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KONCEPCJA FORMOWANIA ZNAKÓW ILOŚCIOWYCH DLA WEWNĘTRZNEJ RESTRUKTURYZACJI DANYCH ZASOBÓW INFORMACYJNYCH

Streszczenie: W artkule przeanalizowano możliwe ujęcia problemu określania znaku ilościowego dla procedury wewnętrzej restrukturyzacji danych informatycznych. Koncepcja znaku ilościowego jest stosowana do klasteryzacji źródłowych danych informatycznych. Tę technikę stosuje się w celu podwyższenia efektywności kodowania poprzez redukcję długości struktur danych reprezentujących daną informację.

Słowa kluczowe: znak ilościowy, wewnętrzna restrukturyzacja elementu, liczba serii jedynek, znak liczby serii jedynek (pojedynczych znaków), znak takich samych liczb bitów

THE CONCEPT OF A QUANTITATIVE SIGN FORMATION FOR THE INTERNAL RESTRUCTURING OF INFORMATION RESOURCE DATA

Abstract: Possible approaches to the formation of a quantitative sign for the internal restructuring of in-formation resource data are analyzed. A concept of a quantitative sign formation for clustering of information resource data is developed in order to improve the efficiency of entropy coding from the position of reducing the length of representing the information.

Keywords: quantitative sign, internal restructuring of elements, number of series of units, sign of a number of series of units, sign of the same number of bits

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1. Introduction

In modern compression algorithms of information resource data (IRD) for the purpose of a more favorable representation of the encoded data, methods of external restructuring are actively used [1 - 19]. However, the methods of the external restructuring of the IRD have a number of significant disadvantages which are set out in the work [20 - 40]. To eliminate the drawbacks of the methods of the external data restructuring of the information resource a fundamentally new approach is developed -the internal restructuring that is to identify the patterns of the internal structure of message elements [41].

The application of the internal restructuring of the data has a number of advantages in comparison with the external one, namely [42-45]: no need to carry out any changes in the data of the information resource; the time for data processing is reduced; the further clustering of message elements will enhance the efficiency of entropy coding in terms of increasing the protection and reduction of the length on providing the information. The aim of the work is to develop a concept for the formation of a quantitative sign taking into account the requirements that are applied to the clustering of IRD [46].

2. The classification of existing approaches to the formation of a quantitative sign

As mentioned above, it is proposed to use its binary representation $[u_\xi]_2$ as the internal structure of message $U(\theta)$ elements u_ξ. The following approaches can act as regularities identified in the internal structure of message $U(\theta)$ elements u_ξ:

1) positioning -a mutual arrangement of identical bits $q_{\xi,\alpha}$ in the general sequence $[u_\xi]_2$, to which message $U(\theta)$ element u_ξ is given;

2) a quantitative approach -a number of similar binary bits $q_{\xi,\alpha}$ in the internal structure $[u_\xi]_2$ of message $U(\theta)$ element u_ξ;

3) a combined approach - involves both the quantitative approach, and the mutual arrangement of bits $q_{\xi,\alpha}$ in the internal structure $[u_\xi]_2$ of message $U(\theta)$ elements u_ξ.

In order to determine which approach corresponds to the above requirements that are applied to the clustering of message $U(\theta)$ elements u_ξ according to the quantitative sign λ_i, it is proposed to analyze the internal structure $[u_\xi]_2$ of message $U(\theta)$ element u_ξ in the case where the length $|u_\xi|_2$ of element u_ξ is 8 bits, i.e. $|u_\xi|_2 = 8$ bits.

Sequence $[u_\xi]_2$ of binary bits $q_{\xi,\alpha}$, $\alpha = \overline{1, |u_\xi|_2}$, to which message $U(\theta)$ element u_ξ is given, is described by the following expression:

$$[u_\xi]_2 = \{q_{\xi,1};\ \ ...;\ \ q_{\xi,\alpha};\ \ ...;\ \ q_{\xi,8}\},\tag{1}$$

where $q_{\xi,\alpha}$ - α-th bit of element u_ξ, $\alpha = \overline{1,8}$.

Fig. 1 shows the options for the sign formation λ_ξ, identified in the internal structure $[u_\xi]_2$ of message $U(\theta)$ element u_ξ with the length $|u_\xi|_2$ equal to 8 bits using the quantitative and combined approaches.

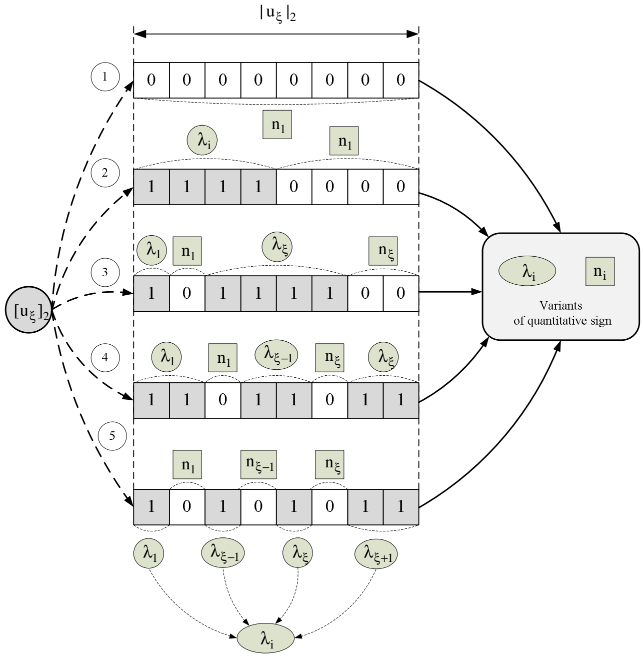

Figure 1. Process of the quantitative sign formation, depending on the internal structure $[u_\xi]_2$ of element u_ξ

The following designations are accepted in Fig 1:

λ_1, $\lambda_{\xi-1}$, λ_ξ, $\lambda_{\xi+1}$ - intermediate values of sign λ_i of the number of series of units (NSU) (a combined approach);

n_1, $n_{\xi-1}$, n_ξ - intermediate values of sign n_i the number of zero bits $q_{\xi,\alpha}$ (i.e. $q_{\xi,\alpha} = 0$) in the internal structure $[u_\xi]_2$ of message $U(\theta)$ element u_ξ (a quantitative approach is used);

λ_i - a value of the sign of series for the number of units of element u_ξ;

n_i -a value of the sign of the number of zero bits $q_{\xi,\alpha}$ in the internal structure $[u_\xi]_2$ of element u_ξ.

Analyzing the options of the internal structure $[u_\xi]_2$ of element u_ξ, which are shown in Fig. 2.1, it can be concluded that as the quantitative sign identified in the internal structure, the following signs can be used:

– sign n_i the number of bits $q_{\xi,\alpha}$ in the internal structure $[u_\xi]_2$ of element u_ξ, which have the same values. It can be both bits $q_{\xi,\alpha}$ with the values equal to zero, and bits with the values equal to one. The sign n_i formation of the number of identical binary bits $q_{\xi,\alpha}$ (NIBB) is implemented while using the quantitative approach without regard to the mutual arrangement of the data bits $q_{\xi,\alpha}$ in the general sequence $[u_\xi]_2$, to which message $U(\theta)$ element u_ξ is given.

– as the second option Fig. 2.1 illustrates a process of the quantitative sign formation by the combined approach. The essence of the combined approach, which is used to form sign λ_i, is as follows:

1. as a quantitative approach ,the calculation of binary bits $q_{\xi,\alpha}$ with a value equal to 1 is used here;
2. in its turn, the approach of individual bits $q_{\xi,\alpha}$ positioning in the general sequence $[u_\xi]_2$,to which message $U(\theta)$ element u_ξ is given ,is closely linked to the quantitative one and it is as follows:

a) not only the calculation of identical binary bits $q_{\xi,\alpha}$ in the internal structure $[u_\xi]_2$ of message $U(\theta)$ element u_ξ is performed ,but also groups (series) of the next consecutive bits $q_{\xi,\alpha}$, which have the same values are identified. Thus, when forming the quantitative sign λ_i the mutual arrangement of identical binary bits $q_{\xi,\alpha}$ in the internal structure $[u_\xi]_2$ of element u_ξ is taken into account.

b) as a result, not the total value of the number of identical bits $q_{\xi,\alpha}$ in the internal structure $[u_\xi]_2$ of message $U(\theta)$ element u_ξ is determined, but the number of series of identical values of the binary bits $q_{\xi,\alpha}$.

3. The sign formation with the use of the quantitative approach

Overall, the sign value of the NIBB is given by the following expression:

$$n_i = \sum n_\xi \,, \tag{2}$$

where n_i - the value of the sign of the NIBB.

Set of the values of sign n_i of the NIBB is given by the following expression:

$$N = \{n_1,...,n_i,...,n_k\} \,, \tag{3}$$

where N - a set of values of sign n_i; n_i, n_k - values of i -th and k -th sign of set N

Accordingly, the set of possible values of sign n_i by which set N will be limited, is described by the following expression:

$$N = \{n_i | 0 \le n_i \le | u_\xi |_2\}, \quad (4)$$

where n_i - possible values of a quantitative sign, $n_i \in Z^{\ge}$.

It should be noted that the maximum power $|N|$ of set N of values of the quantitative sign n_i of the NIBB depends on the length $|u_\xi|_2$ of sequence $[u_\xi]_2$ of binary bits $q_{\xi,\alpha}$, $\alpha = \overline{1, | u_\xi |_2}$, that define the message $U(\theta)$ element u_ξ. It is described by the following expression:

$$| N |_{max} = | u_\xi |_2 + 1, \quad (5)$$

where $|N|_{max}$ - the maximum power $|N|$ of set N of sign n_i of the NIBB values.

In its turn, the maximum number of sets $U(n_i)$ which may be formed in the process of clustering of message $U(\theta)$ element u_ξ according to sign n_i, is determined by power $|N|$ of sign n_i:

$$N(U(n_i)) = | N |, \quad (6)$$

where $N(U(n_i))$ -the number of sets $U(n_i)$, which may be formed in the process of clustering;
$|N|$ - the power of set N of values of a quantitative sign n_i of the NIBB.

In its turn, the maximum number $N(U(n_i))$ of sets $U(n_i)$ which may be formed in the process of clustering message $U(\theta)$ element u_ξ is limited to a maximum power $|N|$ of set N of sign n_i values. It is given by the following expression:

$$N(U(n_i))_{max} = | N |_{max} = | u_\xi |_2 + 1, \quad (7)$$

where $N(U(n_i))_{max}$ - the maximum number $N(U(n_i))$ of sets $U(n_i)$, which may be formed in the process of clustering of message $U(\theta)$ elements u_ξ according to a quantitative sign n_i of the NIBB.

4. A quantitative sign formation using the combined approach

Thus, Fig. 1 shows the option of the quantitative sign λ_i formation, the essence of which is to calculate the NSU (bits $q_{\xi,\alpha}$ whose values are equal to 1) in the internal structure $[u_\xi]_2$ of message $U(\theta)$ element u_ξ.

The value of sign λ_i of the NSU is determined by the following expression:

$$\lambda_i = \sum \lambda_\xi , \quad (8)$$

where λ_i - the value of the sign of the NSU; λ_ξ -an intermediate value of sign λ_i of the NSU.

The set of different values which sign λ_i of the NSU can take, is described by the following expression:

$$\Lambda = \{\lambda_1,...,\lambda_i,...\lambda_n\}, \quad (9)$$

where Λ - a set of different values of sign λ_i of the NSU; λ_i, λ_n - values i-th and n-th sign of set Λ.

The set of possible values of sign λ_i of the NSU, which is limited to set Λ, is described by the following expression:

$$\Lambda = \left\{\lambda_i \middle| 0 \le \lambda_i \le \frac{|u_\xi|_2}{2} + 1\right\}, \ \lambda_i \in Z^{\ge} \quad (10)$$

where $Z^{\ge}$ - the set of positive integers, including 0.

It should be noted that the maximum power $|\Lambda|$ of set Λ of the values of sign λ_i of the NSU is given by the following expression:

$$|\Lambda|_{max} = \frac{|u_\xi|_2}{2} + 1, \quad (11)$$

where $|\Lambda|_{max}$ - the maximum power $|\Lambda|$ of set Λ of values of sign λ_i of the NSU.

In its turn, the number of sets $U(\lambda_i)$, which may be formed in the process of clustering of message $U(\theta)$ elements u_ξ on the sign λ_i of the NSU is determined by power $|\Lambda|$:

$$N(U(\lambda_i)) = |\Lambda|, \quad (12)$$

where $N(U(\lambda_i))$ - a number of sets $U(\lambda_i)$ that can be formed in the process of clustering of message $U(\theta)$ elements u_ξ on the sign λ_i of the NSU;

$|\Lambda|$ - the power of set Λ of the sign λ_i values.

In its turn, the maximum quantity $N(U(\lambda_i))$ of sets $U(\lambda_i)$ is limited to a maximum $|\Lambda|_{max}$ power $|\Lambda|$ of set Λ of values of sign λ_i of the NSU and it is given by the following expression:

$$N(U(\lambda_i))_{max} = |\Lambda|_{max} = \frac{|u_\xi|_2}{2} + 1, \quad (13)$$

where $N(U(\lambda_i))_{max}$ -the maximum number $N(U(\lambda_i))$ of sets $U(\lambda_i)$ that can be formed in the process of clustering of message $U(\theta)$ elements u_ξ on the basis of the quantitative sign λ_i of the NSU.

5. Comparative analysis of approaches to the formation of a quantitative sign for internal restructuring of information resource data

To assess the effectiveness of the application of the analyzed approaches to the formation of a quantitative sign from the position of compliance with the requirements for clustering data of an information resource, it is proposed to analyze the following estimates: the complexity of the mathematical and practical implementation; time required to process encoded data.

A comparative analysis of the results of applying the quantitative and combined approaches in the process of forming a quantitative sign for internal restructuring of information resource data indicates that the combined approach has several advantages over the quantitative one, namely:

- is less time-consuming, since the complexity of the mathematical implementation is reduced (the number of mathematical operations necessary for the formation of the feature is reduced). This is due to the fact that the practical implementation of the quantitative approach involves performing more operations to form a quantitative sign. So the process of forming a quantitative sign for both approaches requires the following operations:

1. comparison operations, the number of which depends on the number of binary digits $q_{\xi,\alpha}$ that determine the internal structure $[u_\xi]_2$ of message $U(\theta)$ elements u_ξ

$$r_\xi = |u_\xi|_2 - 1, \quad (14)$$

where r_ξ - is the number of comparison operations that must be performed to form a quantitative sign.

For the analyzed approaches (quantitative and combined), the number r_ξ of comparison operations necessary for the formation of a quantitative sign is the same, i.e.:

$$r_\xi(n_i) = r_\xi(\lambda_i),$$

where $r_\xi(n_i)$ - the number of comparison operations that must be performed to form a quantitative sign n_i of the NIBB;

$r_\xi(\lambda_i)$ - the number of comparison operations that must be performed to form the sign λ_i of the NSU.

2. Addition operations, the number of which for each of the analyzed approaches is different. So for a quantitative approach, the number of addition operations needed to generate a quantitative sign n_i depends on the number of identical binary bits $q_{\xi,\alpha}$ in the internal structure of message $U(\theta)$ elements u_ξ.

Given that at the initial stage, the number of addition operations is taken equal to 0, i.e.: $s_\xi(n_i) = 0$,

the number of addition operations necessary for the formation of a quantitative sign n_i is limited to the following range of values:

$$0 \le s_\xi(n_i) \le |u_\xi|_2, \quad (15)$$

where $s_\xi(n_i)$ - the number of addition operations that must be performed to form a quantitative sign n_i.

Accordingly, the maximum number $s_\xi(n_i)$ of addition operations that must be performed to generate a quantitative sign n_i for a message $U(\theta)$ element u_ξ is determined by the following expression:

$$s_\xi(n_i)_{max} = |u_\xi|_2, \quad (16)$$

where $s_\xi(n_i)_{max}$ - the maximum number $s_\xi(n_i)$ of addition operations that must be performed to form a quantitative sign n_i (for an element u_ξ).

The number of addition operations that must be performed to form a set N of a quantitative sign n_i is determined by the following expression:

$$s(N) = \sum_{\xi=1}^{\theta} s_\xi(n_i), \quad (17)$$

where $s(N)$ - the number of addition operations that must be performed during the formation of a set N of a quantitative sign n_i for message $U(\theta)$ elements u_ξ.

In turn, for a combined approach, the number of addition operations necessary for the formation of a quantitative sign λ_i of the NSU depends on the number of series of units identified in the internal structure $[u_\xi]_2$ of message $U(\theta)$ elements u_ξ and is limited to the following range of values:

$$0 \le s_\xi(\lambda_i) \le \frac{|u_\xi|_2}{2}, \quad (18)$$

where $s_\xi(\lambda_i)$ - the number of addition operations that must be performed to form a quantitative sign λ_i of the NSU.

Accordingly, the maximum number $s_\xi(\lambda_i)$ of addition operations that must be performed during the formation of the quantitative sign λ_i of the NSU for the message $U(\theta)$ elements u_ξ is determined by the following expression:

$$s_\xi(\lambda_i)_{max} = \frac{|u_\xi|_2}{2}, \quad (19)$$

where $s_\xi(\lambda_i)_{max}$ - the maximum number $s_\xi(\lambda_i)$ of addition operations that must be performed to form the quantitative sign λ_i of the NSU.

Analyzing expressions (16) and (19), we can conclude that the maximum $s_\xi(n_i)_{max}$ number $s_\xi(n_i)$ of addition operations that must be performed to form a quantitative sign n_i is 2 times higher than the maximum $s_\xi(\lambda_i)_{max}$ number $s_\xi(\lambda_i)$ of addition operations that must be performed to form a quantitative sign λ_i of the NSU (for an element u_ξ), i.e.:

$$\frac{s_\xi(n_i)_{max}}{s_\xi(\lambda_i)_{max}} = \frac{|u_\xi|_2}{|u_\xi|_2 / 2} = 2 \Rightarrow s_\xi(n_i)_{max} > s_\xi(\lambda_i)_{max} . \qquad (20)$$

– reduced time required for data processing. This is due to the fact that with a quantitative approach, a more complex practical implementation;
– the complexity of the practical implementation of further clustering of message elements is reduced. This occurs due to the almost 2-fold decrease in the dynamic range of the values of the quantitative sign, as a result of which the number of sets that can be formed using the combined approach is reduced.

Accordingly, for the analyzed case, the number of sets that can be formed using the combined approach is reduced by almost 2 times:

$$\frac{N(U(n_i))_{max}}{N(U(\lambda_i))_{max}} = \frac{9}{5} = 1{,}8 . \qquad (21)$$

Thus, taking into account the above advantages of using a combined approach to form a quantitative sign it is proposed to use a combined approach for internal restructuring of information resource data to increase the efficiency of statistical coding.

6. Conclusions

The concept of a quantitative sign formation for the method of the internal restructuring of data has been developed for a better presentation of the encoded data. A comparative analysis of approaches to the formation of the quantitative sign in terms of compliance with the requirements that are applied to the clustering of information resource data is carried out.

The use of the combined approach for the formation of the quantitative sign has several advantages over the quantitative one, namely:

– it is less laborious as the complexity of mathematical implementation (the number of mathematical operations to form the sign) is reduced;

– data processing time decreases for the formation of the quantitative sign;

– the complexity of the practical implementation is reduced by the dynamic range reducing of the values of the quantitative sign.

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