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METHODOLOGY OF THE ASSESSMENT FOR ALGORITHMIC COMPLEXITY OF PARALLEL IMPLEMENTATION OF THREE-DIMENSIONAL POLYADIC CODING

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Показано, що подальше вдосконалення відеоінформаційних технологій в напрямку підвищення роздільної здатності, неминуче призводить до різкого зростання обсягів відеоданих. У свою чергу, обґрунтовується виникнення суперечності між вимогами з одного боку щодо безпеки, а з іншого — щодо своєчасності її отримання. Одним з ефективних напрямів створення технологій тривимірного кодування є кодові структури, які формуються для тривимірних поліадічних чисел. Проводено розробку методології оцінки складності алгоритмічної реалізації тривимірного трирівневого поліадичного кодування з використанням паралельної схеми обробки. Методологія базується на властивості тривимірного поліадичного кодування, що складається в забезпеченні можливості распаралелювання обчислення коду для всього тривимірного поліадичного числа (ТПЧ). Обґрунтовано, що кількість операцій скорочується як результат наступного розпаралелювання: паралельного обчислення коду за рахунок послідовного попарного укрупнення розрядів за стовпцями; паралельного обчислення коду рядка за рахунок послідовного попарного укрупнення розрядів за рядками.

Ключові слова: тривимірне кодування структур відеоданих, кількість арифметичних операцій.

It is shown that further enhancement of video information technologies in the direction of resolution enhancement that inevitably lead to the sharp growth of video data volumes. Origin of a contradiction between requirements on the one hand concerning safety of the led-up information, and on the other side of relatively timeliness of its receiving is in turn justified. One of the effective directions of creation of three-dimensional coding technologies are the code structures created for three-dimensional poliadic numbers. It is developed methodologies of an assessment of complexity of three-dimensional three-level poliadic coding algorithmic implementation with use of the parallel diagram of processing. The methodology is based on property of the three-dimensional poliadic coding consisting in a possibility to parallelize computation of a code for all three-dimensional poliadic number (TDPN). It is justified that the number of operations is reduced as result of the following multisequencing: parallel computation of a code at the expense of sequential on conjugate enlargement of discharges on columns; parallel computation of line code at the expense of sequential on conjugate enlargement of discharges in the lines.

Keywords: three-dimensional coding of video data structures, number of arithmetical operations.

Introduction

New initiatives which are created in the sphere of information services lately were the reason of high-quality development of video information services. Further enhancement of such systems goes in the direction of resolution enhancement. Here personnel and temporal permission or quantity of the frames created in unit of time is understood; personnel spatial resolution or quantity of the frames which are formed for one video scene; permission of a frame or quantity of the lines and columns used for formation of one picture; permission of pixel.

These circumstances inevitably lead to the sharp growth of volumes of video data. In too time of the characteristic of telecommunication systems, despite increase in their productivity, significantly lag behind growth rates of needs for qualitative video information support.

It is followed by creation of a contradiction between requirements on the one hand concerning safety of the led-up information, and on the other side of relatively timeliness of its receiving. In this regard systems of compression of video data are created [1]. The greatest abbreviation of volumes of video data happens on the basis of elimination of psycho visual redundancy. But such direction is connected to losses of part of information [1].

Respectively for these reasons need of further development of technologies for compression and coding of video information structures is dictated [2–4]. In this direction it is required to provide increase of compression characteristics taking into account abbreviation of redundancy in three-dimensional data structures that defines ***relevance of a scientific and application-oriented perspective*** of researches.

One of the effective directions of creation of three-dimensional coding technologies are the code structures offered in operations [5; 6]. Here code representation is created for three-dimensional poliadic numbers. For lowering of temporal time delays on processing in operations the parallel diagram of implementation of three-dimensional coding is built. However for this technology there is no assessment of implementation complexity on computing devices. Here first of all it is required to evaluate number of operations on three-dimensional processing in case of using the parallel computation technology. Therefore the ***purpose of article researches*** consists in development of the number valuation method of operations on three-dimensional coding.

Development of the valuation method of computing complexity of parallel three-dimensional coding implementation

One of advantages of three-dimensional polyadic coding is opportunity to parallelize computation of a code for all three-dimensional polyadic number (TDPN). It follows from physical features of three-dimensional polyadic numbering process and a choice of bases single system. Then step-by-step formation of a code for different enlargement levels of the three-dimensional data structure (TDDS) will be set by the following ratio [6]:

$$N^{(n_{стб},n_{стб},n_c)} = \sum_{j=1}^{n_{стб}} \left(\sum_{i=1}^{n_{стб}} N_{ji}^{(n_c)} \prod_{k=i+i}^{n_{стб}} V_{jk}^{(n_c)} \right) \prod_{\eta=j+1}^{n_{стб}} V_{\eta}^{(n_{стб},n_c)} =$$

$$= \sum_{j=1}^{n_{стр}} \sum_{i=1}^{n_{стр}} \sum_{z=1}^{n_c} a_{jiz} \prod_{\gamma=z+i}^{n_c} \psi_{ji\gamma}) \prod_{k=i+i}^{n_{стр}} V_{jk}^{(n_c)}) \prod_{\eta=j+1}^{n_{стб}} V_{\eta}^{(n_{стр},n_c)} \Bigg) .$$

This expression allows to parallelize process of three-dimensional polyadic coding.

Determination of number of the operations spent for receiving a code number for all parallelepiped data structure. Because multisequencing for all four stages will be organized for the score on conjugate enlargement of adjacent discharges, we will select quantity of lines $n_{стб}$, quantity of columns $n_{стр}$ and number of sections n_c the multiple of a level 2. Then for formation of a code N_v on the basis of the sequential and recurrent diagram the following number of operations is spent: on formations of a code for a separate vertical — $2n_c$ operations of multiplication and addition; for receiving a code of one plane formed by one column and $n_{стр}$ verticals on n_c each sections — $n_{стр}(2n_c+2)$ operations of multiplication and addition; for formation of a code N_v of all parallelepiped (enlargement on the planes, formed by all columns) it is necessary to execute μ operations of multiplication and addition:

$$\mu = n_{стб}(n_{стр}(2n_c+2)+2) . \quad (1)$$

Follows from the analysis of a formula (1) that the number of operations on compact data representation is equal to an order $O(n^3)$. Therefore for lowering of operations number of coding it is necessary to use the parallelizing diagrams of three-dimensional poliadic numbering.

We will define number of computation operations of a code-number N_v for each stage of multisequencing. In case of multisequencing on separate verticals the summary number of multiplication operations and addition operations μ_1 by formations of a code N_v is on a formula:

$$\mu_1 = n_{стб}\left(n_{стр}\left(2\log_2 n_c + 2\right) + 2\right), \quad (2)$$

where $2\log_2 n_c$ — number of addition operations and multiplication by receiving a code-number of a separate vertical for parallel on conjugate enlargement of discharges a_{jiz} of TDPN.

From comparing of expressions (1) and (2) it is visible that the number of operations μ_1 is less than number of operations μ on value of an order $n_c / \log_2 n_c$ times.

Additional abbreviation of operations number on compression is reached due to multisequencing in the lines. For this option the number μ_2 of multiplication operations and addition operations is equal

$$\mu_2 = n_{стб}(2\log_2 n_c n_{стр} + 2), \quad (3)$$

where $2\log_2 n_c n_{стр}$ — summary number of multiplication operations and addition operations for receiving one plane corresponding to one column and $n_{стр}$ verticals on n_c each sections (this case corresponds to simultaneous parallel computation of all verticals within one column).

Comparing of formulas (1) and (3) shows that the number of operations μ exceeds number of operations μ_2 on value equals $\dfrac{n_{стр}(2n_c+2)+2}{2\log_2 n_c n_{стр}+2}$.

For receiving a code N_v on the basis of simultaneous parallel computation of codes for all verticals of a parallelepiped it is spent μ_3 operations of multiplication and addition

$$\mu_3 = 2\log_2 n_c n_{стр} n_{стб} . \quad (4)$$

Conjoint analysis of expressions (1) and (4) shows that the scoring in number of operations due to transition from recursively – sequential three-dimensional poliadic coding to coding on the basis of multisequencing on all verticals of a parallelepiped reaches value equals

$$\frac{\mu}{\mu_3} = \frac{n_{стб}(n_{стр}(2n_c+2)+2)}{2\log_2 n_c n_{стр} n_{стб}} . \quad (5)$$

The calculations which are carried out on a formula (5) show that for parameters of a parallelepiped equal $n_c = n_{стр} = n_{стб} = 4$, $n_c = n_{стр} = n_{стб} = 8$, and $n_c = n_{стр} = n_{стб} = 16$ the scoring respectively reaches values 14 times, 64 times and 364 times. Value of a scoring of three-dimensional poliadic coding of rather two-dimensional poliadic coding is on a formula

$$n_c\ (2\log_2 n_{стр} n_{стб} + 2) / 2\log_2 n_c\, n_{стр} n_{стб}\ . \qquad (6)$$

Thus the value of a scoring received on the basis of calculations for a formula (6) for $n_c = n_{стр} = n_{стб} = 16$ is equal to 12 times.

On the basis of the explained follows that value of a scoring by number of operations on compression due to transition from recursive and sequential to parallel three-dimensional poliadic coding for parallelepiped parameters $n_c = n_{стр} = n_{стб} = 4$, $n_c = n_{стр} = n_{стб} = 8$ and $n_c = n_{стр} = n_{стб} = 16$ reaches according to values 14 times, 64 times and 364 times.

In the presence of $n_{стб}\, n_{стр}\, n_c$ microprocessors it is possible to organize direct computation of a code-number N_v by known values $A_v = \{a_{jiz}\}$, $1 \le j \le n_{стб}$, $1 \le i \le n_{стр}$, $1 \le z \le n_c$.

In this case each microprocessor shall execute ***one*** operations of multiplication and ***one*** operation of comparing for check on validity of the next element, ***one*** operation of multiplication for count of weight factors of the TDDS previous elements and ***one*** addition operation for receiving a code value of the current integrated element.

Such procedures are required to be executed at all three levels of processing of a three-dimensional data structure.

Then the summary number of operations $\mu_{k_2}^{(\max)}$ for formation of a code-number will be equal to all three-dimensional data structure

$$\mu_{k_2}^{(\max)} = \log_2 (2\, n_{стб}\, n_{стр}\, n_c \text{ (multiplying)} + n_{стб}\, n_{стр}\, n_c \text{ (comparing)} + n_{стб}\, n_{стр}\, n_c \text{ (addition)}) \qquad (7)$$

For a case $n_{стб} = n_{стр} = n_c = n$ the maximum number of operations for parallel coding is on a formula

$$\mu_{k_2}^{(\max)} = \log_2 \left(n^3 (2{,}6 + 1 + 1{,}5) \right) = \log_2 (5{,}1 n^3). \qquad (8)$$

Respectively time $t_{k_2}^{(\max)}$ for formations of a code-number for all TDDS in case of $n_{стб} = n_{стр} = n_c = n$ and time of coding $T_{d_6}^{(\max)}$ of the image frame with sizes $Z_{стр} \times Z_{стб}$ are equal

$$t_{k_2}^{(\max)} = \log_2 \left(5{,}1 n^3 \right) / U_{мп}\ . \qquad (9)$$

$$T_{k_2}^{(\max)} = Z_{стр} \times Z_{стб}\ t_{k_2}^{(\max)} / n^3\ . \qquad (10)$$

Dependence of summary time values $T_{k_2}^{(\max)}$ from n for $U_{мп} = 10^{-10}$ (m.o. / s), received on the basis of ratios (9) and (10), it is provided in table.

Dependence of time of the image recovery $T_{k_2}^{(\max)}$ on the size of a frame and volume of TDDS

Size of a frame	Volume of TDDS n^3	$T_{k_2}^{(\max)}$, sec
1024×1024	512	6×10^{-6}
3000×2000	512	$3{,}3 \times 10^{-5}$
7000×5000	512	$1{,}9 \times 10^{-4}$

Comparative data analysis shows in table that:

– parallel implementation of three-dimensional poliadic coding provides to rather sequential implementation reduction of processing time to 100 times;

– with increase of the TDDS sizes time of coding increases on average by two orders. It is explained by increase of quantity of the three-dimensional data structures processed sequentially;

– the parallel diagram of implementation provides formation in real time of code combinations of video elementary stream compact representation with a frequency of 50 frames per second and with images sizes of 7000×5000 elements.

Conclusions

The methodology of an assessment of complexity of three-dimensional three-level poliadic coding algorithmic implementation with use of the parallel diagram of processing is developed. The methodology is based on property of the three-dimensional poliadic coding consisting in a possibility to parallelize computation of a code for all three-dimensional poliadic number (TDPN). It follows from physical features of three-dimensional poliadic numbering process and a choice of a single bases system. At the expense of it parallel implementation of three-dimensional poliadic coding is developed. Such coding is based on the following stages of multisequencing: parallel computation of a code at the expense of sequential on conjugate enlargement (receiving dipoliadic numbers on columns) discharges on columns; parallel computation of a line code at the expense of sequential on conjugate enlargement (receiving the dipoliadic numbers in the lines) discharges in the lines; multisequencings for formation of verticals codes on the basis of parallel on conjugate enlargement of TDPN discharges; multisequencing at the expense of simultaneous on conjugate enlargement of TDPN discharges on all verticals.

Thus the following results are received:

– parallel implementation of three-dimensional poliadic coding provides to rather sequential implementation reduction of processing time to 100 times;

– the parallel diagram of implementation provides formation in real time of code combinations of video stream compact representation with a frequency of 50 frames per second and with images sizes of 7000×5000 elements.

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