Teaching signals — making it automatic, making it fun *

Jan Černocký and Petr Lampa

Faculty of Information Technology, Brno University of Technology
E-mail: cernocky@fit.vutbr.cz

Basis of signal processing are important part of electrical engineering and computer science bachelor curricula. This paper describes 1. some ways to make the lectures in signals more tractable and accessible to students, 2. a method for automatic generation, checks and evaluation of individual student's projects.

1 Introduction

A course or series of courses on signal processing, systems, etc. usually takes place in the 1st or 2nd year of engineering curricula at schools of information science and electrical engineering. Typically, these courses are not among the most loved by the students, mainly due to a heavy mathematical load (complex numbers, Fourier transforms, statistics). Often, the teachers themselves are partly responsible for this attitude, as they are presenting quite complex mathematical subjects without taking into account that students must be able to "imagine" things in order to understand them. Section 2 of this paper gives some ideas on how to make at least some points in the signal processing course more funny and more tractable.

Section 3 concentrates on another aspect — as these courses are often taught in the Bc. study programmes, they involve "masses" of students. An important part of such course is an *individual project*. In a group of, say, 330 students (which was the number at our faculty in fall semester 2004/05), it is however hard to assign each student an individual project and to evaluate it one-by-one. Assigning one single project for everyone is not a solution too, due to a high risk of plagiarism. Section 3 presents our solution.

Further details (lecture slides, project) can be found on the web pages of signal processing course ISS at FIT (in Czech) [1].

2 Fun in teaching of signals

The courses of signal processing are usually full of equations, among which the students quickly loose orientation and interest. The aim is not to limit the number of equations and convert the lectures to business presentations but rather to make the equations more human, funny and easy to understand. This section presents three examples of such "humanization" of signals, though more would be needed, especially in parts concerning Fourier transforms, Fourier series, etc.

*This work was partially supported by Grant Agency of Czech Republic under project No. 102/05/0278. Jan Černocký is supported by post-doctoral grant of Grant Agency of Czech Republic No. GA102/02/D108.

Figure 1: Complex bottle.

2.1 Complex bottle

Students have typically problem to imagine, how a cosine can be written as a sum of two complex exponentials:

$$C_1 \cos(\omega_1 t + \phi_1) = \frac{C_1}{2} e^{j\phi_1} e^{j\omega_1 t} + \frac{C_1}{2} e^{-j\phi_1} e^{-j\omega_1 t} \tag{1}$$

Here, the complex bottle shown in Fig. 1 can bring some help. The 3D-structure that can be easily made of a PET bottle, 3 wires and a tape can help students understand what is the complex function e^{jx} with varying x, what is changed if we vary the magnitude and period of this exponential, and how adding a complex constant $e^{j\phi_1}$ pre-rotates the signal. It is also easy to show that the $\Re$ part of this exponential is a cosine (turn the bottle so that positive $\Im$ axis points to you), $\Re$ part of this exponential is a sine (turn the bottle so that negative $\Re$ axis points to you) and that the point e^{jx} is always on the unit circle (turn the negative x axis to you).[1]

In the lecture on complex numbers, we usually let circulate 4 complex bottles in the lecture room to a great pleasure of students.

2.2 Linearity

Were the famous equations describing linearity of a system:

$$\text{if} \quad x_1(t) \to y_1(t) \quad \text{and} \quad x_2(t) \to y_2(t) \tag{2}$$

$$\text{then} \quad ax_1(t) + bx_2(t) \to ay_1(t) + by_2(t) \tag{3}$$

clear to you in 1st or 2nd year of engineering studies ? If not, try to look at Fig. 2. A man drinking alcohol is a system, the system's response to one one beer is a small smile. The response to one rum are slightly red ears. If the input of the system are 3 beers and 3 rums, and the system is linear, the response would be a smiling guy with dark-red ears. In case the person is green and possibly vomiting, the system probably was not linear.

2.3 Circular shift

of a discrete signal:

$$x[n] \longrightarrow R_N(n) x[\mod_N(n-m)] \tag{4}$$

is not popular too, as it involves indexing by a modulo function and a post-multiplication by a rectangular window. Though, it's an important function, as the circular convolution

[1] The wires are sharp, so don't push or use chewing gum to secure their extremities :-)

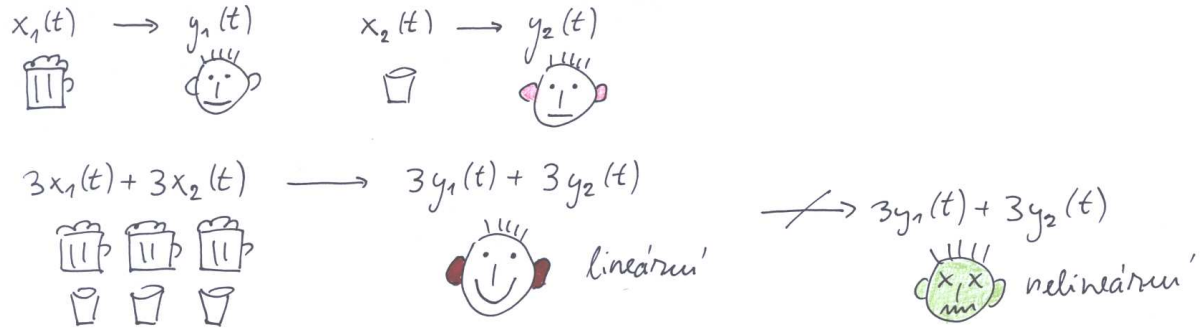

Figure 2: Linearity.

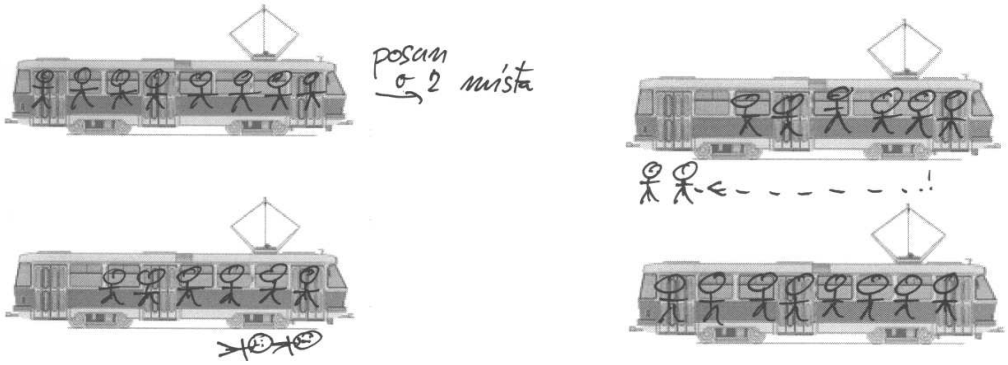

Figure 3: Circular shift.

makes use of it. It can be demonstrated on the example of a full tramway (Fig. 3), where the conductor asks people to move by two persons to the right. Obviously, the two unfortunates will fall out of the front door. They will however immediately climb to the rear one, so that the tramway is again full of people, only the positions have changed.

3 Automating the projects

The project in our signal processing course ISS [1] concentrates on sampling (effects of down-sampling) and random signals (statistical parameters, processing by a linear system, spectral densities) in Matlab. The students are first asked to go through a "study part", where they are given the text, exercises and questions but also a reference solution.

The second part is a test: a system based on Matlab-scripts generates a unique waveform and question-sheet for each student (Fig. 4). To allow students debug their Matlab code, an example question sheet with associated waveform and with reference answers is provided.

Each student enters the answers (yes/no, float values) into the faculty information system [2]. They are then automatically compared to the reference solution (with margins of course). Results are automatically e-mailed back to students and recorded in the evaluation tables in the information system.

4 Conclusions

The first part of the paper describes some ways to make signal processing education more friendly and more fun. The reaction of the students in lecture hall and in the

Your personal signal is xpokor20_11756.wav. Read it in Matlab.

1. What is the length of the signal in [s] ?
2. Determine the maximum frequency in the spectrum of the signal.
3. In case we down-sample with a factor of 2, will we have to cope with aliasing ?
4. Down-sample the signal with a factor of 2. On which frequency is the maximum of the spectrum ?
5. What is the power of the signal related to one sample ?
6. Consider the signal to be one realization of a random process. Determine its standard deviation.
7. Estimate the distribution function and probability density function and estimate the probability that the value of the signal is lower than -0.102555.
8. What is the probability that the value of the signal is in the interval [-0.102555, 0.563248].
9. Perform the unbiased estimation of the first auto-correlation coefficient $R[1]$.
10. Determine the frequency, where the power spectrum density of the signal is maximum.
11. Process the signal by a filter $H(z) = 1 - 0.9z^{-1}$. Determine the magnitude of frequency response of this filter at the frequency determined in question 10.
12. Determine the phase of frequency response of this filter at the frequency determined in question 10.
13. What is the ratio of power spectral densities at this frequency before and after filtering ?

Figure 4: Question sheet for the project.

questionnaires collected at the end of the course were positive and strangely enough, ISS (though still full of equations) has quite a good reputation in the Bc. study programme at FIT.

After automation of exams (one-choice forms and processing the results by a scanner and Perl-scripts), the automation of individual projects was a natural step to make ISS teaching more efficient. This year's experience has shown good results of students in the project and there were no negative reactions. Rather than correcting 330 projects by hand, the spared time of staff can be devoted to more intelligent things like individual consultations with students or research. We find this approach also quite suitable for distance education.

References

[1] Web pages of signal processing course ISS at Faculty of Information Technology, VUT Brno: `http://www.fit.vutbr.cz/~cernocky/sig/`.

[2] Information system of Faculty of Information Technology, VUT Brno: `https://wis.fit.vutbr.cz/FIT/`