International Refereed Journal of Scientific Research in Engineering (IRJSRE)
Volume 2, Issue 3 (March 2017), PP. 27-40

# New model for prediction ofperceived image quality of smartphones

Pinchaszorea
*Department Of Mathematics And Informatics, State University Of Moldova, Chisinau, Republic Of Moldova*

**Abstract:** Digital image processing is an essential feature in most of mobile devices. Smartphones with embedded camera and high definition (HD) resolution display became an essential part in our life. Therefore, image quality plays major role on everyday use of smartphone. Measuring the perceived image quality by the smartphone users plays an important role. In the past decade, a great deal of resources and efforts have been made by smartphones vendors in order to improve image quality and to measure how the smartphones users perceived the image quality. Unfortunately, only limited success has been achieved, the image quality assessment still based on many physical human visual test (HVT). This paper describes the development of an "objective" image quality model that predicts the perceived image quality. The new model improves and reduces the process and cost by providing a new quantitative method to evaluate perceived image quality of color images on smartphone displays. Four image quality factors: brightness, contrast, color saturation and sharpness, were chosen to represent perceived image quality. Image quality assessment model is constructed based on results of human visual tests (HVT) that compared with image analysis by the software application VIQET (VQEG Image Quality Evaluation Tool). During the research the VIQET tool was calibrated based on results from human visual experiments. This paper describes the new model and framework proposed based on human visual tests (HVT) and computer image analysis.
**Keywords:** Perceived IQ (Image Quality), Human Visual Test (HVT),objective image quality assessment, subjective image quality, image quality attributes, VIQET (VQEG Image Quality Evaluation Tool).

## INTRODUCTION

This research proposes a new model consists of a framework and computer based application, the VIQET for smartphones perceived image quality prediction. The framework is composed of a HVTs (Human Visual Tests) procedure and an evaluation by the VIQEG. The VQEG Image Quality Evaluation Tool (VIQET) is an objective, no-reference photo quality evaluation tool. VIQET is an open source tool designed to evaluate quality of consumer photos. In order to perform photo quality evaluation, VIQET requires a set of photos from the test device. It estimates an overall Mean Opinion Score (MOS) for a device based on the individual image MOS scores in the set. This thesis provides a detailed description and analysis of subjective image quality assessment through HVT and objective image quality assessment based on VIQET analysis. The correlations between the metrical and perceptual results indicated that MOS, MSE, PSNR metrics give excellent prediction performance in most cases in terms of both correlation and its variance. According to the group comparison had comparatively better prediction performance than no reference metrics.

The statistical analyses were conducted to check whether the increase of the image quality attributes would lead to improvement in user's perceived image quality. The finding is useful for the mobile phone industry to have a better understanding of the concrete benefit of enhancing the image quality attributes. The proposed quality assessment model is useful also for image quality assessment of any mobile or desktop displays.

One unique feature of this proposed framework was the capability of incorporating existing full reference image quality metrics without modifying them. This research implemented the framework for smartphones displays, and used the framework to evaluate the prediction performance of state-of-the-art image quality metrics regarding the most important image quality attributes for projection displays. The evaluated image quality attributes were brightness, contrast, color saturation and sharpness, however the proposed framework was not bound by the possibilities. All the metric evaluations were supported by the correlation of objective and subjective experimental results In addition, this study also investigated the strategies to extend subjective experiments with baseline adjustment method, which is expected to save quite a lot of time and resources for subjective experiments. In a broader point of view, the originally defined research scope have been fully covered by the research presented in this thesis, all research goals have been successfully achieved, and the corresponding research questions have been answered. The proposed image quality assessment framework was originally designed for smartphones displays, but could be easily adapted to other types of displays with limited modifications.In conclusion, with the results that obtained in this study, that the framework and the new approach provided by this research can be a good process for perceived image quality prediction.

This paper provides a comprehensive overview on the perceived image quality measurements and SW application (VIQET) calibration process. Using a number of HVT for subjective image quality assessment in order to identify the most effective image quality attributes than creating a set of processed images based on the selected image quality attributes to be used as test content for HVT.Running several HVT and analyzing the same images with the VIQET. The scores of HVT and VIQET were analyzed. The VIQET calibrated due to the outcomes of the scores analysis. Once the VIQET has new image quality parameters a new HVT conducted and the whole process done again. This process was done in several cycles in order to achieve the highest correlation between the HVT scores andVIQET scores.Once the VIQET scores were very close to the HVT scores, the counter wise process was ran, analyzing new images first by VIQET than in HVT and found a very high correlation.

## The image quality assessment method

A large number of subjective metrics have been developed that are capable of illustrating subjective assessment to measure the visible differences between a pair of images [2,3, 4]. Considering this wide range of applications, the objective research was separated into two main categories: first, the methods that consider statistical or mathematical measurement (i.e., the image features extraction), and, second, methods that consider the HVS characteristics. Considering VIQET image analyzer measures with incorporation of HVS, that is, image feature extraction using HVS characteristics. A diagram of the proposed approach is shown in Figure 1.

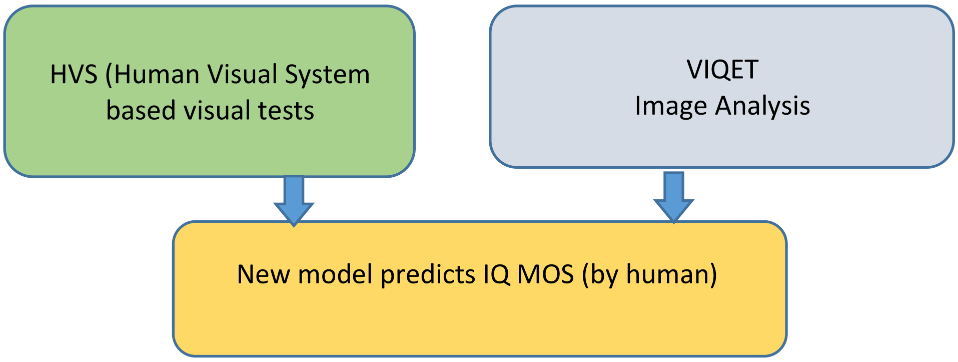


**Fig. 1.** Image quality assessment flow

## Mathematical model for subjective metrics

Most of the objective metrics consider the statistical or mathematical measurement for finding the image artifacts. The mean squared error (MSE) [5] and the peak signal-to-noise ratio (PSNR) [6] are the most widely used pixel-based image quality metrics. These techniques are simple and fast, but widely criticized for not correlating well with human visual perception and require reference images.PSNR is a simple pixel-based comparison method whereas MSE is designed on statistical features for finding differences between reference and original images. They do not consider the relationship between pixels.

Although MSE or PSNR are considered as a quality metrics but these are not consistent with the HVS as they measure every pixel within with equal priority. In addition, no information of structure, contrast, visibility, etc. are considered in these methods. These metrics consider the power of the error signal, but not how it affects the image. In reality pixels at different position create various effects on the HVS. Since image quality is strongly based on subjective observations, these metrics rarely work accurately on quality judgement.

MSE is the differences between corresponding pixels of the reference and the distorted images and it can be defined as:

$$\mathrm{MSE} = \frac{1}{V}\sum_{n=1}^{V}(S_n - \mathrm{MOS})^2 \qquad (1)$$

where V is the number of viewers participated in the Visual tests . S is the corresponding score given by viewer per each individual image in the Visual test.

MOS (Mean Opinion Score) represents the scores average of each image in visual tests.

PSNR maps the MSE in a logarithmic way which is defined as:

$$\mathrm{PSNR} = 10\log_{10}\frac{\mathrm{MAX}}{\mathrm{MSE}} \qquad (2)$$

whereMAXis the maximum value that an image can get according to the scoring table, which is: Poor =1 and Excellent = 5.

PSNR is a popular and widely used metric to evaluate and quantify performance of image processing algorithms. But it exhibits weak performance in perceived image quality assessment due to pixel-wise error computation.

Human vision is sensitive to contrast sensitivity of an image. Therefore, these mathematical models do not always correlate with human perception and fail to predict the perceived quality of an image.

Several experiments were ran in order to measure the prediction performance of MSE and PSNR over MOS. In order to show the performance of MSE over MOS for different level of image quality attributes of 10 different scenes with 5 images in each individual scene e.g. building, hall, bar and room.

## Implementation of subjective image quality assessment

In order for the observers to use a sufficiently large set of IQ attributes, a broad range of images should be used in order to reveal different quality issues. To achieve this, the images were chosen based on the recommendations of VQEG with the criteria: pictures of ten natural image contents captured by smartphones camera in native resolution of 1920x1200 pixels. These ten images will be used as a reference. Each original image will be processed by adding the IQ attributes (brightness, contrast, color and sharpness) than the overall test content will be fifty images.

Test content was created according to the VQEG recommendations in “Recommendation P.913”, ITU-T, 2014 [3]. Contents were carefully selected to represent a wide range of different situations and demands for pictures. Also, recommendations of photo-space standards set by I3A were considered when choosing the image contents. Each original image was processed in order to enhance image quality attributes of: brightness, contrast, sharpness and color Saturation.

The overall test content for human visual tests (HVT) and VIQET analysis includes 50 images (5 images of each scene).

**Fig. 2**. Outdoor day- landscape, people.

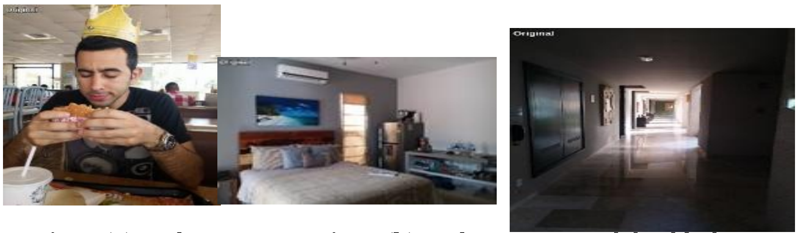

**Fig. 3 (a).** Indoor images. **Fig. 3 (b).** Indoor image with backlight.

**Fig. 4**. Outdoor night.

Images in Figures 2,3 and 4were selected as test content for the subjective image quality assessment. Images in Figure 2 “building”, “lake”, “man” and“taxi” are an example of outdoor day of some of the everyday city landscape.

Images in Figure 3 (a) “king” and“room” are an example of indoor without backlight of some of the everyday scene when pictures are taken indoor without window or door backlight. In this case the main objects are lighted.

Image in Figure 3 (b) “hall” is an example of indoor with backlight of some of the everyday scene when pictures are taken indoor with window or door backlight. In this case the main objects are shaded.

Images in Figure 4 “sunset”, “bar” and “airplane”, are an example of outdoor night with considerable amount of black in the photo and the space was very bright and well-lit. A camera needs to properly meter off the light so that the people don’t get blown out, and so the shadows are precisely dark.

## Test content with controlled image quality attributes

In order to measure the image quality attributes effect on perceived image quality,ten sets of natural images were prepared and four image quality attributes were added to each original image then added four different image quality attributes levels of each single original image as demonstrated in Figure 5.

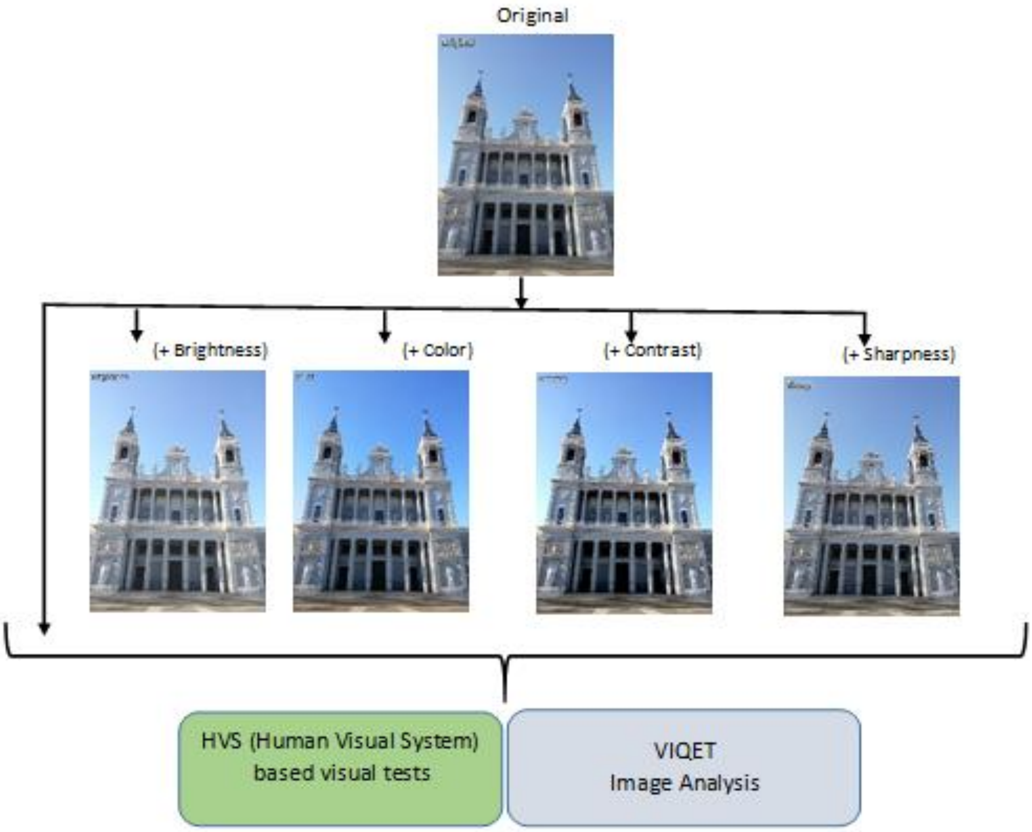


**Fig. 5.** An example of test material processing (“building”)

## The proposed new model for perceived image quality prediction

The new model flow chart in Figure 6, presents the method used in this research which includes subjective IQ assessment via HVT (Human Visual Test) and objective IQ assessment with SW tool (VIQET – VQEG Image Quality Evaluation Tool) which was developed for this purpose.

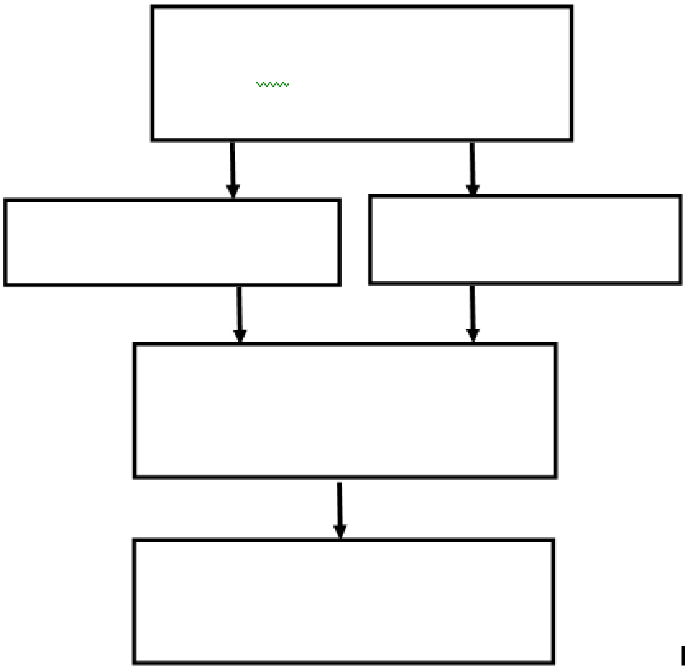

**Fig. 6**. Model of IQ visual tests and image quality evaluation tool

**Human visual test (HVT) and VIQET image analysis**

This part of study begins with an analysis of the images selected for test content for the HVT (Human Visual Tests) by the VIQET (VQEG Image Quality Evaluation Tool).

Design requirements followed by a detailed description of design and development procedures of an objective image quality assessment model.

This new model consists of two parts: first, finding how image quality attributes effect observers’ preferences through HVT, and, second image analysis with the VIQET.

Taking brightness, contrast, color saturation and sharpness as major image quality attributes, because these are the most visible everyday images.

Image quality attributes improve or degrade the perceived visual quality of an image. However, the relationship between the image quality and the level of increasing/decreasing IQ attributes depends on the texture contents of an image. In order to verify this relationship.

Therefore, the results indicate that visibility of image quality is strongly depended on the IQ attributes added to the image.

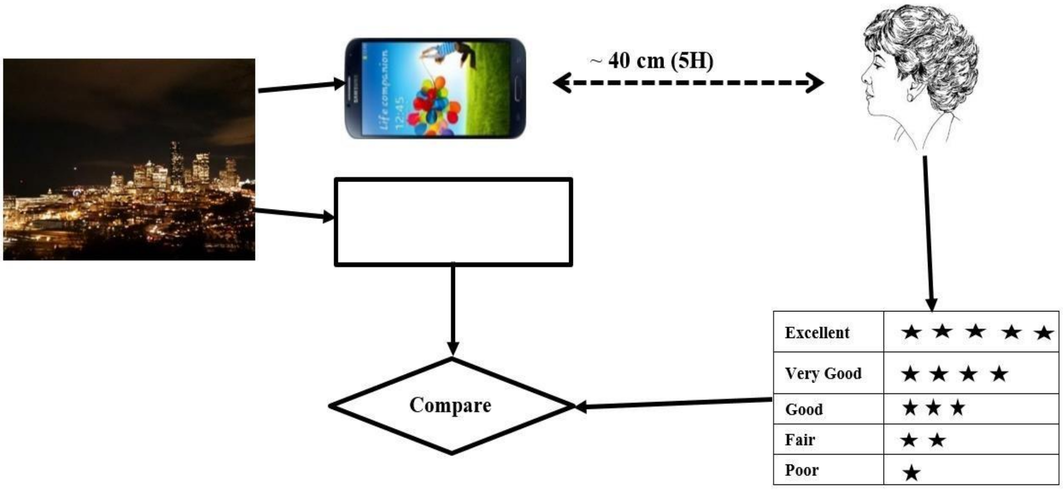


**Fig. 7.** Model of IQ visual tests and VIQET analysis comparison

## Phase I: rating the perceived IQ using HVT

A total number of 35 non-expert (the term non-expert is used in the sense that the viewers' work does not involve television picture quality and they are not experienced assessors) subjects participated in this experiment, including 20 males and 15 females aged between 16 and 30 years.

All of them had normal or correct-to-normal sight. Each subject viewed the images in database with a random order on each mobile device and viewed ten sets of five images in each set (original, + brightness, + contrast, + saturation, + sharpness).

He/she rated his/her perceived image quality in the Absolute Category Rating (ACR) 5-point scale as shown in Figure 8 (corresponding to the perceived quality of “excellent,” “good,” “fair,” “poor,” and “bad”).The environment to the experiments was set following the suggestion of ITU-R recommendation BT.500-13 [7].

Before the formal test, the subjects were asked to rate a few example images to get familiar with the scoring scale and the image browsers.

| | |
|---|---|
| Excellent | ★ ★ ★ ★ ★ |
| Very Good | ★ ★ ★ ★ |
| Good | ★ ★ ★ |
| Fair | ★ ★ |
| Poor | ★ |

Fig. 8. Staring points ranking

## Human Visual Test (HVT) flow chart

The flow chart in Figure 9 provides an overview of the methodology used in this research to test and perform subjective IQ testing. The tests assessed the subjective quality of images material presented on a smartphone display (Samsung Galaxy S5) in a simulated viewing environment.

The display resolution, however, was 1920 X 1080 in all tests. Each subjective experiment collected valid data from 35 participants.

A statistical criterion was used to verify that the data from a viewer were correlated to the average of the other viewers’ data (see chapter III). All viewers were screened prior to participation for normal (20/30) visual acuity with or without corrective glasses (per Snellen test or equivalent) and normal color vision (per Ishihara test or equivalent).

The test material consisted of 50 images, which included the processed images with different IQ attributes. The duration of each image sample was one minute. For each experiment, the image samples were functionally divided into five subsets: original, brightness, contrast, color and sharpness. Subjective test methodology, the ACR (Absolute Category Rating) method with hidden reference. The subjective picture quality of the image samples was assessed, in all subjective tests, using the absolute category rating scale (ACR) method [ITU-T Rec. P.910].

The ACR method is a single stimulus method in which the image samples are presented one at a time, and rated independently using the five-grade image quality scale shown in Figure 8. During the data analysis the ACR scores given to the processed versions were subtracted from the ACR scores given to the corresponding reference to obtain a DMOS. This procedure is known as “hidden reference” (henceforth referred to as ACR-HR). This choice was made because ACR provides a reliable and standardized method that allows a large number of test conditions to be assessed in any single test session. Some experiments were implemented and controlled by software. For these, the viewers performed the experiment using custom made software. The software controlled both the timing and order of presentation of the stimuli.

The order of presentation of the image samples was changed randomly for different groups of viewers. All viewers received instructions, which followed agreed upon guidelines to ensure consistency across subjective experiments. To familiarize the viewers with the assessment tasks and with the levels of image qualities used in the experiment, a small number of practice trials were administered at the beginning of the experimental session. To control the effects of fatigues, a short break was given after about half of the video sample had been assessed.

Accordingly, in this scenario, each experiment included the following steps:

Introduction and instructions to viewer.

Practice images: these test images allow the viewer to familiarize with the assessment procedure and software. They represented the range of distortions found in the experiment. Ratings given to practice clips were not used for data analysis.

Short break. Assessment of second half of the image samples.

The test room conformed to Recommendation ITU-R BT.500-11. In general, a test session involved only one viewer per display assessing the test material. Viewers were seated directly in line with the center of the smartphone display as shown in Figure 7 at a viewing distance equal to five times the height of the picture (i.e., 5H) in all experiments.

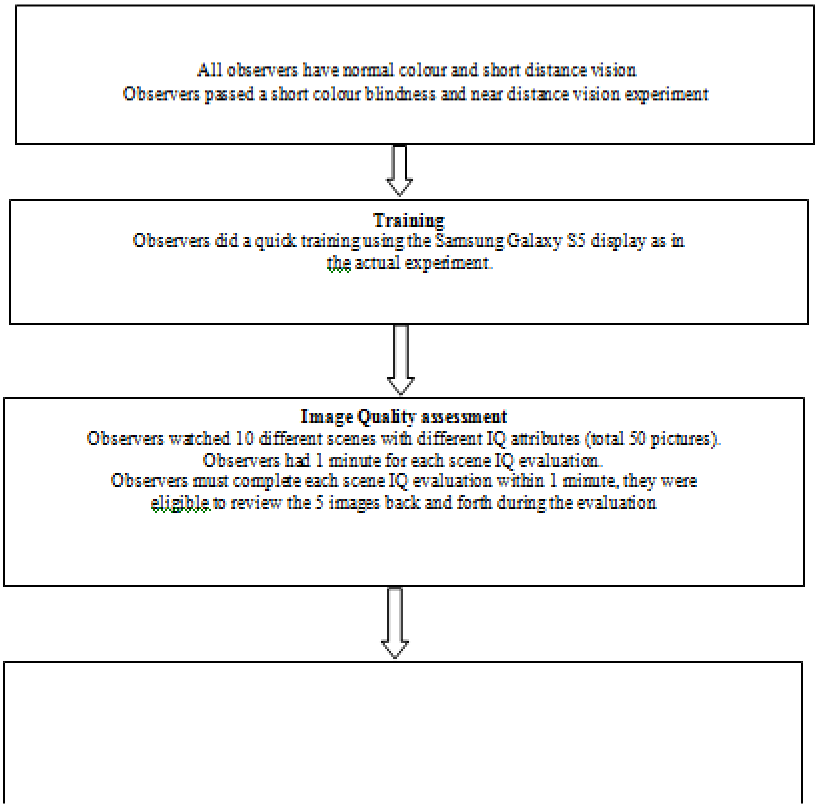


**Fig. 9.** Human Visual Test flow chart

## Phase II: Rating image quality with VIQET

The VQEG Image Quality Evaluation Tool (VIQET) is an objective, no-reference photo quality evaluation tool. VIQET is an open source tool designed to evaluate quality of consumer photos. In order to perform photo quality evaluation, VIQET requires a set of photos from the test device. It estimates an overall Mean Opinion Score (MOS) for a device based on the individual image MOS scores in the set.

- VIQET is an open source project that is available at www.GitHub.com/VIQET.
- The desktop tool installer can be downloaded at: https://github.com/VIQET/VIQET-Desktop/releases
- The source code can be found at: https://github.com/VIQET/VIQET-Desktop

In order to perform photo quality evaluation, VIQET requires a set of photos from the test device. It estimates an overall Mean Opinion Score (MOS) of a device based on theindividual image MOS scores in the set. The estimated MOS of each photo is based on a number of image quality features and statistics extracted from the test photo. The mapping from extracted features to MOS is based on psychophysics studies that were conducted to create a large dataset of photos and associated subjective MOS ratings.The studies were used to learn a mapping from quantitative image features to MOS. The estimated MOS by VIQET falls in a range of 1 to 5, where 1corresponds to a low quality rating and 5 corresponds to excellent quality. Figure10 demonstrates an example of VIQET RGB histogram and Figure 11 demonstrates VIQET Sharpness map.

**Fig. 10.** An example of VIQET RGB histogram

**Fig.11**. An example of VIQET Sharpness map

## VIQET – image quality attributes

Table1.demonstrates an example of VIQET image quality attributes of quantitative image features.

Table 1. VIQET image quality categories

| **IQ feature** | **Score** | **Range** |
|---|---|---|
| MOS (Mean Opinion Score) | 4.5 | 1 – 5 |
| Multi- scale Edge Acutance | 12.14 | Higher is better |
| Noise Signature Index | 99.39 | 0 - 589 |
| Saturation | 123.41 | 0 represents B&W image |
| Illumination | 92.00 | 0 - 255 |
| Dynamic Range | 106.72 | Represents Gary levels |

**Multi-scale edge acutance:** refers to how sharp the outline of objects in an image are and how many edges were detected in the scene. The sharper the image, the higher the multi-scale edge acutance feature.

**Noise signature index:** refers to how noisy or grainy an image is. This feature value ranges from 0 to 589. The higher the index, the grainier the image.

**Saturation:** refers to how vivid and intense a color is. An image with poor color saturation will look washed out or faded. When a color's saturation level is reduced to 0, it becomes a shade of gray.

**Illumination:** refers to how well-lit an image is. An image is considered well-lit if it is bright and has a sufficient amount of detail. Its values ranges from 0-255.

**Dynamic Range:** is the range between the lightest and darkest regions in an image while maintaining details of an image in both the lightest and darkest spots (represented in shades of grey).

## Image quality analysis by VIQET

VQEG Image Quality Evaluation Tool (VIQET) is an objective, no reference photo quality Evaluationtool.

VIQET is a free and open source tool designed to evaluate quality of consumerphotos.Inorder to perform photoquality evaluation, VIQET requires a set of photos from the test device. It estimates an overall Mean Opinion Score (MOS) for a device based on the individual image MOSscores in the set. The estimated MOS for each photo is based on a number of image quality features and statistics extracted from the test photo. The mapping from extracted features to MOS is based on psychophysics studies that were conducted to create a large dataset of photos and associated subjective MOS ratings. The studies were used to learn a mapping from quantitative image features to MOS. The estimated MOS by VIQET falls in a range of 1 to 5, where 1 corresponds to a low quality rating and 5 corresponds to excellent quality.

The same images used in phase I for rating IQ by HVT (Human Visual Test) were required for IQ rating by VIQET to analyze each individual image and get its IQ scores (IQ categories).

## Image quality assessment results processing

After the subjective tests, the credibility of assessment results was checked using the Linear Pearson Correlation Coefficient (CC) suggested by ITU-T Recommendation P.913 [8].
The Pearson Correlation Coefficient CC (see equation 2.3) measures the linear relationship between a model's performance and the subjective data. Its great virtue is that it is on a standard, comprehensible scale of -1 to 1 and it has been used frequently in similar testing.
The LPCC is calculated as follows:

$$CC = \frac{\sum_{i=1}^{N}(Xi-\overline{X})*(Yi-\overline{Y})}{\sqrt{\sum_{i=1}^{N}(Xi-\overline{X})^2}*\sqrt{\sum_{i=1}^{N}(Yi-\overline{Y})^2}} \quad (3)$$

Xi denotes the subjective score MOS(i) in HVT for processed image (IQ attribute added), X denotes the MOS ("objective") of processed image (IQ attribute added) and Yi denotes the subjective score MOSp(i) in HVT of original image (no IQ attribute added), Y denotes the MOS ("objective") of original image. N in equation (2.3) represents the total number of images considered in the analysis.

Therefore, in the context of this test, the value of N in equation (2.3) is: N=10.
The sampling distribution of Pearson's CC is not normally distributed. "Fisher's z transformation" converts Pearson's CC to the normally distributed variable z. This transformation is given by the following equation:

$$z = 0.5 \cdot \ln\left(\frac{1+R}{1-R}\right) \quad (4)$$

The statistic of z is approximately normally distributed and its standard deviation is defined by:

$$\sigma_z = \sqrt{\frac{1}{N-3}} \quad (5)$$

**Table 0.** LPCC of each IQ attributes in HVT (Phase I)

| IQ attribute | Brightness | Contrast | Original | Color Saturation | Sharpness |
|---|---|---|---|---|---|
| **LPCC** | 0.22 | 0.85 | 0.28 | 0.72 | 0.25 |

The values of LPCC of each subject in HVT (Phase I) were calculated. As a result, the number of the valid subjects (i.e., 35) meets the requirement of the Video Quality Experts Group (VQEG).

Table 2.3 lists the LPCC of viewer's rating scores on each IQ attribute after the screening process. The perceived image quality of each image was measured in terms of the average score of all valid subjects, also known as the Mean Opinion Score (MOS) [8].

The subjects in VIQET analysis were also screened according to the screening result in Phase I.

The perceived image quality difference of each image pair was measured in terms of the average score of all valid subjects, also known as the Differential Mean Opinion Score (DMOS) [8].

Then, Cronbach's alpha value was computed to measure the internal consistency of the valid scores on each device. As per the results illustrated in Table 2, the value of alpha of each device is considerably large, which indicates that there is a strong internal consistency among the valid subjects.

## Characteristic of the image quality attributes

Many of the IQAs (Image Quality Attributes) were analyzed in many image quality researches are similar and have common denominators, which enables them to be grouped within more general IQAs in order to reduce the dimensionality and create a more manageable evaluation of IQ. There is usually a compromise between generality and accuracy when it comes to dimensionality. A small set of general IQAs results in lower accuracy, but low complexity, while a higher dimensionality offers accuracy, but higher complexity. Linking most of the above image quality attributes (IQAs) to four different dimensions, considered as important for the evaluation of IQ. This results in a reasonable compromise between accuracy and complexity reduced the IQAs found in the literature to the following four:

- **Color** contains aspects related to color, such as hue, saturation, and color rendition, except lightness.
- **Brightness**is considered so perceptually important that it is beneficial to separate it from the color. Brightness will range from "light" to "dark".
- **Contrast**can be described as the perceived magnitude of visually meaningful differences, global and local, in lightness and chromaticity within the image.
- **Sharpness**is related to the clarity of details and definition of edges.

The four dimensions are general high-level descriptors, either artefactual, i.e., those which degrade the quality if detectable, or preferential, i.e., those which are always visible in an image and have preferred positions. Most of the IQAs found in the literature can be linked with these four IQAs.

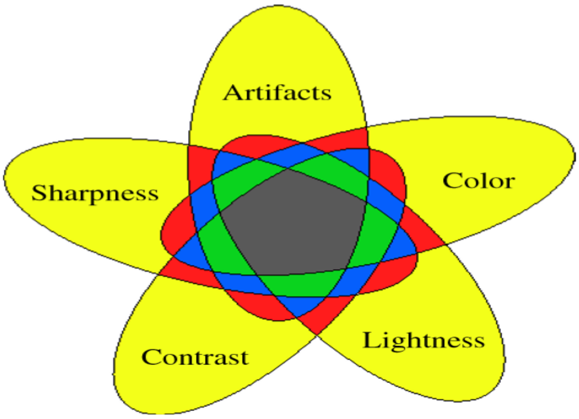


Fig.12.The Venn diagram illustrates how the overall IQ is influenced by Lightness (Brightness), Contrast, Color, Sharpness and Artifacts [9].

### Perceived image quality results of HVT (Human Visual Tests)

The perceived image quality on diverse IQ attributes is firstly investigated based on the rated scores, that is, MOS, for the images categories: Outdoor Day, Indoor and Outdoor Night respectively. Considering the possible influence of the IQ attributes, these images have the same resolution (i.e., 1080P) but in different IQ attributes. Take the high and low quality images with ten randomly selected contents as an example; the relationship between the MOS, MSE, PSNR and the IQ attributes of outdoor day,indoor and outdoor night images were analyzed and it can be seen that there is no significant increase or decrease in the perceived quality, when the brightness is increased. The viewer's perceived quality is not significantly influenced by the change of brightness during the viewing process. In a general sense, the MOS of the images displayed on smartphones are used to demonstrates the difference of perceived image quality across four IQ attributes (brightness, contrast, color saturation and sharpness).

Furthermore, a statistical analysis, that is, the one-way analysis of variance (ANOVA), is further performed to check the significance of influence of the IQ attributes on the perceived image quality. The test is firstly implemented on HVT (Human Visual Tests) while observers gave scores to each image displayed on mobile phone display. The analysis is conducted under different IQ attributes.

### Root Mean Square Error

The accuracy of the objective metric is evaluated using the RMSE (Root Mean Square Error) evaluation metric. The difference between measured and predicted DMOS is defined as the absolute prediction error Perror:

$$Perror(i) = Score(i) - MOSp \quad (7)$$

where the index i denotes the image sample.

While score (i) is the score gave by observer in HVT and MOSp is the predicted MOS (which is the average of all observers' scores). The root-mean-square error of the absolute prediction error Perror is calculated with the formula:

$$RMSE = \sqrt{\left(\frac{1}{N}\sum_{i=1}^{N} Perror(i)^2\right)} \quad (6)$$

where N denotes the total number of images considered in the analysis.

Table 1. Results of the accuracy and signification calculation using RMSE formula

| IQ attribute | Brightness | Contrast | Original | Color Saturation | Sharpness |
|---|---|---|---|---|---|
| building | 0.86 | 0.72 | 0.73 | 0.55 | 0.53 |
| lake | 0.98 | 0.69 | 0.63 | 0.48 | 0.54 |
| man | 0.74 | 0.55 | 0.61 | 0.44 | 0.46 |
| taxi | 0.87 | 0.59 | 0.81 | 0.52 | 0.47 |
| room | 0.64 | 0.55 | 0.68 | 0.50 | 0.53 |
| king | 0.71 | 0.60 | 0.72 | 0.55 | 0.49 |
| hall | 0.87 | 0.65 | 0.84 | 0.49 | 0.58 |
| bar | 0.84 | 0.61 | 0.77 | 0.60 | 0.52 |
| sunset | 0.81 | 0.61 | 0.72 | 0.55 | 0.44 |
| airplane | 0.88 | 0.56 | 0.72 | 0.49 | 0.44 |

**Table 2.** Results of the VIQET image quality analysis

| IQ attribute | Multi-scale Edge Acutance | Noise Signature Index | Saturation | Illumination | Dynamic Range |
|---|---|---|---|---|---|
| Brightness | 13.09 | 170.33 | 68.81 | 81.56 | 101.19 |
| Contrast | 15.71 | 259.47 | 115.78 | 143.20 | 95.95 |
| Original | 13.11 | 185.46 | 95.86 | 112.56 | 102.32 |
| Saturation | 12.23 | 196.91 | 112.25 | 120.26 | 102.43 |
| Sharpness | 27.74 | 236.84 | 96.40 | 173.21 | 103.28 |

**Table 3**. Results of the accuracy and signification calculation using RMSE formula

| IQ attribute | Multi-scale Edge Acutance | Noise Signature Index | Saturation | Illumination | Dynamic Range |
|---|---|---|---|---|---|
| **Brightness** | 15.28 | 447.74 | 117.80 | 68.73 | 22.11 |
| **Contrast** | 23.38 | 653.78 | 156.83 | 108.77 | 45.81 |
| **Original** | 25.17 | 423.56 | 161.52 | 158.08 | 22.69 |
| **Saturation** | 16.04 | 434.79 | 164.69 | 190.45 | 22.67 |
| **Sharpness** | 48.79 | 537.87 | 160.80 | 263.72 | 20.39 |

**Table 4**. Comparison between perceived image quality of IQ Attributes

| IQ attribute | Brightness | Contrast | Original | Color Saturation | Sharpness |
|---|---|---|---|---|---|
| **MOS** | 3.46 | 4.50 | 3.74 | 4.62 | 4.69 |

## Calculation of DMOS values

The data analysis was performed using the difference mean opinion score (DMOS). DMOS values were calculated for each IQ attribute. DMOS values were calculated using the following formula:

$$DMOS = MOSiq - MOSo \quad (8)$$

While MOSiq is the average of MOS of IQ attribute and MOSo is the average of MOS of the original image. In using this formula, higher DMOS values indicate better quality.

**Table 5** DMOS calculations of IQ attributes

| IQ attribute | Brightness | Contrast | Color Saturation | Sharpness |
|---|---|---|---|---|
| **building** | -0.37 | 0.75 | 0.89 | 1.06 |
| **lake** | -0.31 | 0.66 | 0.86 | 0.83 |
| **man** | -0.66 | 0.69 | 0.83 | 0.80 |
| **taxi** | -0.43 | 0.86 | 0.94 | 0.91 |
| **room** | -0.40 | 0.69 | 0.80 | 0.91 |
| **king** | -0.31 | 0.74 | 0.91 | 0.97 |
| **hall** | -0.31 | 0.86 | 0.94 | 1.00 |
| **bar** | 0.06 | 0.94 | 1.00 | 1.11 |
| **sunset** | -0.26 | 0.83 | 0.91 | 1.06 |
| **airplane** | -0.31 | 0.66 | 0.74 | 0.86 |

Table 8 presents the DMOS values of ten images with different IQ attributes. Higher values mean better Image Quality. Sharpness, color saturation and contrast received the highest values respectively.

## Statistical significance analysis

The performance of each objective quality model was characterized by three prediction attributes: accuracy, monotonicity and consistency. The statistical metrics root mean square error (RMSE), Pearson correlation, and outlier ratio together characterize the accuracy, monotonicity and consistency of a model's performance. These statistical metrics are named evaluation metrics in the following. The calculation of each evaluation metric is performed along with its 95% confidence intervals. To test for statistically significant differences among the performance of various models, a test based on the RMSE, tests based on approximations to the Gaussian distribution were constructed for the Pearson correlation coefficient and the Outlier Ratio. The evaluation metrics were calculated using the objective model outputs and the results from viewer subjective rating of the test video clips. The objective model provides a single number (figure of merit) for every tested images. The same tested video clips get also a single subjective figure of merit. The subjective figure of merit for an image represents the average value of the scores provided by all subjects viewing the image. The evaluation analysis is based on DMOS scores for the RR models, and on MOS scores for the NR model. Discussion below regarding the DMOS scores was applied identically to MOS scores. For simplicity, only DMOS scores are mentioned for the rest of the chapter. The objective quality model evaluation was performed in three steps. The first step is a mapping of the objective data to the subjective scale. The second calculates the evaluation metrics for the models and their confidence intervals. The third tests for statistical differences between the evaluation metrics value of different models.

## Conclusions and future work

This paper proposes a new model consists of a framework and software application for smartphone based display image quality assessment. The framework is composed of a HVT (Human Visual Tests) procedure and an evaluation procedure by the SW application VIQEG.

The VQEG Image Quality Evaluation Tool (VIQET) is an objective, no-reference photo quality evaluation tool. VIQET is an open source tool designed to evaluate quality of consumer photos. In order to perform photo quality evaluation, VIQET requires a set of photos from the test device. It estimates an overall Mean Opinion Score (MOS) for a device based on the individual image MOS scores in the set.

- VIQET is an open source project that is available at www.GitHub.com/VIQET.
- The desktop tool installer can be downloaded at: https://github.com/VIQET/VIQET-Desktop/releases
- The source code can be found at: https://github.com/VIQET/VIQET-Desktop

This thesis provides a detailed description and analysis of subjective image quality assessment HVT based and objective image quality assessment based on SW application analysis. The correlations between the metrical and perceptual results indicated that MOS, MSE, PSNR metrics give excellent prediction performance in most cases in terms of both correlation and its variance. According to the group comparison had comparatively better prediction performance than no reference metrics. The statistical analyses were conducted to check whether the increase of the image quality attributes would lead to improvement in user's perceived image quality. The finding is useful for the mobile phone industry to have a better understanding of the concrete benefit of enhancing the image quality attributes. The proposed quality assessment model is useful also for image quality assessment of any mobile or desktop displays.One unique feature of the proposed framework was the capability of incorporating existing full reference image quality metrics without modifying them. In this research, the implementationof framework for smartphone displays used the new model to evaluate the prediction performance of state-of-the-art image quality metrics regarding the most important image quality attributes for projection displays. The evaluated image quality attributes were brightness, contrast, color saturation and sharpness, however the proposed framework was not bound by the possibilities. All the metric evaluations were supported by the correlation of objective and subjective experimental results

In addition, investigated the strategies to extend subjective experiments with baseline adjustment method, which is expected to save quite a lot of time and resources for subjective experiments. In a broader point of view, the originally defined research scope have been fully covered by the research presented in this thesis, all research goals have been successfully achieved, and the corresponding research questions have been answered. The proposed image quality assessment framework was originally designed for mobile devices displays, but could be easily adapted to other types of displays with limited modifications.In conclusion, with the results obtained in this research, the conclusion is the outcome of that new framework and new approach provided by this research can be a good process for perceived image quality prediction.

## Future work

The research, described in this study, is focused on still images image quality assessment based on four IQ attributes. The continuation of this research will deal with video material in HD (High Definition) content. he perceived image qualiJty of live video is a new challenge in the image quality assessment field. The ecommended IQ attributes for future research can be: frame rate conversion quality, band width limitations, video compression/decompression artifacts, motion artifacts and more. Also, since the VIQET tool for image analysis is an open source application it is highly recommended to use the current version as starting point in order to improve it and make it up to date for future IQ attributes and objective image quality assessment.

## ACKNOWLEDGEMENTS

Special thanks to my supervisors for great suport and advice:

**Prof. Dr.habil. Florentin PALADI**

Vice-rector for research, Moldova State University.

**Prof. Dr. Tudor Bragaru**

Associate Professor, Mathematics and Informatics Department, Moldova State University.

## REFERENCES

[1]. P. G. Engeldrum. Image quality modeling: Where are we? In Image Processing, Image Quality, Image Capture, Systems Conference, pages 251–255. IS&T, 1999.

[2]. F. Yang and S. Wan, "Bitstream-based quality assessment for networked video: a review," IEEE Communications Magazine, vol. 50, no. 11, pp. 203–209, 2012.

[3]. ITU-T, "Methods for the subjective assessment of video quality, audio quality and audiovisual quality of Internet video and distribution quality television in any environment," Recommendation P.913, ITU-T, 2014.

[4]. Kolmogorov-SmirnovTest,http://www.physics.csbsju.edu/stats/ KS-test.html.

[5]. T. De Pessemier, K. De Moor, A. J. Verdejo et al., "Exploring the acceptability of the audiovisual quality for a mobile video session based on objectively measured parameters," in Proceedings of the 3rd International Workshop on Quality of Multimedia Experience (QoMEX '11), pp. 125–130, Mechelen, Belgium, September 2011.

[6]. T. Kallio and A. Kaikkonen, "Usability testing of mobile applications: a comparison between laboratory and field testing," Journal of Usability Studies, vol. 1, pp. 4–16, 2005.

[7]. ITU, "Methodology for the subjective assessment of the quality of television pictures," ITU-R Recommendation BT 500-13, ITU Radio communication Sector, 2012.

[8]. ITU-T, “Methods for the subjective assessment of video quality, audio quality and audiovisual quality of Internet video and distribution quality television in any environment,” Recommendation P.913, ITU-T, 2014.

[9]. Marius Pedersen, Nicolas Bonnier, Jon Y. Hardeberg, and Fritz Albregtsen. Attributes of image quality for color prints -Journal of Electronic Imaging, Jan-Mar 2010/Vol. 19(1).