A Collaborative Responsive and Fully Customizable System for Image Quality Assessment Based on Subjective Visual Perception

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Abstract— **This paper describes a new system for image quality assessment related to subjective visual perception. The novelties of the contribution consist in the realization of a Web-based collaborative platform, which (a) allows a set of human observers to cooperate to the process of Mean Opinion Score generation in a complete asynchronous and distance-online participation, and (b) is fully responsive, thus the images can be tested on different devices, not only monitors or television sets, but also smartphones. A new method for the analysis of the results is also proposed; it is based on visual tables, which arrange the semantic of the experimental data in colored patterns, useful for understanding the properties of both images and observers. A set of target images has been identified and included in a Web based prototype to which testers can freely connect. The system is fully customizable because the code is freely available for download; in this way the programmer may easily change all the main parameters (images, number of impairments levels, type of impairment, and so on). Experimental results are reported and commented, with considerations on the possible applications of the system in different contexts.**

Keywords - subjective image quality assessment; visual analisys, collaborative Web-based process.

I. INTRODUCTION

Image quality assessment is an important task in modern multimedia processing, since the perceived quality can greatly influence the use of image information and the quality of experience [1-2]; moreover, the subjective evaluation of the perceived quality of a digital image is considered the most reliable method, since it can faithfully reflect the judgment of the human observer [3]. Unfortunately, organizing subjective image quality assessment experiments is very time consuming and requires a high economic effort and commitment. In this paper, a new system for subjective image quality assessment is proposed. The system was developed at the Department of Electrical, Computer and Biomedical Engineering (University of Pavia, Italy) and it has the main purpose of supporting scientists in the realization of experiments for subjective assessment of the quality of digital images. The most used approach (in the following, the *traditional approach*) in literature is to carry out the evaluation of the perceived quality experimentally using a set of human observers, which are asked to rate the perceived quality in different situations. In this process, there are several issues that matter:

- The choice of human observers is particularly critical, since they must be sufficiently educated on the standardized protocol to be used in the experimental evaluation and must also have peculiar characteristics, e.g., normal or corrected to normal visual acuity, a good sensitivity to colors, a good ability to maintain high attention and concentration as the experiments can also last several minutes.
- The realization of the experiments for perceptive evaluation of image quality in the laboratory are often too expensive and time consuming. The setup of the necessary hardware can involve the use of a high volume of resources and efforts.
- The choice of the set of images to be evaluated can also greatly influence the results of the experiments. Generally, the choice is made according to the type of impairment to consider. There are many datasets of digital images freely downloadable to be used in the experiments, for example the very well-known databases by the Laboratory for Image & Video Engineering (LIVE) [4].

For many years, the subjective assessments of image quality have been realized following the traditional approach, which has been particularly relevant in some applications, e.g., in television broadcasting [5]. Since 2009, some innovative proposals began to appear [6-8], with the intent to replace or to be alternative to the traditional method. They were based on a *crowdsourcing approach*, namely the possibility of recruiting observers on the Web and the realizations of the experiments using a Web-interface. This approach has several advantages and disadvantages, which must be properly balanced. The crowdsourcing approach reduces costs, as it is not necessary to set up an effective evaluation environment in the laboratory (hardware set up and staff commitment). Furthermore, the recruitment phase of the observers can also be delegated to another subject (e. g., an external company, as in [8]) or using collaborative platforms, i.e., social networks. The main disadvantage of this approach is that you lose the control over the choice of observers and the standardization of the method. For this reason, it is very important to provide observers with a precise and detailed protocol with all the instructions they must follow, including those relating to the implementation

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of the experiment, for example the distance from the monitor, lighting, or other details. However, there is no guarantee that the observer follows the protocol correctly as the process of expressing the opinion on the perceived quality is not supervised. Although the last aspect seems particularly critical, the results in the literature have been encouraging in identifying the crowdsourcing approach as very similar if not equivalent to the traditional approach, by comparing the Mean Opinion Score (MOS) in both the approaches on the same target dataset, with a high correlation coefficients and confidence interval [8].

The main goals of the project here reported try to overcome some of the problems of both the traditional and the crowdsourcing approaches, by proposing a hybrid system. Moreover, an innovative tool for analyzing human observer reliability is described, to fill the gap in literature on the critical issue of the selection of subjects involved in the experiments.

The rest of the paper is organized as follows: Section II describes the goals addressed and the method implemented in the system. Section III describes the experiment design and analysis. Section IV provides some further ideas for using the system in different applications. The acknowledgement and conclusions close the article.

II. Goals and Methods of System Implementation

The proposed system is a hybrid between the traditional approach and the crowdsourcing approach. It was called Subjective Image Quality Assessment (SIQA) project [9] and it is based on a Web interface for experimental evaluation of the perceived quality. However, the possibility of downloading the entire project and installing a stand-alone configuration (still maintaining the web interface) allows to use it also for the traditional approach. We called it a hybrid system because it clearly can be exploited while retaining the positive aspects of both solutions, e.g., the traditional and the crowdsourcing approach. In fact, there are two methods for using the SIQA system:

- Offline method: the open-source code [10], was developed in Phyton, under Massachusetts Institute of Technology (MIT) License; it can be freely downloaded and used as it is or modified to adapt the experiments to your commitments. This is like the traditional approach, but for the user interface (a web browser) and the image dataset (freely downloadable o replicable). This method can also guarantee the important aspect of customization (see Section II.A, Innovations of the System).
- Live method: by taking the "Live Test" on the SIQA website [9]. This is performed on a subset of images and, clearly, it follows a pure crowdsourcing approach. However, it can be used for the important phases of the traditional approach of *training* the observers and their *warming-up* at the beginning of the subjective quality assessment experiments [3]. Therefore, the system is useful regardless of which approach (traditional or crowdsourcing) you use and can be adapted to different experimental contexts.

The two operating methods also guarantee some innovative aspects, with respects to the current state-of-the-art, which are detailed in the next paragraph.

A. *Innovations of the System*

Using the SIQA system in one or both the methods before described, you can have some interesting and innovative advantages:

- You can decide to have full control over the choice of observers, as in the traditional approach, or to relax it (crowdsourcing approach).
- You can choose one of the approach or both according to your needs: for example, you could choose the crowdsourcing approach for a test phase or for the selection of observers and then choose a more traditional approach to improve the standardization of the process and obtain the real experimental data.
- The SIQA Web site is fully responsive, so it can be used to test human observer perception on different kind of devices, including smartphones. Evaluating user experience on smartphone has become more and more important over the years [11].
- The possibility of completely downloading all the code and being able to modify it allows the scientist to easily replace the image datasets (taking it form the many available in literature [4] or a personalized dataset) and modify their characteristics, for example the number of levels and type of impairment, the type of images (gray-level or color images, resolution, format, or compression standards).
- The possibility of changing the quality impairment is very important: it can be not only noise, compression, or other engineering parameters, but also coming from other disciplines, to extend the concept of *image quality* to other fields, for example psychology, which is interesting in communication and advertisement (see Section IV, Examples of Application of the System).

Besides the SIQA system, in the paper an innovative tool, called *Visual MOS Table*, for analyzing the experimental data is proposed and described. It is a visual tool: by arranging the MOS values in a bidimensional table and with a simple but effective use of colors, it is very simple to analyze which images in the dataset can be considered "outliers" in the perceptual process. Moreover, the *Visual MOS Table* can be used also to identify which human observers are too strict, or too permissive, in assessing quality.

B. *Impression or quality?*

At first glance, SIQA project may seem very similar to systems used for user impression evaluation, such as the so popular solutions of photo sharing on Web. However, there are some substantial differences: first, in a subjective quality assessment task (as in SIQA project), opinion score is statistically evaluated not only for what concern the average, but also the standard deviation, which gives relevant information about the homogeneity of the evaluation task.

Moreover, in a real subjective evaluation experiment, the user does not choose the image to rank, and the set of assessed images is the same for all the subjects. These constraints do not apply to standard photo impression evaluation. For this reason, SIQA project evaluate the subjective quality (as defined in literature), rather than a simple user impression on the Web.

III. EXPERIMENT DESIGN AND ANALISYS

The system is fully compatible with the method recognized in the literature among the best ones for subjective evaluation, i.e., the single stimulus Absolutely Category Rating (ACR) test [5]; in fact, in literature, there is no evidence that a double stimulus method is more accurate than a single stimulus [12]. Moreover, the single ACR stimulus is one of the best in optimizing time effort of the experiments, especially if we need to put a temporal limit to each experimental session (in general no more than 30 minutes). The single stimulus ACR method ask the observers their opinion about the perceived quality of only one image at time, by expressing a rank according to five scores, from 1 to 5, according to a well-known equivalence, shown in Table I. The values of the scores are collected on a pool of images and for a set on human observer, and the standard results of MOS and its Standard Deviation (SDOS) are provided.

The SIQA system has been tested first in a set of closed experiments (i.e., inside the laboratory) on different kinds of images (color, grey levels) and different visual impairments (lossy compression, noise addition, blurring) of increasing severity. On the SIQA Web site [9] the results of these preliminary tests are available by clicking on the second button (i.e., "Download presentations") in the section Download (see Figure 1).

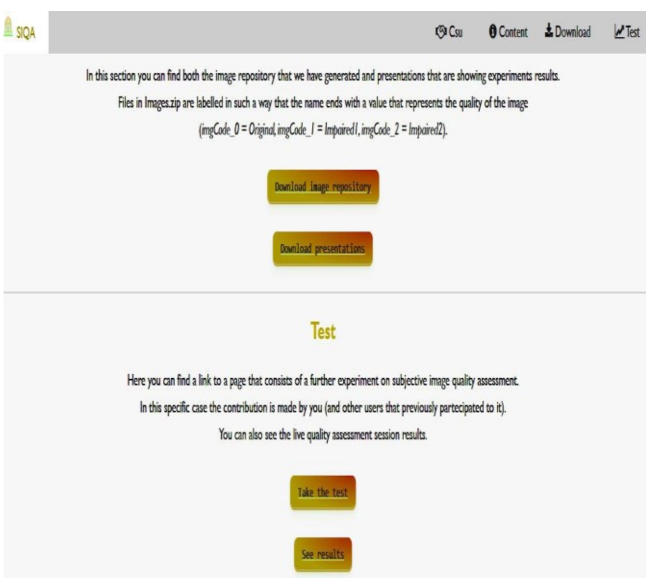

Figure 1. The Donwload Section (on the top) and the Live Test Section (on the bottom) of the SIQA Website (https://siqa.pythonanywhere.com).

TABLE I. THE FIVE SCORES OF THE ACR METHOD

Score	Perceived Quality	Perceived Impairment	Colors in Visual MOS Tables[a]
5	Excellent	Imperceptible	Green
4	Good	Just Perceptible but not annoying	Light Green
3	Fair	Perceptible and slightly annoying	Yellow
2	Poor	Annoying	Light Red
1	Bad	Very annoying	Red

a. The meaning of this field is explained in Section III.A

As explained in the previous paragraph on innovations, there are two design methods: Live (online) Test and Offline test. The first correspond to the crowdsourcing approach, the second to the traditional one. In the Live Test is available by connecting to the SIQA Website and by clicking on the button "Take the test". The test is performed using a pre-defined set of three different versions of ten color images: "original", "impairment1" and "impairment2". The ten original images are depicted in Figure 2. The impaired versions are obtained from the ten original ones, by applying the standard Joint Photographic Experts Group (JPEG) compression algorithm, with different quality levels. Degradation on impairment1 images should be less visually noticeable than the one on the impairment2 images.

Figure 3 shows a moment of the score expression in the interface of SIQA. The score is requested by a simple mouse click; other interfaces, for example in [13], store the score using a visual stimulus recording, by an eye tracker. However, we have decided the simplest mouse-driven interface because we want to assure the possibility to use the Live Test also on other devices, e.g., smartphone (where mouse click is substituted by a simple touch).

The entire test on the thirty images takes approximately ten minutes. We have chosen this duration because it can be easily used to select the observers in trial test or for the reheat phase in traditional experiments. The strictly controlled conditions of traditional test are replaced with simple instructions to the observer:

- Observe all the images under similar conditions: (viewing distance, brightness, artificial lighting, screen contrast).
- Give an evaluation for each image in a maximum time of 15 seconds.
- Wear contact lenses or prescription glasses, if any.
- Take the test only once.

After the test, the scores expressed by the online observer are added to the set of previously stored scores in the system, and MOS and SDOS are updated. They plots are available by clicking on the button "See Results". For brevity, only the MOS experimental data are reported and analyzed in the paper (SDOS values are available online).

At the time of writing this paper, the values of MOS for each image and each level of impairment are the ones shown in Figure 4: on the x-axis there are the ten images of Figure 2. The three MOS plots refer to the different levels of JPEG quality (Original, Impairment1 and Impairment2). The trend of MOS is perfectly consistent with the levels of impairment ("original MOS" is always over the impairment1, which is always over impairment2). Only for one image (i.e., image "tree", showing section of a tree trunk, see Figure 2g) the three values are very closed: 3.79, 3.66, and 3.37, for, respectively, the original, impairment1, and impairment2 image. A possible explanation of this fact is that probably the radial symmetry of the texture of image "tree" does not allow users to clearly perceive the block distortion, which is typical for JPEG compression.

Figure 2. The ten images for the Live Test: (a) Water (b) Books (c) Hand (d) Dogs (e) Tiger (f) Mountains (g) Tree (h) London (j) Poppies (k) Bear.

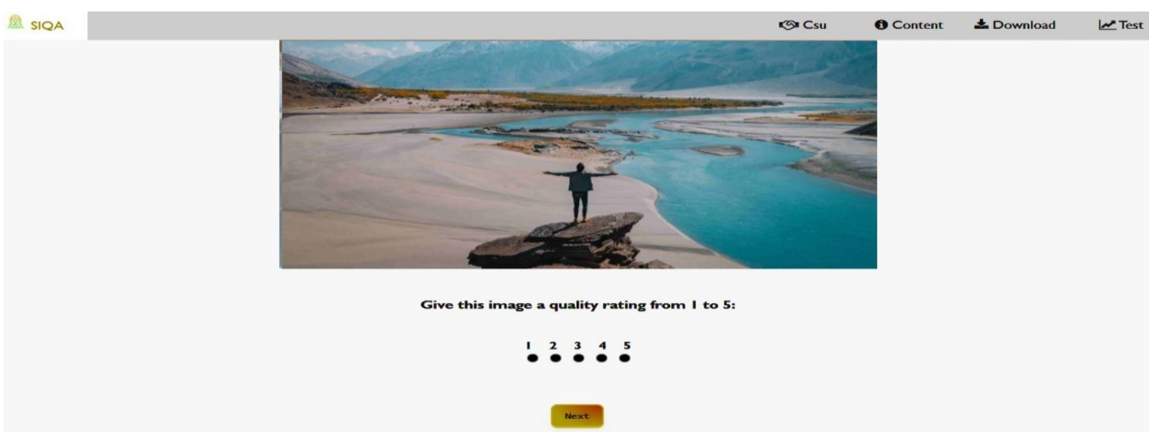

Figure 3. Example of the opinion expression for image "Mountains" in the Live Test.

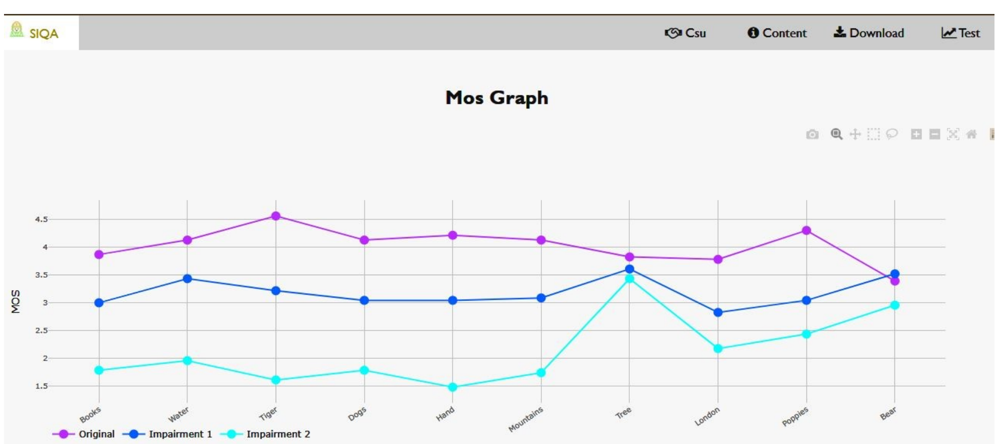

Figure 4. The MOS computed in the Live Test for the ten images of Figure 2.

The second design method is the Offline test. On the SIQA Web site [9] a set of 135 preloaded images (45 original and 90 impaired versions) are available by clicking on the first button (i.e., "Download image repository") in the section Download. In the following paragraph, a discussion of the analysis of the MOS experimental data are discussed to show the application of the visual tool called *Visual MOS Table*.

A. A new tool for experiment analysis: the Visual MOS Table

The image repository for Offline method refers to gray-level images; Figure 5 shows the first ten (original) images. We have used them in an experiment of subjective image quality assessment to show the utility of *Visual MOS tables*.

The experiments consider three levels of quality, i.e., Unimpaired (e.g., Original), Slightly impaired (JPEG lossy compression, quality factor 25) and Highly impaired (JPEG lossy compression, quality factor 12). The MOS has been measured for 13 expert observers (Evaluator 1-13) and 8 non-expert observers (Evaluator 14-21). Figure 6 shows the *Visual MOS Table*, created on the MOS data collected in the experiments. The table cells are colored to reflect the MOS values: green and light green for MOS 5 and 4, yellow for MOS 3, light red and red for MOS 2 and 1. Data are arranged in two dimensions: the first refers to the columns, and columns containing data of the same level of quality define an *Area of quality level*. In Figure 6, the *Area of quality level* "Unimpaired" is highlighted with a blue box. By analyzing an *Area of quality level* across the columns, it is very fast and easy to identify images which are outliers in the process of subjective quality assessment. For example, in the *Area of quality level* "Unimpaired" yellow and red (light and dark red) cells refer to outlier images, i.e., images that have achieved a different score than one would expect. In Figure 6, for expert observers, image "Wuhan", "Baby" and "Building" have collected five and four outliers (over 13 observers). This suggest that they are the most difficult images to rank correctly.

The *Visual MOS Table* can be analyzed also in the other dimension, by row. In this case the Area refer to homogeneous experimental constraints *(Area of constraint)*. In the example, we distinguish between expert vs. non-expert observers and in Figure 6 the *Area of constraint* "non-expert" is identified by a purple horizontal box. In this case, it is possible to identify human observers who are not well suited to effectively carry out perceptual judgment. Therefore, the system is useful not only to assess image quality, but also "tester (human observer) quality". For example, among the non-expert area, the Evaluator n. 16 has judged almost every image with very high opinion score (all the cells are green, independently on the real quality!). By analyzing the *Visual MOS Table*, we also discover that among experts, the Evaluator n. 12 was unable to distinguish between images at the highest quality level (Unimpaired) and that of intermediate quality (Slightly Impaired), since all the cells in the line "Evaluator n. 12" are green in the two *Areas of quality*. Therefore, Evaluator 12 and 16 could be considered outliers and could be discarded by the pool of observer in a next experiment. We suggest using the *Visual MOS Table* also to assess the "quality" of the human observers. The choice of observers is a very crucial point for the success of the subjective evaluation of perceived quality experiments and the *Visual MOS Table* can be a valid help to assist this task.

IV. Examples of Applications of the System

The system can be customized by downloading the code and modifying the parameters, for example the number of impairment levels or the constraint conditions. These customizations reflect on the *Visual MOS Table* by adding further *Areas of quality* or *Areas of constraints*. For example, instead of using the two constraints expert vs. non-expert observers, constraints may be changed in "observing on the monitor" and "observing on the smartphones", if the goal of the experiment is to investigate the impact on perceived quality on different screen.

Another interesting application is to the definition of a more extensive concept of *quality*; if only one *Area of quality* is used, observers could be asked to evaluate not so much the perceived quality at the increasing levels, but the effectiveness in the transmission of a semantic message. Suppose for example to have five images and that the task is to evaluate how they are perceived by the humans for what concerns the efficacy in an advertisement message. By analyzing the Visual MOS Tables you can easily find which is the best image which obtained the highest score (i.e., the highest number of "green" or light green cells), possibly studying different viewing hardware (television or smartphones).

V. Conclusion and Future Work

The paper describes a hybrid system for both traditional and crowdsourcing subjective assessment of image quality using a classical single stimulus ACR method. An innovative visual tool has been also described for the analysis of MOS experimental data, both for finding outliers in the image set or in the human observers. Future work will try to adapt the SIQA system to: (a) evaluation of video quality and (b) to rehabilitation of patients with cognitive deficits. In the latter case, instead of measuring the perceived quality, the human observer would be asked to express a judgment on the semantic of image, to check the ability of the patient to recognize different targets (faces, situations, environments).

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Figure 5. The first ten images of the downloadable dataset; in figure, only the original unimpaired version are shown.

	Unimpaired images										Slightly impaired images										Highly impaired images									
	01 - Wheel	02 - Boat	03 - Rides	04 - Wuhan	05 - Guy	06 - Beach	07 - Car	08 - Pedestrians	09 - Baby	10 - Building	01 - Wheel	02 - Boat	03 - Rides	04 - Wuhan	05 - Guy	06 - Beach	07 - Car	08 - Pedestrians	09 - Baby	10 - Building	01 - Wheel	02 - Boat	03 - Rides	04 - Wuhan	05 - Guy	06 - Beach	07 - Car	08 - Pedestrians	09 - Baby	10 - Building
	"**Expert**" evaluators group																													
Evaluator No. 1	5	4	3	5	5	4	4	5	3	5	3	3	2	5	3	4	3	3	3	4	2	2	1	3	2	1	1	2	1	2
Evaluator No. 2	4	5	5	5	4	5	2	5	3	5	3	5	3	5	4	5	2	4	5	5	1	2	1	4	5	2	1	5	3	5
Evaluator No. 3	5	5	5	3	5	5	5	5	4	5	3	4	3	2	3	2	3	4	3	4	2	1	2	2	2	2	1	3	4	4
Evaluator No. 4	5	5	4	4	4	5	5	5	4	3	3	5	2	2	2	4	4	3	2	3	1	1	1	3	1	2	1	1	2	2
Evaluator No. 5	5	5	5	5	5	5	5	5	3	5	2	5	3	3	5	3	4	5	5	3	1	1	1	3	3	1	1	3	4	1
Evaluator No. 6	3	4	5	4	4	4	5	5	5	4	3	3	2	3	3	3	3	3	3	3	2	2	2	2	2	2	1	2	2	2
Evaluator No. 7	5	5	5	3	4	4	4	5	4	3	2	3	2	2	2	1	2	3	3	3	1	1	1	2	1	1	1	1	1	1
Evaluator No. 8	2	4	5	5	4	3	5	4	5	4	2	2	2	3	2	2	3	3	4	2	1	1	1	1	1	1	1	2	1	1
Evaluator No. 9	5	4	5	1	5	5	1	5	5	4	3	4	2	3	4	2	3	2	3	3	3	2	1	5	1	2	1	1	2	1
Evaluator No. 10	5	4	4	3	4	4	5	4	4	3	2	3	2	4	3	3	3	3	4	3	1	1	1	2	2	1	1	2	2	2
Evaluator No. 11	5	5	5	4	5	5	4	5	5	3	3	3	3	3	2	3	3	3	3	4	1	1	1	3	1	2	1	2	2	3
Evaluator No. 12	5	5	5	4	5	4	5	5	5	5	4	5	4	5	4	4	5	5	5	4	2	2	2	5	5	2	3	4	4	5
Evaluator No. 13	5	4	3	3	3	4	3	4	3	4	2	2	2	2	2	2	2	3	2	2	1	2	2	2	1	1	1	1	1	2
SD of MOS for "**Expert**" evaluators group	1,0	0,5	0,8	1,2	0,7	0,7	1,3	0,4	0,9	0,9	0,6	1,1	0,7	1,2	1,0	1,1	0,9	0,9	1,1	0,9	0,7	0,5	0,5	1,2	1,4	0,5	0,6	1,2	1,2	1,4
	"**Non-expert**" evaluators group																													
Evaluator No. 14	3	4	5	5	2	3	5	4	3	5	4	4	4	4	3	3	4	2	3	3	3	4	2	3	1	2	2	3	2	4
Evaluator No. 15	4	4	4	5	4	4	5	5	5	4	5	2	2	3	3	3	3	4	4	5	1	1	1	3	1	1	1	3	3	3
Evaluator No. 16	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	4	5	5
Evaluator No. 17	4	4	4	5	4	3	5	5	4	4	4	4	4	3	4	4	2	4	3	5	3	2	1	2	1	1	2	1	2	2
Evaluator No. 18	4	4	4	3	4	3	3	3	4	4	3	3	2	1	2	2	1	3	3	4	1	1	2	2	1	1	1	2	2	1
Evaluator No. 19	5	5	3	4	5	3	4	3	3	2	3	4	2	3	4	3	3	4	2	4	2	2	1	3	2	2	1	2	2	2
Evaluator No. 20	5	5	5	5	5	5	5	5	5	5	4	3	3	5	4	3	3	3	3	3	1	1	1	3	1	1	2	3	3	1
Evaluator No. 21	3	3	3	4	4	3	3	4	4	3	2	2	2	3	2	2	3	3	3	2	1	1	1	2	1	1	2	1	2	2
SD of MOS for "**Non-expert**" evaluators group	0,8	0,7	0,8	0,8	1,0	0,9	0,9	0,8	0,8	1,1	1,0	1,1	1,2	1,3	1,1	1,0	1,2	0,7	0,9	1,1	1,5	1,6	1,4	1,0	1,4	1,4	1,3	1,1	1,1	1,4
Global SD of MOS	0,9	0,6	0,8	1,1	0,8	0,8	1,2	0,7	0,8	0,9	0,9	1,1	0,9	1,2	1,0	1,0	1,0	0,8	1,0	1,0	1,1	1,1	0,9	1,1	1,4	0,9	1,0	1,1	1,1	1,4
	0,9										1,0										1,2									

Figure 6. The *Visual MOS Table* for the experiments of subjective quality assessment on the first ten images of the downloadable set (see Figure 5). The blue and purple rectangles define the *Area of quality level* and the *Area of constraint* of the table, respectively.