# HUMAN VISION MODELS OF IMAGE QUALITY EVALUATION FOR JPEG2000 COMPRESSION DESIGNED IN MATLAB

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## I. Introduction

One of the main reasons of image quality evaluation is introduction and employment of the image compression methods and them corresponding formats.

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), which is based on many observers that evaluate image quality. These tests are time demanding expensive and 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 observers are not needed [2], but generally these testing have bad correlation ($\rho = 0.4 - 0.7$) with objective criteria.

The third way of image quality evaluation is usage of a human visual model (HVS) [3, 4]. HVS model combines and uses both the objective and subjective methods. These HVS models can model only parts of human vision that we need (e.g. spatial resolution, temporal motion, color fidelity, color resolution...) [3]. A majority of these models requires a tested image and its corresponding matching reference in order to determine the perceptual difference between them. HVS models can be divided into two groups. The first group comprises one-channel models [2, 3] that can be characterized by computing with the whole image. In the second one there are multi-channel models [2, 3, 4] that simulate the neuron response of the brain cortex. The response is selective to spatial frequencies and orientations. These models decompose the image into the 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 image quality.

## II. Methods

We select a set of testing images that were tested by subjective, objective and HVS models. These images cover selected types of scenes that are very frequent in video streams (face colors, homogeneous color fields, textures, text, details, people, green color). In Fig. 1 there are shown testing images.

Portrait Fruit Posters

Square Garden

Fig. 1: Set of tested images.

*Subjective quality testing*

For the subjective testing we designed a subjective testing laboratory fulfilling ITU-R recommendations (BT.500-10) for subjective image quality testing.

DSCQS (Double Stimulus Continuous Quality Scale)
test method has been chosen because it is especially suitable for evaluation of perceived differences between the original and compressed images with a wild range of compression ratios and methods. The observers is asked to observe a pair of pictures, each from the same source, one is the reference image (in our case of 100 % picture quality), and the second one is distorted by a compression. The reference image is first in order. The evaluating sessions last 30 minutes in which the picture pairs are presented in a random order and random impairment levels covering all required combinations of compressions. Each pair were switched each 10 seconds. The continuous scale from 0 to 100 was used for quality assessment. The range is covered by the word expressions for the picture quality as Excellent, Good, Fair, Poor and Bad. According to recommendation at least 15 observers should be used. They should not be experts on assessment of the picture quality. We have used only students as observers, it is not ideal covering a spectrum of ages, but on the other hand they have prerequisite for quite good eyesight. The eyesight was tested by Snell's optotype test fat a viewing distance of 5 meters.

*Objective quality testing*

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

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

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

*Human visual system model testing*

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

The first designed model (HVS1) has been derived from characteristics of the existing models [2, 3, 4]. The model comprises color transformation (pictures are transformed from R, G, B to the CIE Lab color 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 quatization, oriented channels computation and quatization (oriented channels are computed parallel with the contrast channels), computation of distance metrics and final weighting. It involves 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 the optical part, retina and the brain cortex transform functions. This modeling respects theory and practical experiences 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 edge orientations are 0° and 90°. Important frequencies bands are: the base band, which represents information of scene brightness, and some higher bands, which represent information about important details (edges) in the image. Combinations of frequency bands and orientations create a model of visual perception. The last step of this processing employees computing of difference metric as a Just Noticeable Difference (JND).

Both models were implemented in MATLAB environment.

*Normalization*

The outputs of all methods were normalized to a range of subjective test scale 0 – 100 so that the image quality evaluation algorithms can be compared. We used linear normalization:

$$normalized\_quality = 100 - k*quality,$$

where $k$ was computing as minimum MSE difference between subjective results and selected methods. Then was computed average constant $k$ for all scenes.

## III. Results

For quality testing we tested original and JPEG 2000 compressed images presented in Fig. 1. For subjective testing we used 15 observers. For the objective testing we selected MSE and MAE method. For HVS testing we use two models described above. Some of the results are presented Fig. 2.

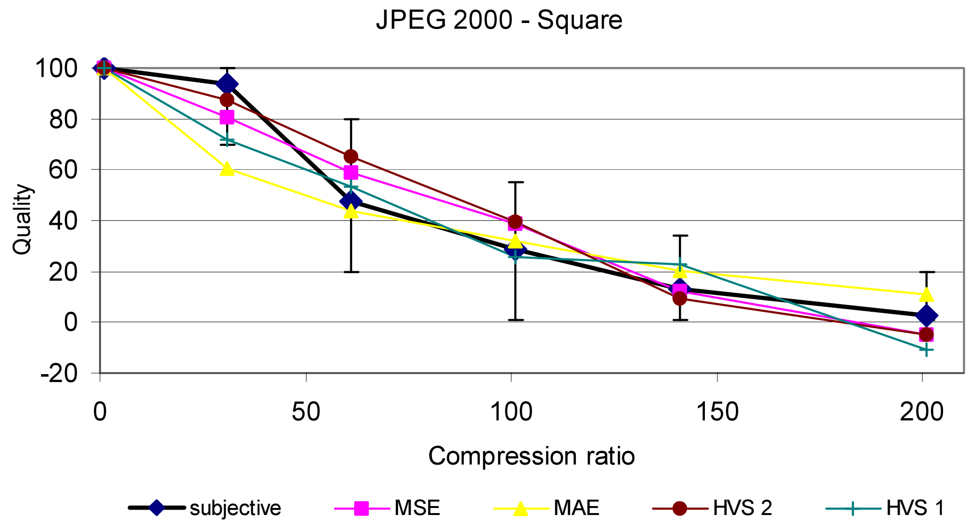


Fig. 2: Results of normalized testing of JPEG2000 image Square.

This figure presents normalized results of selected methods for figure Square. All methods have very good corresponding with subjective testing. You can see negative numbers of image quality it is caused by normalization. This effect shows Table 1. Where HVS1 are data obtained by HVS model. HVS1n are data normalized to subjective testing (constant $k$ is computed). HVS1na are normalized data with $k$ constant over all tested scenes as show Table 2. Values of constant are in the last row of the Table 1. Table 2. shows example of values of constant $k$ via all tested scenes and their average values. It shows range of the constant (variance). This variance is the best for HVS 2 model. This fact shows Fig. 4 or Fig 5.

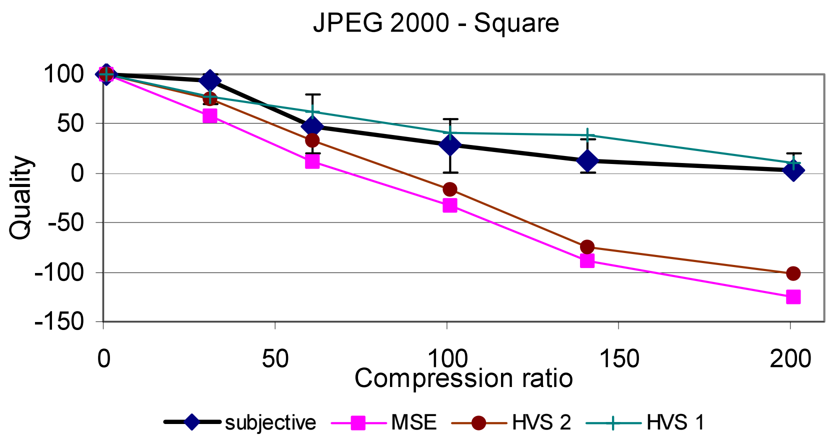


Fig. 3: Results of normalized average testing of image Square.

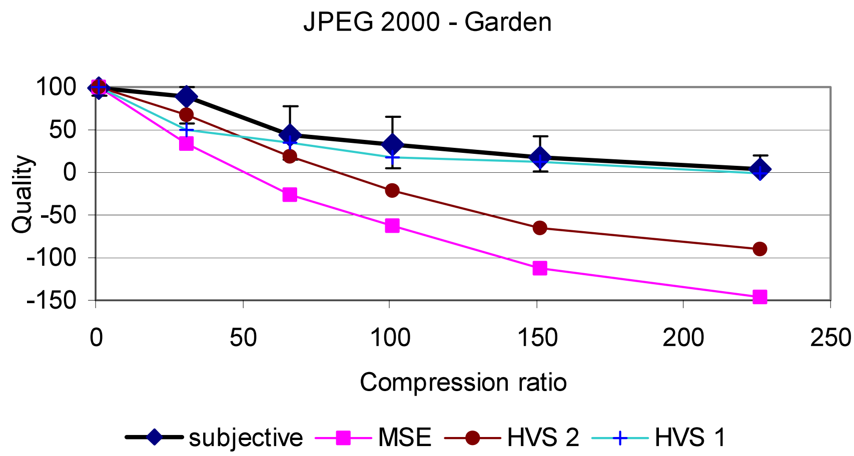


Fig. 4: Results of normalized average testing of image Garden.

Table 1. Example of HVS1 results.

| CR | HVS1 | HVS1n | HVS1na |
|---|---|---|---|
| 1 | 0 | 100 | 100 |
| 31 | 1001,13 | 72,06846 | 77,59470 |
| 61 | 1676,47 | 53,22625 | 62,48041 |
| 101 | 2660,74 | 25,76532 | 40,45261 |
| 141 | 2766,31 | 22,81986 | 38,08991 |
| 201 | 3975,99 | -10,93010 | 11,01733 |
| k | | 0,0279 | 0,0223 |

Table 2. Values of *k* via all scenes and selected methods.

| *k* | MSE | HVS1 | HVS2 |
|---|---|---|---|
| Girls | 1,7251 | 0,0251 | 4870,0 |
| Fruit | 0,2695 | 0,0208 | 697,0 |
| Posters | 0,0626 | 0,0192 | 247,6 |
| Square | 0,2308 | 0,0279 | 748,8 |
| Garden | 0,1936 | 0,0189 | 751,5 |
| Average | 0,4963 | 0,0223 | 1463,0 |

## IV. CONCLUSIONS

In Fig. 2 there are (normalized) results of image quality evaluation by methods selected above. These results show suitability of using HVS models for image quality evaluation. Main criterion for assessment of the image quality is good correspondence with human perception that is represented by subjective DSCQS test. Fig 3. shows good correspondence for almost all methods that is given by normalization method (finding of minimal MSE). The best robust method for all scenes is HVS 1 model, following HVS 2 model than MSE as is presented in Fig. 4. Generally image quality testing based on mathematical approaches like HVS model, MSE and MAE are cheaper and less time demanding then subjective one.

## REFERENCES


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