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Extensions to OpenDICE: Batch Image Assessment and Additional Target Support

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Abstract

In this paper we present extensions to our digital imaging quality assessment software, OpenDICE. We have added three features; batch image assessment, the support to very large size targets and two additional color patch targets. Batch image assessment provides the capability to monitor imaging device performance over long time periods. The addition of the very large size targets provides more comprehensive and accurate resolution assessment of the imaging system at different locations and orientations. The inclusion of two more color targets enhances color target profiling performance assessment.

1. Introduction

In 2016, we developed the open source software, OpenDICE, as an alternative approach to measure and monitor the image quality recommendations in the Federal Agencies Digitization Guidelines Initiative (FADGI)[1] *Technical Guidelines for Digitizing Cultural Heritage Materials*. We recently released version 1.1, with the expectation that it will become an indispensable tool for quality management within the cultural heritage community.

Digital imaging quality assessment is crucial for worldwide cultural heritage digitization centers to achieve accurate and consistent digitization results. There have been a variety of standards established to assess different imaging quality factors, including resolution [1, 2, 3], intensity (e.g., OECF) [4], color accuracy [5, 6], noise [7], dynamic range [8], sharpness [1, 9], and geometric distortion [10], just to name a few. The assessment is generally implemented by scanning or taking a picture of a standard target board, for example, the X-Rite ColorChecker SG chart[2] or GoldenThread™ (also called DICE) target[3] (see Figure 1). Regions of interest (ROI) with different features are then extracted from the picture. Finally the quality factor values are derived from those ROIs. For example, color accuracy can be measured by computing the difference (e.g., ΔE2000 [11, 12]) between the target image values with the reference values provided by the manufacturers, while the image sharpness can be evaluated by the modulation transfer function (MTF) [13, 14] or the spatial frequency response (SFR) [15].

Currently available imaging quality assessment applications include DICE, delt.ae[4], iQ-Analyzer™ [5], and Imatest™ [6]. In particular, the commercial software DICE was developed to follow the FADGI criteria, and became a de facto standard software in digital preservation and archiving. Delt.ae provides similar analysis as DICE, and it is free for public use. However, the resulting report is oversimplified with only patch color measurements (RGB and CIE LAB values). Users can only see the assessment details only by pointing to individual patches. Moreover, the technical support of the software is limited. iQ-Analyzer™ and Imatest™ do not relate directly to FADGI guidance. We developed OpenDICE to address the above issues, which consists of three assessment categories: tonescale, color accuracy and resolution.

Figure 1*. Examples of targets for device color accuracy assessment. Left: ColorChecker SG chart; Right: GoldenThread™ target.*

We presented the software at the 2016 Archiving Conference [20] and at 2016 FADGI meetings. Based on the comments from early users, we have enhanced the software in these aspects: batch image assessment to monitor long term device performance variations, very large size target support for comprehensive resolution assessment at different locations and orientations and the inclusion of two additional color targets for profiling assessment.

This paper is organized as follows. Section 2 briefly introduces the background of image quality assessment. Section 3 presents our new works extending the OpenDICE software to

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[1] Guidelines – Federal Agencies Digitization Guidelines Initiative. http://www.digitizationguidelines.gov/guidelines/

[2] ColorChecker Digital SG. http://xritephoto.com/ph_product_overview.aspx?ID=938

[3] Image Science Associates. http://www.imagescienceassociates.com/

[4] Delt.ae – Online image quality assessment. http://delt.ae

[5] iQ-Analyzer. http://www.image-engineering.de/products/software/376-iq-analyzer/

[6] Imatest | Image Quality Testing Software & Test Charts. http://www.imatest.com/

support batch image assessment and the additional targets. Experimental results of the extensions are presented in Section 4. We draw conclusions in Section 5.

2. Background

Given an input image of a supported target, we implement imaging quality assessment by first locating the ROIs of different features on target boards, then deriving the quality factor values from those regions and comparing the derived values with the ground truth according to preselected criteria. As introduced in Section 1, we mainly focus on three categories of imaging quality factors: tonescale, color, and resolution assessment.

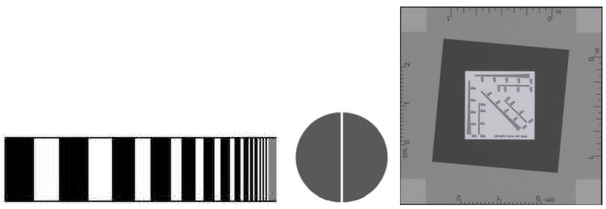


***Figure 2**. Examples of targets for MTF/SFR analysis. From left to right: sinusoidal, slit and slanted edge targets.*

Tonescale factors consists of the OECF (opto-electronic conversion function), white balance, illuminance uniformity, and noise. Tonescale factors are always derived from the pre-selected neutral/gray ROIs on the target charts. The OECF curve shows the measured brightness at different density values. The difference between the measured and the desired brightness values show the tonescale error. White balance measures the illuminance effect and imaging color artifacts on objects, which is computed as the intensity difference of the RGB channels. We compute the illuminance uniformity and noise as the peak intensity difference and intensity variance (or standard deviation), respectively.

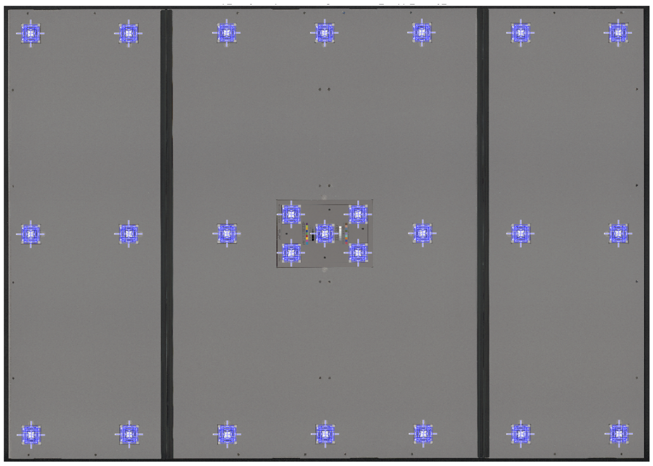
Color accuracy is computed as the color difference (e.g., ΔE2000) between the color patch measurements and the corresponding ground truth. Given an input target image, the input RGB values of the ROIs are converted to the CIE LAB values using the embedded image icc profile, which are then applied to the ΔE2000 computation together with the true values. The ground truth can be either obtained from the target chart manufacturer or measured by users with devices such as colorimeters, spectrodensitometers, or spectrophotometers following the ISO standards [5, 17, 18]. To obtain accurate colors of the patches, our approach [19] employing robust statistics may be applied to overcome the inter- and intra-equipment variations. Besides the color difference, color registration error is another factor of color accuracy, i.e., the accuracy of the color channel alignment. It is derived from the edge regions on the target by computing the intercept difference of the fitted edge lines in RGB channels.

Imaging resolution assessment mainly focuses on image sharpness [16], which determines the amount of detail that an imaging system can reproduce. It is usually measured by the MTF or SFR, which are two ways to characterize the system responses (MTF magnitude) with respect to different signal frequencies. In practice we may either directly measure the system responses to periodic patterns (e.g., sine pattern bars in Figure 2) of different frequencies, or we can conduct a frequency transform (e.g., Fourier transform) to derive the system response on an input signal indirectly. The input signal is generally an ideal image edge, which can be derived as the *edge spread function* (ESF) using slanted edges or the *line spread function* (LSF) using slit targets. Figure 2 shows examples of the above three targets (test charts). Indirect methods are often used due to their simple implementation, and the slant edges are always included in common target boards for the SFR computation. Interested users are referred to the review on those approaches [13].

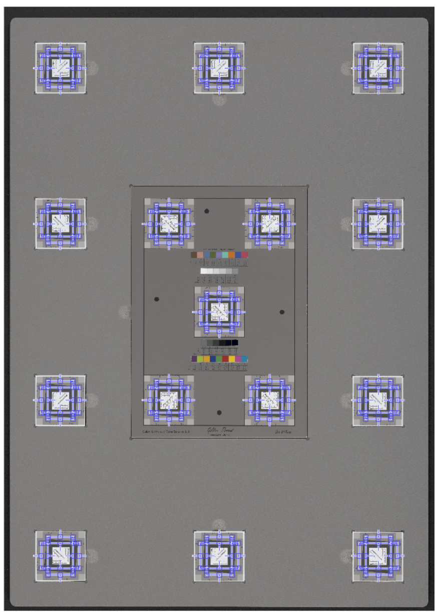
3. OpenDICE Extensions

We implemented the following extensions for OpenDICE.

1. **Batch image assessment**. This extension is to monitor imaging device performance variations over a long time period. At the Library of Congress, the Prints & Photography Division and the Geography & Map Division collected the Colorchecker SG and DICE target images daily for six months. We used these collections as the samples for our experiments. For efficient batch processing, the software has been revised to process a large set of images sequentially by scanning a user designated folder. Unlike the individual image processing version, there is no user interaction to adjust the OECF curves and manual detection of ROI during the assessment process. The only user interaction happens right after the ROI detection of each image, which requires user confirmation that the detection result is correct. If not, the program skips the image and proceeds to the next. This is to ensure the correct results while maintaining an efficient assessment process. After the assessment of all the images of the same target, the software draws the curves of different imaging quality factor values, which should be ideally a constant line. Large variations on the curves indicate either system performance or setting changes, which should be analyzed by the system operator and appropriate corrective action taken.
2. **Large size target image assessment**. In order to precisely characterize the resolution performance of the imaging system (sensor and lens) at different locations and orientations, we take images of large size target boards (66″×47″ and 17″×24″), which consist of ROIs distributed evenly on the boards. After the ROI extraction, we compare the SFR curves and sampling efficiency values at those locations with different orientations. Ideally, these resolution measurements should be approximately the same. Figure 3 shows the two targets we use for resolution assessment at 300ppi, 600ppi, and 800ppi scanning settings. The ROI detection in the large size targets follows the same principle as the regular DICE target in OpenDICE, i.e., the black circles in the middle DICE target are identified first, based on which the relative locations of other ROIs are detected respectively according to the pre-measured distances to the center DICE target.



Target 1: 66″×47″



Target 2: 17″×24″

***Figure 3**. Two large size targets for resolution assessment.*

3. **Color targets support**. In addition to the Colorchecker SG target, we added two other color targets to OpenDICE in order to provide alternative tools for color accuracy assessment and also the capability to evaluate the target profiling accuracy. The two targets are IT8.7/2 target with 264 patches, and our newly designed Next Generation Target (NGT) with 130 patches, see Figure 4. For example, we can use profiling tools such as basICColor Input®[7] to construct the CIE icc profiles for each of the targets, which are then applied as the input profiles for the scanner. This cross test provides a comprehensive way to compare the profiling performance of these targets.

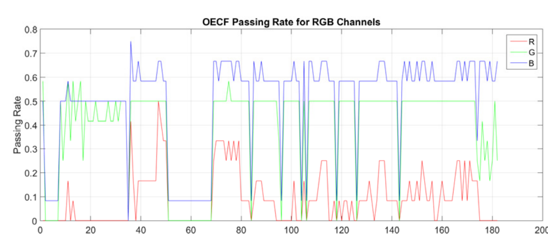
IT8.7/2 target

NGT

***Figure 4**. Two color targets for profiling accuracy assessment.*

4. Experiments of OpenDICE Extensions

The Library of Congress developed OpenDICE using the Matlab™ 2015a programming environment and compiled the program as stand-alone software for distribution. As introduced earlier, the batch image assessment version evaluates the collections of both DICE and Colorchecker SG target images, and presents the performance variations over the evaluation period. With a DICE target, Figure 5 shows the example curves of OECF passing rates (# of patches passed / 12 gray patches), ΔE2000 of the 30 patches, and the high frequency response of the resolution measurements. It can be seen from the curves that there are some large variations at different dates, which should be analyzed by the operator to identify the possible causes.



[7] basICColor Display
http://www.basiccolor.de/basiccolor-display-5-en/

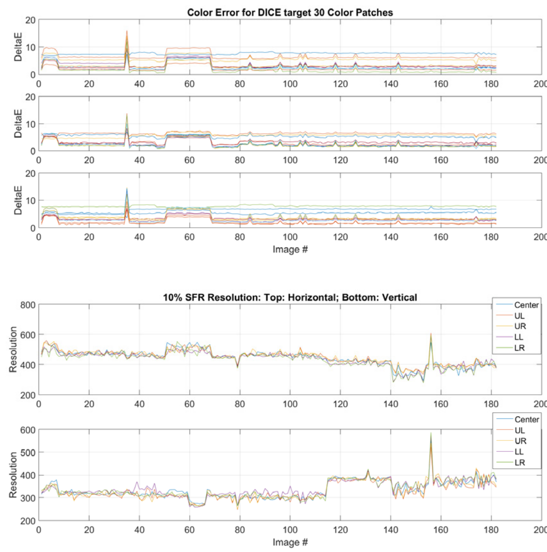
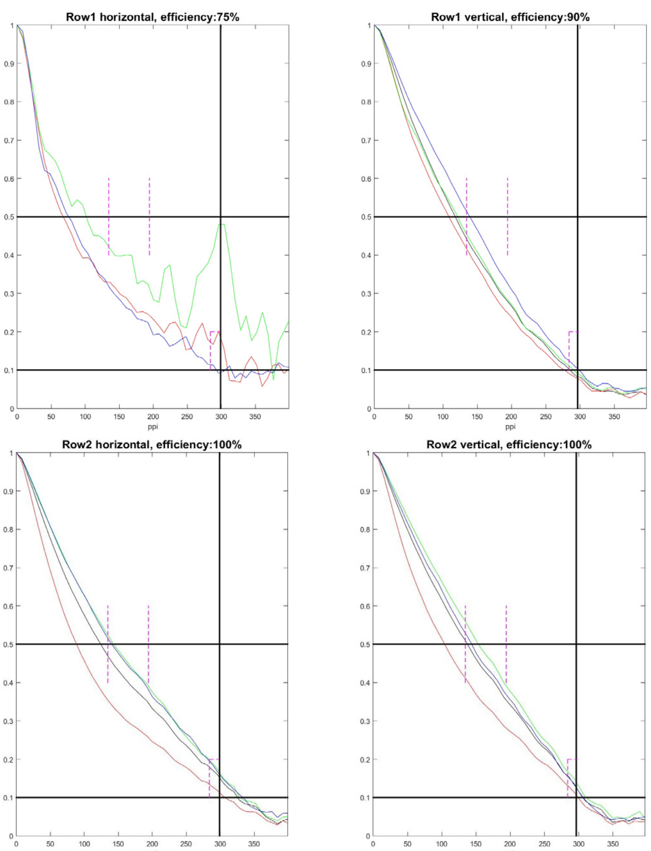


Figure 5.*Example curves to show the imaging quality factor variations.*

We employ the large size targets for a comprehensive resolution assessment. After the ROI detection as shown in Figure 3, we derive and compare the SFR curves and sampling efficiency values at different locations with different orientations. Using the first target in Figure 3 as the example, we show the average SFR curves and sampling efficiency values at different rows for a comparison, see Figure 6.



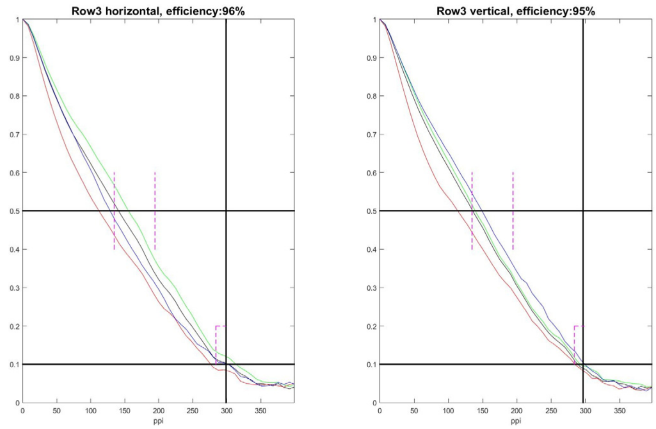


Figure 6. *Example of average SFR curves and sampling efficiency values at different rows of the first large size target (scanned at 300ppi).*

Figures 7 presents the tonescale and color accuracy assessment windows for a NGT. Both windows provide the same tabs as the Colorcheker SG target evaluation using OpenDICE. The IT8.7/2 target assessment results are presented in the same windows. Resolution assessment is not applicable to both color targets. For profiling performance comparison, we may create the icc profiles using different targets, then take pictures of the targets using the profiles. This cross test experiment may be employed for target profiling performance comparison.

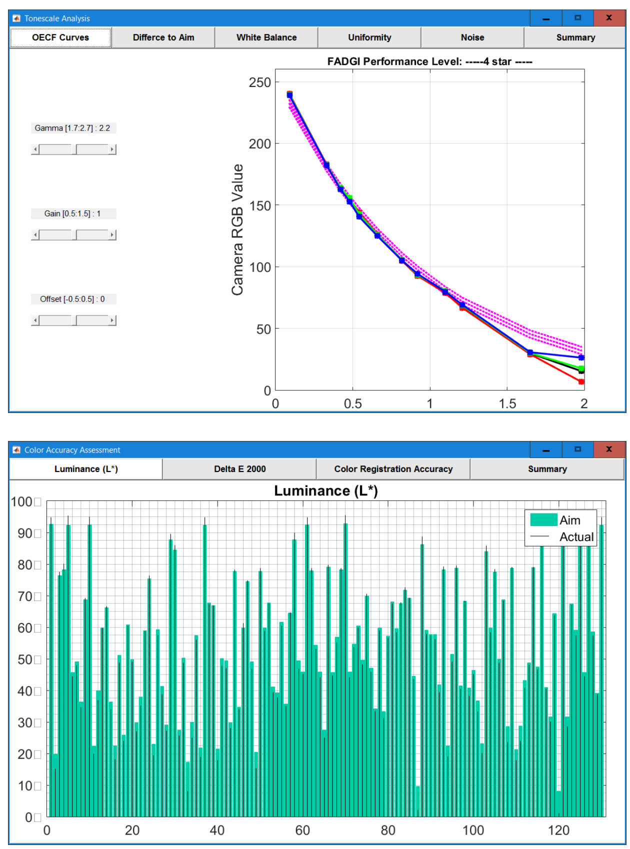


Figure 7. *Example of tonescale and color accuracy assessment windows for a NGT.*

5. Conclusion

OpenDICE is a next-generation quality assessment tool based on and compatible with the proven DICE quality management system. OpenDICE software is available at no cost to the user, and is certified for FADGI conformance monitoring. OpenDICE provides both manual and batch target analysis and allows data export for long term process monitoring and statistical analysis.

The original DICE program established quality standards for federal agencies participating in the FADGI program, and has become a standard for cultural heritage image quality monitoring. OpenDICE builds on this history and provides an open license alternative to DICE. OpenDICE is available for download at www.digitizationguidelines.gov.

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Author's Biography

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