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METHOD OF DECODING OF BINARY SEQUENCES, INVARIANT TO STATISTICAL

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Development of compression methods which are based on the principles of information redundancy elimination which are essentially different from statistical — methods of structural coding — is actual. The rule about unambiguity of representation of binary sequence by serial number of invariant coding is described and proved. According to this rule at set values of structural signs for binary sequence it is possible to create only one serial number of invariant coding and only one binary sequence can be restored by the value of serial number of invariant coding at the set restrictions on value of structural signs. The rule about restoration of binary sequence by invariant decoding according to which the initial sequence can be restored without any curvatures on the basis of values of serial number of invariant coding and structural signs — quantity of bit changes and quantity of '1' elements in binary sequence is described and proved. The analytical structural scheme of the offered method of invariant decoding is created.

Keywords: compression, structural code, structural signs, bit transitions, structural group.

Актуальною є розробка методів стиснення, які ґрунтуються на принципах усунення інформаційної надмірності даних, принципово відмінних від статистичних — методів структурного кодування. Описане та доведене правило про однозначність представлення двійкової послідовності порядковим номером інваріантного кодування, згідно з яким при заданих значеннях структурних ознак для двійкової послідовності можна сформувати лише один порядковий номер інваріантного кодування, і навпаки, за значенням порядкового номера інваріантного кодування при заданих обмеженнях на значення структурних ознак можна відновити лише одну двійкову послідовність. Описане та доведене правило про відновлення двійкових послідовностей шляхом інваріантного декодування, відповідно до якого вихідну послідовність можна відновити без внесення жодних викривлень на підставі значень порядкового номера інваріантного кодування та значень структурних ознак — кількості бітових переходів та кількості одиничних елементів у двійковій послідовності. Сформовано аналітично-структурну модель запропонованого методу інваріантного декодування.

Ключові слова: стиснення, структурне кодування, структурні ознаки, бітові переходи, структурна група, пікове співвідношення сигнал/шум.

Research actuality

Reduction of time of data transmission in information and telecommunication systems and networks (ITCSSN) for the purpose of the organization of fast and reliable data exchange between subscribers and reduction of expenses on data transmission is one of key tasks of the modern information theory. Special standards, protocols and data processing methods which are components of information and software functioning of information system are developed for this purpose. One of solutions of this task is application of compression algorithms of digital images which due to the high informational content make the greatest part of all information which is transmitted by ITCSN, but at the same has the greatest volume. As a result of compression the image size decreases at the expense of what time of its transmition by network decreases and the space for its storage is saved.

The modern technologies of images compression provide high compression degree at the expense of reduction of psychovisual redundancy and the subsequent statistical coding of transformant of orthogonal transformations. Psychovisual redundancy is reduced as a result of zeroing of a high-frequency component of transformant on condition of their subsequent quantization. Statistical methods of compression — Haffmen's coding (for the JPEG standard) and arithmetic coding (JPEG-2000) — are used for coding quantized transformant. There are some disadvantages of these methods of coding: [1; 3; 8]:

– the number of machine operations for the processing of transformed images can take to 70 % from total number of operations of compression procedure; it is predetermined by that it is necessary to consider the number of operations for statistics calculation, creation of the coding tables and the organization of double-pass processing of data;

– the number of the operations for performance of statistical coding of transformant reaches 80 % from total number of operations which are spent for the images compression, and can exceed number of operation for performance of transformations (for modes which provide high quality of the recovered image);

– due to the need code combinations synchronization and marking on limits of processed fragments of the transformed image complexity of hardware-software realization of coding procedure increases considerably;

– parallel processing of statistical codes is difficultly implemented;

– processing of high-coherent images decreases the degree of compression that is caused by increase of values of high-frequency transformant components and also by need of use of the coding tables and markers;

– statistical coding won't provide additional compression of transformant in case of the presence of a zero series with small length.

Therefore development of compression methods which are based on the principles of information redundancy elimination which are essentially different from statistical — methods of structural coding — is actual [5; 6].

During the previous scientific researches the method of structural coding, invariant to statistical (a method of invariant coding — IC) which provides reduction of structural redundancy according to the value of the structural signs was offered [8]. Such structural signs were discussed:

1. Total amount of bit changes from a '1' element to '0' element and from a '0' element to '1' element in binary sequence $A=\{a_1,a_2,...,a_n\}$:

$$s=S(\{a_i\}_{i=\overline{1,n}})=\sum_{i=1}^{n}|a_{i-1}-a_i|,\ a_0=0.$$

2. Total amount of '1' elements in binary sequence $A=\{a_1,a_2,...,a_n\}$:

$$e=E(\{a_i\}_{i=\overline{1,n}})=\sum_{i=1}^{n}a_i.$$

Binary sequences which are characterized by identical values of structural signs, can be grouped in structural group.

Let's designate structural group which is defined by a sign S, as $\Upsilon(s)$, sign e — as $\Upsilon(e)$, set of these signs — as $\Upsilon(s,e)$.

Definition of procedure of invariant coding was formulated. According to it the invariant coding (IC) — is the assignment of sequence by its serial number in structural group $\Upsilon(s,e)$. The value of an invariant code will be less than the decimal value of binary sequence. According to this the compression will be provided.

During researches the analytical model of a method of invariant coding also was created. The value of the invariant code $NUM(\{a_i\}_{i=\overline{1,n}})$ for binary n bits long sequence according to values of structural signs — number of bit changes and quantity of '1' elements — is calculated according to a formula:

$$NUM(\{a_i\}_{i=\overline{1,n}})=\sum_{i=0}^{dec(\{a_i\}_{i=\overline{1,n}})}sign\left[1-sign|\Delta_i|\right]-1.\quad(1)$$

$$\Delta_i=sign(1-sign|e-E(bin(i,n))|-$$
$$-sign(1-sign|s-S(bin(i,n))|).$$

$S()$ — function of definition of number of bit changes in expanded binary sequence:

$$S(\{a_i\}_{j=\overline{1,n}})=\sum_{j=1}^{n}|a_{j-1}-a_j|,\ a_0=0;$$

$E()$ — function of definition of quantity of '1' elements in binary sequence:

$$E(\{a_i\}_{j=\overline{1,n}})=\sum_{j=1}^{n}a_i;$$

s — number of bit changes between '0' and '1' and '1' and '0' in binary sequence $A=\{a_1,a_2,...,a_n\}$, $s=S(\{a_i\}_{i=\overline{1,n}})$;

e — quantity of '1' elements in binary sequence $A=\{a_1,a_2,...,a_n\}$, $e=E(\{a_i\}_{i=\overline{1,n}})$;

$dec()$ — function of definition of decimal interpretation of binary sequence n bits long:

$$dec(\{a_i\}_{i=\overline{1,n}})=\sum_{j=0}^{n-1}2^{n-j-1}a_{j+1}=0;$$

$bin(i,n)$ — function of definition of n bits long binary interpretation of decimal number i:

$$bin(i,n)=(a_1,a_2,...,a_n)=$$
$$=\{a_j:a_j=2\cdot\left\{\frac{\left[\frac{i}{2^{j-1}}\right]}{2}\right\},\ j=\overline{1,n}\};$$

[] — calculation of the integer part of number; {} — rest calculation from integer division;

$sign()$ — function:

$$sign(x)=\begin{cases}-1,\ x<0,\\0,\ x=0,\\1,\ x>0.\end{cases}$$

In Fig. 1 the structural and analytical scheme of a method of invariant coding is presented.

After development of a method of binary sequences invariant coding the new scientific problem of development of inverse procedure to — restoration of initial binary sequence — appears.

Article purpose

The purpose of article is development a method of binary sequence restoration — a method of invariant decoding (IdC) — according to values of an invariant code and structural signs which characterize the coded binary sequence.

For achievement of this purpose it is necessary to carry out the following tasks:

1. To formulate and prove the rule about unambiguity of representation of binary sequence by invariant code.

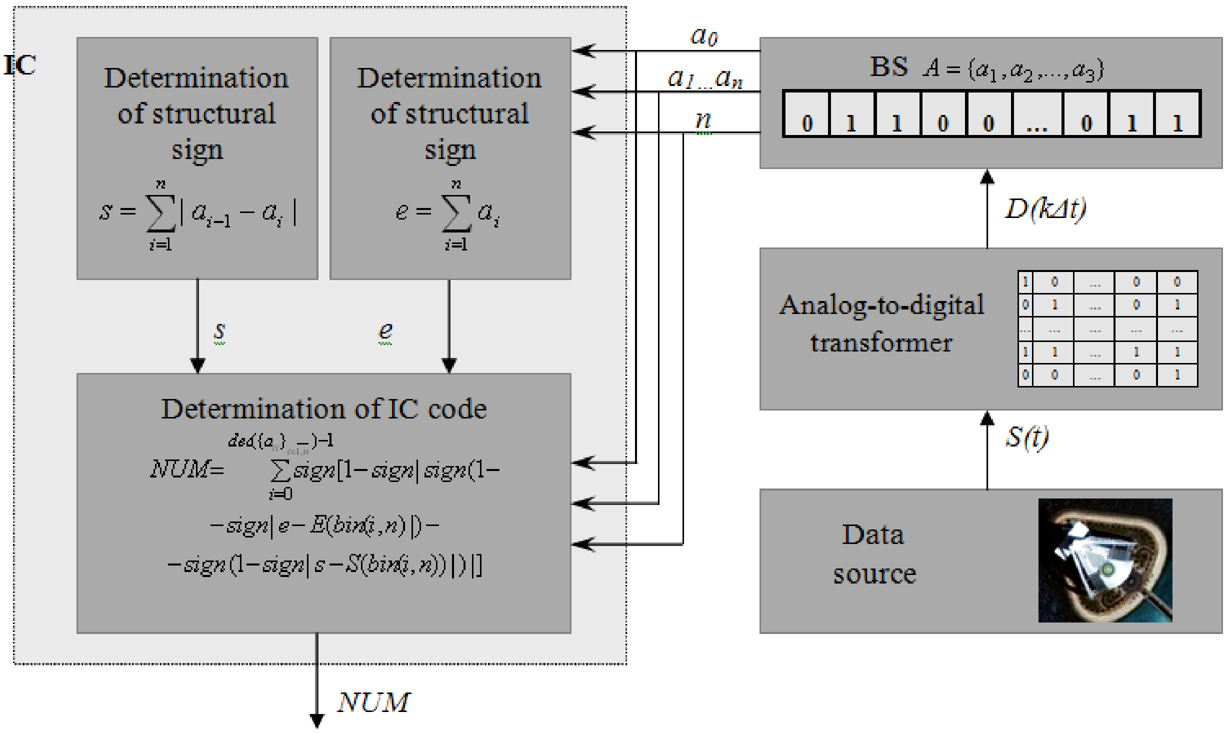

Fig. 1. The structural and analytical scheme of a method of invariant coding

2. To formulate and prove the rule about restoration of initial binary sequence according to the IdC method.

3. To create the structural and analytical scheme of the IdC method.

Statement of the main material

Lets define analytical representation of procedures of binary sequences coding and restoration according to the IC method [7; 9]:

$$NUM(\{a_i\}_{i=\overline{1,n}}) = coding(\{a_i\}_{i=\overline{1,n}}, s, e, n);$$

$$A^* = decoding(NUM(\{a_i\}_{i=\overline{1,n}}), s, e, n);$$

Here $coding(), decoding()$ — operators of coding and restoration of binary sequence, respectively.

$A = \{a_1, a_2, ..., a_n\}$, $A^* = \{a_1^*, a_2^*, ..., a_n^*\}$ — the initial and restored n bits long binary sequences, respectively. $NUM(\{a_i\}_{i=\overline{1,n}})$ — serial IC-number of sequence A, which is characterized by quantity s of binary changes and quantity e of '1' elements.

Let's prove that serial IC-number unambiguously defines binary sequence according to the set values of length of binary sequence and values of structural signs — quantity of bit changes and quantity of '1' elements.

So procedure of decoding restores initial sequence without any distortions in restored information structure:

$$a_i = a_i^*, \; i = 1...n. \qquad (2)$$

Rule 1. About unambiguity of representation of binary sequence by serial IC-number. At set value of structural signs s and e for binary sequence $A = \{a_1, a_2, ..., a_n\}$ it is possible to create only one serial IC-number $NUM(\{a_i\}_{i=\overline{1,n}})$. To the contrary, by value of serial IC-number $NUM(\{a_i\}_{i=\overline{1,n}})$ at the set restrictions on quantity s of binary changes and quantity e of '1' elements it is possible to restore only one binary sequence A, that is the condition (2) is satisfied.

Proof. Let's assume that the conditions stated in the rule 1 aren't carried out that is except of $A = \{a_1, a_2, ..., a_n\}$ there is such sequence $A^* = \{a_1^*, a_2^*, ..., a_n^*\}$ for which

$$NUM(\{a_i\}_{i=\overline{1,n}}) = NUM(\{a_i^*\}_{i=\overline{1,n}}).$$

According to expression (1):

$$NUM(\{a_i\}_{i=\overline{1,n}}) = \sum_{i=0}^{dec(\{a_i\}_{i=\overline{1,n}})} sign[1 - sign\,|\Delta_i|] - 1. \quad (3)$$

$$NUM(\{a^*_i\}_{i=\overline{1,n}}) = \sum_{i=0}^{dec(\{a_i^*\}_{i=\overline{1,n}})} sign[1 - sign\,|\Delta_i|] - 1. \quad (4)$$

$$\Delta_i = sign(1 - sign\,|e - E(bin(i,n))| -$$
$$- sign(1 - sign\,|s - S(bin(i,n))|).$$

If $A \neq A^*$, it can be assumed that $A > A^*$, so $dec(\{a_i\}_{i=\overline{1,n}}) > dec(\{a_i^*\}_{i=\overline{1,n}})$. Then expression (3) can be written as follows:

$$NUM(\{a_i\}_{i=\overline{1,n}}) = \left[\sum_{i=0}^{dec(\{a_i^*\}_{i=\overline{1,n}})} sign\left[1 - sign\,|\,\Delta_i\,|\right] - 1\right] +$$
$$+ \sum_{j=dec(\{a_i^*\}_{i=\overline{1,n}})+1}^{dec(\{a_i\}_{i=\overline{1,n}})} sign\left[1 - sign\,|\,\Delta_j\,|\right].$$

Taking into account expression (4):

$$NUM(\{a_i\}_{i=\overline{1,n}}) = NUM(\{a_i^*\}_{i=\overline{1,n}}) +$$
$$+ \sum_{j=dec(\{a_i^*\}_{i=\overline{1,n}})+1}^{dec(\{a_i\}_{i=\overline{1,n}})} sign\left[1 - sign\,|\,\Delta_j\,|\right].$$

$\Delta_j = 0$ for $j = dec(\{a_i\}_{i=\overline{1,n}})$, therefore minimum value of $\sum_{j=dec(\{a_i^*\}_{i=\overline{1,n}})+1}^{dec(\{a_i\}_{i=\overline{1,n}})} sign\left[1 - sign\,|\,\Delta_j\,|\right]$ is 1. Then

$$NUM(\{a_i\}_{i=\overline{1,n}}) - NUM(\{a_i^*\}_{i=\overline{1,n}}) \geq 1,$$

that contradicts our assumption and consequently the rule 1 is proved.

Rule 2. About restoration of binary sequence by invariant decoding (IdC). Initial sequence $A = \{a_1, a_2, ..., a_n\}$ can be restored without any curvatures on the basis of values of serial IC-number NUM, quantity s of bit changes and quantity e of '1' elements according to the rule:

$$\{a_i\}_{i=\overline{1,n}} = bin[\sum_{j=0}^{2^n-1} j\cdot(1 - sign\,|\,NUM - (1 - sign\,|\,\Delta_j\,|)\,|), n]; \quad (5)$$

$$\Delta_j = sign(1 - sign\,|\,e - E(bin(j,n))\,| - sign(1 - sign\,|\,s - S(bin(j,n))\,|).$$

$S()$ — function of definition of number of bit changes in expanded binary sequence:

$$S(\{a_i\}_{j=\overline{1,n}}) = \sum_{j=1}^{n} |\,a_{j-1} - a_j\,|, a_0 = 0;$$

$E()$ — function of definition of quantity of '1' elements in binary sequence:

$$E(\{a_i\}_{j=\overline{1,n}}) = \sum_{j=1}^{n} a_i;$$

s — structural sign, number of bit changes between '0' and '1' and '1' and '0' in restored binary sequence;

e — structural sign, quantity of '1' elements in restored binary sequence;

$bin(i,n)$ — function of definition of n bits long binary interpretation of decimal number i:

$$bin(i,n) = (a_1, a_2, ..., a_n) =$$
$$= \{a_j : a_j = 2\cdot\left\{\frac{\left[\frac{i}{2^{j-1}}\right]}{2}\right\}, j = \overline{1,n}\};$$

[] — calculation of the integer part of number;
{} — rest calculation from integer division;
$sign()$ — function:

$$sign(x) = \begin{cases} -1, x < 0, \\ 0, x = 0, \\ 1, x > 0. \end{cases}$$

Proof. During the restoration of initial binary sequence all decimal interpretations of n n bits long sequences are analyzed. It is provided by assignment of values from 0 to $2^n - 1$ the counter of the sum j. In the analysis of every sequence, calculation of its structural signs — quantity of bit changes and quantity of '1' elements with functions $E(bin(j,n)), S(bin(j,n))$ is carried out.

At coincidence of the calculated parameters to values of structural signs e, s of restored binary sequence which were transferred to the decoder parameter Δ_j will accept value 0. It will mean that the decoder defined binary sequence which belongs to the same structural group $Y(s,e,n)$ as restored sequence. Thus set value of serial IC-number NUM will be reduced by 1: $NUM - (1 - sign\,|\,\Delta_j\,|)$. According to definition serial IC-number is an amount of all binary sequences which belong to the same structural group as processed sequence and are less than it.

Therefore at achievement j-value of decimal interpretation of restored sequence $j = dec(\{a_i\}_{i=\overline{1,n}})$ the expression $NUM - (1 - sign\,|\,\Delta_j\,|)$ will accept value 0, so the expression $1 - sign(NUM - (1 - sign\,|\,\Delta_j\,|)$ will accept value 1. At $j \neq dec(\{a_i\}_{i=\overline{1,n}})$ this expression will always return value 0 and consequently under the sign of the sum there will be only one component which corresponds $j = dec(\{a_i\}_{i=\overline{1,n}})$. Use of function $bin()$ will provide a reconstruction of binary sequence $A = \{a_1, a_2, ..., a_n\}$ from its decimal interpretation.

In Fig. 2 structural analytical scheme of a method of invariant decoding is presented.

The digital-to-analog converter provides transformation of the digital signal $D^*(k\Delta t)$ received from a channel to information signal $S(t)$ of a message source by means of resampling and a dequantization of a digital signal and its representation in the form of an analog signal which describes primary message — language, music, the image, measurement of parameters of environment, etc. [6].

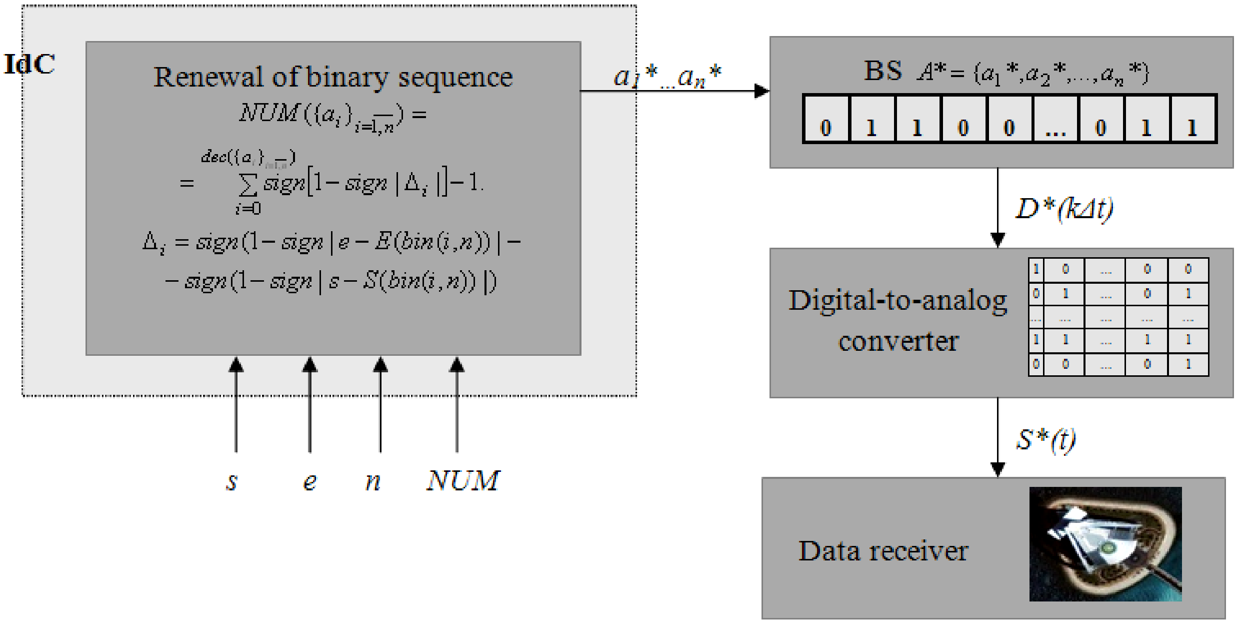

Fig. 2. Structural analytical scheme of a method of invariant decoding

Conclusion

In this article the method of restoration of binary sequence according to value of an invariant code which is offered.

This method, unlike existing approaches, is based on recovery of information about bit structure of binary sequence on the basis of values of structural signs — quantity of bit changes and quantity of '1' elements in initial binary sequence — and serial IC-number, created taking into account these values (a method of invariant decoding, IdC).

The structural and analytical scheme of the offered method of invariant decoding is created.

Scientific novelty of the research described in article consists in the following:

1. The rule about unambiguity of representation of binary sequence by serial number of invariant coding is described and proved for the first time.

According to this rule at set values of structural signs for binary sequence it is possible to create only one serial number of invariant coding and only one binary sequence can be restored by the value of serial number of invariant coding at the set restrictions on value of structural signs.

2. The rule about restoration of binary sequence by invariant decoding according to which the initial sequence $A = \{a_1, a_2, ..., a_n\}$ can be restored without any curvatures on the basis of values of serial number of invariant coding NUM and structural signs — quantity s of bit changes and quantity e of ‘1’ elements in binary sequence is described and proved.

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