

THE USE OF MATLAB AND SIMULINK IN SIGNAL AND SYSTEM THEORY COURSE

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Abstract

Since the vast majority of topics in Signal theory, a new course in the first grade of Cybernetics and Robotics bachelor programme on Czech Technical University in Prague, are completely new for students, Matlab and Simulink environment has been chosen to get rid of fear of complicated topics and to teach the skill and easiness of the use of theoretic formulas. After introducing the basic theoretic background and solving simple examples to “believe the formulas”, students fluently proceed to verify the results in the Matlab and Simulink and create more difficult and interesting problems. They create their own scripts and enjoy audio and image processing. This paper shows some examples of interesting tasks solved in Matlab and Simulink to serve as an inspiration for similar courses on technical oriented universities.

1 Introduction

Signal theory, a new course in the first grade of Cybernetics and Robotics bachelor programme, has been created on Faculty of Electrical Engineering on Czech Technical University in Prague this year. The course introduces a theory of non-linear and linear systems including a state space approach and linearization process and a theory of continuous and discrete signals. It explains basics of Fourier series and transforms, Laplace transform, Z-transform, Bode and Nyquist plots, analog and digital filtering. It also shows basic applications such as audio and image processing, correlation etc.

Since the vast majority of these topics are completely new for the first-grade students and some subjects like Laplace transform are excluded from math courses in the reconstruction of the new study programme, it is full responsibility of the Signal theory course to teach the theoretic background, elementary calculations but also the use of these techniques on more complex problems. For that reason, the Matlab and Simulink environment has been chosen to get rid of fear of complicated topics and to teach the skill and easiness of the use of theoretic formulas.

After introducing of the basic theoretic background and solving simple examples to “believe the formulas”, students fluently proceed to verify the results in the Matlab and Simulink and create more difficult and interesting problems on the computer. While differential equations are solved via Symbolic Math Toolbox, the Simulink is used for numerical analysis of linear and also non-linear differential equations with initial conditions and external sources presenting e.g. oscillations of pendulum in a wind created by force of a ventilator.

Students create their own scripts and enjoy audio and image processing in Signal Processing Toolbox and Image Processing Toolbox. The Symbolic Math Toolbox is also used for Laplace and Z-transform. Fourier transform, Bode and Nyquist plots and digital filtration are processed in the Signal Processing Toolbox. Edge detection in images or shift detection and summation of large amount of pictures of the same subject in a noise via correlation serve for additional motivation for following courses in higher grades. The Matlab and Simulink greatly helps to teach so many important topics in such a short time.

This paper shows some examples of interesting tasks solved in Matlab and Simulink to serve as an inspiration for similar courses on technical oriented universities.

2 Simulink Simulations – Pendulum in Windy Conditions

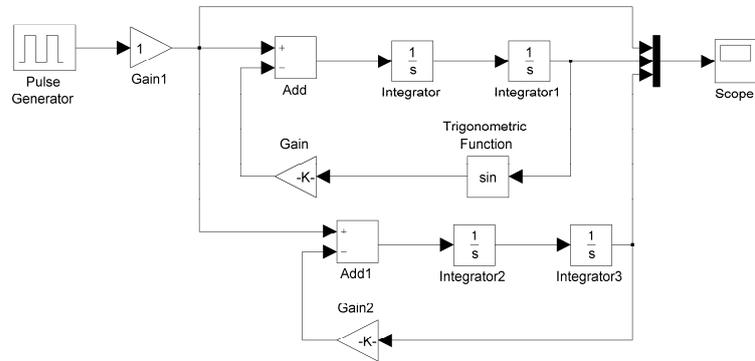
The Simulink is used as a tool for numerical solving of differential equations describing systems. As an example of continuous system, an pendulum with external source of force, wind created by force of a ventilator, was chosen (Fig. 1a). Students analysed differences in the response (angle of the pendulum) of non-linear

$$\ddot{\theta} + \frac{g}{l} \sin \theta = \frac{T_C}{ml^2}, \quad (1)$$

and linearized (for small deviations)

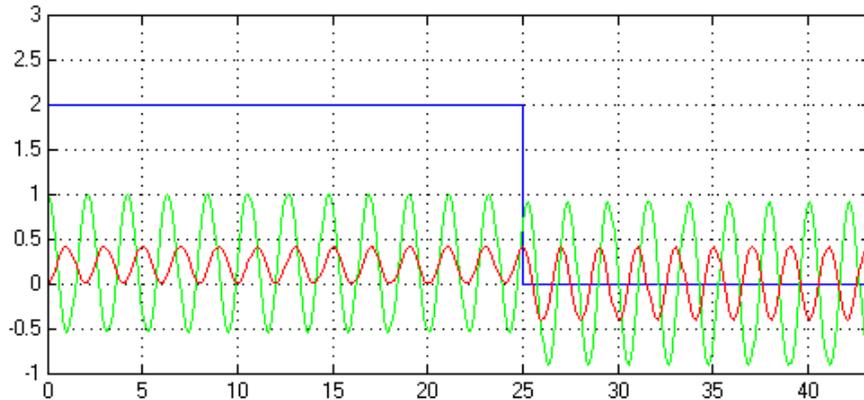
$$\ddot{\theta} + \frac{g}{l} \theta = \frac{T_C}{ml^2} \quad (2)$$

models (Fig. 1b) to different inputs, where θ stands for angle of deviation, m is weight and l is length of the pendulum, g is gravitational acceleration, T_C is total external source moment. The output oscillations of non-linear and linear models have different frequencies. When the external source of moment is present, the oscillations are biased (Fig. 1c).



(a)

(b)



(c)

Figure 1: Pendulum in windy conditions, (a) situation scheme, (b) Simulink scheme both for non-linear and linear model, (c) simulation results.

3 Matlab

Students make their own scripts in Matlab for digital signal processing and basic familiarization with Fourier, Laplace and Z-transform.

3.1 Fourier Synthesis and Analysis

For spectral representation of signals [2], students model a sound of organ by summation of three harmonic components. Tones sorted in a scale are analysed and displayed via spectrogram and played as an audio. A function of the first harmonic for the tone pitch recognition is emphasized in the lecture, higher harmonics make a color of the tone.

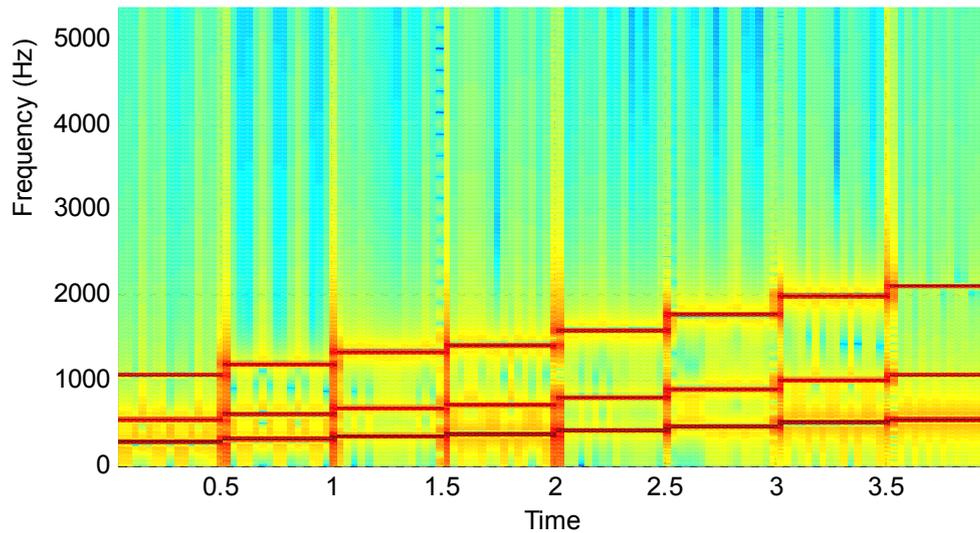


Figure 2: Spectrogram analysis of organ audio.

3.2 Laplace Transform

After easy manual calculations of Laplace transform [1], students begin more complicated computations in Symbolic Math Toolbox. However, it is shown that unpremeditated inputs can lead to misleading results. In order to find the Laplace transform of time-delayed exponential function, one can input wrong formula automatically assuming conditions which has to be explicitly entered into the Matlab. As shown in the Fig. 3, only the third variant leads into the expected result

$$\frac{1}{s+a} e^{-st_0} \quad (3)$$

```
clear all
syms t t0 s a

laplace(exp(-a*(t-t0)), t, s)
laplace(exp(-a*(t-t0)) * heaviside(t-t0), t, s)
t0 = sym('t0', 'positive'); laplace(exp(-a*(t-t0)) * heaviside(t-t0), t, s)
```

Figure 3: Two incorrect and one correct way of finding the Laplace transform of time-delayed exponential.

3.3 Correlation Analysis of Noisy Pictures

To demonstrate the power and abilities of correlation function [4], large number of realizations of randomly shifted image in noise were generated (Fig 4a). In the second step, the shifts were detected via the 2D correlation function, pictures were aligned and summed in order to suppress the noise (Fig 4b).

3.4 Digital Filtration

At first, students filter audio signals in order to understand the low-pass, high-pass, band-pass and band-stop terms. Next, they filter electrocardiogram (ECG) with power supply noise (50 Hz) with many types of digital filters and learn the IIR filter can damage the shape of the signal due to the non-linearity of phase spectrum which can lead to incorrect medical interpretations of the heart function.

At last, they use filters in image processing in order to detect edges of the picture [3]. Sobel edge finding operation described in the Matlab help of conv2 function was used to demonstrate the technique (Fig. 5).

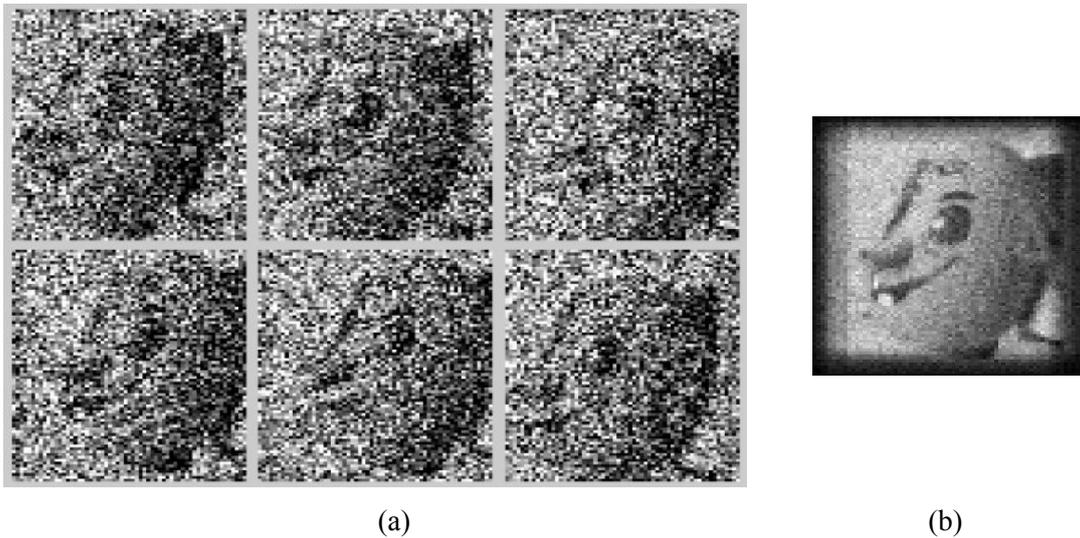


Figure 4: (a) Six realizations of randomly shifted image, (b) reconstruction from 36 realizations.



Figure 5: Edge detection – 2D filtration of figure 1a.

4 Conclusion

This paper shows the use of Matlab and Simulink to motivate students in Signal and Systems oriented lectures.

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