EVALUATION OF TWO DEVELOPED MODELS OF HUMAN VISUAL SYSTEM FOR ASSESSMENT OF THE PERCEPTUAL IMAGE QUALITY

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Abstract

The article deals with evaluation of image quality by various methods and comparison of their results. Generally, there are several ways how to assess image quality. Three main approaches are: subjective testing, objective testing and image quality evaluation using a human visual system (HVS) model. The subjective testing is based on human perception, the objective one on mathematical computing and the human visual system models on mathematical modelling of human vision respecting features of the human perception. Then, the described methods and two designed models of HVS are used for image quality evaluation on a set of images. Results of the modelling were compared with results of the subjective and objective methods.

Key Words
Human Visual System, Model, Image Quality

1. Introduction

One of the main reasons for image quality evaluation is use of the image compression techniques. The image compression is used to eliminate data irrelevancy and redundancy for an effective data transfer and storage. It is difficult to find a balance between quality and compression ratio. This is a basic task of the digital coding and compression and the reason for image quality evaluation.

The first approach to the image quality evaluation is subjective quality testing (e.g. DSIS – Double Stimulus Impairment Scale, DSCQS – Double Stimulus Continuous Quality Scale, SCM – Stimulus Comparison Method, SSM – Single Stimulus Method, SSCQM – Single Stimulus Continuous Quality Evaluation). This testing is based on many observers that evaluate image quality. These tests have a very strict definition of observational conditions [1].

The second approach is the objective image quality testing (e.g. SNR – Signal to Noise Ratio, MSE – Mean Square Error, MAE – Mean Absolute Error) based on mathematical calculations. The objective quality evaluation is easier and faster then the subjective one because the observers are not needed [2, 3]. Nevertheless, these objective criteria don’t fully respect characteristics of the human perception. Generally, the results are not in a good agreement with the perceived image quality assessment.

The third way how to assess the image quality is the use of a human visual system (HVS) model. Human vision model combines and uses both the objective and subjective methods. This way of the image quality evaluation becomes a today’s trend [4, 5]. These vision models can model only some parts of the human vision that we need (e.g. spatial resolution, temporal motion, colour fidelity, colour resolution...) [4]. A majority of these models requires a tested image and its corresponding matching reference in order to determine the perceptual difference between them. Human vision models can be divided into two groups. The first group comprises one-channel models [2, 4] that can be characterised by computing with the whole entire images. In the second group there are multi-channel models [2, 4, 5] that simulate the neuron response of the brain cortex. The response is selective to spatial frequencies and orientations. These models decompose the image into many spatial frequency bands and/or orientations. Then, separate thresholds are set for each channel. At the end of the processing the channels are weighted and summed in order to get a number that represents the overall image quality.

The aim of this study is comparison of two designed models with both the subjective and objective methods for image quality evaluation. Tests are carried out using a group of standardised test images.

2. Methods

Subjective quality testing

For the subjective testing we have prepared a subjective testing laboratory respecting ITU-R recommendations BT.500-10 for image quality testing. The overall scheme of the designed laboratory is presented in Fig. 1.
General viewing conditions for subjective assessments:

- The initial luminance ratio should be less than 0.02.
- Maximum observation angle should be less than 30°.
- Peak luminance 200 cd/m².
- Monitor without digital processing.
- Surroundings illuminance at the position of the screen 200 lux.

![Setup of the subjective quality testing lab.](image)

**Figure 1.** Setup of the subjective quality testing lab.

**Test method DSCQS**

(Double Stimulus Continuous Quality Scale)

We have chosen test method DSCQS because it is especially useful when we need to measure the image quality of distorted images relatively to the corresponding reference (original image). The assessor is asked to observe a pair of pictures, each from the same source, one is reference (in our case 100% picture quality), and the second one is distorted by compression. The reference image is in the first position. The evaluating sessions last 30 minutes in which the picture pairs are presented in a random order and random impairments covering all required combinations of compressions. Images from A-reference and B-distorted groups are sequentially presented to the groups of observers, so that they can create their assessment. They see each the picture for a period of 10 seconds. The results are presented by the mean of continuous scale with a range from 0 to 100.

**Objective quality testing**

MSE and MAE were chosen as the objective quality testing methods. They are defined as follows:

\[
\text{MSE} = \frac{1}{MN} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (x_{ij} - y_{ij})^2
\]

\[
\text{MAE} = \frac{1}{MN} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} |x_{ij} - y_{ij}|
\]

**Human visual system model testing**

We tested quality of the pictures using two models of the human visual system.

The first designed model (HVS1) has been derived from characteristics of the existing models [2, 4, 5]. The model comprises colour transformation (pictures are transformed from R, G, B to the CIE Lab colour space L, a, b), four-level Gaussian pyramidal decomposition (filtering with 2D Gaussian core and decimation by 2 is repeated step by step three times), contrast channels computation and quantization, oriented channels computation and quantization (oriented channels are computed parallel with the contrast channels), computation of distance metrics and final weighting. It has 5 levels of computing in L, a, b channels, 10 levels in each L, a, b contrast channels and 5 levels in each L, a, b oriented channels. Together there are 60 channels. To get one value that describes the overall image quality we use weighting of selected channel distances.

The second designed model (HVS2) simulates function of retina and the brain cortex transform functions. This modelling respects theory and practical experience with image quality testing. That helped researchers to discover some basic properties of the human visual system (e.g. sensitivity to some frequency bands and edge detection). The most important orientations are 0° and 90° for edges. From the frequency bands is important the base band, which represents information of scene brightness, and some higher bands, which represent information of important details (edges) in the image. Combinations of frequency bands and orientations create the model of visual perception. The model can be easily implemented as the banks of frequency oriented selective filters. The last step of this processing is computing of a difference metrics as a Just Noticeable Difference (JND) map. The averaged JND map represents the overall image quality.

The outputs of all methods are normalised so that the image quality evaluation algorithms can be compared.

**3. Results**

Concerning the subjective testing we tested original and compressed (JPEG, JPEG2000, LWF) images of LENA with DSCQS test. For the objective and HVS testing we selected MSE and MAE method for JPEG compression. We used two HVS models described above. Results of the subjective testing are in Fig. 2.
Results of testing with all the described methods are presented in Fig. 3.

![Subjective testing of LENA compressed images](image)

Figure 2. Subjective quality testing

4. Conclusion

The results in Fig. 2 show comparison of various compressed methods evaluated by a group of observers. The best results has LWF compression format. In Fig. 3 there is comparison of image quality evaluation by methods selected above. These results show suitability of HVS models for image quality evaluation. Main criterion for assessment of the image quality is a good correspondence with the human perception that is represented by the subjective DSCQS test. Good correspondence with this criterion has HVS2. This model shows a good correspondence with subjective testing better than MAE and comparable with MSE testing. Testing based on mathematical approaches like HVS model, MSE and MAE is cheaper and less time demanding then the subjective tests.

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References