

MATLAB-based Applications for Image Processing and Image Quality Assessment – Part I: Software Description

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Abstract. *This paper describes several MATLAB-based applications useful for image processing and image quality assessment. The Image Processing Application helps user to easily modify images, the Image Quality Adjustment Application enables to create series of pictures with different quality. The Image Quality Assessment Application contains objective full reference quality metrics that can be used for image quality assessment. The Image Quality Evaluation Applications represent an easy way to compare subjectively the quality of distorted images with reference image. Results of these subjective tests can be processed by using the Results Processing Application. All applications provide Graphical User Interface (GUI) for the intuitive usage.*

Keywords

Image quality evaluation, image processing, quality metrics, QoE.

1. Introduction

Image processing is one of the most important area of multimedia applications and it is known, these applications can be found almost everywhere in the modern world. Because of that, the number of people working with images is rapidly increasing which means, that demand for image processing tools also grows. Images are being compressed, decompressed, sent over the internet, modified or distorted in various ways and all these things affect their quality. It is the key element for multimedia to be able to assess the quality changes, predict them and eventually correct them.

The best way of quality assessment is subjective testing by a group of human observers but it is time-consuming and costly, the conditions of measurement must be precise and observers must be well instructed. A set of images can be used only once for each observer, otherwise the results would not be relevant, so there is a constant need for new images or observers, what is even more difficult.

The above described problems lead to objective quality metrics. Its upside is obvious – evaluation is easy, quick, cheap and could be also used to evaluate quality in data-transporting processes. The main issue is that we are not able to simulate human visual system (HVS) yet. Objective quality criteria could be divided into three main groups – No-reference quality metrics, Reduced-reference quality metrics and Full-reference quality metrics.

Full reference image quality metrics compare distorted images to their original that is proclaimed to be qualitatively the best. The ways, in which they are doing so, differ. The pixel-based metrics look at the differences between corresponding pixels regardless of the information in the picture. These criteria are very simple and easily computable but do not correlate too much with the results of subjective tests. The HVS based metrics are much more complicated but also show much better results. They have their roots in psycho-visual models of HVS. As it was said before, these models are unfortunately not exact. Each of them is good at simulating one aspect of HVS but fails in the others. This was widely discussed in [1]. Completely new look at full reference image quality assessment brought metrics [2], [3] using information fidelity, which works with loss of information, that can human brain ideally extract from the image during the distortion process.

Although implementations of many above described metrics are available for free download and use, it is convenient to have them altogether in one application. The other applications provide simple software for subjective quality assessment, tool for processing their results and software suitable for further image processing – distortion simulation or increase of quality.

This paper is organized as follows. Section 2 discusses state of the art applications for Image Quality Assessment. Section 3 describes the Image Processing Application. Section 4 is about the Image Adjustment Application. The Image Quality Evaluation Applications are described in section 5. Section 6 belongs to the Results Processing Application. Section 7 discusses the Image Quality Assessment Application. In section 8 this paper is concluded and the future work possibilities are discussed.

2. State of the Art Applications for Image Quality Assessment

This section is about existing applications for Image Quality Assessment.

The first application that should be mentioned is called MeTriX MuX Visual Quality Assessment Package and is available at [4]. It contains 12 most popular metrics based on pixels, HVS and information fidelity. It does not provide any GUI so the usage is not too intuitive. It is basically the set of functions that could be called by user's source code in MATLAB.

Another image quality assessment package is available at [5]. It provides only pixel-based criteria and also does not have GUI.

Very complex tool with GUI was proposed in [6]. Its advantage is in evaluating series of pictures at once. Besides standard pixel-based, HVS-based and information fidelity based criteria also some no-reference and reduced-reference metrics are implemented. The application creates the excel file with results instead of showing them directly in GUI. The authors also proposed the application for quality assessment of video sequences, subjective quality evaluation and correlation analysis.

This paper contains introduction to five image processing and image quality applications that were developed based on students' works [7], [8], [9] within the agreement with ESEO Institute in France and then the applications were adopted and completed at CTU Prague and extended with the other functions and GUI.

3. Image Processing Application

The first application to be described is the Image Processing Application. It is very useful for simulation of various types of distortion or increasing the quality of pictures. Users have the following options: Intensity Transformations, Spatial or Frequency Domain Filtering and Noise Addition. Also the simplest objective quality metrics are implemented. The application provides user-friendly GUI and Help to make it easy to work with. Demonstration of the GUI is in Fig. 1. What can be really helpful is the usage of so called Temporary Images. It means that the program does not work with the originally loaded image but with its automatically created copy, hence there is no danger of original picture loss. It is also possible to save the image after every change made as a temporary image, and then modify it using another type of distortion.

The Intensity Transformations work with the pixels of image on which the spatial domain techniques are applied. There are two possibilities in this section. The first one is the Intensity Adjustment which is based upon the *imadjust()* function in MATLAB. It enables users to set low and high intensity thresholds. Values lower or higher

respectively, are then clipped. The shape of the curve mapping the intensity values can be modified by changing gamma parameter. The other option is adjustment by using image intensity histogram. If the original image (or image with better dynamic range) is available, it can be loaded and its histogram will be automatically applied on the input image. This could lead to increase of dynamic range and therefore higher contrast. For the situations where no image of better quality is available there is a possibility of bimodal Gaussian function usage. It models histogram with two modes. This is especially well suited for images with large dark areas.

The second section of this application is Spatial Domain Filtering. It is divided into linear and non-linear filtering. The proposed linear filters are: Motion, Sobel, Prewitt, unsharp, laplacian, disk, average and gaussian. The computation is based on *imfilter()* function in MATLAB so there are three more options: Filtering Mode – convolution or correlation, Size Option – original or full and Boundary Option – replicated, symmetric or circular. It is also possible to define a personal filter matrix. Non-linear filters are two – Median Filter and Adaptive Median Filter. Median Filter calculates the median value of the pixels in neighborhood and replaces the center pixel with this value which especially increases the quality of images with “salt&pepper” noise field. The Adaptive Median Filter ranks the pixels in neighborhood and uses the value obtained from this to replace the center pixel. It is able to adapt itself to the exact type of image. The size of the neighborhood for both filters is set by user as the parameter. (Adaptive Median filter has flexible size of neighborhood so the parameter defines the maximum size).

The Frequency Domain Filtering section consists of filters defined in spatial domain transferred to the frequency domain by FFT and filters defined directly in frequency domain. The first ones are based on MATLAB function *freqz2()* which computes the frequency response of FIR filter. User can choose from the same set of filters as in linear spatial domain filtering (plus logarithmic filter) or define his own filter matrix. The latter ones are Butterworth, gaussian or ideal low or high pass filters. It is also possible for user to take a look at 3-D representation of any chosen filter by checking the “Show Generated Filter” square. The last thing to be mentioned in this section is the choice between Simple Padding and Square Padding which affects the execution time of Fast Fourier Transformation (FFT) that is used for transforming to the frequency domain.

The next part of Image Processing Application serves for comfortable addition of noise fields. There are five possible noise field types available: Gaussian, “salt&pepper“, lognormal, Rayleigh and exponential. Probability density function of the chosen noise field with relevant parameters is shown just before the noise field is applied into the image. The dependence of calculations of the noise fields on the parameters can be found in Tab. 1.



Fig. 1. Image Processing Application’s interface.

Noise field type	Parameters	Dependence
gaussian	mean, variance	noise = mean + variance · randomNumbers
“salt&pepper“	salt, pepper	salt – probability of white pixels pepper – probability of black pixels
lognormal	A (offset), B (shape)	noise = A · exp (B · randomNumbers)
Rayleigh	A, B	noise = A + (-B · log (1 – randomNumbers)) ^{1/2}
exponential	A	noise = (-1/A) · (1 – randomNumbers)

Tab. 1. Dependence of noise field types on parameters.

The last section is dedicated to basic objective image quality measures. Provided metrics are SNR, PSNR and percentage MSE. These pixel-based criteria are the simplest ones but they are also the most widely used.

4. Image Quality Adjustment Application

In this section, the Image Quality Adjustment Application will be described. It represents very useful tool for increasing quality of images. Its main advantage is that it makes a series of pictures with different degree of applied method. The user chooses one of the following methods: 2D high pass filtering, gaussian filtering, unsharp mask filtering and addition of the edge (with Prewitt or Sobel filter). Then the coefficient from zero to two has to be chosen, by which the filter matrix will be multiplied and the number of pictures the application should make. It will then generate the series and save it into the specified

folder. The coefficient is for every image multiplied by its serial number so the degree of filtering is different for every generated picture. The interface of the application is shown in Fig. 2.

5. Image Quality Evaluation Applications

These applications serve for subjective image quality assessment. There are two very similar applications. Both of them are divided in two parts – single reference picture evaluation and twin reference pictures evaluation. In the first one the series of distorted images are being compared to the reference image. In the later one every reference picture has its own “distorted twin” in such a way subject evaluates couples of images. The interface for both of the applications is the same (Fig. 3).

The user has to choose the folder with reference image (or images) and the folder with distorted images. Then the number of parameters has to be defined. These parameters have to be specified in the name of each picture. Detailed description could be found in the User Guide available with the software. There are also two possible scales for evaluation – from 0 to 100 and from -3 to 3.

The first one is well suited for evaluations, where the reference image is the one with the highest quality. The second one assumes that some of images being evaluated could have higher subjective quality then the reference.

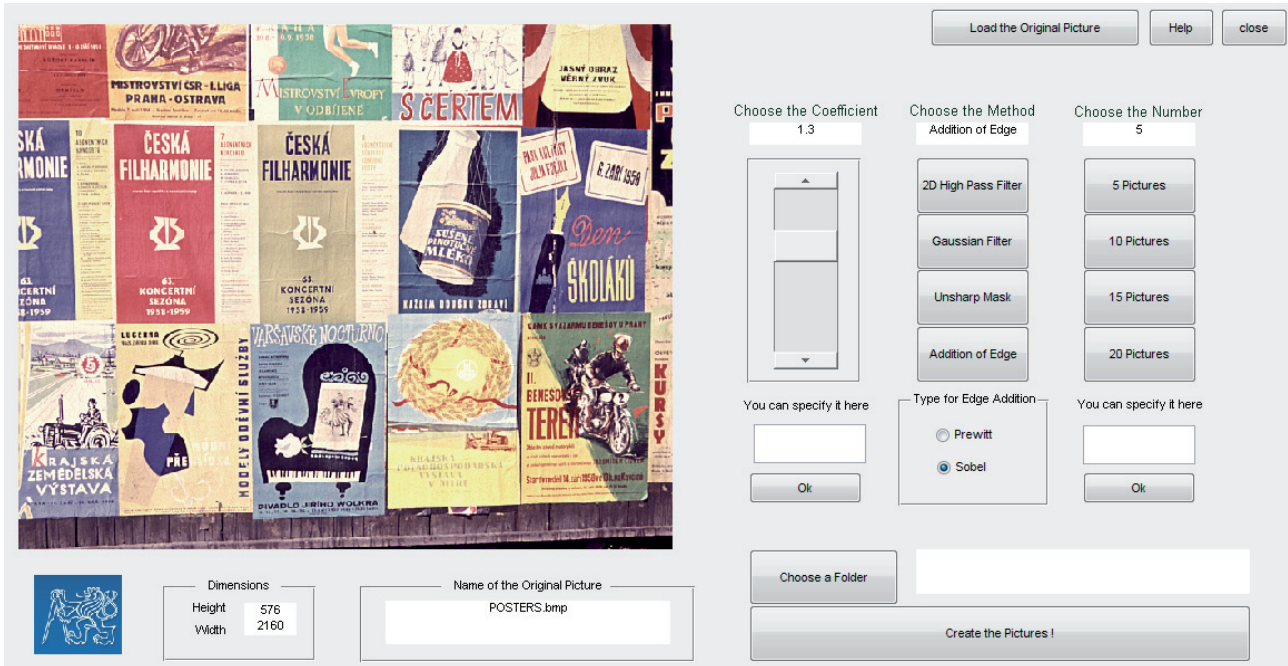


Fig. 2. Image Adjustment Application's interface.

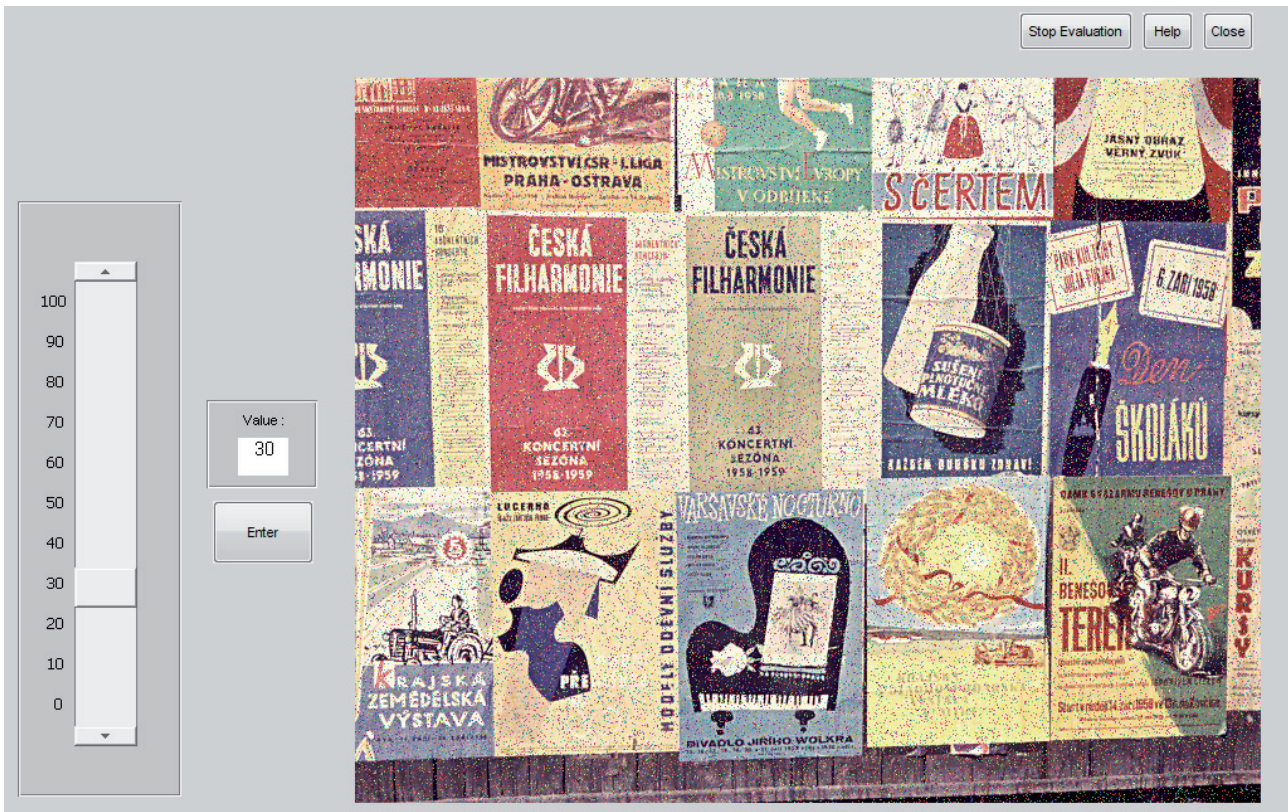


Fig. 3. Image Quality Evaluation Application's interface.

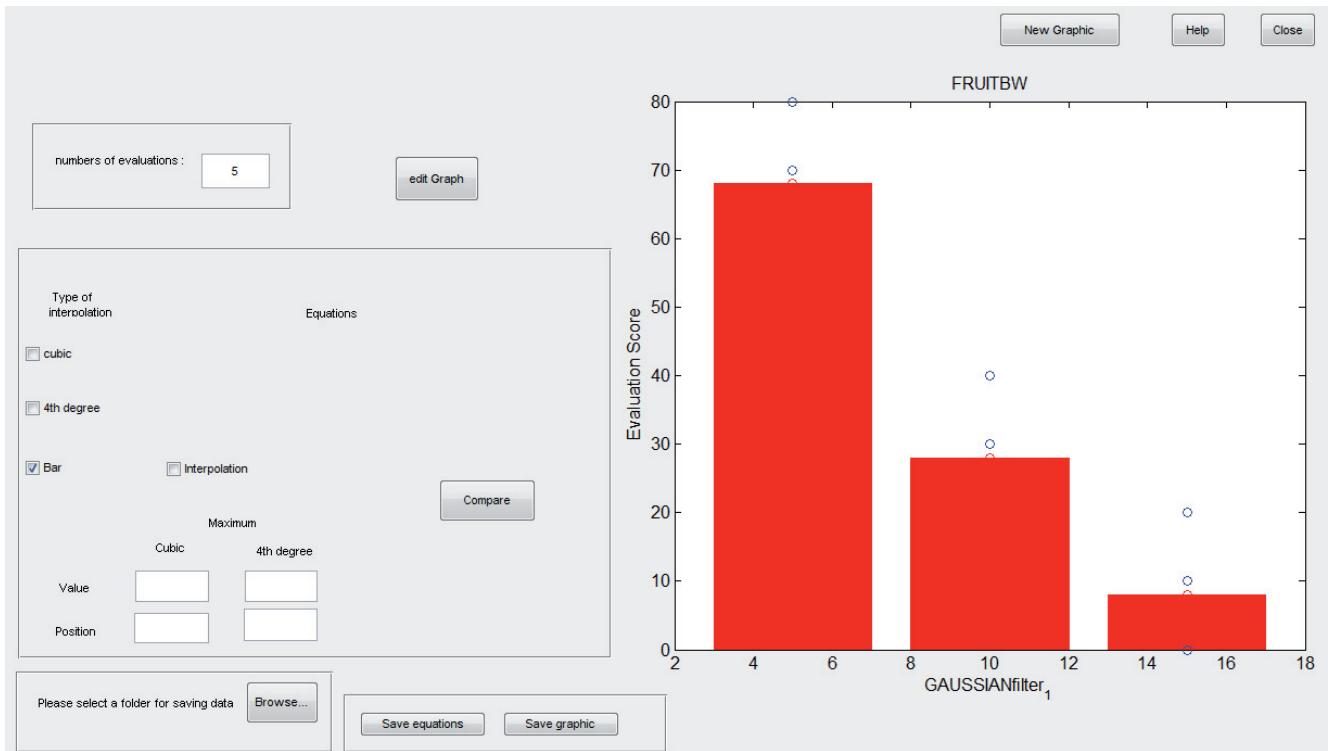


Fig. 4. Results Processing Application's interface.

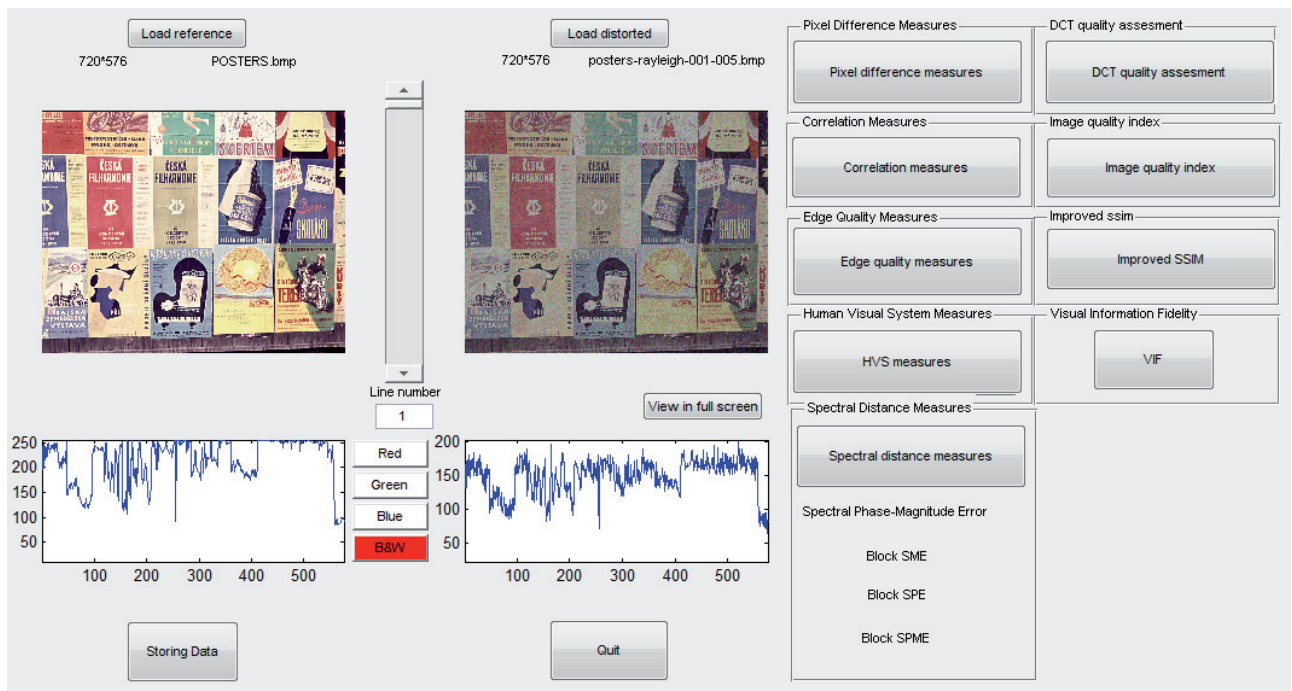


Fig. 5. Image Quality Evaluation Application's interface.

When the evaluation is started the gray picture is shown for 5 seconds. Then the subject has 10 seconds to take a good look at the reference picture after which the gray picture is shown again for 5 seconds. Afterwards the acoustic signal indicates that the distorted picture is on the

screen and subject has 20 seconds to define its quality. The last 5 seconds are announced by the acoustic signal. He can also enter the value anytime during those 20 seconds and thus terminate the evaluation of that particular image. This way it goes on until there are no more images for

assessment. After the evaluation, the results are saved as text file and the graph is shown. One of the applications generates the bar graph unlike the other one, where the results are visualized as a curve.

6. Results Processing Application

This application represents a tool well suited for processing of the results obtained by subjective image quality assessment. Its input is the folder with the text files user can get from above described applications. The data are transformed into graph of discrete values. The user can choose cubic or 4th degree polynomial interpolation. Calculated values of parameters could be then saved as a text file or as a picture including the graph with the curve. The other way of data interpretation is in a form of bar graph. The interface of this application is in Fig. 4.

7. Image Quality Assessment Application

The last application to be described is the Image Quality Assessment Application. It consists of 21 objective full reference image quality metrics divided into 7 sections: Pixel-based metrics, correlation measures, edge quality measures, HVS-based metrics, spectral distance measures, DCT-based metrics and metrics based on information fidelity. The list of all metrics is in Tab. 2.

Pixel-based metrics	MSE, SNR, PSNR, Universal Image Quality Index [11]
Correlation measures	Correlation, Cross-Correlation, Czekanowski distance
Edge quality measures	Pratt Distance, Edge Stability
HVS-based metrics	Absolute HVS Error, HVS MSE, SSIM [10], MS-SSIM [10]
Spectral distance measures	Spectral Magnitude Distortion, Spectral Phase Distortion, Weighted Spectral Phase-Magnitude Distortion, Block Spectral Magnitude Distortion, Block Spectral Phase Distortion, Block Weighted Spectral Phase-Magnitude Distortion
DCT-based metrics	DCT metric
Information fidelity metrics	VIF [3]

Tab. 1. Full reference objective image quality metrics provided by the Image Quality Assessment Application.

The user uploads reference and distorted image and then can calculate the metric values by simple clicking on the metric section. The application's GUI is in Fig. 5. For colored images there is also a possibility of calculating values for red, green, blue or luminance components independently.

Most of the metrics were computed using their definitions but some more complicated criteria (SSIM, MS-SSIM, UIQI, VIF) implementations were downloaded directly from author's web pages [10], [11], [3].

8. Conclusion

The aim of this paper is to present the MATLAB-based applications for image processing and image quality assessment developed at Multimedia Technology Group (MMTG), Faculty of Electrical Engineering (FEE), Czech Technical University (CTU) in Prague. Those can be used for the scientific or learning purposes. They represent the complex, user-friendly tools for adjustment of images and their quality.

The main extension that could be done is new methods and metrics addition. Applications for subjective quality assessment could be modified to be compatible with some kind of special hardware, such as evaluating slides, to make them even more suitable for precise conditions in laboratory.

Part II of this paper contains the experimental results. In case of interest about the test use of presented applications please contact the main authors at CTU in Prague.

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