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METODA DYNAMICZNEGO KODOWANIA ZASOBÓW INFORMACYJNYCH WIDEO W SYSTEMACH ROBOTYCZNYCH

Streszczenie: W niniejszej pracy omówiono model opisu informacji do reprezentowania istotnych elementów zapisu video. Dokonano tego w formie liczb o specjalnej notacji (tzw. structural positional numbers), z uwzględnieniem w kodzie występowania własności globalnych oraz lokalnej nierowności sąsiednich elementów. Istotnym komponentem kodowania jest opis współrzędnych jasności w obrazie video, co uzyskano poprzez identyfikację obszarów spójnych. Omówiona metoda przetwarzania obrazów video jest oparta na własnościach kodu reprezentujacych obraz video. Zapis kodowy jest tworzony przez wypełnianie bazowego kodogramu otrzymywanego z liniowej macierzy reprezetującej współrzędne komponentów jasności. W artykule przedstawiono także porównawcze oszcowanie efektywności działania technologii redukcji volumenu bitów z zapisie video w systemach łączności.

Słowa kluczowe: usługi informatyczne, systemy robotyczne, komponent jasności, kwantyzacja, kontrola przepływności (przesyłu bitów w jednostce czasu)

METHOD OF DYNAMIC VIDEO INFORMATIONAL RESOURCES ENCODING IN ROBOTIC SYSTEMS

Abstract: The information model for the representation the totality of coherence areas significant elements of video was developed in the form of the structural positional numbers with the presence of properties of global and local inequality of adjacent elements. A significant component encoding coordinate brightness description of the video image by identifying areas of coherence was developed. A method for processing video images based on the fact that the layout area code constructions of video image produced by filling a base codogram obtained for line array of significant coordinate brightness component. First established method for processing video images based on the formation of layout design code. The comparative estimation of efficiency of functioning of technologies of reduction of a bit volume of videos in the infocommunication systems is given.

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Keywords: information services, robotic systems, brightness component, quantization, bit rate control

1 Introduction

The development of spheres of state activity, society and personality is accompanied by full-scale processes of informatization. A key component here is the timely exchange of information between users, using wireless info communication technologies. However, in recent years, the greatest demand is emerging for the provision of video information services. At the same time, the required requirements for video services using modern information communication systems are not met. So, there is a contradiction caused by the mismatch between the requirements of video services and the performance characteristics of wireless info communication networks. Hence reducing video delivery delays with the use of wireless info communication technologies to improve the quality of video information services is an urgent scientific and applied task.
The main characteristics of the methods of increasing the volume of life are temporary $\tau(\Theta; S_{tr}; S_{pr})_{del}$ delay in the delivery of the video in the info communication networks, which is by the formula:

$$\tau(\Theta; S_{tr}; S_{pr})_{del} = \tau(\Theta; S_{tr})_{tr} + \tau(\Theta; S_{pr})_{enc} + \tau(\Theta; S_{pr})_{rec} . \quad (1)$$

Here $\tau(\Theta; S_{tr})_{tr}$ - delayed transmission of encoded videos, $\tau(\Theta; S_{tr})_{tr} = V_{beg} / \eta \cdot S_{tr}$; S_{tr} - characterization of the information communication networks on the speed of data transmission; V_{beg} - the initial bit volume of the video, $V_{beg} = v \cdot Z_{lin} \cdot Z_{col}$; v - the number of bits per representation of a single video element; $\tau(\Theta; S_{pr})_{enc}$, $\tau(\Theta; S_{pr})_{rec}$ - time delays for video encoding and reconstruction, respectively; η - the level of bit volume reduction.
The highest level of visual assessment of video perception is achieved for coding methods that do not take into account the reduction of psycho-visual redundancy. But for such methods the level of bit volume reduction does not exceed 2 times. Therefore, to improve the technology of bit volume reduction with flexible controlled constraints on the level of visual assessments, it is proposed to use pre-processing, which is to describe structural and statistical dependencies based on the detection of coherence domains. Therefore, the purpose of the research is to create methods for reducing the bit volume of videos with a controlled level of visual ratings on their perception, to improve the quality of video services using infocommunication networks based on the identification of areas of coherence. The problem and related topics were discussed in many references [1-35].

2. Developing a model for assessing the informative nature of video images

There are two basic approaches to building functionality φ_{regr} regression description of the coherence domain. But there are several disadvantages to these approaches, such as: low bit rate reduction; the complexity of algorithmic embodiment increases; the level of visual assessment decreases.

The following are suggested to address the shortcomings of the existing regression description generation methods. Area of coherence $X^{(\xi)}$ is regarded as a composition of two sequences $X'^{(\xi)}$ and $X''^{(\xi)}$, which respectively contain elements with equal and unequal values, taking into account the indicator $\delta^{(loc)}$ local insignificance, $X^{(\xi)} \xrightarrow{\delta^{(loc)}} \{X'^{(\xi)}; X''^{(\xi)}\}$. There may be sections at the same time for which the following conditions are fulfilled:

$$x_{\xi,\gamma} = \ldots = x_{\xi,\gamma+r} = \ldots = x_{\xi,\gamma+R_\xi-1}; \quad x_{\xi,\gamma+r_1} \neq \ldots \neq x_{\xi,\gamma+r_2} \neq \ldots \neq x_{\xi,\gamma+r_3}, \tag{2}$$

where r_τ - areas of coherence with heterogeneous structural content relative to the inequality of the elements.

Aggregate consideration of the lengths of coherence regions by significant elements is interpreted as a non-uniform linear-scaling form of the video fragment. Therefore, it is proposed to form arrays from separate lengths of significant coherence domains $\Delta R^{(u)}_{m,n}$, and treat them as structural positional numbers with a basis system that sets maximum values for the dynamic range in rows, namely:

$\Delta R^{(u)}_{m,n} = \{\Delta R''_{i,j}\}$, that is $0 \le \Delta R''_{i,j} \le \Delta R''_{\max,i} - 1$, $i = \overline{1, m}$.

Then the maximum cost level is the number of bits $V(R)_{m,n}$ on the code representation of such an array $\Delta R^{(u)}_{m,n}$ is given by the expression:

$$V(R)_{m,n} = [n\sum_{i=1}^{m} \ell og_2(w(R)_i) + 1]. \tag{3}$$

The average number of bits $\overline{V(R)}_{m,n}$, having to code description of one length of the coherence region is estimated by the formula:

$$\overline{V(R)}_{m,n} = [n\sum_{i=1}^{m} \ell og_2(w(R)_i) + 1] / m\ n. \tag{4}$$

Adequate minimum amount $\overline{H(R)}_{\min}$ The redundancy that is eliminated is estimated by the ratio:

$$\overline{H(R)}_{\min} = (1 - \frac{[\sum_{i=1}^{m} \ell og_2(w(R)_i) + 1]}{m\, \ell og_2 \Delta R''_{\max}}) \cdot 100\%, \tag{5}$$

analysis of which shows that its level will be higher than zero, $\overline{H(R)}_{\min} > 0\%$.

Here $\ell og_2 \Delta R''_{\max}$ - the maximum number of bits spent on representing a code of one length of significant coherence area, without regard to structural constraints.

It is proposed to form arrays from separate sequences of significant elements of coherence domains $G^{(u)}_{m,k}$, namely:

$$G^{(u)}_{m,k} = \{g_{i,j}\},\ G_k = \{g_1;...;g_j;...;g_k\}, \quad (6)$$

where G_k - k - measured sequence of significant coherence areas;

g_j - element of one of the sequences $X''^{(\xi)}$, $\xi = \overline{1,n}$.

Then such arrays for which elements are conditioned:

$$g_{1,1} \le w(g)_1 = g_{max} + 1; \quad g_{i,j} \le w(g)_i = g_{max};$$

$$i = \overline{2,m} \text{ for } j = 1 \text{ и } i = \overline{1,m} \text{ for } j \ge 2, \quad (7)$$

are called structural position numbers with global and local inequality of adjacent elements. From here, the average number of bits per element $\overline{V(g)}_{m,k}$, which falls on one element of an array $G^{(u)}_{m,k}$, is defined by the following expression:

$$\overline{V(g)}_{m,k} = \frac{[\ell og_2(g_{max}+1) + (k-1)\ell og_2 w(g) + k\sum_{i=2}^{m}\ell og_2(g_{max})] + 1}{m \cdot k}, \quad (8)$$

and the corresponding minimum number $\overline{H(g)}_{min}$ redundancy with such a formula:

$$\overline{H(g)}_{min} = (1 - [\frac{\ell og_2(g_{max}+1)}{8mk} + \frac{\ell og_2 w(g)}{8m} + \frac{\sum_{i=2}^{m}\ell og_2(g_{max})}{8m}]) \cdot 100\%. \quad (9)$$

It can be seen that its level will be much higher than zero, $\overline{H(g)}_{min} > 0\%$.

Maximum total cost of the quantity $\overline{V}(max)_{m,n}$ bits that, on average, account for one significant area of coherence when presented by the approaches created, are estimated by the formula:

$$\overline{V}(\max)_{m,n} = \overline{V(R)}_{m,n} + \overline{V(g)}_{m,k} + V^{(w)}, \quad (10)$$

where $\overline{V(R)}_{m,n}$, $\overline{V(g)}_{m,k}$ - the maximum number of bits to be spent on average per code representation of the length of a significant coherence region and its significant elements;

$V^{(w)}$ - pooling the number of bits in service data (basics of arrays $\Delta R^{(u)}_{m,n}$ and $G^{(u)}_{m,k}$).

Where the minimum level value η_{min} bit volume reduction is defined by equation:

$$\eta_{min} = (8\sum_{i=1}^{m}\sum_{j=1}^{n} R_{i,j}) / \overline{V}(max)_{m,n} . \quad (11)$$

In the same time, the estimates showed that the minimum value for reducing the bit volume of images with high saturation of structural parts reaches from 1.8 to 5 times, and the average saturation from 2 to 8 times. This creates the potential for building compact presentation methods based on the proposed approach.

The process of such coding is suggested to be organized by examining strings G_i arrays $G_{m,k}^{(u)}$ as numbers for which the following conditions are true:

$$g_j \neq g_\chi , \quad j,\chi = \overline{1, k} ;$$

$$g_{1,1} \leq w(g)_1 = g_{max} + 1 ; \quad g_{i,j} \leq w(g)_i = g_{max} ;$$

$$i = \overline{2,m} \quad \text{for} \quad j=1 \quad \text{and} \quad i = \overline{1,m} \quad \text{for} \quad j \geq 2 . \quad (12)$$

Then the corresponding code value $E(\delta^{(loc)}; g)_i$ from the position of two hierarchies and depending on the size $\delta^{(loc)}$ local insignificance is determined by the following relations:

$$E(\delta^{(loc)}; g)_i = \sum_{\xi=1}^{\nu_{ok}} \sum_{r=1}^{R''_\xi} Q(\delta^{(loc)}; g)_{i,\xi}^{(r)} ; \qquad g_0 = w(g) . \quad (13)$$

Here ν_{ok} - the number of significant areas of coherence in a row;

R''_ξ - the number of significant elements in ξ areas of coherence;

$Q(\delta^{(loc)}; g)_{i,\xi}^{(r)}$ - weighting factor for $(\gamma + r)$ a significant element ξ an area of coherence structured in i row array $G_{m,k}^{(u)}$.

In this case, based on the property of the code values of structural numbers, the maximum number of bits on their representation will have a limit $V(g)_i$ from above, as shown by the following inequality:

$$\ell og_2 E(g)_i \leq V(g)_i = k\,\ell og_2 (w(g) - 1) . \quad (14)$$

Here $w(g)_i$ - a dynamic range of significant elements of the coherence domain.

The process of segmenting the codograms of truncated structural-positional numbers is to decompose them into D code parts given by the following expression (Fig. 1):

$$V(R)_i = \bigcup_{d=1}^{D} \Delta_d V(R)_i , \quad (15)$$

where $\Delta_d V(R)_i$ - length d segment i codograms of truncated structural positional.

Moreover, the length of such a segment depends on the number of insignificant bits in the corresponding basic code structure, and is determined by the ratio:

$$\Delta_d V(R)_i = \Delta V = V_{nec} - V(g)_d \,. \tag{16}$$

Then the process of filling the basic codogram is to integrate into the positions of insignificant elements of the corresponding segment of the codogram insignificant linear-scaling component of the video. To determine the length of an integrated segment, calculate the length ΔV sequences of insignificant bits in the base codogram, the following expression is used:

$$\Delta V = V_{nec} - V(g)_i > 0 \,. \tag{17}$$

Then if the inequality holds:

$$V(g)_i < V_{nec} \,, \tag{18}$$

then the relevant segment is integrated with the required length.

3. Comparative evaluation of the performance of video bit reduction

The analysis of the experimental estimates allows us to conclude that the level of bit volume reduction for the created method exceeds the level achieved by known methods by an average of 10% in terms of providing a peak signal-to-noise ratio of 55 dB. Estimates of time delays $t(\Theta;S_{tr};S_{pr})_{del}$ for video delivery, depending on their spatial resolution and mobile data rate, shown in the diagrams in Fig. 1. The analysis of the diagrams in this figure makes it possible to conclude that the averaged over different classes of videos the delivery time for the developed method for the existing method is on average 1.3 times, which is caused by an additional increase in the level of bit volume reduction and reduction of processing delays.

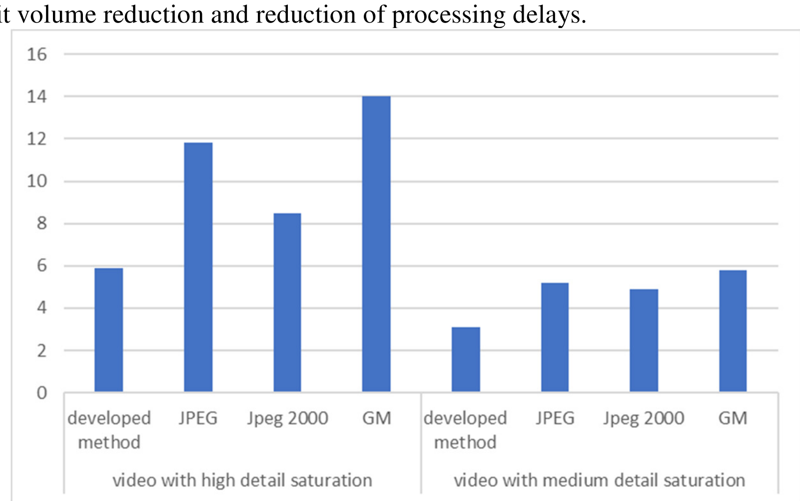

Figure 1. Size charts $t\,(\Theta; S_{tr;}\, S_{pr})$ video class of processed videos for V_{beg}=2048×1536×24=75 Mbps, S_{tr} =2,048 Mbps

Accordingly developed technology, compared to the known peak-to-peak signal-to-noise ratio of 40 dB using existing microprocessor technologies of the mobile segment, enables real-time delivery of video clips with a spatial resolution of about 24 MP.

4. Conclusion

An information model of representation of a set of significant elements of video coherence areas in the form of structural positional numbers with the presence of properties of global and local inequality of adjacent elements is developed. As a result, it was proved that the minimum value of the bit reduction level of images with high saturation of structural parts reaches from 1.8 to 5 times, and the average saturation from 2 to 8 times. A method of video processing was developed on the basis that the layout of the code structures of the video section was made. A model for estimating the level of video bit rate reduction based on the detection of coherence domains is constructed. This allows you to evaluate the effectiveness of the methods created in terms of reducing the various types of redundancy.

The validity of the obtained results is confirmed by: the adequacy of the results of experimental and theoretical studies on the level of reduction of the bit volume of the videos and time processing costs obtained on the basis of software implementation and mathematical model; the consistency of the results obtained with the provisions of information theory and positional coding methods.

For the first time, an information model for representing a set of significant elements of the video coherence areas in the form of structural positional numbers with the presence of properties of global and local inequality of adjacent elements has been created. The distinctive features of the model are the consideration of the previous uneven thinning of the regions of coherence by elements with equal values; retaining information on significant elements of the coherence domain from the standpoint of global and local sensitivity. This makes it possible to evaluate the content of such a description and to obtain estimates of the minimum amount of redundancy that can potentially be eliminated.

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