

The instruction on application of the model demoprogram for non-binary codes decoding on the basis of multithreshold error correction algorithm in channels with a large noise level.

The given instruction is prepared for maintenance of fast start and correct results interpretation of the soft version of multithreshold decoding (MTD) algorithm for the symbolical data.

Special non-binary (symbolic) codes with majority decoding and actually highly effective algorithm of their decoding designated further as QMTD, for the first time were open in [1-2] and then are described in [3-7], and also in other works of the author.

Until recently Reed - Solomon (RS) codes were actually unique non-binary codes which could be used in various digital systems. However their opportunities always appear very much limited owing to small length of these codes and rather significant complexity of their decoding. For this reason RS codes of length no more than 256 really till now were applied, that corresponds to the symbolical alphabet of the same or even the smaller size. Thus, RS codes usage with the symbol size more than 1 byte (8 bits) is more than problematic.

Suggested demoprogram of non-binary MTD allows to work with codes of any way large length at use of absolute any symbolical alphabet which size does not depend at all of a used code length. Codes of symbolical type with majority decoding simultaneously for simplification of all procedures of coding/decoding and for increase of their efficiency are constructed as well known binary codes so, that in a symbolical code both generating, and verifying matrixes will consist only of "zeroes" and "ones". It allows to reduce all procedures of coding only to operations of addition, subtraction and comparison of the integers forming any simple group on addition. It allows to lower in addition considerably volume of calculations in QMTD.

As a whole given demoprogram QMTD and the instruction keep ideology of demoprogram and instructions for a binary convolutional code with the code rate $R=3/4$. This demo was already during two years submitted on our web-site at educational page. The purpose of the new suggested demoprogram and its instruction is demonstration of high overall QMTD performance under conditions of the large noise with simultaneously achievable very big productivity (speed of decoding). For this purpose the program module **QMTD.exe** reads out the input data from a file **qmtdd.c** and then works, carrying out decoding of sequence of the coded data in non-binary block code. As really non-binary codes are especially useful in concatenated coding circuits and in systems of storage reliability increase in the superbig databases where usually small redundancy of coding always takes place, the program well illustrates opportunities of low redundancy code with big code rate $R=0,95$.

Specially for underlining very high real noise immunity of QMTD algorithm for a code with code rate $R \sim 1$ at the big noise level (when the error probability in non-binary channel is close to $p_0 \sim 10^{-2}$) decoder works with rather long code, which length is $n=80000$ symbols. Thus, the length of an information part of a code is equal 76 000 symbols, and check part is 4000 symbols. The size of symbols can vary from 4 bits (for 16 symbols alphabet) up to 26 bits (the alphabet of 2^{26} symbols). As is well known, QMTD algorithms are iterative procedures which can repeat any set number of correction attempts for all symbols of the accepted code in some order. In the program the number of iterations also can vary in some limits, sufficient for revealing opportunities of decoder QMTD on productivity and on adjusting ability. Besides in input data file volumes of modeling (expressed by number decoded information symbols) are set, and also for error probabilities in the channel, believing, that values of errors always get out casually and in regular form among all their possible values as it usually takes place in q-ary symmetric channels.

Let's consider concrete input parameters of coding system modeling.

Input data file **gmtdd.c** has the following kind:

```
kst=339   erl=10000
ndkdd=1000000   iterat=5
          apstart= 0.015   apincr= 0.001   apend= 0.0011
          qs=65536
          =====
          qs=67108864 2^26
          qs=65536   2^16
          qs=256     2^8
          qs=16      2^4
```

The first parameter **kst** should be the whole positive number in a range 1 - 999. This number determines an initial condition of the random-number generator on the basis of which the error stream of the channel is generated;

erl - the limiting error quantity of the decoder after which achievement process of decoding stops and occurs transition to the channel with smaller error probability;

ndkdd - volume of modeling of process of correction of the mistakes, expressed by number of the decoded symbols. We shall remind, that in language C ++ there are restrictions on representations of the big integers. Therefore it is undesirable to appoint **ndkdd** more big, than billion;

iterat - quantity{amount} of iterations (attempts of repeated correction) decoding;

apstart - initial error probability in the channel;

apincr - a step of error probability reduction in the channel;

apend - final minimal error probability in the channel at modeling QMTD work;

qs - the size of the alphabet of a used code. The minimal value **qs**=16. For convenience of a code creation this parameter should be chosen as a degree of the two. It allows to realize in the given modeling program group on addition through the elementary mask. Below the line of comment examples of a possible choice values for **qs** are shown. If **qs**> 2^{26} , than **qs**= 2^{26} . Certainly, in real code systems with QMTD applications the symbol sizes can be defined by architecture of the used processors operating, probably, with many bytes simultaneously. It results in growth of reliability of coding at the big noise level and simultaneously increases productivity of a discussed class decoders due to growth of parallelism in work of the decoder, which one continues to be a very simple.

. All help data below the comment line in an input file do not influence process of decoding as the last symbol reading out by the program – is **qs**, and this parameter is placed before comment line.

Let's consider further a listing of demoprogram results for multithreshold non-binary codes decoding in output file **graft.c**, submitted below.

```

block QMTD block length N=80000 symbols R=19/20, symbol =>from 4 to 26 bits
Current time: Tue Apr 17 19:32:50
kst=339
ndkdd=1000000 nnbl=14 new ndkdd=1064000
iterat=5
pstart=0.015000 pincr=0.001000 pend=0.001100
qs=65536
=====
time work= 140 ms 0 s
*****
=>=>=> channel noise p0=0.015000
block= 1 194 errors
block= 2 15 errors
block= 3 324 errors
block= 4 5 errors
block= 5 18 errors
block= 7 312 errors
block= 8 29 errors
block= 9 188 errors
block= 10 298 errors
block= 11 30 errors
block= 12 44 errors
block= 13 3 errors
=>=>=> channel noise p0=0.015000

Ps channel Ps decoder Ns decoded err Sdec
1.500e-002 1.372e-003 1064000 1460
time decoding total work 2187 msec 2 sec delta=2 sec
decoder speed= 486000 symbols/s

*****
=>=>=> channel noise p0=0.014000
block= 3 1 errors
block= 7 12 errors
=>=>=> channel noise p0=0.014000

Ps channel Ps decoder Ns decoded err Sdec
1.400e-002 1.222e-005 1064000 13
time decoding total work 4140 msec 4 sec delta=1 sec
decoder speed= 544000 symbols/s

*****
=>=>=> channel noise p0=0.013000
=>=>=> channel noise p0=0.013000
Ps channel Ps decoder Ns decoded err Sdec
1.300e-002 0.000e+000 1064000 0
time decoding total work 6000 msec 6 sec delta=1 sec
decoder speed= 572000 symbols/s
*****
Current time: Tue Apr 17 19:32:56
-===== end =====--

```

First lines are heading of the finished program data printed: length of the code block 80000, code rate $R = 19/20$ and allowable the sizes of the code symbols, expressed by bits number which are necessary for representation of code symbols: from 4 up to 26 bits for given demo, and also date and current time.

Then completely all those input data which were present at an input file are then repeated that have been actively used by demoprogram during work. Here it is necessary to pay attention that after a volume of decoded symbols which were in an input file, there are two new parameters **nnbl** and **new ndkdd**. They are determined by that the program before the beginning of work calculates the quantity of code blocks, that it is necessary for decoding to realize set volume of experiment. For this purpose it increases the set volume of the decoded data on so much symbols that this volume of modeling was multiple to 76000 symbols, i.e. to length of an information part of the code block. The quantity of the decoded blocks and new number of information symbols in them is printed in addition to the volume of work entered into the program.

Further there are resulting data of decoder work in the program final print list.

First the operating time in ms on preparation of preliminary conditions of modeling is printed: formation of data files and preliminary calculations that borrows time ~ 140 ms - at listing. Further there is a seal of starting error probability in the symmetric non-binary channel and actually the data about decoder work with each block accepted from the channel. If the block is decoded wrongly even in one symbol its number and error quantity is printed. Certainly, if the general number of mistakes in all incorrectly decoded blocks will exceed size **erl** from an input file, experiment will be completed earlier, than it is defined by parameter **nnbl**.

After end of experiment at the set starting value of error probability in the channel there is a seal of data on results of modeling QMTD work. The seal of probability p_0 the channel repeats and lower there is a line of the basic statistical data: again p_0 , error probability for QMTD per symbol **Ps decoder**, volume of experiment among decoded information symbols **Ns decoded** and total QMTD errors in the decoded symbols of the accepted digital stream **err Sdec**. Further the full operating time of the program, and also time delta - decoding time of the data below is underlined at the current error probability in the channel.

At last, the major parameter - speed of work of the program demoversion QMTD, expressed in the symbols decoded per a second below is underlined. In the resulted modeling description it is shown for: **channel noise $p_0=0.013000$**

decoder speed = 572000 symbols/s .

It means, that at two-byte symbols of a code since the symbol size is specified in the input data of the program **qs=65536**, speed of decoding in bits is equal $V=572000 \cdot 16 = 9,152$ Mbit/s. We shall emphasize, that this listing is formed on rather slow portable computer and the length of processing symbols is chosen also rather small - 2 bytes. At a choice of longer code symbols, for example, 4 - 16 bytes and in case of application of essentially more productive it is already wide accessible personal computers as have already successfully shown experiments with various types of the personal computer, productivity QMTD can reach $20 \div 60$ Mbit /s even for such program variant of realization which is submitted here. Certainly, this major parameter shows very small complexity of realization of the given algorithm of decoding, in case of hardware creation its even rather simple realization with some number of possible receptions accelerating its work, will allow to lift decoding speed up to sizes about several hundreds megabits a second, that undoubtedly meets the requirements, showed practically to all means of the error control in systems of data transmission and in systems of storage of the information at disks and in the superlarge digital databases. More detailed characteristics of QMTD are resulted in [4] where ways of the further growth of efficiency of its work are specified also.

It is necessary to note also, that real productivity of the program QMTD version submitted here, actually is much higher measured during work of the decoder because given demo during

modeling algorithm still has time to carry out a full cycle of works on formation of entrance data files, for their coding and even modeling of the qualitative non-binary channel with independent errors.

After end of data listing about decoding at the current noise level, the program reduces error probability in the channel by size **apincr** then there is a modeling work QMTD at smaller noise level, etc.

If at some error probability experiment has come to the end without mistakes of decoding the program stops work irrespective of the set minimal error probability in the channel.

Work of the program can be suspended at any moment by pressing an any key of the computer keyboard. Repeated pressing of a key allows to continue experiment on a set of statistics. If the second pressing will be on a key 'e' (Latin), the program will finish work with listing the statistical data at the current value of noise level of the channel.

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There are enough resulted data for use all opportunities of our demo placed at specialized web-site SRI of the Russian Academy of Sciences www.mtdbest.iki.rssi.ru. Moreover, its opportunities allow to receive a lot of new characteristics of QMTD algorithm which even yet has been not published in a scientific press. The author gives the unconditional right to all interested persons to analyze QMTD opportunities for high-rate codes and to publish the results on this interesting theme independently. As the program really realizes very high speeds of decoding, it is possible to say, that a set of statistics in volume about 10^9 symbols (up to $3 \cdot 10^{10}$ bits!) even for a computer with rather average productivity demands only ~one hour of its work (roughly). In case of the publication of such article the demoprogram author is ready to place this article also on our web-site on MTD methods (certainly, after the agreement of the author of article) and to discuss the further direction of joint researches in this and adjacent areas of the theory and technique of coding.

We invite everybody for cooperation and fast joint promotion new coding methods in real technical systems!

THE LITERATURE (in Russian only)

1. Золотарёв В.В. Multithreshold decoding in non-binary channels. - Questions of radio electronics, series ЭВТ, issue12, 1984, pp. 73-76.
2. Золотарёв В.В. Algorithm of the symbolical data correction in computer networks. - In trans.: " Questions of cybernetics ", BK-105, AH the USSR, Scientific council on a complex problem "Cybernetics", M., 1985, pp. 54-62.
3. Золотарёв В.В. Multithreshold decoding for information streams with a byte structure. - Mobile systems, M., 2006, №3, with 25-27.
4. Золотарёв В.В. Ggeneralization of MTD algorithm on non-binary codes. – “Mobile systems”, M., 2007, №2, pp. 15-19.
5. Золотарёв В.В. Theory and multithreshold decoding algorithms. - M., «Radio and communications», «Hot Line - Telecom», 2006, 270 p.
6. Золотарёв В.В., Овечкин Г.В. Noiseproof coding. Methods and algorithms. The Reference Book. M., «Hot Line - Telecom », 2004, 126 p.
7. Specialized web-site SRI of the Russian Academy of Sciences www.mtdbest.iki.rssi.ru.