A MULTIPLE ATTRIBUTES IMAGE QUALITY DATABASE FOR SMARTPHONE CAMERA PHOTO QUALITY ASSESSMENT

Wenhan Zhu†, Guangtao Zhai*, Zongxi Han*, Xiongkuo Min*, Tao Wang*, Zicheng Zhang† and Xiaokang Yang†

† MoE Key Lab of Artificial Intelligence, AI Institute, Shanghai Jiao Tong University, China
* Institute of Image Communication and Information Processing, Shanghai Jiao Tong University, China

ABSTRACT

Smartphone is the superstar product in digital device market and the quality of smartphone camera photos (SCPs) is becoming one of the dominant considerations when consumers purchase smartphones. How to evaluate the quality of smartphone cameras and the taken photos is urgent issue to be solved. To bridge the gap between academic research accomplishment and industrial needs, in this paper, we establish a new Smartphone Camera Photo Quality Database (SCPQD2020) including 1800 images with 120 scenes taken by 15 smartphones. Exposure, color, noise and texture which are four dominant factors influencing the quality of SCP are evaluated in the subjective study, respectively. Ten popular no-reference (NR) image quality assessment (IQA) algorithms are tested and analyzed on our database. Experimental results demonstrate that the current objective models are not suitable for SCPs, and quality metrics having high correlation with human visual perception are highly needed.

Index Terms— Image quality assessment (IQA), Smartphone camera photo, subjective assessment, no-reference (NR) metrics.

1. INTRODUCTION

Smartphone has been one of the most popular digital devices in the past decades, with more than 300 million smartphones sold every quarter in the world wide. Most of the smartphone vendors, such as Apple, Huawei, Samsung, launch their new flagship smartphones every year. People use smartphone cameras to shoot selfie photos, film scenery or events, and record videos of family and friends. The specifications of smartphone camera and the quality of taken photos are major criteria for consumers to select and purchase smartphones. Many smartphone manufacturers also introduce and advertise their smartphones by introducing the strengths and advantages of their smartphone cameras. Currently in the market, several teams and companies, such as DxOMark [1], evaluate the quality of smartphone cameras. However, the scores and rankings of smartphone cameras they announced are subjectively graded by several photographers and experts, which is not easy to reproduce and deploy in practical image processing systems [2]. Therefore, automatically and reliably evaluating the quality of photos taken by smartphone cameras becomes a urgent need for smartphone manufacturers and consumers.

In the last two decades, image quality assessment (IQA) has been widely researched in the field of image processing and analysis. Plenty of popular image databases have been constructed to study this topic, for instance, LIVE [3], CSIQ [4] and TID2013 [5]. Numerous objective no-reference (NR) IQA algorithms have been proposed to predict the perception of human vision without reference image [6]. Most of NR metrics are aimed at evaluating the quality of general distorted images based on different feature extraction methodologies, for example, NIQE [7], which is developed from spatial natural scene statistic (NSS) features, HOSSA [8] that is on account of aggregation of high order statistics, BPRI [9] and BMPRI [10] that are based on pseudo reference images and NFERM [11] that applies free energy principle to design the algorithm. In addition, there are some objective models proposed to estimate specific distortions, such as blur [12, 13] and contrast [14]. Also, some algorithms are designed for different types of images, such as, screen content images [15] and 360-degree images [16].

However, most of these objective IQA methods are developed to assess the overall perceived quality of the image degraded by various simulated distortions, which rarely exist in photos taken by the modern smartphone cameras. The factors that primarily influence the quality of smartphone camera photos can be classified into some specific properties, such as exposure, color, noise and texture. Thus, the above-mentioned models may be invalid for smartphone camera quality assessment, while objective evaluation methods specifically designed for the purpose of smartphone camera quality assessment are relatively rare. The evaluation for smartphone camera photo (SCP) is still in a lack in the IQA field.

So, in this paper, we establish a new smartphone camera photo quality database for promoting the study of smartphone camera photo quality assessment. Specifically, we first construct a Smartphone Camera Photo Quality Database (SCPQD2020), which consists of 1800 SCPs taken from 120 scenarios using 15 different smartphones. Next, we adopt the purpose-made scoring interface and evaluation criteria to conduct the subjective experiment. Four ratings scored
Fig. 1. Samples of the SCPs taken by eight different smartphones of one scene in SCPQD2020. (a) iPhone 7, (b) iPhone XS max, (c) Huawei P20, (d) Huawei P30 Pro, (e) Samsung Note9, (f) Samsung S8+, (g) HTC U12, (h) Pixel2.

from different aspects, including exposure, color, noise and texture for each SCP are computed via the subjective experiment. After that, we compare ten successful NR IQA metrics on this database. Results demonstrate that the current IQA models do not work well in assessing the quality of SCPs, and quality measures having high correlation with human visual perception are highly needed. A part of this database is already released in the IEEE ICME2020 Grand Challenge [17].

The remainder of this paper is organized as follows. The detailed subjective assessment methodologies for SCPs are introduced in Section 2. Comparisons and evaluations of some objective quality metrics on the SCPQD2020 database are presented in Section 3. Finally, some conclusive remarks are given in Section 4.

2. SUBJECTIVE QUALITY ASSESSMENT
To investigate quality assessment of SCPs, a targeted image database is constructed which includes SCPs with different smartphones and different scenes. We gather the subjective scores for each SCP from four aspects in the form of MOS.

2.1. Image Materials
The image database is composed of 1800 photos taken from 120 scenes using 15 smartphones. The goal of this database is to evaluate the photo shooting performances of smartphone cameras designed for ordinary consumers. Therefore, we restore all smartphones to the factory settings and shoot the photos in the default mode. In addition, we ensure that all images for the same scene have the same mainbody content and the same illumination intensity as far as possible. Also, we attempt to avoid the mobile objects, such as walking pedestrians and moving cars, appearing in the center of photos.

These 15 smartphones cover a wide price range and different manufacturers, which are iPhone 7, iPhone X, iPhone XS max, Huawei P20, Huawei P30 Pro, Huawei Mate20 Pro, Samsung S8+, Samsung S9+, Samsung S10+, Samsung Note9, Mi9, HTC U11, HTC U12, Pixel2 and Pixel3. We maintain the original resolutions of these 15 smartphones: eleven of $4032 \times 3024$, two of $3648 \times 2736$, one of $3968 \times 2976$ and one of $4000 \times 3000$. For the purpose of ensuring the consistency of the color gamut of all images, we employ the sRGB color gamut. iMazing HEIC Converter [18] is applied for iPhones to convert the Display P3 color gamut to the sRGB color gamut. Our database includes various challenge scenes, e.g. high dynamic scenes, backlight scenes, night scenes, colorful scenes, portrait scenes and distant scenes. Fig. [1] illustrates samples of the SCPs of one scene shooted by eight different smartphones.

2.2. Subjective Experiment Methodology
To collect ground truth quality ratings of these SCPs, we conduct the subjective experiment on our database. We develop a user interface using Tkinter in Python to show the photos and gather scores as illustrated in Fig. [2]. In our graphical interface, four photos for a scene taken by different smartphones will appear at a time. Under a zoom number degree of no more than 100%, the user can select the area of interest (AOI) on any one of four images to zoom in. After determining the AOI of the scene, the same AOI in these four images will be aligned by pressing the “Match” bottom. The user can select the attributes, which are exposure, color, noise and texture in our experiment, to score their perceptual ratings.

Unlike other subjective experiments conducted on the traditional image quality assessment, we consider the quality of image in four attributes instead of the overall perception quality. Therefore, we consult the experts of the photography and
refer to ITU-R REC. BT.500-13 [19] to come up with our own standards for evaluation. The quality scale scored from 1 to 5, with a minimum interval of 0.1. Table 1 lists the details of the subjective evaluation criterion of this scale. In addition, we set the evaluation criteria for grading the four attributes (exposure, color, noise and texture) respectively. The details of evaluation criteria are listed as follow and the examples of evaluation criteria are illustrated in Fig. 3.

- **Exposure**: Observing a region that has both bright part and dark part, the subjects need to determine whether or not there is overexposure and evaluate the degree of overexposure (Especially in night scenes, overexposure may cause losing of details).
- **Color**: Looking around the whole photo, the viewers should pay close attention to the problem about color cast and white balance.
- **Noise**: Viewing the region that the content is simple and the color is monotonous, such as sky, wall of pure color and dark area, the subjects are required to assess the degree of luminance noise.
- **Texture**: Examining the area that has abundant high frequency information, such as leafs, grass and buildings in the distance, the subjects are requested to consider the blurriness, sharpness and reality of this area.

![Fig. 2. Screenshot of the interface of subjective experiments.](image)

| Score | Quality            | Standards                                      |
|-------|--------------------|------------------------------------------------|
| 5     | Excellent          | Excellent, pleasant                            |
| 4     | Good               | Fairly clear, slightly distortion              |
| 3     | Fair               | Perceptible, has minor flaw but passing        |
| 2     | Poor               | Slightly annoying, has obvious defect          |
| 1     | Bad                | Quite annoying, unacceptable                   |

In experiment stage, we employ EIZO RX440 LED display with 2560×1600 resolution to show the photos. The viewing distance is set to 1-1.5 times the display height (76 cm). The illuminance of the experimental environment is kept low for comfortable and distinct view. Since this experiment requires knowledge of the field of photos and careful observation, we recruit three experts in photography to assess the quality of SCPs from four attributes. Graders will take a break when they rate for more than half an hour. After the subjective experiment, we gather scores given by all observers. Then, we average the scores of subjects and obtain the final mean opinion score (MOS) of each SCP. Each image’s MOS is presented as:

\[
MOS_j^{(p)} = \frac{1}{N_i} \sum_{i=1}^{N_i} u_{ij}^{(p)}
\]

where \(N_i\) is the number of valid subjects and \(u_{ij}^{(p)}\) is the score of image \(j\) in attribute \(p\) assigned by the \(i\)-th subject.

**3. COMPARISON OF OBJECTIVE QUALITY ASSESSMENT MODELS AND DISCUSSION**

IQA algorithms for natural image have achieved a remarkable progress over the past decades. Plenty of successful IQA metrics have been provided to automatically predict the perceptual quality of distorted images. However, traditional quality assessment always focus on the overall perception quality of images, while the quality of SCP consider four attributes. Especially, the factors of color and exposure are rarely researched in traditional quality assessment. Thus, the accuracy of existing metrics on evaluating the quality of SCPs needs to be measured and compared.

Since the task of smartphone camera IQA has no reference image, we only select NR IQA models to test. Here, we implement 10 successful NR IQA models which...
In this paper, we focus on a new quality assessment problem about smartphone camera images. First, a new image database SCPQD2020, including 1800 SCPs taken from 120 various scenes by 15 different smartphones, has been built to investigate the subjective quality of SCPs. Each SCP is evaluated from four attributes, which are exposure, color, noise and texture. Moreover, we compare ten successful objective NR IQA models on the SCPQD2020 database. According to the results of performance analysis, we find that no current objective NR model works well, and the quality measures having high correlation with human visual perception are highly needed. This database has been partially released.
in IEEE ICME2020 Grand Challenge and will be completely and publicly available later.

5. REFERENCES

[1] DxOMark, “How DXOMARK scores smartphone rear cameras explaining DXOMARK Camera,” https://www.dxomark.com/

[2] Zhou Wang, Alan C Bovik, Hamid R Sheikh, and Eero P Simoncelli, “Image quality assessment: from error visibility to structural similarity,” IEEE Transactions on Image Processing, vol. 13, no. 4, pp. 600–612, 2004.

[3] H. R. Sheikh, Z. Wang, L. Cormack, and A. C. Bovik, “LIVE image quality assessment database release 2,” 2005.

[4] Eric C. Larson and Damon M. Chandler, “Most apparent distortion: Full-reference image quality assessment and the role of strategy,” Journal of Electronic Imaging, vol. 19, no. 1, pp. 011006, 2010.

[5] Nikolay Ponomarenko, Lina Jin, Oleg Ieremeiev, Vladimir Lukin, Karen Egiazarian, Jaakko Astola, Benoit Vozel, Kacem Cheddi, Marco Carli, Federica Battisti, and C.-C. Jay Kuo, “Image database TID2013: Peculiarities, results and perspectives,” Signal Processing: Image Communication, vol. 30, pp. 57–77, 2015.

[6] Anish Mittal, Anush Krishna Moorthy, and Alan Conrad Bovik, “No-reference image quality assessment in the spatial domain,” IEEE Transactions on Image Processing, vol. 21, no. 12, pp. 4695–4708, 2012.

[7] Anish Mittal, Rajiv Soundararajan, and Alan C Bovik, “Making a completely blind image quality analyzer,” IEEE Signal Processing Letters, vol. 20, no. 3, pp. 209–212, 2013.

[8] Jingtao Xu, Peng Ye, Qiaohong Li, Haiqing Du, Yong Liu, and David Doermann, “Blind image quality assessment based on high order statistics aggregation,” IEEE Transactions on Image Processing, vol. 25, no. 9, pp. 4444–4457, 2016.

[9] Xiongkuo Min, Ke Gu, Guangtao Zhai, Jing Liu, Xiaokang Yang, and Chang Wen Chen, “Blind quality assessment based on pseudo-reference image,” IEEE Transactions on Multimedia, vol. 20, no. 8, pp. 2049–2062, 2017.

[10] Xiongkuo Min, Guangtao Zhai, Ke Gu, Yutao Liu, and Xiaokang Yang, “Blind image quality estimation via distortion aggravation,” IEEE Transactions on Broadcasting, vol. 64, no. 2, pp. 508–517, 2018.

[11] Ke Gu, Guangtao Zhai, Xiaokang Yang, and Wenjun Zhang, “Using free energy principle for blind image quality assessment,” IEEE Transactions on Multimedia, vol. 17, no. 1, pp. 50–63, 2015.

[12] Niranján D Narvekar and Lina J Karam, “A no-reference perceptual image sharpness metric based on a cumulative probability of blur detection,” in Quality of Multimedia Experience (QoMEx), 2009, pp. 87–91.

[13] Phong V Vu and Damon M Chandler, “A fast wavelet-based algorithm for global and local image sharpness estimation,” IEEE Signal Processing Letters, vol. 19, no. 7, pp. 423–426, 2012.

[14] Yuming Fang, Kede Ma, Zhou Wang, Weisi Lin, Zhijun Fang, and Guangtao Zhai, “No-reference quality assessment of contrast-distorted images based on natural scene statistics,” IEEE Signal Processing Letters, vol. 22, no. 7, pp. 838–842, 2014.

[15] Ke Gu, Shiqi Wang, Huan Yang, Weisi Lin, Guangtao Zhai, Xiaokang Yang, and Wenjun Zhang, “Saliency-guided quality assessment of screen content images,” IEEE Transactions on Multimedia, vol. 18, no. 6, pp. 1098–1110, 2016.

[16] Matt Yu, Haricharan Lakshman, and Bernd Girod, “A framework to evaluate omnidirectional video coding schemes,” in International Symposium on Mixed and Augmented Reality (ISMAR), 2015, pp. 31–36.

[17] Guangtao Zhai, Wenhan Zhu, and Xiongkuo Min, “Qa4camera: Quality assessment for smartphone cameras,” https://qa4camera.github.io/

[18] iMazing HEIC Converter, “A tiny and free desktop app for converting Apple’s new iOS photos from HEIC to JPG or PNG,” https://www.imazing.com/zh/heic/

[19] Rec. ITU-R BT.500-13, “Methodology for the subjective assessment of the quality of television pictures,” Jan, 2012.

[20] Wufeng Xue, Xuanqin Mou, Lei Zhang, Alan C Bovik, and Xiangchu Feng, “Blind image quality assessment using joint statistics of gradient magnitude and laplacian features,” IEEE Transactions on Image Processing, vol. 23, no. 11, pp. 4850–4862, 2014.

[21] Lin Zhang, Lei Zhang, and Alan C Bovik, “A feature-enriched completely blind image quality evaluator,” IEEE Transactions on Image Processing, vol. 24, no. 8, pp. 2579–2591, 2015.

[22] Qingbo Wu, Zhou Wang, and Hongliang Li, “A highly efficient method for blind image quality assessment,” in
International Conference on Image Processing (ICIP),
2015, pp. 339–343.