal, sampling at frequency of 10 kHz.

Figure 3: Experiment used for explaining signal sampling a) code written by students and b) discrete-time signal at sampling frequency of 10kHz

2.1.2. Exercise for Convolution Sum

This exercise allowed students to practice the convolution sum of two discrete-time signals. As widely known in literature [30,31], the input-output relationship for Linear Time-Invariant Systems (LTI) is described in terms of a convolution operation, thus, this kind of concept is essential in LTI systems, since the response of an LTI system to the unit impulse input allows us to find its output to any input signals. More particularly, this exercise has introduced the convolution sum fundamentals, such as denoted by Equation 2:

$$y[n] \;=\; x[n] * h[n] = \sum_{k=-\infty}^{\infty} x[k]h[n-k] \tag{2}$$

In this case, the output of any discrete-time LTI system is the convolution of the input x[n] with the impulse response h[n] of the system. In Figure 4 is shown the definition of the impulse response h[n] and the relationship of Equation 2.

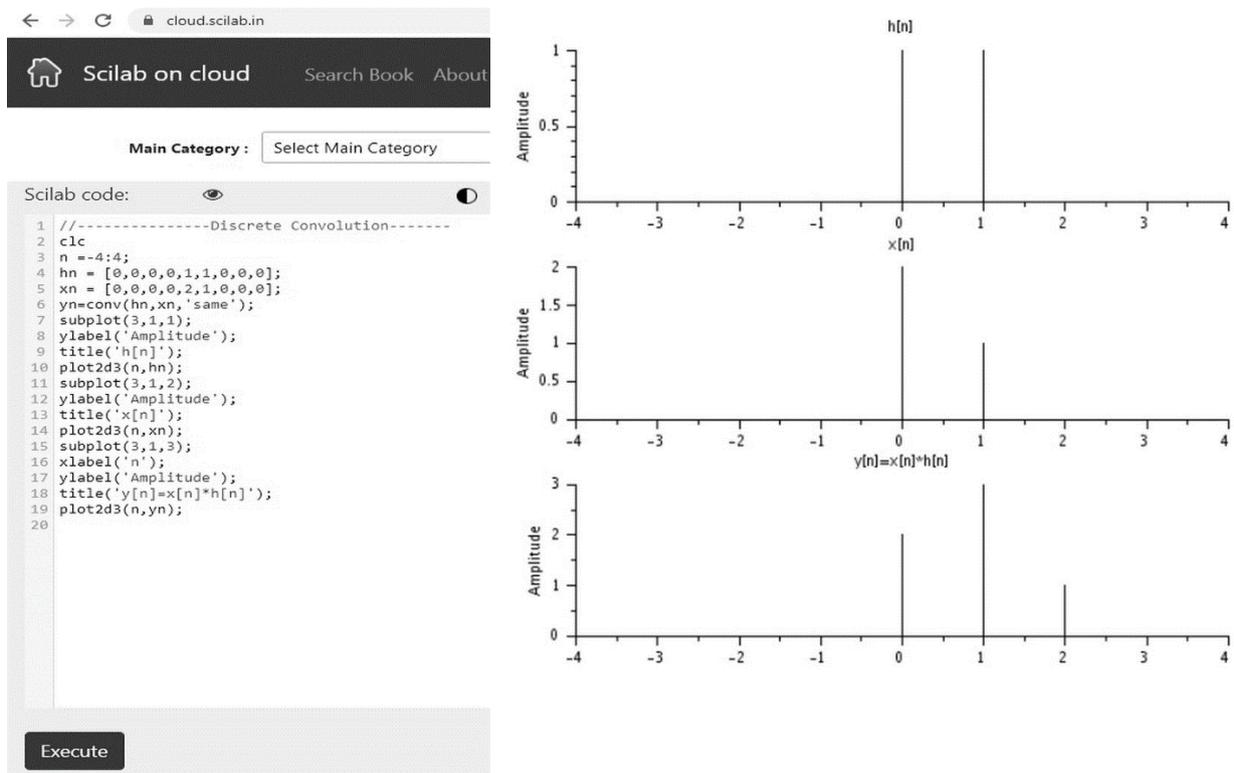**Figure 4:** Discrete-time LTI system and its output defined by convolution

Figure 5: Convolution sum implemented in the Scilab-Cloud a) code written by students and b) results after processing convolution sum with $x[n]$ and $h[n]$ signals

It is important to highlight that the convolution operation is widely applied for solving several kind of problems, in telecommunications, audio processing, or simply using as a filter [32]. As discussed with the students in the classroom, the convolution process can be applied for filtering and filter design, by implementing, for example, a Savitzky-Golay (SG) filter to smooth the data. As described by some works [34], the SG differentiation filter can be considered as a kind of low-pass filter. Nowadays, the convolution operation is related to fundamentals of the deep neural networks in image processing and for fault diagnosis in electrical machines, among other applications [33]. For this exercise, the convolution sum has been implemented by students using a discrete 1-D convolution function of Scilab. The inputs signals are x[n] and h[n], as shown in figure 5a and the results are shown in figure 5b. These results were compared to the analytical mathematical reasoning solved by the students.

2.1.3. Exercise for Fourier Analysis

This exercise allowed students to better understand the Fourier transform for a periodic-continuous signal and/or for a periodic-discrete signal, using the so-called Discrete Fourier Transform (DFT), by implementing some codes in the Scilab-Cloud environment. As well known in literature [30-33], Fourier decomposition is very important, since a wide variety of signals are inherently created from superimposed sinusoids, such as audio signals. As a first exercise, the students have evaluated a square signal created from superimposed sinusoids. The following Equation 3 has been implemented:

$$
s(t) =
$$
$$
1.27 * (\sin(2\pi * 400t) + 0.33 * \sin(2\pi * 1200t) + 0.2 * \sin(2\pi * 2000t) + 0.143 *
$$
$$
\sin(2\pi * 2800t) + 0.11 * \sin(2\pi * 3600t) + 0.0909 * \sin(2\pi * 4400t)) \tag{3}
$$

The $s(t)$ signal was created considering 400 Hz as a fundamental frequency (fo) and frequency harmonic components as $3fo$, $5fo$, $7fo$, $9fo$ and $11fo$. The Equation 3 was derived from a Fourier series for a square wave, as shown in Equation 4. Figures 6a and 6b show a code written by the students in the Scilab-Cloud tool and a square wave generation using a Fourier series. The students noted that by increasing the number of harmonics, the resulting signal is more similar to a square wave.

$$
x(t) = \frac{4}{\pi} \left[\sin(2\pi fot) + \frac{1}{3}\sin(2\pi 3fot) + \frac{1}{5}\sin(2\pi 5fot) + \frac{1}{7}\sin(2\pi 7fot) + \frac{1}{11}\sin(2\pi 11fot) + \cdots \right] \tag{4}
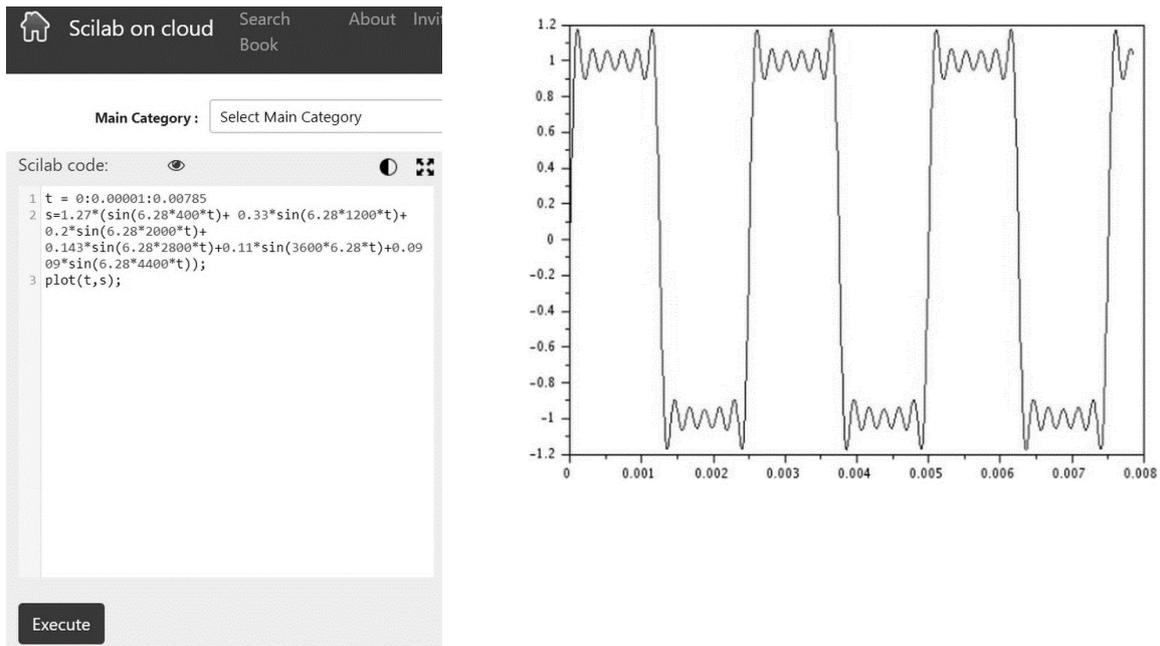$$

Figure 6: Square wave created using a Fourier series in the Scilab-Cloud a) code written by students and b) wave generated after code processing
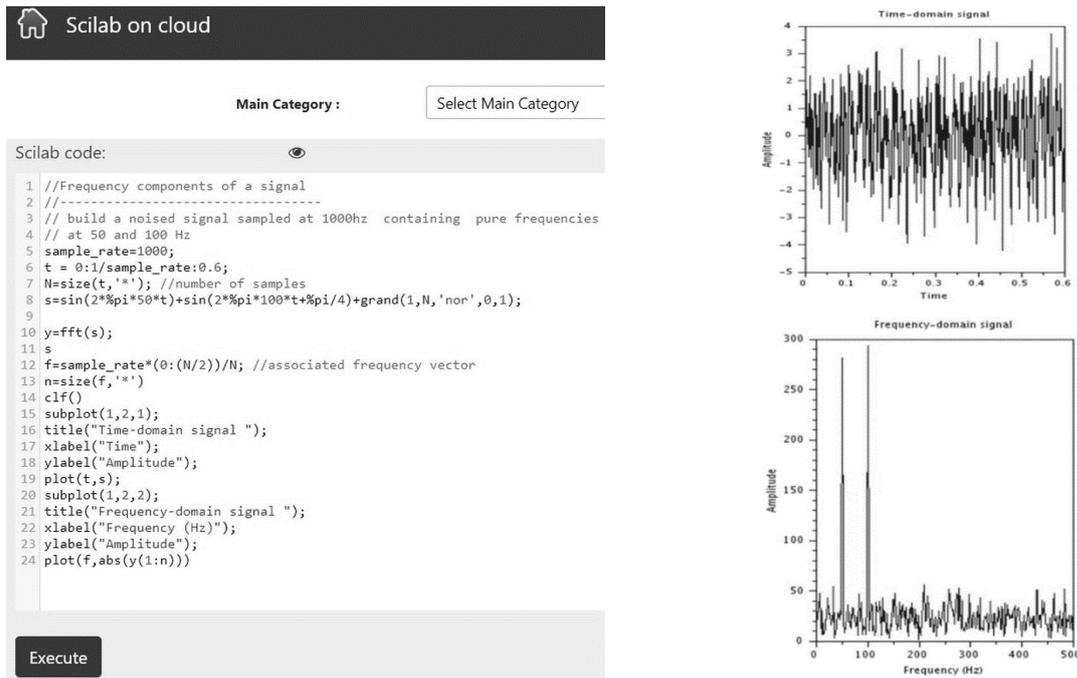

Figure 7: FFT applied in a time-domain signal in the Scilab-Cloud a) code written by students and b) time and frequency-domain results after code processing

As a second exercise (Figure 7), the students wrote a code in order to build a noised signal sampled at 1000 Hz, containing pure frequencies at 50 and 100 Hz. Figure 11b shows both the time and frequency-domain of the original signal. As discussed with students, this frequency-domain signal allows us to diagnosis electrical and mechanical faults in rotating electrical machines, for example, by observing some kind of specific frequencies in

vibration signals and/or in the electrical current. In the next section, we describe the results after applying a survey with undergraduate students.

3. Results and discussion

In order to analyze the effects of the use of Scilab-Cloud for learning digital signal processing concepts and to assess the degree of satisfaction on the students' part, an anonymous survey was conducted. This survey addressed seven questions and the responses were sorted around five levels: TDA (I totally disagree); DA (I disagree); IND (Indifferent); A (I agree); and TA (I totally agree). The questionnaire was applied to the set of 34 undergraduate students of electrical engineering, in order to evaluate the facilities provided by the Scilab-Cloud tool and the students perception regarding its application for DSP issues. As shown in Table 1, the most students have agreed (23,8%-TA and 47,6%-A) that the Scilab-Cloud was useful, particularly considering no prior installation required (question 1). It is important to describe that some students comment that many exercises can be easily performed on their cell phones, for example. In addition, the most students have agreed that the Scilab-Cloud is easy to learn new instructions and commands (16,7%-TA and 66,7%-A), as well as they recommend using this cloud tool to other colleagues (68,4%-TA and 10,5%-A). The results obtained for question 4 disclosed that the most students have also agreed that the use of Scilab-Cloud has contributed significantly to understand concepts in DPS issues (27,8%-TA and 55,6%-A). Another relevant result, also shown in Table 1, is related to the student´s opinion regarding the use of Scilab-Cloud to better understand some complex concepts in DSP, such as the convolution sum and/or Fast Fourier Transform, for example. The most students have agreed that Scilab-Cloud is an important tool for learning this kind of theory, by applying and executing codes (58,8%-TA and 41,2%-A). Moreover, as shown in Table 1 (question 6), the most students have agreed that their motivation to learn DSP concepts has increased with the use of the Scilab-Cloud tool, and this environment can also be useful for learning new engineering concepts (question 7). Figure 8 summarizes the results presented in Table 1, thus, it is possible to observe that at least 70% of the students agree that Scilab-Cloud provides relevant resources for learning DSP concepts, when considering the themes evaluated in questions 1 to 7. Therefore, the Scilab-Cloud might be useful not only for the DSP learning purposes, but also to understand some engineering problems by using this simulation tool in Education and Research Institutions. A relevant point is the possibility to use simple devices, such as a mobile phone and/or tablets, wherein the software installation is not necessary.

Table 1: Questions and results of the opinion survey

| Question	TA (%)	A (%)	IND (%)	DA (%)	TDA
	(students)	(students)	(students)	(students)	
Q1: The Scilab-Cloud was useful for me, particularly considering no prior installation required	23,8%	47,6%	23,6%	5%	0%
	(8)	(16)	(8)	(2)	
Q2: The Scilab-Cloud environment is easy to learn new instructions and commands	16,7%	66,7%	11,1%	5,5%	0%
	(5)	(23)	(4)	(2)	
Q3: Would you recommend using Scilab-Cloud to other colleagues?	68,4%	10,5%	21,1%	0%	0%
	(23)	(4)	(7)	(0)	
Q4: The use of Scilab-Cloud has contributed significantly to understand concepts in DSP issues.	27,8%	55,6%	11,1%	5,5%	0%
	(9)	(19)	(4)	(2)	
Q5: The use of Scilab-Cloud environment also contributes to a better understanding of some complex concepts in DSP, such as the convolution sum.	58,8%	41,2%	0%	0%	0%
	(20)	(14)	(0)	(0)	
Q6: My interest in learning DSP concepts has increased with the use of Scilab-Cloud	16,7%	67%	11,1%	5,5%	0%
	(6)	(22)	(4)	(2)	
Q7: Scilab-Cloud tool can be useful for learning new engineering concepts	63,2%	10,5%	10,5%	15,8%	0%
	(21)	(4)	(4)	(5)	
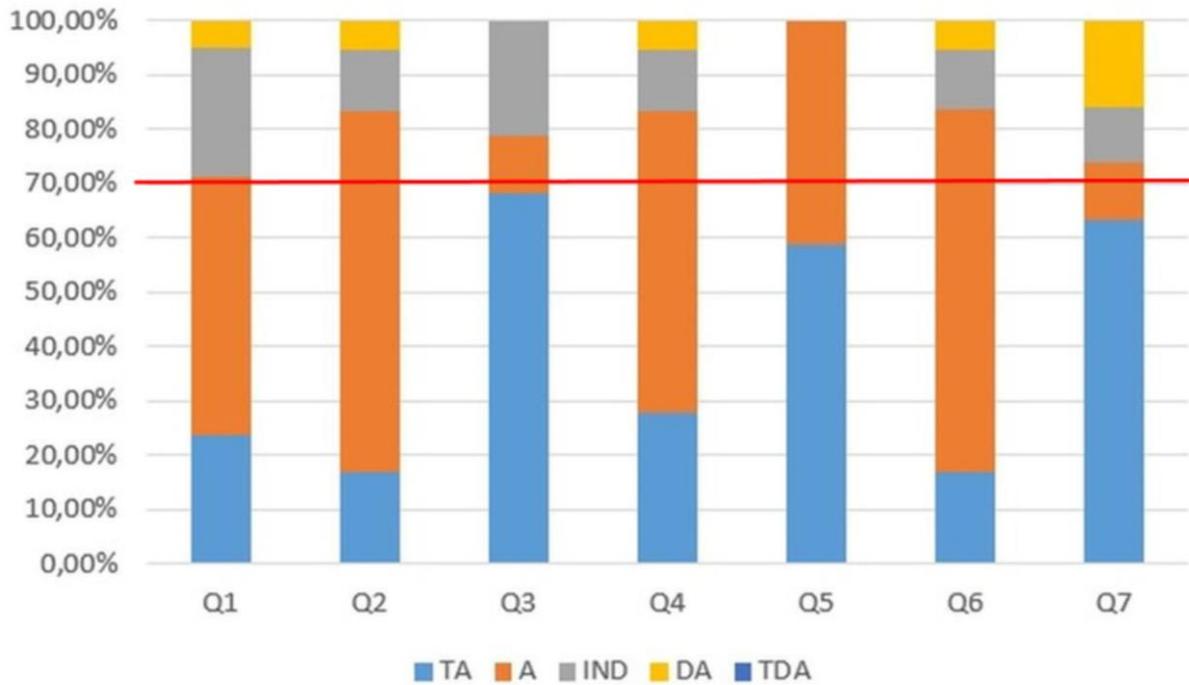
Figure 8: Summarization of the results presented in Table 1

Finally, a last evaluation has been performed considering additional comments supplied by the students. For this purposes, the following suggestion was proposed: "*Please, cite two or three things (concepts) discussed in the classroom that have been better understood using Scilab-Cloud*".

Table 2: Additional comments supplied by the students

ID	Student Comments
1	*"It is clearer to understand the differences between a discrete-time signal and a continuous-time signal."*
2	*"It is clearer to understand the lag between signals"*
3	*"Graphical visualization allows us to better understand signal sampling"*
4	*"It is very interesting editing codes and visualize graphs using my mobile phone"*
5	*"It is clearer to understand the concept related to Linear Time-Invariant Systems (LTI)"*

As shown in Table 2, from the student´s point of view, there are many resources that could be used in the Scilab-Cloud tool, in order to improve the learning of digital signal processing issues.

4. Conclusion

This paper proposes the use of Scilab-Cloud platform for teaching digital signal processing concepts in electrical engineering curricula. The conducted experiments in a classroom allowed us to better understand the benefits provided by the Scilab-Cloud tool on each specific DSP topic. In general, more than 70% of the students have

agreed that this kind of platform is able to improve the learning skills in the digital signal-processing field. Even for basic signals evaluation, but mainly for complex discrete-time and continuous-time signals treatment, the Scilab-Cloud is an interesting alternative tool to foster and motivate students for learning DSP skills. Moreover, this platform could be very useful in the future not only for this matter, but also for teaching other engineering subjects. It should be noted that the Scilab Cloud, developed by FOSSEE group at India, has incorporated an Xcos tool, which is possible to simulate mathematical models using the blocks and Xcos diagrams in a similar way that the "Simulink" tool in Matlab software. Therefore, the students will be able to simulate other DSP problems in this new cloud visual tool. Finally, some Scilab-Cloud limitations should be investigated in the future, such as the data size and number of iterations, in order to better define the wide use of this kind of tool in the engineering education field.

Aknowledgements

References

[1]. Baicher. G.S, Sherrington. J.A, Learning about digital signal processing using spreadsheets and simulation software, Engineering Science and Education Journal, pp. 41-48, 1996.

[2]. Zoltowski MD, Allebach JP, Bouman CA. Digital signal processing with applications: a new and successful approach to undergraduate DSP education. IEEE Trans Educ.,39:120- 126, 1996.

[3]. Toral. S.L, Barrero. F and Torres. M.R.M, Analysis of utility and use of a web-based tool for digital signal processing teaching by means of a technological acceptance model, Computes & Education, pp. 957-975, 2005.

[4]. Toral. S.L, Barrero. F, Torres. M.R.M and Gallardo. S, Interactive multimedia teaching of digital signal processors, Computer Applications in Engineering Education, pp. 88-98, 2007.

[5]. B. Balamuralithara, and P.C. Woods, Virtual laboratories in engineering education: the simulation lab and remote lab, Computer Applications in Engineering Education, pp. 108-118, 2008.

[6]. Marozas V, Dumbrava V. Motivating the students to study the basics of digital signal processing by using virtual learning environment. Elektronika ir Elektrotechnika. 102:pp. 87- 90, 2010.

[7]. Algudah Y.A, Al-Qaralleh, E. Project based learning to enhance teaching digital signal processing. International Conference on Interactive Mobile and Computer Aided Learning (IMCL).pp.32.35, 2012.

[8]. So. S, A research-oriented project that motivates undergraduate students in digital signal processing, Proceedings of the 2013 AAEE Conference, Gold Coast, Australia, pp. 2-11, 2013.

[9]. B. L. Sturm, J. D. Gibson, Signals and systems using Matlab: An integrated suite of applications for exploring and teaching media signal processing, in Proc. Annu. Conf. FIE, pp. F2E-21–F2E-26, 2005.

[10]. Kulmer. F, Wurzer. C.G, Geiger. B.C, The magnitude response learning tool for DSP education: a case study, IEEE Transactions on Education, pp. 282-289, 2016.

[11]. Cobos. M, and Roger. S, SART3D: A Matlab toolbox for spatial audio and signal processing education, Computer Applications in Engineering Education, pp. 1-15, 2019.

[12]. Vieira. E.B, Busch. W.F, Prata, D.M and Santos. L.S, Application of Scilab/Xcos for process control

applied to chemical engineering educational projects, Computer Applications in Engineering Education, pp. 1-12, 2018.

[13]. Botana, F., Abanades, M.A., Escribano, J. Using a free open source software to teach mathematics, Computer Applications in Engineering Education, pp. 1-8, 2012.

[14]. R. Belu, and I.N.C.Husanu, Using a virtual platform for teaching electrical machines and power systems courses, ASEE Annual Conference and Exposition, pp.1-18, 2013.

[15]. Vatansever. F and Yalcin. N.A, e-Signals & systems: a web-based educational tool for signals and systems, Computer Applications in Engineering Education, pp. 1-17, 2017

[16]. Gonzales. A, Turning a traditional teaching setting into a feedback-rich environment, International Journal of Educational Technology in Higher Education, pp. 1-21, 2018.

[17]. Britain, S., Liber, O. A framework for pedagogical evaluation of virtual learning environments, Educational Cybernetics: Reports. Paper 2, https://hal.archives-ouvertes.fr/hal-00696234/document. 2004, Accessed 30 Sep, 2019.

[18]. Salinas, I., Gimenez, M.H., Gotor, V.P.C, Ortiz, R.S, Monsoriu, J.A. Design and evaluation of a three-dimensional virtual laboratory on vector operations, Computer Applications in Engineering Education, pp. 1-8, 2019.

[19]. Kurelovíc, E.K., Rako, S., Tomljanovic, J. Cloud computing in education and student´s needs, 36th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), pp. 856-861, 2013.

[20]. Encalada, L.W., Sequera, J.L.C. Collaboration in the cloud for online learning environments: an experience applied to laboratories. Creative Education, pp. 1435-1445, 2015.

[21]. King, T. S. Reviews of cloud computing for education: services and benefits. International Journal of Social Sciences, pp. 1299-1305, 2015.

[22]. Magyar, Z., Záková, K. Using Scilab for building of virtual lab. 9th International Conference on Information Technology Based Higher Education and Training (ITHET), pp. 280- 283, 2010.

[23]. Encalada, L.W., Sequera, J.L.C. Model to implement virtual computing labs via cloud computing services. Symmetry, pp. 1-15, 2017.

[24]. Boukil, N., Ibriz, A. Architecture of remote virtual labs as a service in cloud computing, International Conference on Cloud Technologies and Applications, pp. 1-6, 2015.

[25]. Choudhary, S., Raj, V., Sanmugasundaram, K., Patel, G.S., Moudgalya, K. Scilab on cloud and textbook companion project: a web 2.0 service for open source education, International Conference on Cloud Computing and Big Data, pp. 438-443, 2013.

[26]. Martinez, J.A.G., Lorenzo, M.L.B., Sánchez, E.G. Cloud computing and education: a state-of-the-art survey, Computers & Education, Elsevier, pp. 132-151, 2015.

[27]. Baldassarre, M.T., Caivano, D., Dimauro, G., Gentile, E., Visaggio, G. Cloud computing for education: a systematic mapping study, IEEE Transactions on Education, v. 61, pp. 234-244, 2018.

[28]. Qasem, Y.A.M., Abdullah, R., Jusoh, Y.Y., Atan, R., Asadi, S. Cloud computing adoption in higher education institutions: a systematic review, IEEE Access, v.7, pp. 63722-63744, 2019.

[29]. Mousa-Al, A. Cloud computing: bridging the link between industry and the classroom, International Journal of Electrical Engineering & Education, pp. 1-21, 2019.

[30]. Lathi. B.P, Linear systems and signals, Second Edition, Oxford University Press, Second Edition, 2004.

[31]. Hayes, M. H, Schaum's outline of theory and problems of digital signal processing, McGraw-Hill, 1999.

[32]. Smith, S.W, The Scientist and Engineer's Guide to Digital Signal Processing, California Technical, 1999.

[33]. Ma S, Liu W, Cai W, Shang Z, Liu G. Lightweight deep residual CNN for fault diagnosis of rotating machinery based on dephwise separable convolutions, IEEE Acess, pp. 57023-57036, 2019.

[34]. Luo, J., Ying, K., Bai, J. Savitzky-Golay smoothing and differentiation filter for even number data, Signal Processing, Elsevier, pp. 1429-1434, 2005.