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AUTOMATIC SLANTED EDGE TARGET VALIDATION IN LARGE-SCALE DIGITIZATION PROJECTS

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Abstract: *Covering the need for standards and guidelines in the workflow of paper document conservation through scanning, the article proposes a methodology for ensuring high quality scans in terms of image sharpness and an improved algorithm for computing the Modulation Transfer Function (MTF) of a scanning system using the slanted edge method.*
Key words: *target validation, sharpness, slanted edge, MTF*

1. INTRODUCTION

Paper documents such as newspapers, books and other prints suffer in time of various forms of autonomous decay that can affect paper. In the 1980's and 1990's research was carried out (e.g. the *Metamorfoze* project in the Netherlands) to develop reliable methods and standards for the conservation of paper heritage material that was considered of national importance.

When research programs first started, microfilming was a reliable method to preserve the content of an endangered document. However, in recent years, digitization is preferred over microfilming, leading to an additional challenge of converting pre-existing microfilms to digital media, in order to avoid handling the original documents, a process which is both costly and potentially damaging for the decaying prints.

A further direction pursued in recent years is converting scanned documents into electronic files, especially for large electronic libraries, for easier access to documents and operations such as editing, word searching and text-to-speech. In order to ensure high output quality for content conversion systems, based on optical character recognition (OCR), the input image fed to the OCR system must be verifiably the best obtainable when scanning the original documents.

There are nevertheless a number of issues to be tackled before digitization can definitively be used as a conversion method for preservation and access. Standards and guidelines, the workflow, the metadata, long-term storage and retrieval of digital images all have to be developed and dealt with.

This article proposes a methodology for calibrating scanners to ensure optimal quality in the digitization of both microfilms and paper prints, covering the issue of image sharpness validation.

2. IMAGE SHARPNESS ASSESSMENT

The sharpness of a photographic imaging system or of a component of the system (lens, film, image sensor, scanner, enlarging lens, etc.) is a quality factor that determines the amount of detail that can be reproduced. It is characterized by a parameter called *Modulation Transfer Function* (MTF), also known as spatial frequency response, which is a measure of the response of an optical system to varying intensities of light. The MTF is strictly the response to parallel lines whose brightness varies from minimum to maximum in a sinusoidal function (*Optikos*, 1999).

Traditional methods for MTF measurements were initially designed for devices forming continuous images and can produce erroneous results, because the sampling of digital devices is not properly taken into consideration (Estribeau & Magnan, 2004). Additionally, MTF results can depend on the chosen technique (sine target or bar target utilization, slit or knife-edge technique).

The proposed method is an improved version of the slanted edge method described in the ISO 12233 methodology and the SAFECOM methods (*SAFECOM*, 2006).The slanted edge method involves the analysis of a portion of an image containing an edge slightly tilted with respect to the detector and, compared to other methods, has the advantage of requiring a small number of pixels from a single image to be processed.

3. SHARPNESS VALIDATION METHODOLOGY

This section details a methodology suitable for calibrating document or microfilm scanning equipment with respect to the image sharpness quality factor.

3.1 Initial Setup

The workspace conditions (illumination, color temperature, etc.) and scanning procedure should match the requirements mentioned in the *Metamorfoze* project guidelines (*Metamorfoze*, 2007). For measuring image sharpness, a special target shall be constructed, containing five calibration targets (four near the corners and one in the center) such as the QA-62 target (presented in Figure 1)with four slanted edges as sides of a rectangle. The target must be scanned and validated at regular intervals (e.g. at the beginning of the day) or after any change in scanning parameters (e.g. resolution, scaling factor for microfilms, etc.).

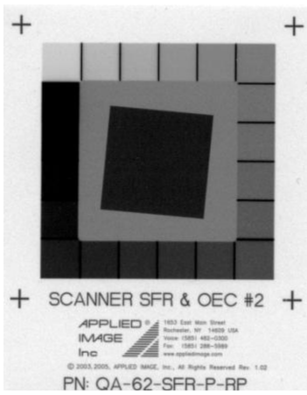

Fig. 1. Quality Assurance 62 sharpness calibration target

3.2 Detecting the Region of Interest

Automated sharpness validation techniques can be applied on the scanned target. To detect the five slanted rectangles in the target image, a conversion to black-and-white followed by 4-connected (black) pixel detection can be applied. By analyzing the shape of the connected regions, the rectangles can be recognized and their slant angles can be checked to meet certain limits (e.g. between 2 and 5 degrees).

For each of the five rectangles, image sharpness shall be measured by processing the pixels contained in four regions of interest (RoI), corresponding to the slanted edges of the rectangle. Each RoI must have a minimum size of 80 by 60 pixels (see Figure 2), containing a portion of a slanted edge in the middle.

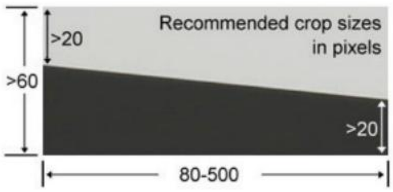

Fig. 2. Best minimum cropped region of slanted edge

3.3 Modulation Transfer Function Computation

The algorithm for computing the MTF and the associated frequency response graph is derived from the International Standard 12233 (*SAFECOM,* 2006). The following steps are performed for each RoI of each QA-62 target and, depending on the employed scanning color space, for each RGB color channel plus combined luminance channel (Y = 0.299 × Red + 0.587 × Green + 0.114 × Blue) for document scans, or just the grey channel for grayscale microfilm scans:

(1) For each pixel column in the RoI (rotated to the position of the top edge RoI, for reference purposes) the position of the separation line between the background and the slanted rectangle is determined by maximizing the difference of the sums of two groups of consecutive pixels (e.g. 5 pixels), each pixel weighted by the distance to the middle.
(2) The least-squares fit line through the coordinates found at point (1) is determined and is used to approximate the separation border between the background and the slanted rectangle.
(3) The pixels in the RoI no further than a predetermined distance (normally 1mm, around 12 pixels at 300DPI) from the fitted line (on both sides) are selected and distance-color tuples are formed using their distance to the fitted edge and their gray level. These values represent the Edge Spread Function (ESF) which is the system response to the input of an ideal edge (Kohm, 2004). The ESF is super-sampled because of the slanted edge which induces differences in the sub-pixel location of the projected pixels onto the perpendicular. A vertically oriented edge would only allow to obtain the horizontal Spatial Frequency Response (SFR) of the detector.
(4) The ESF must be resampled to a fixed interval by accumulating the projected pixels into “bins” having the width a fraction of the pixel pitch. This can be achieved by filtering the pixel values with a triangle filter of unit height and the width of a bin. Thus, the value associated to each bin is the weighted average of the pixels filtered by the triangle function centered in the bin. This allows analysis of spatial frequencies beyond the normal Nyquist frequency (*SAFECOM,* 2006). The number of bins per pixel distance is usually chosen as 4. Higher values may lead to insufficiently populated or empty bins.
(5) The equally spaced ESF samples obtained at (4) are derived (*d/dx*) in order to obtain the Line Spread Function (LSF). A Hamming windowing function is applied to force the derivative to zero at the endpoints (*SAFECOM,* 2006).
(6) The normalized magnitude of a linear Fast Fourier Transform performed on the LSF yields the MTF (see Figure 3).

Care must be taken in selecting the number of points calculated along the ESF with respect to the sampling rate in order to obtain the desired number of points in the resulting MTF. The frequency axis of the MTF must scaled to represent the calculated MTF in terms of the Nyquist frequency of the imaging system, defined as the highest sinusoidal frequency that can be represented by a sampled signal and is equal to one half the sampling rate of the system (Kohm, 2004) – always 0.5 cycles per pixel.

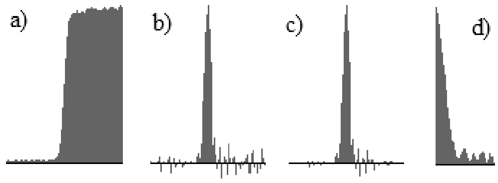

Fig. 3. (a) ESF, (b) LSF, (c) Hamming LSF, (d) MTF plots

For maximum precision in sharpness measurement, steps (3) to (6) in the MTF computation algorithm can be repeated for the interpolated line at step (2) rotated by slight angles in steps of ± 0.1 degrees, taking into consideration only the MTF curve with the highest values.

3.4Sharpness Specification

For a scanning system to pass sharpness validation certain criteria must be defined. Relevant indications are found by checking the frequency at which the MTF graph drops to 10% of its initial, zero frequency value. Values above 70% of the Nyquist frequency are desirable. The frequency corresponding to half the maximum MTF value (MTF50P) is also a good sharpness metric. Furthermore, internal sharpening (performed by firmware in scanning equipment) can be detected by comparing the peak MTF value with the initial value. A ratio below 1.2 is acceptable (*Metamorfoze*, 2007).

4. CONCLUSION

The paper presents a methodology and an algorithm to assess image sharpness based on the Modulation Transfer Function (MTF) of the scanning system. However, more detailed methodologies for calibration of scanning equipment are required to avoid geometric and color distortions, and to improve tonal reproduction and color accuracy. These will be addressed in our future research, together with more accurate methods for determining the MTF.

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6. REFERENCES

Kohm, K. (2004). Modulation Transfer Function Measurement Method And Results For the Orbview-3 High Resolution Imaging Satellite,*Proceedings of ISPRS XXXV,* Istambul, July 2004

Estribeau, M. & Magnan, P. (2004). Fast MTF measurement of CMOS imagers using ISO 12233 slanted-edge methodology, *Proceedings of SPIE*, Vol 5251

Optikos. (1999). How to Measure MTF and other Properties of Lenses. Optikos Corporation, Cambridge, USA. *Available from:*http://www.optikos.com/Pdf_files/how_to_measure_mtf.pdf*Accessed:*2010-08-01

SAFECOM.(2006).*Public Safety Statement of Requirements for Communications & Interoperability,* The SAFECOM Program Department of Homeland Security, pg.99-103, Vol II, version 1.0, August 2006

Metamorfoze. (2007).*Metamorfoze Preservation Imaging Guidelines*, Koninklijke Bibliotheek: National Library of the Netherlands, The Hague, June 2007