Description
demo versions of the program MPDDEMO-2016,
illustrating the principles of the multithreshold decoder (MTD) work.

The program is an exe-module that is running with the Windows OS, which showcases the work of multithreshold decoder (MTD) in the case of its use to decode a block code of length n=2 000 bits with code rate R=1/2 and minimum code distance d=23.

Before running the program, you must first unpack the standard software zip-file, rewritten from the first page "About the method" of the website ***www.mtdbest.ru*** . Disk memory is less than 100 Kbytes.

After that, the program may be launched by double-clicking at the **mtddemo-2016.exe** module.

The program simulates the continuous transmission and subsequent decoding an infinite sequence of code blocks and can be completed at any time, as usual for Windows applications, by clicking on the "**x**" in the upper right corner of the screen window.

To choose suitable for monitoring the work principles of the decoder, repeatedly pressing "g" ("greater") to accelerate its work and press "l" ('less") (both English register) to slow the operation of the model.

The work of the demoprogram begins with the formation at the display screen of three colored blocks of data arrays, each of which consists of 1000 squares corresponding to the binary data of the received code, in the information and check symbols which contain exactly 1000 bits. The first upper block called "**difference**" is a control array and its role will be visible in the further description.

The demo program begins its work by simulating data transmission over a noisy communication channel. First, the middle 1000-bit information block named "**information**" is filled in. The fill color of the respective squares is changing during data transmission. Errors in the transmitted information bits are marked in red.

Then comes the filling of the received check bits of the lowest array at the screen named "**Syndrome**". Transmission errors in its check characters are marked in blue.

Then, as is always done in the linear codes, syndrome of the received message is calculated. It is necessary for error correction, because it fills the zeros and ones which only depend on the errors of the code block. The result of the calculation is stored in the lower "**syndrome**" block. The syndrome "1" defined by errors in the check symbols still remain blue. And those "1" of the syndrome, i.e. the squares of the lower data array, which have appeared due to errors in information symbols, are

colored red. Thus, from the presentation of the syndrome array before the decoding process, it is clear that the main number of "1" in the syndrome array is associated with errors in the information symbols of the code, which must be corrected.

After calculating the syndrome, the main reusable attempt to decode all the information symbols of the code begins. The purpose of decoding is to correct all information errors in the middle array of the demonstrating picture, with a high level of noise in the channel. In the proposed version of the demodecoder, the transmission is simulated at a very high noise level of a binary symmetric channel without memory (BSC) with an average error probability of about 0.06. This is a very high probability of error for the code rate R=1/2, inaccessible to the algebraic codes decoders and to decoders working according to the Viterbi algorithm (VA) and to sequential decoders for convolutional codes..

The decoder discussed below, as it can be seen from the final results of its operation, does not make any errors even at the selected very high noise level. It corrects all errors after no more than 10 consecutive attempts to correct the information. But the absence of final errors for a long, but very limited period of the decoder work in this demo is not proof of its always error-free operation. Thus, the demo version offered to the attention of specialists cannot be used for a collection of the MTD algorithm error statistics even for given specific parameters of the channel model. This demo movie only illustrates a successful process of strict movement sequence MPD solutions to the decision of the optimum decoder (OD) every time at change the decoded information symbols of the code.

The purpose of settings made in the model of demodecoder is to illustrate the importance of precise selection of the parameters of all circuit elements of the decoder, which only can ensure success in implementing the idea of multiple updating of the decisions to the decoder that implements the MTD algorithm. We also emphasize that the code used in the MTD must also be built in accordance with all strict requirements and restrictions, providing a minimum level of error propagation (EP) in majoritarian decoding schemes.

Consider the main process of decoding. It begins with the appearance of one black square in the middle information register and more than twenty of the same squares (cells) in the lower syndrome register. This is the place of the information symbol from which the error correction process begins. In the future, the squares moving along the information array correspond to the next information symbol selected for this decoding step, for which the MTD calculates the usual sum of zeros and ones on the threshold element according to the checks that are marked black in the syndrome array. Information characters, all related checks, character in the upper array "**Difference**" relating to the character being decoded, are always inverted (0 -->1 and 1--> 0), if the number of "1" on the threshold element inputs are greater than the number of zeros. After that the threshold element (TE) is shifted to the next decoded symbol. It corresponds to the transition to a new group of checks relative to it, etc. Due to position movement of the decoded symbol, the background color tones

of the middle register change, which allows us to distinguish already decoded symbols from those that have not till been changed.

After each change of the information symbol in the middle register in the upper control register "difference" it is marked in white, if the decision of the threshold element (TE) was correct, and green, if it was wrong. If an incorrectly changed symbol on one of the next iterations has been corrected again, the color of the corresponding cell is again changed to the background color for this array. Because the contents of the checks for each decoding symbol in the syndrome array is also changed (inverted) every time, if the information symbol of the code is corrected, then when the successful promotion of the decoding process, mainly the colors of the syndrome red cells is modified in a background color, although sometimes there are other color changes.

The decoding process is accompanied by dynamic control of its parameters, which are displayed in the block of current values of decoding processes in the lower right corner of the screen. The number of the decoded block, the iteration number, and the current distance of the MTD decision to the received message are shown. The last parameter is the key for the MTD algorithms and in accordance with the basic theoretical provisions of the Optimization Theory (OT) on the MTD properties, it only decreases at all stages of decision-making on decoded symbols. Strict monotone decrease of the distance of each new decision of MTD about the next decoded symbol is proven in the Main theorem of MTD. This is true for the entire code block as a whole, even if the decoder makes an erroneous decision about a particular information bit at some steps. These are such the properties of multidimensional digital spaces. Continuously displayed distance value changes from the initial weight of a syndrome that is defined immediately after its computation, until the final minimum-weight error in a received block, as of the end view of the decoded blocks it will follow that all of the information error in the presented to demonstrate the MTD blocks are corrected. If the MTD at the end of the error correction procedure has not corrected any information errors (in reality it is a rare case, but it always necessarily occurs!) then the final diagnosis figures would be different. Thus, at each decoding step, the current observed distance is equal to the total number of colored (different from the background tone of the blocks) squares in the "difference" and "syndrome" arrays, because they contain ones, and in the cells whose colors correspond to the background for these arrays are zeros. For easy control, the weight of the noise vector and the initial weight of the syndrome at the start of the correction process are shown when the current block decoding in the lower left corner of the screen.

The decoder has a limit of 10 decoding iterations of the received message. If, after a certain number of code views on some, for example, the 5th iteration MTD does not change any information symbols of the block, the decoding is terminated and it is considered that the procedure for the operation of the MTD for this block is completed. The distance of the decoder decisions to the received message and the results of the threshold element at all iterations are calculated.

After completion of the decoding procedure of each block in the lower left corner it shows the original value of the random number sensor RAND=7, the length of the information block K = 1000 and a code distance d=23.

Below is shown a line containing the number of decoded characters (1000), the number of errors in the received information characters, then in the check characters of this block, and finally, the number of errors after each iteration of decoding. Zeros at the positions of the last iterations correspond to the absence of decoder errors in the block after the completion of its processing.

Next on the left- there are the weights of the syndrome. The first number is the starting weight (distance to received message) of the syndrome, and then starting from the fourth position - the weight of the syndrome after each iteration. In the case of correct decoding after the last iteration (it takes place throughout whole real time of the demorecorder work, which is usually available for the audience of our cartoon) the weight of the syndrome coincides with the weight of the errors in the check array. Since the ones caused by errors in information symbols, are absent in the syndrome, because the decoder is very efficient, then it means that all the final states of the decoder arrays, when there are not any red cells in the syndrome block, match the correct final decisions of the MTD. Since MTD performs the number of decoding characters, which is simply proportional to the length of the code, its complexity increases with the length of the code only linearly. And the optimal decoder (OD), looking through 2^{1000} possible decisions, would have to perform a number of operations greater than the number of atoms in the Universe. But the decisions of the MTD with theoretically minimal complexity usually always coincide with the decisions of namely such (absolutely unreal!) the best in probability of error an optimal exhaustive search decoders. This is the main achievement of the Optimization Theory (OT) and MTD algorithms.

After decoding the next block, the upper control block is temporarily erased from the display screen. At its place, integral data are displayed for all blocks processed during decoder simulation, indicating the total number of processed information symbols, errors in information and check symbols, as well as the total number of errors remaining after each decoding iteration.

You can always click in the drop-down **File** menu on the line **Pause** and stop the current picture on the screen, for example, for a more in-depth analysis of the numerical data related to the decoding procedure. Pressing **Pause** again resumes the processes of the cartoon.

All comments and suggestions on this MTD demo program work can be sent to the author.

Version of the cartoon **mpddemo-2016.exe** for WINDOWS can be controlled with the menu in the upper left corner.

At our portals there are also two special demo versions of error correction programs based on MTD algorithms, suitable for laboratory work on the methods of multithreshold decoding. They permit to students or trainees on courses of improvement of qualification of specialists the different tasks on the codes selection and intensity of the flow of channel errors to study the principles of operation and various features of this efficient algorithm.

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