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Ye.A.Gayev Dr. Eng. Sci., Prof. (*National aviation university, Ukraine*)
K.Khavray student (*NAU, Ukraine*), *A.Skoroded student* (*NAU*)
A.Linnick student (*NAU*), *O.Boiko student* (*NAU*),
D.Malinina student (*NAU*), *A.Baboriga student* (*NAU*)
M.Borosentsev student (*NAU*), *P.Karengin student* (*NAU*)
V.Kalmykov student (*NAU*), *A.Rychik student* (*NAU*)
Yu.Simakin *student* (*NAU*), *T.Pruss student* (*NAU*)

Digital Laboratory of Information Processes Theory: an innovative educational approach

An innovative approach to teaching Information Processes Theory is suggested that lies in intensive exploitation of mathematical and programming environments like MATLAB and Java that enhance student's understanding of each problem by easy programming it and by their simulation and learning with easy programs made by students. Measurement of information quantity, entropy of transmission channels, learning conditional probabilities, simulation of coding and decoding, code transfer in noiseless channels as well as coding in noised channels are discussed.

1. Motivation. Aim of the work. Teaching of Information Processes Theory, a significant subject in education experts in modern information technology, is based on old textbooks like [1-3] in Ukraine and many other countries. Despite their authors are very famous because of their significant contribution to the subject in the past, the textbooks do not account the drastic progress in computation during this period, appearance, for example, power leading-edge computation packages like MATLAB, MatCAD etc. The same concerns more resent popular books [4], etc. This lies in contradiction with recent pedagogical methodologies like Discovery-Based Learning [5,6] the main idea of which is to encourage students to find the answer themselves and, possibly, reproduce original discoveries in the subject. First author propagates and develops such approach in [7] and in many other publications. This is a first attempt to demonstrate results in general Information Theory, Coding and Code Transfer [1-4,8-10]. These results were obtained in close cooperation between the first author and the most active third-year students of National Aviation University who are equitable authors of this paper.

The general Information Theory was created during past 65 years from about 1930 till the end of the last century [1,9]; its formation completely supplemented the rise of the modern computer technology and communication means. The task of our education and research group, entitled in the list of authors, was to reproduce main problems and discoveries in the mentioned discipline by means of easy programming them in MATLAB or/and in Java. This methodology focusses students to the problem, stimulates them and provides instrumentations for further experimenting with the problem. Corpus of those programs and gathered experience forms the Digital Laboratory entitled in this article.

There were some physical laboratories in National Aviation University in the past where students were able to measure practically, for example, probability properties of a noisy transmission channel, error correction ability of codes, etc. [10].

It is sad to say that we do not have such laboratories. That is why it is our hope that this our work will be useful to our university and to others.

2. Measurement of information quantity, that for transmission channels. Research starts from more advanced entropy calculation of an alphabet with *m* symbols by means of MATLAB commands from its Command Window

>> *p*=[*p*1, *p*2, . . ., *p*m]; %entering probabilities of symbols
>> *H*=-*sum*(*p* .* *log*2(*p*))

that uses so called 'matrix philosophy' of MATLAB. They are worth to incorporate into MATLAB program *Entropy.m*. The later may be generalized to *ChannelEntropy.m* to forecast all three sorts of conditional entropies of data transmitting channels. Original investigations of frequencies of natural language symbols (English, Ukrainian, Russian) [1] may be easily reproduced at this stage, if students develop simple programs that analyze texts. Some results demonstrates Fig. 1. Similar, frequency of double or even triple combination of symbols may be analyzed and demonstrated by means of 2*d* or 3*d* mattresses.

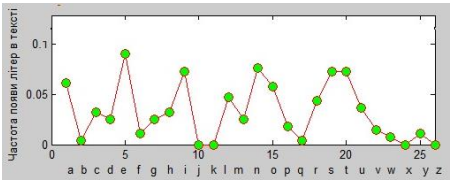

Fig. 1. Frequencies of English letters in long texts

3. Simulation of coding and code transfer in noiseless channels. Coding is a crucial technique in Information Processes Theory. MATLAB's data types *struct* and *cell* allow to freely work with text data alike *char*[ ] in Java. Simple programs were developed that substitute message characters to a set of others encrypting them in such a way. Coding messages into Morse alphabet, for example, is demonstrated in the Fig. 2. One may see a text message encoding there. Similar, return convert is possible. Fragment of symbol correspondence set is seen as well. A special button ♫ converts Morse text into sound.

Especially important are binary codes. It is no problem in developing similar programs for binary encoding, but decoding programs require some sophisticated logics to realize, especially in the case of inhomogeneous codes. This concerns also Shannon–Fano and Huffman coding for which programs were suggested as well. It may be exciting to exchange coded messages through modern transmission devices. For this, a Java program was suggested and tested that links mobile phone with notebook, or two mobile phones.

4. Learning conditional probabilities. Conditional probabilities are the main theoretical instrumentation of the information science. For corresponded problems a reliable generator of occasional number set with given probabilities is required. A special student projects were devoted to this. One of programs *RandIpi*1*pi*2*pi*3*.m* or *RandIpi*1*pi*2*pi*3*.java* generates occasional numbers 1, 2 or 3 with probabilities *p*1, *p*2 and *p*3 correspondingly (*p*1+*p*2+*p*3=1). This allows to simulate, as an example, the

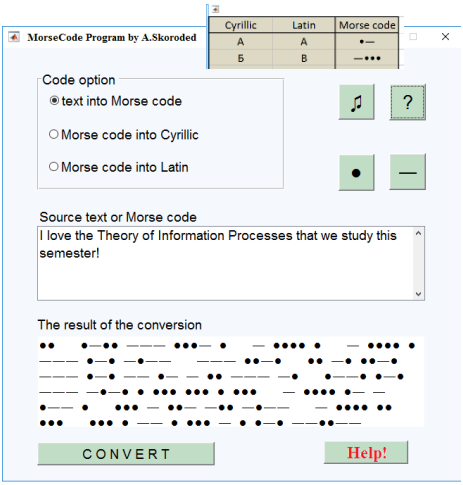

Fig. 2. GUI-program of coding by Morse alphabet and back along with Morse character set fragment

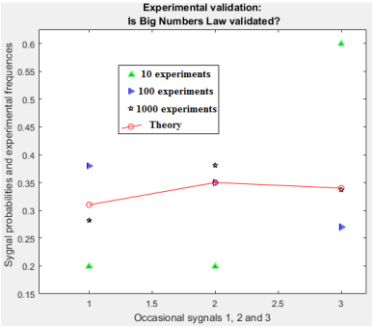

Fig. 3. Computer experiments validated a two cascade conditional process

following rather unevident problem: let First Cascade of an occasional process generates those numbers with probabilities p_{10}, p_{20} and p_{30}; there are three other generators in the Second Cascade characterized with nine probabilities $\{p_{11}=p(1\backslash 1), p_{21}=p(2\backslash 1), p_{31}=p(3\backslash 1), p_{12}=p(1\backslash 2), p_{22}=p(2\backslash 2), \ldots, p_{23}=p(2\backslash 3), p_{33}=p(3\backslash 3)\}$. What is the statistical relation between occasional events of the First and Second Cascades? MATLAB- and Java-programs were designed by coauthors that 'play' this game and manifested the Big Number Law of the 'Full Probability' formulae. Fig. 3 demonstrates theoretical forecast of 1-, 2- and 3-appearance probabilities in the Second Cascade (red line) with experimental frequencies of that obtained as result of 10, 100 and 1000 experiments. One may see 'convergence' experiments to theory.

Similar programs *RandI_pi*1.*m* and *RandI_pi*0.*m* were elaborated that produce occasional binaries 1 (*true*) and 0 (*false*) with probabilities, correspondingly, $p1$ and $p0$ to be used in next section.

5. Coding in noised channels. The problem is here to observe correlation between messages being send and those received provided that 'noised' binary transmission channel is characterized by conditional probabilities $p_1=p(1/1)$, $q_1=p(0/1)$, $p_0=p(0/0)$ and $q_0=p(1/0)$ where $p_1+q_1=1$, $p_0+q_0=1$. Graphical MATLAB-program realizing such task is demonstrated in the Fig. 4.

The problem of 'clever codes' is considered that lies in deliberate use of code redundancy to develop error-detecting and error-correcting codes. Special intermediate programs were developed to analyze transmitted codes by one of known methodologies, correct errors and supply messages further to recipient. This allows to simulate visually those different techniques.

Conclusion. Collection of programs, some of which were briefly discussed over, forms the 'Digital laboratory' that illustrates main topics of the "Information

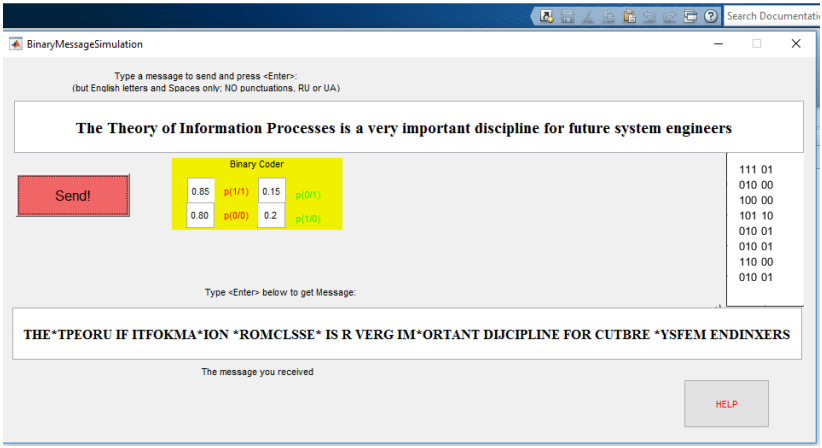

Fig. 4. Simulator of a transmission channel with binary noise in action

Processes Theory" and facilitate mastering the latter. Besides, development of particular program by student focuses her or he to corresponded technology thus making it more clear. Such Discovery-Based Learning [5,6] seems to be the most effective education methodology.

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