A multi-criteria method of compressed video sequences comparison

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Abstract – **A multi-criteria method is presented for comparison of compressed video images. As criteria are used: bit rate of video stream, subjective quality evaluation of compressed video sequence and objective quality evaluation of compressed video sequence using Average Peak Signal-to-Noise Ratio (APSNR) metric.**

Keywords - **video compression, multi-criteria method of compressed video sequences comparison.**

I. INTRODUCTION

Compromise between the quality of digital moving images and the volume of video or video stream bit rate is one of the most important problems that must be addressed when designing systems for digital transmission and display moving images. Mostly objective technical criteria are taken into account, but practice shows that it does not fully reflect the human perception of image. The paper presents a formalized proposal of combining for objective criteria and subjective criteria, and develop assessment methods for compressing digital moving images. For this purpose, three-dimensional normalized criterion function is used. Later in the paper a description of the methodology and results of benchmarking the quality of the image compression are presented. Image compression has been performed in two parts using four video codecs for the value of bit stream data rate in the range 300-1000 kbit / s. To solve the problem of selection of the best clips two methods in the construction of a single criterion: the method of compromise function equal to the distance from the point of ideal functions and the method of compromise equal weighted sum of partial criteria has been used.

II. FORMULATION OF THE PROBLEM OF CHOOSING AN OPTIMAL VIDEO SEQUENCE

Parameters of the compression of digital motion images have a direct impact on the quality of encoded video. Most of the parameters is universal and has a common, similar importance to many codecs. There is also a group of advanced settings specific to each codec families. Knowledge of compression parameters allows optimal use of tools offered by video codecs, to achieve better image quality without increasing the size of the output file. Each generation of a compressed video sequence can be assessed using several criteria [1]. The paper proposes to adopt a simplified assessment associated with the only three criteria. A method presented below can be applied to a larger number of criteria. Assumed that each generated video sequence will be assessed by using the criterion (three dimensional) $\boldsymbol{f}=(f_1,f_2,f_3)$, where the criteria have the following interpretation:

f_1 - video stream bit rate,
,f_2 - subjective assessment of the quality of video sequence,
f_3 - objective quality of video sequence, based on metrics APSNR.

Assume that video sequence is better when it has:

- lower bit rate
- greater value of subjective assessment,
- greater value of metrics APSNR.

In order to standardize the nature of the criteria (all criteria to maximize) introduced a transformation of criterion f_1 and it has been replaced by the criterion - f_1. Hence, a new relationship with the original criterion function is as follows:

$$\boldsymbol{g}=(g_1,g_2,g_3) \quad (1)$$
$$g_1=-f_1 \quad (2)$$
$$g_2=f_2 \quad (3)$$
$$g_3=f_3 \quad (4)$$

The task of optimization [2] has the form:

$$\langle \boldsymbol{SW}, \boldsymbol{g}, \geq \rangle \quad (5)$$

where the symbol "≥" describes the dominate relation, and $\boldsymbol{SW}$ – set of the evaluated video sequences.

Criterion space is defined by:

$$\boldsymbol{Y}=\{\boldsymbol{g}=\boldsymbol{g}(sw)\in R\times R\times R : sw\in \boldsymbol{SW}\} \quad (6)$$

- set of values of criterion of video sequences evaluation, where R denotes the set of real numbers. Dominate relation "≥" is defined as follows

$$(\boldsymbol{g}^1,\boldsymbol{g}^2)\in \geq \Leftrightarrow \underset{i=1,\ldots,3}{\forall} g_i^1\geq g_i^2 \wedge \underset{i=1,\ldots,3}{\exists} g_i^1 > g_i^2 \quad (7)$$

where $\boldsymbol{g}^1=(g_1^1,g_2^1,g_3^1)$, $\boldsymbol{g}^2=(g_1^2,g_2^2,g_3^2)$.

III. SOLUTION TO THE PROBLEM OF CHOOSING AN OPTIMAL VIDEO SEQUENCE

Solution to the problem consists in determining the set of dominating points and then (if the set is empty) the set of nondominated points.

$$\boldsymbol{SW}_N^{\geq}=\{sw\in \boldsymbol{SW} : \boldsymbol{g}(sw)\in \boldsymbol{Y}_N^{\geq}\} \quad (8)$$

where

$$Y_N^{\geq}=\{g\in Y : \text{does not exist } v\in Y \text{ and } v\neq g, \text{that } (v,g)\in \geq\}.$$

The set $\boldsymbol{SW}_N^{\geq}$ will have at least 2 elements, hence we have to choose a solution from the set based on additional criteria. We can use one of two methods [2] the construction of a single criterion:

1. method of compromise function equal to the distance from the ideal point,
2. method of compromise function equal to the weighted sum of partial criteria.

Both methods require a normalization of criterion functions (usually bring their values to the 0-1 interval).

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Ad 1. In the method we have to determine the ideal point, not necessarily belonging to the set, which is the best solution according to the decision maker. In our case, the point may be the ideal point $\overline{\overline{\boldsymbol{g}}} = (1,1,1)$. In our case, we apply as a the compromise function the geometric distance from the ideal point as follows:

$$\text{for } sw \in \boldsymbol{SW}_N^{\geq} \qquad \mathrm{d}(sw) = \sqrt{\sum_{j=1}^{3}[1-\tilde{g}_j(sw)]^2} \tag{9}$$

To make the optimal choice to be determined

$$sw^* \in \boldsymbol{SW}_N^{\geq} : d(sw^*) = \min_{sw \in \boldsymbol{SW}_N^{\geq}} d(sw) \tag{10}$$

Ad 2. We introduce the criterion function as follows

$$h : \boldsymbol{SW}_N^{\geq} \rightarrow \mathrm{R}^+ \tag{11}$$

where

$$h(sw) = \sum_{j=1}^{3} \alpha_j \tilde{\boldsymbol{g}}_j(\mathrm{sw}) \text{ for } sw \in \boldsymbol{SW}_N^{\geq} \tag{12}$$

There is a constraint

$$\forall_{i=1,..,3} \alpha_i > 0 \quad \text{and} \quad \sum_{i=1}^{3} \alpha_i = 1$$

Optimal selection shall be made appointing

$$sw^* \in \boldsymbol{SW}_N^{\geq} : h(sw^*) = \max_{sw \in \boldsymbol{SW}_N^{\geq}} h(sw) \tag{13}$$

IV. METHODOLOGY OF COMPARATIVE STUDIES OF COMPRESSED MOVING IMAGES

Input material for comparative studies, there are two pieces of video files stored on the DVD media. The length of fragments in both cases is 3 minutes. The video fragments used to test differ in their nature scenes. The first part of the video contains a static scene, taking place in one room, without any sudden changes of images. The second part is the dynamic of the large number of rapid changes in the frame and brightness. Video compression has been carried out for four codecs: 3ivx MPEG-4 5.0, x264, DivX 6.8.5 and On2 VP7.

Coding was carried out in one pass mode for the video stream constant bit rate (CBR), with a target bit rate in the range 300-1000 kbit / s. Resolution of generated video sequences, the speed of displaying frames are identical with the input sequences.

Subjective assessment of quality of compressed images has been carried out by the simultaneous play of input material and compressed (in the original resolution) on a single monitor. The scale of subjective assessment is from 0 to 1, where one is the best quality compressed image. Assessment is subject to the general impression of visuals, color fidelity, the traffic flow and level image blocks.

Objective quality of compressed images was carried out using the measurement of the average peak signal to noise ratio (APSNR), by MSU Video Quality Measurement Tool 2.01 [3] for luminance component (Y-YUV). Although the method consisting in determining the peak signal to noise ratio, gives only an approximate assessment of the reconstructed image is widely used as an objective method of assessing the quality of the image compression [3]. To determine the value of the peak signal to noise ratio shall be calculated mean squared error (MSE) as a dependency:

$$MSE = \frac{1}{n\,m}\sum_{i=0}^{n}\sum_{j=0}^{m}\left\{[f(i,j) - f'(i,j)]^2\right\} \tag{14}$$

where

n, m – image dimensions

$f(i, j)$ – representation of the original image

$f'(i, j)$ – representation of compressed image after reconstruction

Then we determine the logarithmic peak signal to noise ratio

$$PSNR = 10\log_{10}\frac{L^2}{MSE} \quad [dB] \tag{15}$$

where $L = 2^B - 1$ – maximum value of the pixel component for B-bit representation of the color (for B = 8 bits L=255).

For moving images the PSNR value is determined by comparing each frame of the original image with a corresponding frame of compressed image after the reconstruction. To assess the quality of all video compression a metric of averaged (for all video frames) peak signal to noise ratio (APSNR) has been introduced as a arithmetic mean for all video frames.

V. CONCLUSIONS [1]

For the first video sequence using the method of compromise function with the ideal point, the best was a sequence corresponding to a sequence of video bit rate equal to 529 kbit/s compressed with codec 3ivx MPEG-4. For the second method of compromise, a weighted sum of partial criteria, the best was a sequence corresponding to a sequence of video bit rate equal to 1000 kbit / s compressed with On2 VP7 codec.

For the second video sequence using the method of compromise function equal the distanc from the ideal point, the best was a sequence corresponding to a sequence of video bit rate equal to 436 kbit / s compressed with codec, On2 VP-7. For the second method of compromise, a weighted sum of partial criteria, the best was a sequence corresponding to a sequence of video bit rate equal to 986 kbit / s compressed with On2 VP7 codec. The analysis of the results shows that the best codec to compress the dynamic scene is On2 VP7.

REFERENCES

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