Image Quality of Archiving Systems Measured Using the UTT and Metamorfoze Guidelines

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Abstract

Predictable quality and constant quality are cost-reducing factors in a digitization workflow. This goes both for the digitization of paintings and the letters of Vincent van Gogh and for the mass digitization of newspapers, books and periodicals. Specifications and especially the Metamorfoze guidelines are designed for the digitization of all types of originals and guarantee a predictable and constant technical quality. The main principle of the Metamorfoze guidelines is 'to measure is to know'. Measuring is objective and is carried out using technical test pattern and standardized algorithms. In the everyday digitization workflow, the UTT (Universal Test Target) incorporates all patterns and will replace all other technical targets. The UTT and the evaluation software available for it are designed to give a quick insight into the technical quality of an image and thus work time and cost reducing. The technical quality is measured using various ISO-standards and following the Metamorfoze guidelines. Partly due to the development of the UTT and the software, technical improvements have been implemented in the Metamorfoze guidelines. In this paper, we will discuss how to work with the UTT, the software and we will discuss the latest developments within the Metamorfoze guidelines.

We will also discuss the use of the UTT by Zeutschel, scanner manufacturers, and the new UTT service of Image Engineering.

Metamorfoze

Metamorfoze, the Dutch national program for the preservation of the paper heritage, started in 1997. The program is financed by the Ministry of Education, Culture and Science and is jointly coordinated by the Koninklijke Bibliotheek (KB) – the National library of the Netherlands – and the Dutch National Archives. The aim of the program is to preserve paper originals that are threatened by autonomous decay.

Metamorfoze has formulated a draft version of guidelines for digitization in September 2007. The essence, the basic principle, of the Metamorfoze guidelines is: everything that can be visually perceptible in the original must also be perceptible in the digital derivative, in the same contrast ratio. The derivative must be as good (as is technically possible within a realistic workflow) as the original. Correct exposure and correct tonal capture are essential in order to realize this goal.

To ensure that the preservation image contains all the visible information of the original, in other words: to ensure correct exposure and correct tonal capture, a well structured and clear relation between the original and the surrogate must be ascertained. In order to be able to assess this relation objectively, guidelines and technical targets are used.

Technical targets are captured and analyzed with special software to provide information on technical aspects such as:

- Correct tonal capture (Opto Electronic Conversion Function, OECF, ISO 14524)
- Noise (Standard Deviation, ISO 15739)
- Signal to noise ratio (SNR, , ISO 15739)
- Uniform illumination (Shading)
- Colorcast
- Color accuracy (Delta E, CIE 15.2)
- Detail reproduction, sampling efficiency and sharpening (ISO 12233, ISO 16067)
- Geometric distortion
- Color misregistration (ISO 16067)

For all of these technical aspects tolerances are given in the Metamorfoze guidelines, which the derivatives must comply with.

The starting point for drawing up the tolerances is not to aim for the highest quality attainable but to define the minimal quality required. The tolerances have been drawn up for the digitization of three different types of original.

1. Originals that can be considered works of art.
2. Unique and general library and archival materials.
3. Non-unique and general library and archival materials.

In order to assess the technical criteria described above, various technical test targets were required:

- Kodak Gray Scale Q-13 or Q-14, to measure the OECF, Noise and SNR.
- Color Checker SG, to measure the color accuracy, OECF, color cast, Noise and SNR
- QA-62-SFR-P-RP, to do MTF measurements
- QA-2, to measure geometric distortion
- White piece of paper with a L* value between 95 and 90 to measure uniform illumination

These technical test targets had to be digitized as 4 different images and subsequently analyzed with the following software packages: Photoshop CS4, IE-Analyzer and Imcheck. The digitization and subsequent analysis of the test targets is time consuming and needs to be done daily before starting production. The digitization of the books, newspapers or periodicals should only be started if the technical test targets are in line with the Metamorfoze guidelines. Therefore, the scans of the test targets undergo careful technical testing by the digitization company. In the KB, the scans of the test targets (of KB digitization projects),

are checked once more. These examinations, however, are very time consuming.

The KB (National library of the Netherlands) in cooperation with IE (Image Engineering Dietmar Wueller) and FMI (Fachverband fuer Multimediale Informationsverarbeitung) has therefore designed the Universal Test Target, in 2009 in order to reduce the number of required targets from 5 to 1.

The main advantage of working with a single technical test target and a single software package is time. You win time both in digitizing the target – only 1 scan instead of 4 – and in analyzing the target. Another advantage is the fact that all separate technical targets are now placed in a fixed position. Discussions concerning the correct positioning of a target in the frame are an issue of the past.

Apart from the objective technical assessment an image must always be checked visually for artifacts.

Universal Test target

The Universal Test Target is a test target, which is designed to provide insight into the image quality of various types of high end cameras, scanners, flat bed scanners, and feed through scanners following the current ISO-standards and the Metamorfoze Guidelines. The target is available in the DIN sizes A4 to A0 rounded to full centimeters, mounted on dibond with a reference file. This reference file contains all the L* a* b* values of the UTT and provides information about the ΔE, ΔC*, ΔL* values between the produced UTT and the UTT specifications. The reference file can be used in the UTT software. Every UTT chart has got a unique number. This number is corresponding with the reference file. It is also possible to buy unmounted versions without reference files.

Designed as a 420 x 300 mm (app. A3) chart the basic UTT target can repeatedly be put together to sizes up to A0 or even bigger. To utilize the scanners full dynamic range the target is produced on glossy material.

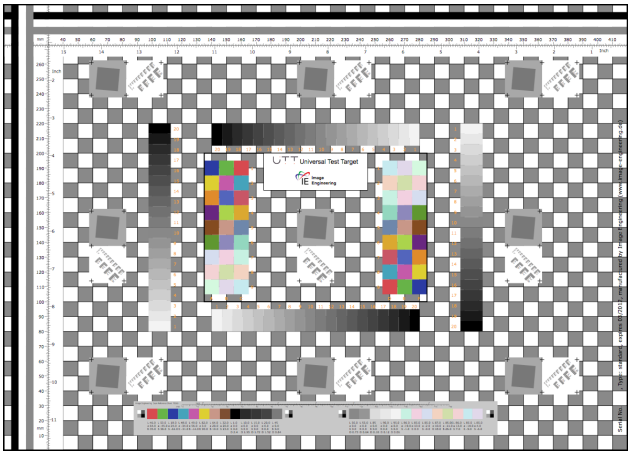

Figure 1: The UTT A3 Version

The different structures of the targets are:

- Grey bars and scales: The Grey bars and scales are designed in a way that they go through the whole width and length of the target. They are used to measure uniformity and determine potential banding problems.
- Slanted Edges and visual resolution structures: the slanted edges are designed according to ISO 16067 to measure the spatial frequency response from which resolution, sampling efficiency, color misregistration, and acutance can be derived. The slanted edges are spread over the whole target at equal distances of 140 mm.
- Grey scales: The grey scales are designed to measure the tonal curve (OECF), the dynamic range, the white balancing, and the noise and signal to noise ratio in the image.
- Color Patches: The color patches are used to measure the color accuracy of the image
- Checkerboard: The checkerboard is used to measure shading and distortion.

In order to use the UTT for all types of digitization it is important that the target is technically sound. And that the technical quality is safeguarded in the production of the UTT. Therefore the KB, IE and FMI have drawn up technical specifications UTT must comply with. These specifications have been put down in a document.

The Universal Test Target has been produced by Image Engineering Dietmar Wueller since September 2009. But as the UTT is an open standard other manufacturers may join in in the near future. On the UTT website the technical specifications of the UTT are available. This enables a broad use of the target. Other manufacturers of technical targets and analysing software will be able to produce the UTT themselves and include it in their software packages.

The UTT target is designed to quickly and efficiently assess the calibration of a camera or scanner, on a daily basis, before or during production. When calibrating a scanner or a camera you need to execute several operations: white balancing, focusing, correct illumination, making a tonal correction curve, making a color correction profile. To calibrate a camera or scanner you still need a Color Checker SG. To make a tonal curve you can either use the Color Checker SG, the grey scales of UTT or the Kodak Gray Scale.

The advantage of performing a quality check of the calibration with a single target is primarily that it saves time and thus money in the digitization process. The cooperation of the KB with the German Confederation FMI also offers a great advantage. The Confederation consists of manufacturers of digitization equipment and service providers for digitization. Never before have scanner manufacturers, digitization companies, and libraries, archives and museums used one and the same target to indicate the technical quality of scanners and cameras. This will greatly improve the communication between the different parties and therefore also the technical quality of the digital files.

Zeutschel, the German-based manufacturer of scanners, uses UTT for the calibration of its scanners at the factory. They also use UTT for on-site calibration after the scanners have been delivered. Image Engineering is planning to start a technical support service. This service consists of: technical assessment of a UTT scan and advice on how to improve the scan technically if necessary. This service will be aimed mainly at the cultural heritage sector.

Innovations in the Metamorfoze Guidelines

As a result of the development of the UTT and the new control software, the following, important changes have been carried out in the Metamorfoze guidelines:

- Exposure tolerances based on ΔL*
- Highlight Gamma has been given a new name: Gain Modulation
- Gain Modulation is based on formula: Sample ΔL* / Reference ΔL*
- Colorcast tolerances are based on ΔC* and ΔE
- Uniform illumination tolerances based on ΔL*

The advantage of these new calculations is that we can work more accurately with UTT.

Exposure tolerance based on ΔL*

The exposure tolerances in the Metamorfoze Guidelines were based on F-stop (1 F-stop = 0.30 density). The Kodak Gray Scale, which has always played an important role in de Metamorfoze Guidelines, is based on F-stop. When designing the gray scales of the Universal test target we have based the gray scales on L* values rather than on F-stop differences. As a result, the exposure tolerances are also no longer specified in F-stops but in Delta L. The new exposure tolerance is:

Max ΔL* = 2

The new exposure tolerance Max ΔL* = 2 is based on the original tolerances of the 1/12th F-stop overexposure and underexposure in the highlights and subsequently rounded off.

UTT Patch number 1	Density	L*
+ 1/12th F-stop	0.032405	97.15
1	0.057405	95
- 1/12th F-stop	0.082405	92.89

The consequence of these new exposure tolerances is that it is slightly more flexible related to the dark patches compared with the former F-stop based exposure tolerance. Former exposure tolerance:

UTT Patch number 18	Density	L*
+ 1/12th F-stop	1.923453	10.51
18	1.948453	10
- 1/12th F-stop	1.973453	9.51

The new exposure tolerance Max ΔL = 2

UTT Patch number 18	Density	L*
	1.851900	12
18	1.948454	10
	2.052740	8

The new exposure values are slightly more lenient, but also more realistic. Human eyes function according to L* calculations and not according to logarithmic calculations.

Obviously, it is not allowed to slightly underexpose in the first patch of the greyscale of the UTT, following the standards, nor is it allowed to slightly overexpose in the second patch, following the standards. The ΔL* between patch 1 and patch 2 in the digital image must be more or less similar to that in the original. In the draft version of the guidelines (2007) Metamorfoze introduced a value for this: the Highlight Gamma. The term Highlight Gamma has now been changed to: Gain Modulation.

Gain Modulation

The term Highlight Gamma has been changed to Gain Modulation because the calculation is no longer done based on the 8-bit pixel values but on the basis of L*, a*, and b* values. The usability of the Gain Modulation is improved. The Highlight gamma used to be calculated in the high lights only. When digitizing works of art the Gain Modulation can be calculated throughout the entire grey scale, from L* 95 to L* 5. When digitizing unique library materials and archive materials the Gain Modulation is calculated in the high lights only. The Gain Modulation can be calculated in various ways:

New Formula Gain Modulation based on ΔL
Sample ΔL/ reference ΔL

Or since a* and b* should remain close to 0 for neutral patches

New Formula Gain Modulation based on ΔE
Sample ΔE/ reference ΔE

According to the Metamorfoze guidelines the Gain Modulation in the high light area must always lie between 0.80 and1.08 (80 % - 108 %).

At this moment we mainly work with the Gain Modulation based on ΔL* and calculated between the neutrals. The calculation is generally done between a high L* value and a low L* value, so for example between L* 95 and L* 90.

Color Cast

In the Metamorfoze guidelines the tolerance for color cast was described in a tolerance for an 8-bit pixel value per RGB channel of +3 and -3. Now the color cast is described by ΔC = 2 and ΔE = 2,83. The advantage of working with L* a* b* values is that it is much more accurate. The neutrals in a UTT gray scale can, within the fixed tolerances, have an a* or b* value that is slightly over or under 0,00. By using the tolerances for ΔC and ΔE as a basis when measuring a UTT exposure, color cast can be established quite accurately. The small deviations in the neutrals of

the UTT will no longer matter. So the advantage of these new calculations is that you can work more accurately with the UTT. Thus, the guidelines have entered a new advanced level of precision. It is important that a reference file is made based on the real L* a* b* values of the used UTT and that the calculation of a UTT image takes place on the basis of this reference file. To reach the required accuracy the used UTT taget should be the version that comes with individually measured reference values. Every UTT has a unique number which corresponds with the number of the reference file. In the future we want to supply the UTTs with a bar code. The UTT control software should then be able to read the bar code and search the corresponding reference file on the internet. Image Engineering will build a database with the reference files of the UTTs that have been sold.

Uniform Illumination

In the draft version of the Metamorfoze Guidelines (2007) the tolerances for uniform illumination are based on F-stops and paper size and are described in 8-bit pixel values in eciRGBv2 or in Adobe RGB (2008). To calculate the tolerances in ΔL* the upper limit L* value of 97 for the white patches in the background pattern of the UTT is used and the shading tolerance level in F-stops converted into L* values is used as a base.

Tolerances uniform illumination

UTT	Artwork	Unique	Not unique
DIN A-3	ΔL* 3	ΔL* 3	ΔL* 3
DIN A-2	ΔL* 4	ΔL* 4	ΔL* 4
DIN A-1	ΔL* 5	ΔL* 5	ΔL* 5
DIN A-0	ΔL* 6	ΔL* 6	ΔL* 7

UTT and the Metamorfoze Guidelines

Working according to the guidelines has many advantages. One major advantage is the fact that the production becomes technically predictable and repeatable. Another major advantage is the fact that the technical quality is unrelated to the type or model of camera or scanner that has been used. For companies or organizations that work with different machines this means that the quality of their production is uniform. For clients who work with different companies it also means that the production is of uniform quality. Besides this, the tolerances that are defined in the Metamorfoze guidelines are based on the minimum performance that may be required rather than the maximum performance that may be attained. Thus, the Metamorfoze guidelines are quite realistic. Besides this, the guidelines provide a clear insight into the technical possibilities and restrictions of different scanners and cameras. Consequently, the guidelines are also important to the manufacturers of scanners and cameras.

The Metamorfoze guidelines are input-oriented. In other words: clear definitions are made to what the first camera or scanner file must be like. For specific output-oriented goals a generic revision of a specific set of digital files may be advisable. This generic revision might be clearly defined using the UTT. In a newspaper digitization project which focuses on high-quality OCR, for example, the scans of the newspaper might be given a generic revision. Newspaper type, for example, which is difficult to read because of the discoloration of the paper and letters. These scans may need a slightly higher contrast and sharpening to improve the OCR quality. This revision might be defined using the UTT.

UTT software Pass and Fail criteria

The first screen that the users of the UTT software get to see is an Overview screen. In this screen the following criteria are listed: OECF, Noise, Color, Resolution, Shading, Distortion, Lines. For all these criteria, color codes indicate whether or not this specific criterion complies with the guidelines. Green means good, red means not good. After this screen you can click to a second screen, Numerical page. This screen provides values for all criteria mentioned before. You can see to what extent a technical item complies with or deviates from the guidelines. After Numerical page there are 10 other pages which give a graphical insight into the quality of the following criteria: Tonal Reproduction, White balance, Gain Modulation, STD, SN/r, Resolution, Color, Distortion, Lines.

UTT analysis results in IPTC Metadata

All the technical data yielded by the analysis of a UTT scan are saved in a TXT file. The output of data is quite high. A UTT DIN A-3 yields 27 pages of data, printed on both sides. A highlight report is stored in the IPTC (International Press Telecommunications Council) metadata section of the analysed digital file to ensure it does not get lost.

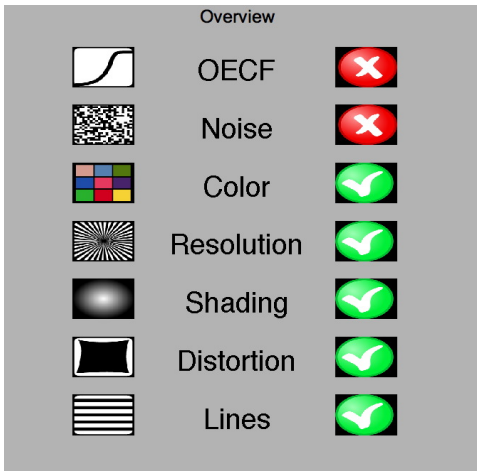

Figure 2: The results overview window

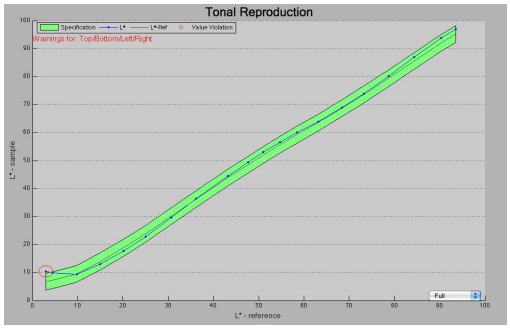

Figure 3: The tonal range with the green tolerance range.

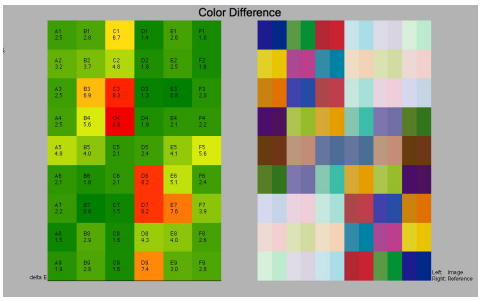

Figure 4: The color accuracy.

UTT software and technical knowledge

The user of this software must be able to interpret the technical concepts mentioned in this article, such as OECF, Sampling Efficiency, Gain Modulation and Noise. This concerns both the operator who must assess whether his camera or scanner is still calibrated correctly, as well as the quality manager of a heritage institution who must assess whether the digital files have been made according to the Metamorfoze guidelines. The UTT target and the software give a quick and efficient insight into the technical quality of a scan. But in order to understand the technical information knowledge is needed. It is advisable that the client has outlined a clear and generally supported policy on this, as the UTT software can reject a scan that deviates marginally from the Metamorfoze guidelines.

It is for example possible that the Gain Modulation between L* 95 and L* 90 is 79%. The UTT software now indicates that the Gain Modulation is insufficient and that the scan has been rejected. According to the Metamorfoze guidelines the Gain Modulation has to be 80% at the lowest. An operator has to act now and adjust his camera or scanner. For the readjustment of the Gain Modulation in the high lights a new tonal correction curve has to be made, as well as maybe a new icc profile. This is a lot of work that requires a high level of technical knowledge. A quality manager may, with a gain Modulation of 79%, decide to reject the entire day's production, according to the results of the UTT software. But he or she can also look at scans of the originals. And, depending on the type of original, decide on the harm that is done by the fact that, in the highlights, the Gain Modulation marginally deviates from the Metamorfoze guidelines. And subsequently to decide whether or not to reject that day's production.

Not all of the archives may have personnel that is experienced enough to run the tests and interpret the results. This does not mean that these archives cannot digitize their assets. One way to deal with that is of course to train the operators and provide the required knowledge that way. Another way is to work with a consultant in the beginning to set up the system correctly. After that the daily scan of the UTT can be sent to a service provider who runs the analysis and contacts the archive in case of any problems and provides possible solutions for them.

Future UTT projects

The KB in cooperation with IE has designed a small technical test target: the Scanner Reference Chart, which is intended to replace the Kodak Gray Scale Q-13 or Q-14 and the mini Color Checker. At this moment, the Kodak Gray Scale Q-13 or Q-14 and the mini Color Checker are placed beside the originals that are scanned. With the aid of these test targets we assess, at random, the technical quality of the scans. The Scanner Reference Chart gives an insight into the OECF, MTF, color accuracy and horizontal or vertical distortion. Image Engineering is now developing a software module for the Scanner reference Chart.

For the scanning of 35 mm and 16 mm microfilms, Metamorfoze has recently developed a microfilm scanning target. This target gives an insight into the performance of the microfilm scanner in terms of sampling efficiency and horizontal or vertical distortion. In the near future, images of the UTT on 35 mm microfilm will be tested. In case of a positive outcome, a UTT on microfilm will be used as a microfilm scanning target for 35 and 16 mm as well.

Metamorfoze & UTT

Before Metamorfoze can start using the new UTT card and software on a wide scale, these must be tested extensively. Various software packages, technical test targets, scanners and cameras will be compared.

Last year, at the IS&T conference at Arlington Hans van Dormolen presented the paper: Metamorfoze Preservation Guidelines: One size fits all.' With the introduction of the UTT this concept has been expanded considerably.

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[7] Center for Digital Imaging http://www.cdiny.com/
[8] Federal Agencies Digitization Guidelines Initiative http://www.digitizationguidelines.gov/

Author Biography

Hans van Dormolen: After working for 15 years as a professional photographer Hans van Dormolen started in 1999 a career as imaging specialist for the National Library of the Netherlands. He is responsible for the technical quality of preservation substitutes, analog and digital. He is the author of the Metamorfoze Preservation Microfilming Guidelines and co author of the Metamorfoze Preservation Imaging Guidelines. Hans is a member of IS&T and he was nominated for an IS&T award in 2008.

Dietmar Wueller studied photographic sciences from 1987 to 1992 at the University of Applied Sciences Cologne (Germany). Since 1997 Dietmar Wueller runs an independent test lab for digital cameras and scanners that has also developed to one of the leading suppliers for test equipment for digital image capture devices. He became the German representative for ISO TC42 WG18 in summer 2000, is a member of the board of the European Color Initiative, and besides running his company he works on his PhD thesis on noise measurements at Leeds University.