

# Influence of use of the MATLAB as underlying technology on development of the curriculum for the course in signals and systems

Radojka Krneta, Miroslav Bjekić, Adam Dostanić, Marko Acović

University of Kragujevac

Technical faculty in Čačak, Svetog Save 65, 32000 Čačak, Serbia

Phone: (381) 32 302 762 Fax: (381) 32 342 101 E-mail: radojka@tfc.kg.ac.yu

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**Abstract – This paper presents an experience in developing of the new course curriculum for signals and systems theory within the frame of Bologna declaration with emphases on new teaching and learning paradigm. Using of MATLAB software is suggested not only as underlying technology for better understanding of abstract mathematical description of signals and systems analysis and synthesis but also as modern tool for simulations and modelling in all engineering courses and in many engineering tasks.**

## 1. INTRODUCTION

Signal and Systems is characteristic course in many electrical engineering curricula over the world. The intention of the Signal and Systems course is to teach the students fundamental electrical engineering science concepts related to analysis and synthesis of continuous and discrete signals and systems. Acquired accomplishments and skills facilitate better understanding of different levels of abstractions, so students appreciate how a specific engineering problem can be attacked in different ways. Having this in mind in the course development we try to give the connection between theoretical accomplishments and computer simulation skills that will enable designing of concrete application by top-down design approach, i.e. from system behaviour to circuit construction.

Since this course is the introductory for the courses from senior years in Computer engineering curriculum, like Digital Signal Processing, Telecommunication, Continuous Linear Control Systems, Digital Control Systems, Nonlinear Control Systems, in the course designing we also considered their needs and gives a particular attention to firm intersection of theoretical accomplishments and skills to use appropriate tools for solving engineering tasks.

For tools that will help to students to better understand and accomplishment the course topic and gives them the skills for further study as well for their professional life, we select the MATLAB software, which is the most spread underlying technology for similar courses in the world. We used it for computer-based exercises, self-supporting student learning in sense learning-by-doing as well as tools for explanation of abstract mathematical models at lessons. At the last we exploit the available solutions in the MATLAB as well we made own simple examples. The course is naturally tailored to the widespread use of computers for processing and designing applications from any computer engineering course.

Signals and Systems course will be offered also to senior students who didn't attend courses like this, as well to the other engineers interested in theory of signals and systems. For both we will establish course web page with available support for self-learning and experiments with MATLAB.

## 2. GOALS, SIGNIFICANCE AND BENEFITS OF COURSE IN SIGNAL AND SYSTEMS

The goals, significance and benefits of course in Signal and Systems are multifaceted:

- The course gives basic knowledge about signals as abstract description of natural phenomena and deals with these phenomena by their description by mathematical systems of equations.
- Learn students to abstract thinking and formulate the engineering task as mathematical problem which can be solved by means of different, appropriate selected tools. With other words, at the first time they are learned how in praxis they will be able successfully solve different problems and tasks.
- They will receive basics skills for use MATLAB particularly and an appropriate tools in generally in their further study and of course in their profession.
- The teaching and learning methodology introduced by this course will serve as an example in evolution and renovation of other courses in preparing to implementation so called Bologna program.

The goals of the course are accomplished through topics introduced in the class schedule, see Table 1.

### 2.1 Teaching methodology

In preparation of a teaching and learning methodology the methodology called "Learning-by-doing" is have been considered. That methodology facilitates continuous acquiring of knowledge in addition to students challenging for self-supporting solutions of problems. To motivate students to actively participate in new teaching and learning paradigm we take next measures:

- 1) We give altogether nine homework assignments per course which each have two parts. The first parts has classical task and the second parts have continuous acquiring of knowledge for continuous engagement of students in classroom through discussion with lecturer and

week	class	topics
1	1,2	<ul style="list-style-type: none"> <li>• Concept and categorization of signals</li> <li>• Characteristic types of signals (continuous, discrete and digital, stochastic)</li> <li>• Mathematical models of typical signals</li> </ul>
2	1,2	<ul style="list-style-type: none"> <li>• Fourier analysis (Fourier transformation of continuous and discrete signals, Properties of Fourier transformation, Parseval theorem)</li> </ul>
3	1,2	<ul style="list-style-type: none"> <li>• Sampling theorem and sampling process</li> <li>• Signal spectra</li> </ul>
4	1,2	<b>Intermediate exam</b>
5	1,2	<ul style="list-style-type: none"> <li>• Concept and categorization of systems. Continual and discrete systems. Properties of systems.</li> </ul>
6	1,2	<ul style="list-style-type: none"> <li>• Response characteristics</li> </ul>
7	1,2	<ul style="list-style-type: none"> <li>• System description (differential and difference equation, state space model, graph presentation)</li> </ul>
8	1,2	
9	1,2	<ul style="list-style-type: none"> <li>• System description in complex domain (Laplace and z-transform)</li> <li>• Transfer function of continual and discrete systems. Algebra of transfer function</li> </ul>
10	1,2	<ul style="list-style-type: none"> <li>• Frequency characteristics of continual and discrete systems</li> </ul>
11	1,2	<b>Intermediate exam</b>
12	1,2	<ul style="list-style-type: none"> <li>• Filters (types and features, analogue filters, digital filters)</li> </ul>
13	1,2	<ul style="list-style-type: none"> <li>• Analog filter design using MATLAB tools</li> </ul>
14	1,2	<ul style="list-style-type: none"> <li>• Digital filter design using MATLAB tools</li> </ul>
15	1,2	<b>Intermediate exam</b>

Table 1: Signal and system course - topics

other fellow-students about elaborated topic and through their active participation in solving problems on exercises classes.

2) We set a server where students could form web discussion forum for exchange of their opinions, ideas, questions and answers concerning to lectures, solving of home works, and preparing of exams.

3) Interactive web-based tools (many of them for Signal and System and DSP courses available on the web) enable dynamic visualization and user interaction, allowing students to actively engage with the tools and enjoy an enhanced learning experience.

4) Students could contact and their lecturer or lecturer assistant by e-mail (if somebody of them have problem with public discussion in classroom or at web forum).

5) Availability of lectures, laboratory exercises, homeworks, projects and necessary software on the Faculty Web site provides virtual classroom for students anywhere and anytime (Virtual classroom laboratory)..

Classes of written exercises and MATLAB exercises follow lecture classes every week. Computer-based laboratory exercises created by MATLAB software facilitate students by system design skills without special prerequisites beyond programming skills.

All materials - lectures, solved and unsolved problems related to topics of course, MATLAB tutorial, MATLAB solved problems, web-based tools like as interactive Java applets and homework assignments available for students

at home page of Signals and systems course. Solutions of homework assignments and exams are also available on the web after deadline.

Examining methodology (homework assignments, intermediate exams, the project at the end of the course) facilitates continuous evaluation of student knowledge and evaluation of different student's skills (theoretical through the exams and practical through the project) [9].

Students have nine homework assignments per course. Three homework assignments are providing before each of three intermediate exams. Homework assignments consists several tasks. Some of tasks encourage students to use MATLAB and interactive web tools for solving problems. Through preparing and writing intermediate exams students efficiently accomplish in particularly topics, but also in complete course because every next intermediate exam has questions from previous topics. Particular exams consist of two parts: quiz on general knowledge from specific topics, that student have to pass for writing part of intermediate exam. Writing exam has for tasks, out of which three are related to the most recent course topics and one is related to an older one.

The project is anticipated at the end of course and contains all course topics. It is complex task that fosters students' mind by demand of connecting of his theoretical and practical skills. Building of project implies appliance of MATLAB solution. During the building of project discussions between students on the web forum and also in small groups where one advanced student or lecturer assistant is tutor are recommended.

At the end of course also final exam expected for those students who not satisfied with mark gained based on their homeworks, intermediate exams and project. Final exam also expected for those students who didn't pass all these preexam engagement.

### 3. MATLAB AS UNDERLAYING TECHNOLOGY IN SIGNAL AND SYSTEM COURSE

The usage of MATLAB as a computational tool is international. It allows so many theoretical concepts to be easily implemented.

MATLAB should be use throughout the course in signals and systems to complement and simplify various computational aspects of the theory.

The usage of MATLAB in this course is to generate computer implementations of the techniques for signal and system analysis and synthesis. Assignments of computer exercises in parallel with traditional written problems can help students to develop a stronger intuition and deeper understanding of signals and systems theory.

Many MATLAB solutions for every topic of the course in signal and systems are available on the Web and also in the latter book for signals and systems. MATLAB raises programming to a data-processing abstraction, thus minimizing the dependence on strong coding abilities to get results [7].

A very good theoretical base for using MATLAB can be found in the HELP menu of MATLAB as well as in on-line user's guides for certain MATLAB toolboxes.

MATLAB offers wide range of toolboxes that perform specialized tasks by usage of predefined functions. Three toolboxes are particularly appropriate in the study of signals and systems: the control system toolbox, the signal processing toolbox and the symbolic math toolbox. Student can get explanation and deeper understanding of some physical process by using predefined functions from toolboxes and writing only few code lines with minimal programming skills. Consequently, creating MATLAB exercises for this course isn't big problem. For example:

For the topics covered with classes in first week MATLAB inline objects are convenient as symbolic representation of a function i.e. signal in time domain.

By using MATLAB command  $C=CONV(A,B)$  that convolves vectors A and B we can effectively illustrate convolution process.

The calculating of Fourier series coefficients can be mathematically complex even for simple periodic signals. Symbolic Math Toolbox highly simplifies that calculating. By executing of command  $FFT(X)$  MATLAB computes the discrete Fourier transform (DFT) of the vector X.

Reach set of predefined functions for time domain analysis and frequency domain analysis of both continual and discrete linear time invariant systems (LTI) is available in the control system toolbox. LTI Viewer is a graphical user interface (GUI) that simplifies the analysis of linear time-invariant systems. You can use the LTI Viewer for design tasks to specify both time and frequency domain requirements in analysis plots. Control toolbox contains tools for classical design of control systems (root locus design) and also modern techniques such as state space modelling and pole placement design.

MATLAB has toolbox for filter design which specified as one topic in Table 1. With this toolbox we can easy design as analog so digital filters. Characteristic functions for filters design are: BUTTORD, CHEB1ORD, CHEB2ORD and ELLIPORD. All mentioned functions calculate minimal order and cutoff frequency of a digital or analog filter for required designed specifications of some filter. Also, we can convert analog to IIR (Infinite Impulse Response) digital filter by using command BILINEAR or IMPINVAR for bilinear or impulse invariance method for transformations, respectively. For design FIIR (Finite Impulse Response) digital filters we can use windows functions as HANNING, HAMMING and BLACKMAN. All functions return the N-point symmetric adequate window as a column vector. For example, FIR1 function implements the classical method of windowed linear-phase FIR digital filter design and REMEZ designs a linear-phase FIR filter using the Parks-McClellan algorithm. FIR1 designs filters in standard lowpass, highpass, bandpass, and bandstop configurations.

For the course topics specified in Table 1, numerous MATLAB examples are in textbooks that provided for students who study signals and systems [1], [2], [3], [4], and [6]. Many MATLAB solutions for teaching and learning signals and systems we can found on the Web. Some of them we will use for improvement of our course in Signals and Systems. A short overview for four MATLAB tools is given in the next section.

#### 4. MATLAB AS UNDERLAYING TECHNOLOGY IN SOME COURSES IN SIGNAL AND SYSTEMS

As Signals and Systems classical course at all electrical engineering departments there are many especially created MATLAB supported tools for interactive learning and of signals and systems. Most of them available at home pages of these departments.

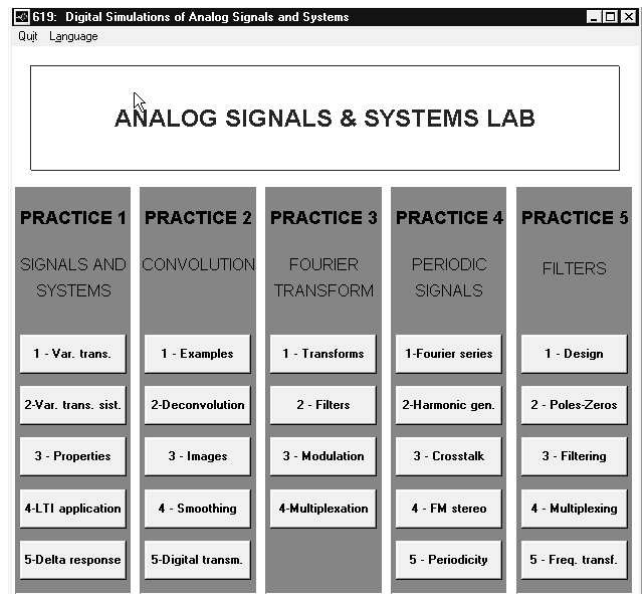


Figure 1: First window of the program for graphical exercises in Signals and systems [17]

Simulation software developed by Gasull, Sayrol, Salavedra, Moreno and Vallverdu [17] is devoted to the practical study of analog signals and systems.

The program exhaustively exploits the graphical tools provided by MATLAB to obtain a user-friendly environment. It can be used as a self-instruction teaching material. On the other hand it contains a complete and very large set of graphic exercises that makes it unique First window of the program showed in Fig. 1.

Control Tutorials for MATLAB [18] designed to help you learn how to use MATLAB for the analysis and design of automatic control systems. They cover the basics of MATLAB, the most common classical control design techniques (PID, root locus, and frequency response), as well as some modern (state-space) control design. The (Fig. 2): each tutorial is a white box. There are also four examples which are followed through the tutorials (each example page is indicated in the image map by a blue dot).

The SSUM (Signals and Systems Using MATLAB) [19] package is a collection of demonstrations and exploratory applications programmed in MATLAB to illustrate important, insightful, and inspiring concepts of media signal processing, using audio, image, and video.

Lecturers from Electrical Engineering & Computer Science University of California, Berkeley, developed a set of laboratory exercises based on MATLAB and Simulink for a new introductory signals and systems course at Berkeley [20]. The purpose of these exercises is to help reconcile

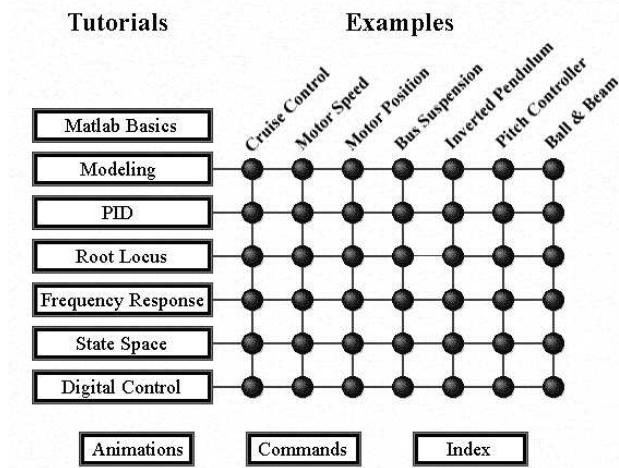


Figure 2: The map of Control Tutorials for MATLAB [19]

the declarative (what is) and imperative (how to) points of view on signals and systems.

## 5. CONCLUSION

The richness of MATLAB solutions and interactive tools for signals and systems study is very applicable for suggested teaching and learning methodology called learning-by-doing.

Relevance of the usage of MATLAB as underlying technology also in realization of different engineering courses in general is about changing methodology of engineer work - Using of modern tools for simulations and modelling is a change of stereotype of classical engineer work. Engineers with MATLAB programming skills will be able to coordinate the projects in different engineering fields.

By suggested teaching and learning methodology the control of learning is passed from teachers to students, students interest in engineering is aroused and motivation for learning is increased.

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