Czech technical university in Prague

Faculty of Electrical Engineering

Digitization of Motion Picture Films

BACHELOR THETHIS

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Prague 2018

ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

Fakulta Elektrotechnická

Digitalizace kinematografických filmů

BAKALÁŘSKÁ PRÁCE

Bakalant: Alexander Cherepanov

Vedoucí práce: Ing. Martin Bernas, CSc.

Praha 2018

ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

ZADÁNÍ BAKALÁŘSKÉ PRÁCE

I. OSOBNÍ A STUDIJNÍ ÚDAJE

Příjmení: **Cherepanov** Jméno: **Alexander** Osobní číslo: **397830**

Fakulta/ústav: **Fakulta elektrotechnická**

Zadávající katedra/ústav: **Katedra radioelektroniky**

Studijní program: **Komunikace, multimédia a elektronika**

Studijní obor: **Multimediální technika**

II. ÚDAJE K BAKALÁŘSKÉ PRÁCI

Název bakalářské práce:

Digitalizace kinematografických filmů

Název bakalářské práce anglicky:

Digitization of Motion Picture Films

Pokyny pro vypracování:

Analyzujte dosaženou rozlišovací schopnost při digitalizaci archivních filmů z 40. až 80 let 20. století. K dispozici máte různé vzorky resolvometrických i uměleckých černobílých i barevných filmů 35 mm a 16 mm i jejich digitalizované verze v rozlišení 8K, 4K a 2K. Výstupní data jsou k dispozici ve formátu DPX. Na vybraných vzorcích vyhodnoťte dle možností analýzou obrazových testů i metodou odezvy na hranu MTF funkci pro různá rozlišení i typy filmů. Pro různé typy filmů vyhodnoťte dosaženou rozlišovací schopnost a diskutujte optimální volbu rozlišení.

Seznam doporučené literatury:

[1] Stump, D.: Digital Cinematography. Fundamentals, Tools, Techniques and Workflow. Focal Press, 2014, ISSBN 978-0240-8179-1-0
[2] Jícha,M., Šofr,J. a kol.: Živý film. Digitalizace filmů metodou DRA. Lepton Studio, 2016, ISBN 978-80-904503-4-9

Jméno a pracoviště vedoucí(ho) bakalářské práce:

Ing. Martin Bernas, CSc., katedra radioelektroniky FEL

Jméno a pracoviště druhé(ho) vedoucí(ho) nebo konzultanta(ky) bakalářské práce:

Datum zadání bakalářské práce: **16.02.2018** Termín odevzdání bakalářské práce: **25.05.2018**

Platnost zadání bakalářské práce: **30.09.2019**

Ing. Martin Bernas, CSc. podpis vedoucí(ho) práce	podpis vedoucí(ho) ústavu/katedry	prof. Ing. Pavel Ripka, CSc. podpis děkana(ky)

III. PŘEVZETÍ ZADÁNÍ

Student bere na vědomí, že je povinen vypracovat bakalářskou práci samostatně, bez cizí pomoci, s výjimkou poskytnutých konzultací.
Seznam použité literatury, jiných pramenů a jmen konzultantů je třeba uvést v bakalářské práci.

.

Datum převzetí zadání Podpis studenta

Affidavit

I declare that the presented work was developed independently and that I have listed all sources of information used within it in accordance with the methodical instructions for observing the ethical principles in the preparation of university theses.

Prague, date . . . .

Čestné prohlášení

Prohlašuji, že jsem předloženou práci vypracoval samostatně a že jsem uvedl veškeré použité informační zdroje v souladu s Metodickým pokynem o dodržování etických principů pri přípravě vysokoškolských závěrečných prací.

V Praze, dne . . . .

Acknowledgements

My sincere gratitude I want to express to my teacher Ing.Martin Bernas, CSc. for supervising me during preparation of this work, great advice and help with the experiment. I would also like to thank Ing. Jiří Folvarčný for providing this research with unique resolvometric test samples and briefing me with valuable information regarding main topic of this thesis.

Poděkování

Moje upřímné poděkování chci vyjádřit mému učiteli Ing.Martin Bernasovi, CSc. pro dohled nad průběhem této práce, skvělé rady a pomoc při experimentu. Rád bych také poděkoval Ing. Jiřího Folvarčného za poskytnutí unikátních resolvometrických testovacích vzorků a informování mě cennými údaje a fakty o hlavním tématu této práce.

Abstract

This bachelor thesis contains information about digitization process and how to evaluate quality of outcome. I have written about digitized Image Quality Factors and methods commonly used to measure them. The work reports a brief information on test source supporting it with illustrations. I have described programs that might be used in evaluation process and how to use them. "Experiment" part is dedicated to using described methods on practice. As a last step I have compared quality of two scan stations and discussed whenever those are suitable for purposes of digital preservation of film archive.

Index Terms

digitization of film, film archive, film, 35 mm film, preservation, bar pattern test, MTF, rise distance, Matlab, OZX2-A, 2K, 4K, 8K, resolution, scanner, sharpness, NorthLight, ScannStation, 35mm, DPX format

Anotace

Tato bakalářská práce obsahuje informace o procesu digitalizace filmu a hodnocení výsledné kvality. Práce se zabývá především metodami hodnocení rozlišení digitálního obrazu a způsobem jejich měření. Práce obsahuje informace o použitých obrazových testech, včetně jejich grafického zobrazení. Dále jsem popsal programy, které jsem použil pro jejich vyhodnocení. V závěru jsou vyhodnoceny získané výsledky, porovnána rozlišovací schopnost obou použitých skenerů a diskutována jejich vhodnost pro účely digitalizace filmových archivů z hlediska prostorového rozlišení.

Klíčová slova

digitalizace filmů, filmový archiv, 35 mm film, konzervace, čárovy test, MTF, odezva na hranu, Matlab, OZX2-A, 2K, 4K, 8K, rozlišení, skener, ostrost, NorthLight, ScannStation, DPX format

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1. Introduction

Main task set for this Bachelor thesis requires to:

“Analyze the resolution achieved in the digitization of archival films from the 40s to 80s of the 20th century. You have various samples of resolvometric and art black and white and color films 35 mm and their digitized versions at 8K, 4K and 2K. Output data is available in DPX format. On selected samples, evaluate as many options as possible image test analysis as well as the MTF edge response method for various resolutions and film types. For different films evaluate its resolution and discuss optimal version.”

Digital format is far more superior to analog format in terms of storing data. It takes way less physical space and is less of a subject to damage by time. Digital preservation of old film archives is important by reason of maintaining heritage and cultural fund collected by previous generations.

However, digitization has its own disadvantages. Digitization will not produce exact copy of the original material but create a new version of it. Process has its own characteristic features, which one will call flaws and other name is as hallmark and even unique stylistics.

The purpose of this study is to discard all possible subjective judgments and evaluate output quality of digitization process in term of straightforward preservation of source information.

In first part of this work I am explaining term “Digitization” and describing its process from sampling to quantization. Also, I am introducing equipment that was used.

Second part explains possible method of objective evaluation output digital quality, as well as Image Quality Factors affecting the outcome of the entire process.

Next, I am describing my actions that took place during evaluation process, right after information about test subjects which I was granted during this research. I will compare equipment and tell if it meets minimal requirement for digital preservation.

2. Digitization

The digitization (not to be mistaken with digitalization or digital preservation) term is usually understood as the process of converting information stored in analog format into a digital format by generating a series of numbers that represent original image, object or signal. Commonly final digital representation is in the binary form. In advance of process itself it is important to evaluate overall condition of source materials. In particular instance of converting cinematographic films of the twenties and the forties main issues and defects are:

- chemical corrosion
- physical damage such as scratches
- outwear
- color and transparency loss.

Quality of digital representation, on the other hand, depends on device efficiency and process of conversion itself. [2]

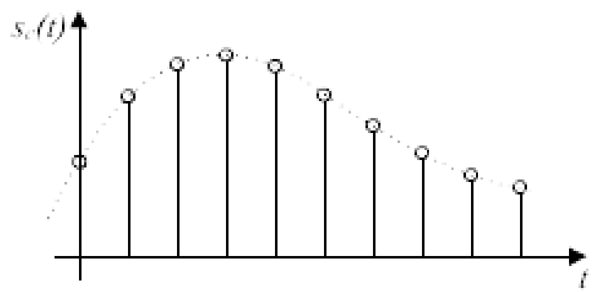
2.1. Process of conversion

Analog to digital conversion process consists of two phases.

2.1.1. Sampling

Sampling or discretization over time means taking samples from continuous signal at regular time intervals. This time intervals are inversely related to sampling frequency. $f_S = \frac{1}{T_S}$

Output of sampling over time is discrete-time signal (pic. 2.1.1.1).



Pic.2.1.1.1
Samples from continuous signal

An error-free reconstruction of the baseband signal from its samples is possible if the signal is frequency-limiting and the sampling frequency is at least twice the bandwidth. This is so called Nyquist–Shannon sampling theorem:

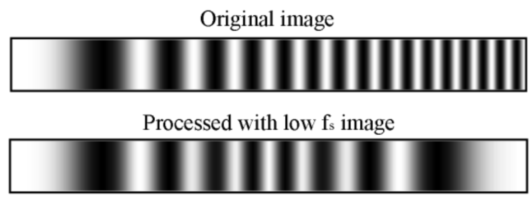
$$f_S \geq 2 * f_{max}$$

Where:

f_{max} – *maximum frequency of the original signal.*

Insufficiently dense sampling moiré, aliasing or stroboscopic effect.

Number of samples used during discretization process is directly related to output resolution. The less samples would be taken, the more information would be lost.[7]



Pic.2.1.1.2
Example of aliasing

2.1.2. Quantization

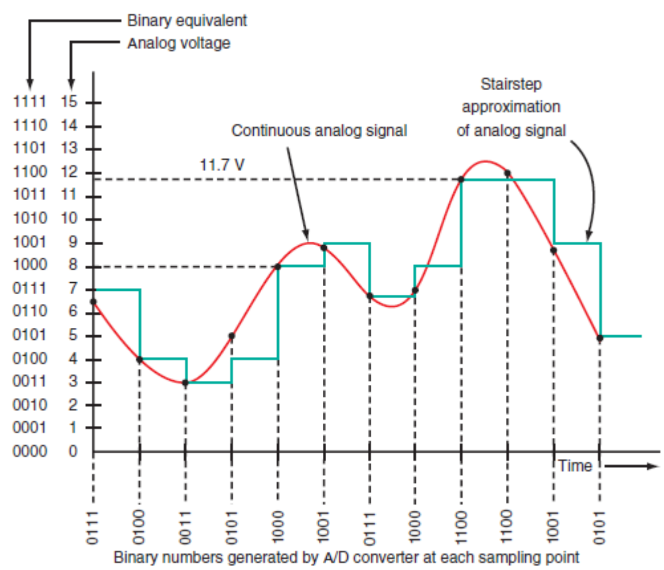
Quantization or discretization in values means assigning discrete levels to values of the signal samples. This process limits real number of samples to finite. Number N of quantization levels is given by the number of bits n per sample.

$$N = 2^n$$

Common bit value for nowadays digitizing process is 12 or 16.

Quantification causes irreversible loss of information and this distortion .is called quantization noise.

The number of levels increases the digital space needed to store the image, and it is important to find a balance between file size and level of details that still affects the quality. [7]



Pic.2.1.2.1
Quantization levels corresponding to samples

2.2. Equipment

Two types of scanners exist that can be used to make a digital copy of a film. First type is so-called bed flatbed scanner. It has tiny photosensor that gradually passes by recording bits of information consequentially composing final output. Second type is station based scanner. Such a model takes a picture of the whole frame at once. There are no advantages for one type over another in terms of quality, but station based scanners are more suitable for digitizing long filmstrips, since they automatically scrolls frame by frame while flatbed scanner requires constant human assistance. [1]

For the purposes of this study, following devices were used:

2.2.1. Northlight 2 Film Scanner

Pic.2.2.1.1
Northlight 2 Film Scanner

Declared resolution: Up to 160[lp/mm]

CCD sensor based scanner that is claimed to be “the benchmark for quality in the high-end film restoration market”.

Station uses LED light source to transfer image from film to sensor.

Capable to work with different film formats – 16mm, Super16mm, 2/3/4/8 perf 35mm

Outputs images in resolution from 2K to 8K with Bit-Depth of 10 or16-bit.

2.2.2. Lasergraphics ScannStation

Pic.2.2.2.1
Lasergraphics ScannStation

Declared resolution: N/A

CCD sensor based scanner under the slogan of “high-quality pin registered digital film mastering scanner”

Capable to work with different film formats – 8mm, Super 8mm, 9.5mm, 16mm, Super 16mm, 17.5mm, 28mm, 35mm, and 65/70mm (5-perf)

Outputs images in resolution from 1.2K to 5K Resolution with Bit-Depth of 10 or16-bit.

Bought stations export digitized files in various media formats including DPX.

2.3. DPX format

Digital Picture eXchange is unique modification made by The Society of Motion Picture and Television Engineers (SMPTE) form the Kodak Cineon format that is used to store digital motion picture data in a bitmap file format. More specifically to store a single frame of a motion picture or video data stream. As far as main purpose of this format is resolution and device independence, DPX supports any available Color Space and up to 64-bit depth. DPX files are used to store and exchange digital moving picture sequences between a wide variety of electronic and computer systems. The file format is most commonly used to represent the density of each color channel of a scanned negative film in an uncompressed "logarithmic" image where the gamma of the original camera negative is preserved as taken by a film scanner. DPX provides, in fact, a great deal of flexibility in storing color information, color spaces and color planes for exchange between production facilities. [ANSI/SMPTE ST 268M:2003 – STANDARD]

3. Evaluation process

3.1. Image Quality Factors

There are several significant Key Performance Indicators, that determining Image Quality of scanned image listed down below.

- Preservation of original form of the image. This parameter decreases under the influences of lens used in scanning equipment distortion. The most common defect is an aberration that causes straight lines to curve near the edges of images.
- Color accuracy and noisiness of the image. Color accuracy is affected by the Bayer color filter array and by the signal processing and white balance algorithm in the camera or RAW converter. Accurate color does not have the same meaning as “pleasing” color. In either way, which parameter is more critical in pictorial filmography such it is in medical and technical spheres is a subject for another debate and will not be further discussed in this research. Noise is inevitable and always present part of the image resulted by the basic physical phenomenon — the photon nature of light and the thermal energy of heat — inside image sensors and amplifiers. Noise scales severely with pixel size and thus decreases with the scale of sensor.
- Blemishes are visible spots or marks in the image, caused by sensor defects or by dust in front of the sensor and accruing in photographic equipment, such as DSLRs and Handy Cams, but completely unacceptable in professional film scanners.
- Sharpness is the most important image quality factor that determines the amount of detail an image can convey. Sharpness is directly related to contrast and defined by the boundaries between zones of different tones or colors. Image blur can be caused by many various reasons. Max image sensor resolution and its general imperfection. The curvature of the lens. Motion blur arising during capturing each frame. And signal processing. [3]

3.2. Sharpness measurement

There are two main methodic on how to evaluate sharpness brief information about which is provided down below.

3.2.1. Rise distance

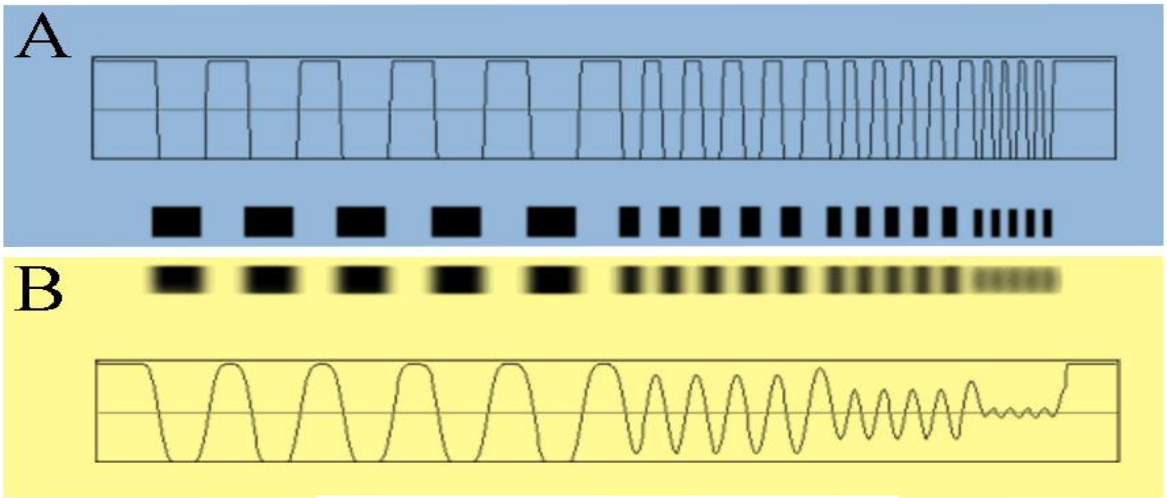
First option is to measure sharpness using the rise distance (or edge response method) of the edge, in particular, the distance (in pixels, millimeters, or fraction of image height) for the pixel level to go from 10% to 90% of its final value. This is called the 10-90% rise distance. Whereas rise distance is a satisfactory indicator of image sharpness, it has a considerable limitation. There is no simple way to calculate the rise distance of a complete imaging system from the rise distance of its components— from a lens, digital sensor, and software sharpening.

Two ready-to-use solutions for this method exist online: Quick MTF and Imatest Master. Both programs are being sold for a very high price, but Quick MTF conveniently offers a free trial period. Thereby this particular software will be used for the purpose of this research.

To avoid this issue, measurements are made in frequency domain, where frequency is measured in cycles or line pairs per distance (millimeters, inches, pixels, or image height). Where cycles/pixel (C/P) and line widths/picture height (LW/PH) are more convenient for digital sensors, but more important for purposes of this study line pairs per millimeter [lp/mm] is the most common spatial frequency unit for film. [3]

3.2.2. MTF

Modulation Transfer Function (MTF), which is generally identical to Spatial Frequency Response (SFR). Brief explanation supported with illustration is below (pic.3.2.2.1).



Pic.3.2.2.1

Both sections display sine pattern with corelated bar MTF pattern, but section A contains original data and section B data with distortion. Plots display the lightness (modulation) of the bar pattern. Blur, whatever its origin is, causes contrast to drop at high spatial frequencies. The modulation of the sine pattern (which consists of pure frequencies) is used to calculate MTF.

By definition, the low frequency MTF limit is always 100% or 1[-].

3.2.2.1. The equation for MTF

From the lightness axis are being derived minimum and maximum values.

$$C = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$

Where:

C – contrast;

Vmax – maximum value of lightness;

Vmin – minimum value of lightness.

But this is only output amount of contrast present on scanned image.

To properly calculate MTF input values are needed.

$$MTF = \frac{C_{in}}{C_{out}}$$

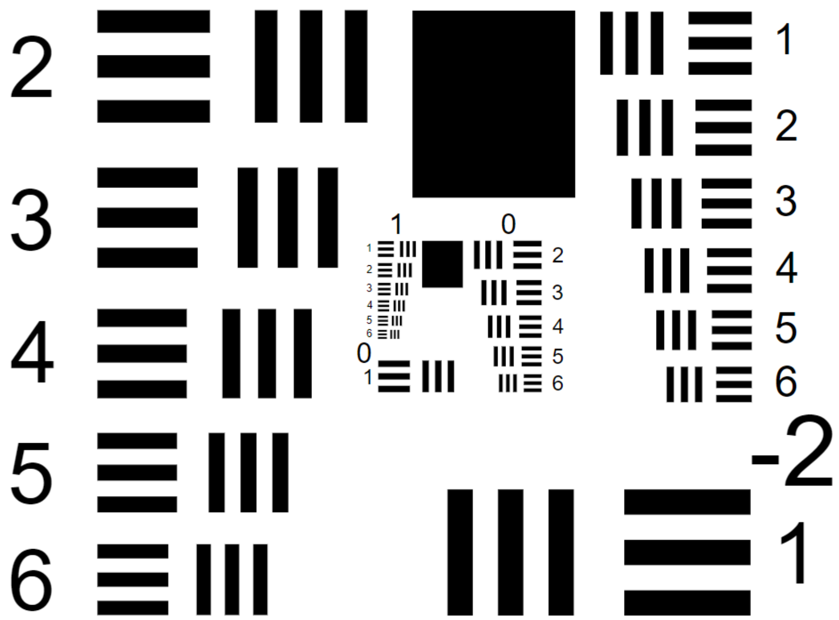
Where:

C_{in}*– input contrast value;*

C_{out}*– output contrast value;*

MTF is the Fourier transform of the impulse response— the response to a narrow line, which is the derivative (d/dx or d/dy) of the edge response.

In order to run a resolution test image of a bar pattern is needed (such an image contains several patterns with different bar frequencies placed ad different angles – example pic.3.2.2.1.1). The goal is to find the highest spatial frequency [lp/mm] where the bars are visibly distinct. This value is also called "vanishing resolution" and corresponds to an MTF of roughly 10-20%. [3]

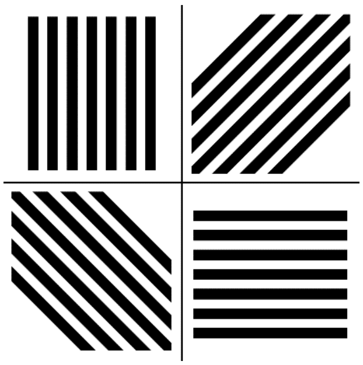


Pic.3.2.2.1.1
USAF 1951 chart

3.3. Ideal MFT values

The eye is relatively insensitive to detail at spatial frequencies where MTF is low (10% or less), but it does not necessary mean picture that have Function values over is storing enough primary data, also it does not establish a boundary of satisfactory quality. Somewhat pleasing amount of contrast was set at the 0.3 mark by Kodak.

Complete test chart would have bar patterns placed at four angles of rotation at is shown in illustration(pic.3.3.1). Evaluation is considered as successful if at least one segment reaches 30% level mentioned before. This is the established methodology.



Pic.3.3.1

Resolvometric tests compiled for the purpose of quality control of the recording equipment usually have in it 15 identical charts placed as shown on illustration (pic.4.1) Charts intended for advanced measurements contains bar pair pattern with frequencies up to 200[lp/mm].

To be qualified as “Excellent” output image has to meet two major requirements:

- Minimal MTF response value of 0.3 on minimal frequency of 140[lp/mm] at every chart placed on test subject
- difference in between center and corner charts does not exceed 15%

Following same rules "Very good" scan supposed to provide minimal frequency of 110[lp/mm] and "Good" of at least 80[lp/mm].

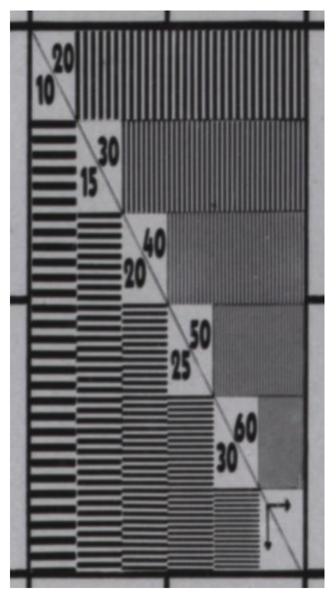
Where Excellent is identification of extremely sharp at any viewing distance. About as sharp as most inkjet printers can print. "Very good" means large prints (A3 or 13×19 inch) look excellent, though they won't look perfect under a magnifier. Small prints still look very good. And "Good" means large prints look OK when viewed from normal distances, but somewhat soft when examined closely. Small prints look soft but adequate. [4][5]

3.4. OZX2-A – Film Copy Machine

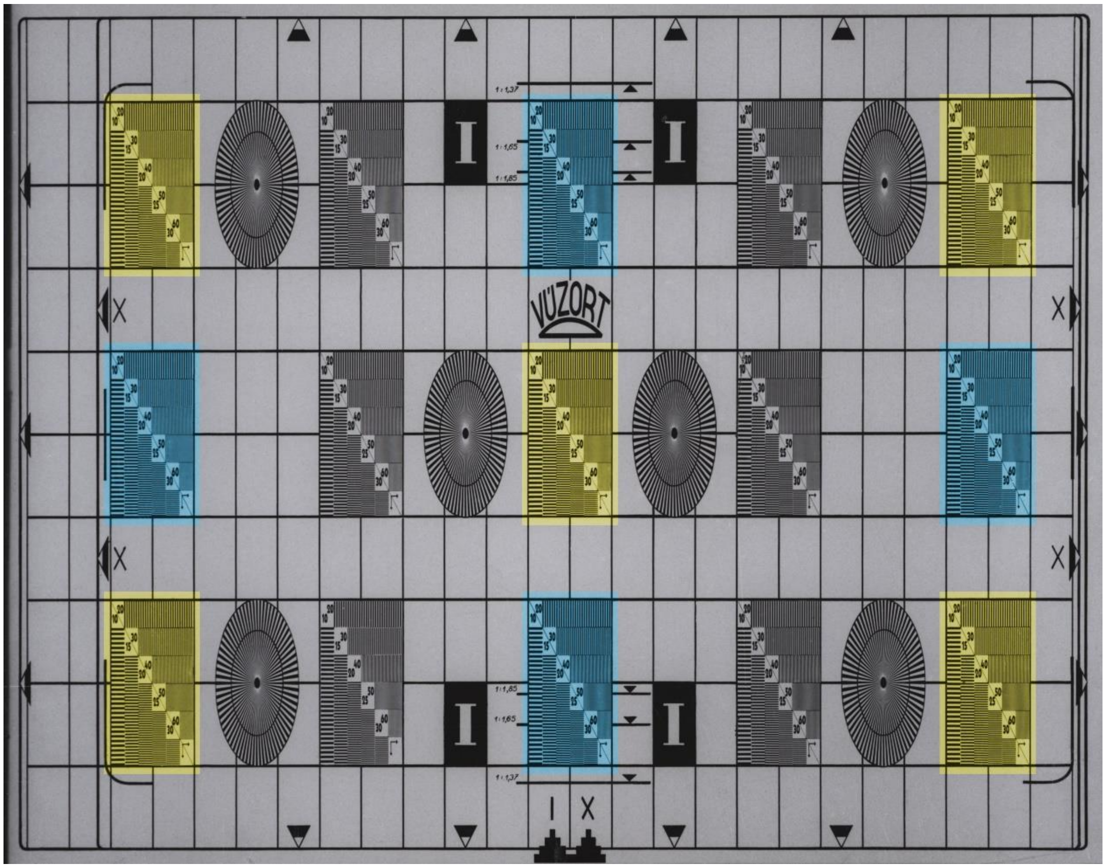
OZX2A is a device designed for making precise analog clones of film. Machine was produced in year 1960. Limited amount was spread thought the European countries and exemplars that are not destroyed by time are still meeting the requirements for "Good" output. Despite the fact that the device is designed to create analog copies it will be main point of comparison in this research. OZX2A shows minimal MTF response to frequencies levels 80-100[lp/mm] of 0.3 on each segment of test image (center and corners). [6] According to the measurements made by Ing. Antonín Vajčner actual resolution is 100[lp/mm]

4. Experiment

I have been provided with VUZORT (Czech: Výzkumný ústav zvukové, obrazové a reprodukční techniky; stands for Research Institute of Sound, Image and Reproduction Techniques) test 35mm filmstrips from 1959 determined to evaluate quality of projection optics in cinemas(pic.4.2). Charts on this test contain bar patterns mentioned before contains 10 different frequencies up to 60[lp/mm] in two angles of rotation. 10 15 20 25 30 in vertical direction and 20 30 40 50 60 in horizontal.



Pic.4.1
single 10-60 chart



Pic.4.2 - 10-60 Positive VUZORT resolvometric test

Main points of interest are labeled as yellow. Charts that are labeled as blue will be evaluated to gain further information on possible distortion (such as barrel distortion) caused by imperfection of scanner optic system.

4.1. Matlab program

Main advantage of making an evaluation program in Matlab is its built-in DPX codec. On the other hand, Matlab does not load all the data from original DPX file and therefore researched images open as plain black boxes without adjustments. This means as a first step original signal must be multiplied by some value (experimentally established for each tested images) in order to bring brightness back to the image.

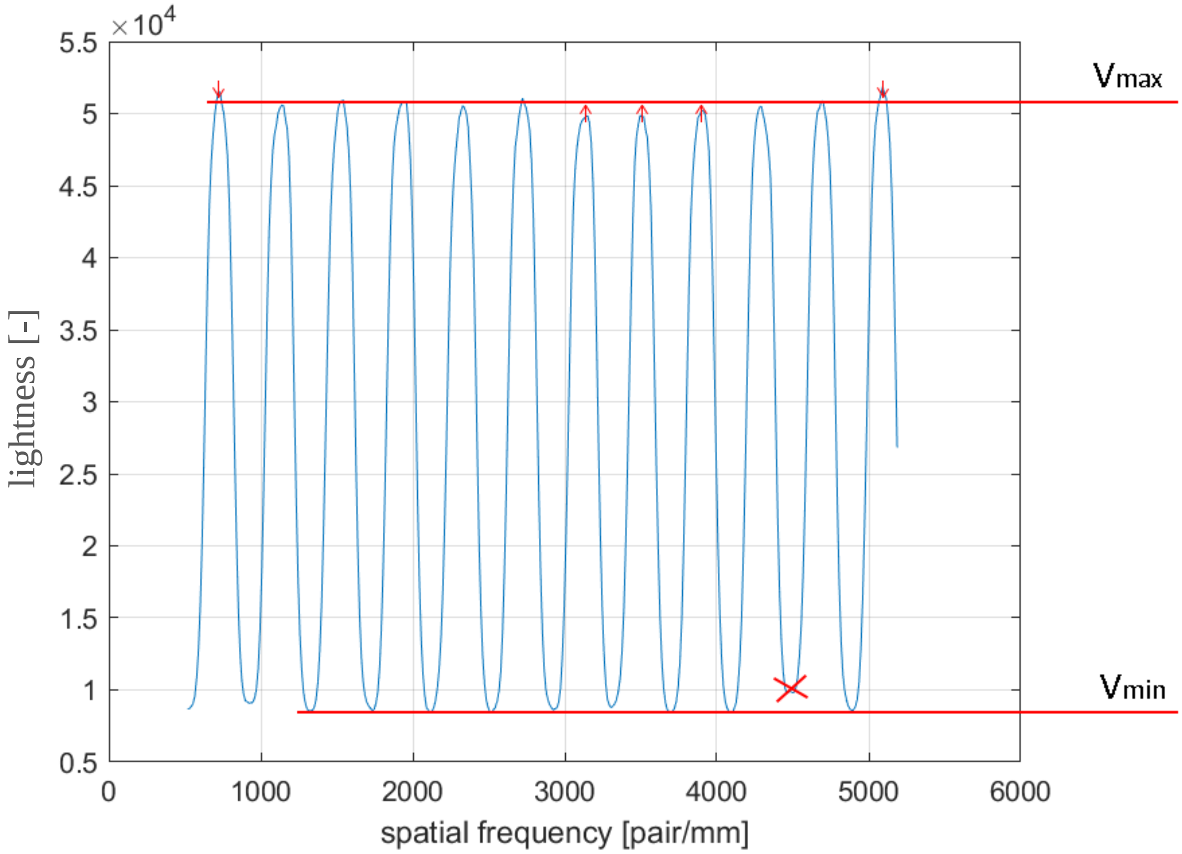
As second step Matlab flips and tills image in right position and then offers active box for user to choose specific chart for evaluation.

Next user is asked to choose Vertical and Horizontal bar pattern of certain frequencies. At this point seems logical for program to evaluate every frequency one by one automatically, when in fact this process requires a lot of human assistance in order to avoid mixing of frequencies. Also output contrast values are not always unequivocal and clear. Also, physical damages on the film can affect the results and values obtained from these spots must be removed from evaluation as errors.

In any event, after calculations, the program draws graphs (pic.4.1.2) of contrasts of corresponding frequencies and save those with proper name.

This is followed by user manually finding maximum and minimum values of contrast eliminating errors and finding the arithmetic mean.

Full Matlab code can be find as Apendix.1.



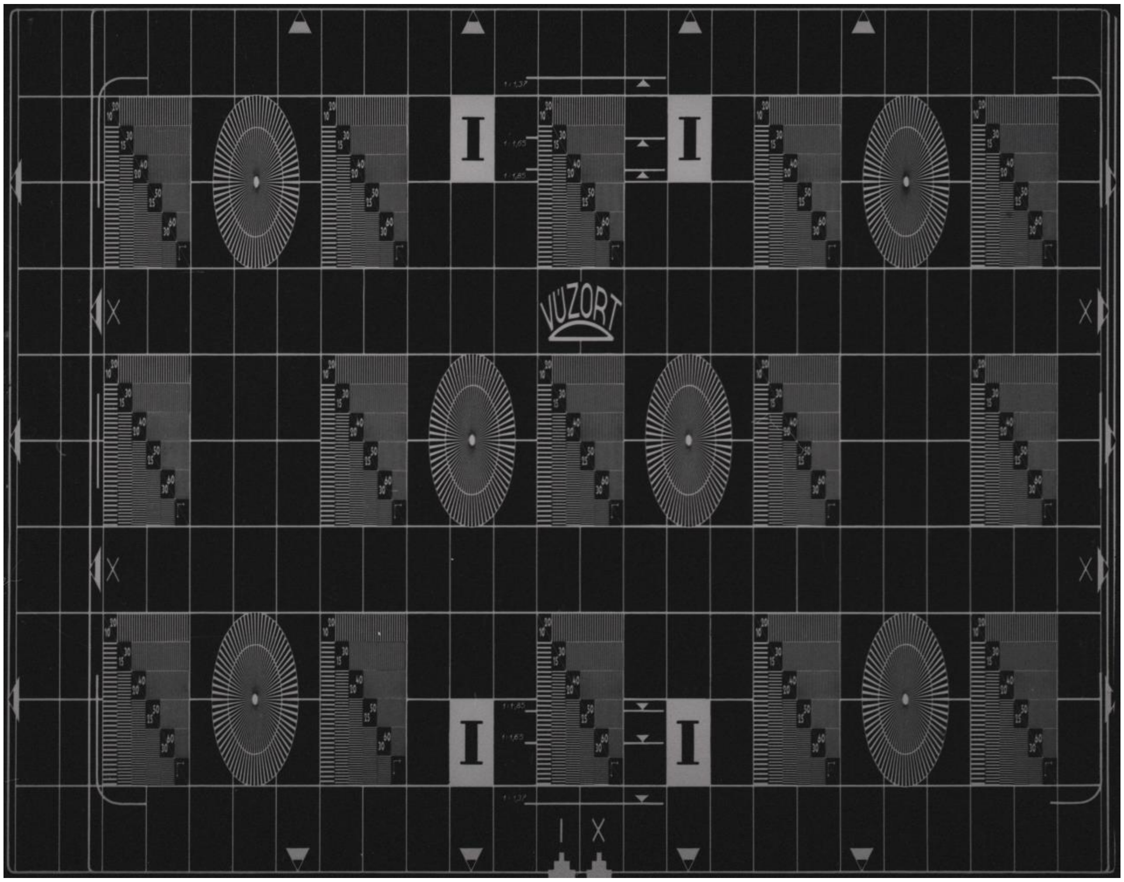
Pic.4.1.2
Matlab evaluating program output

4.2. List of tests

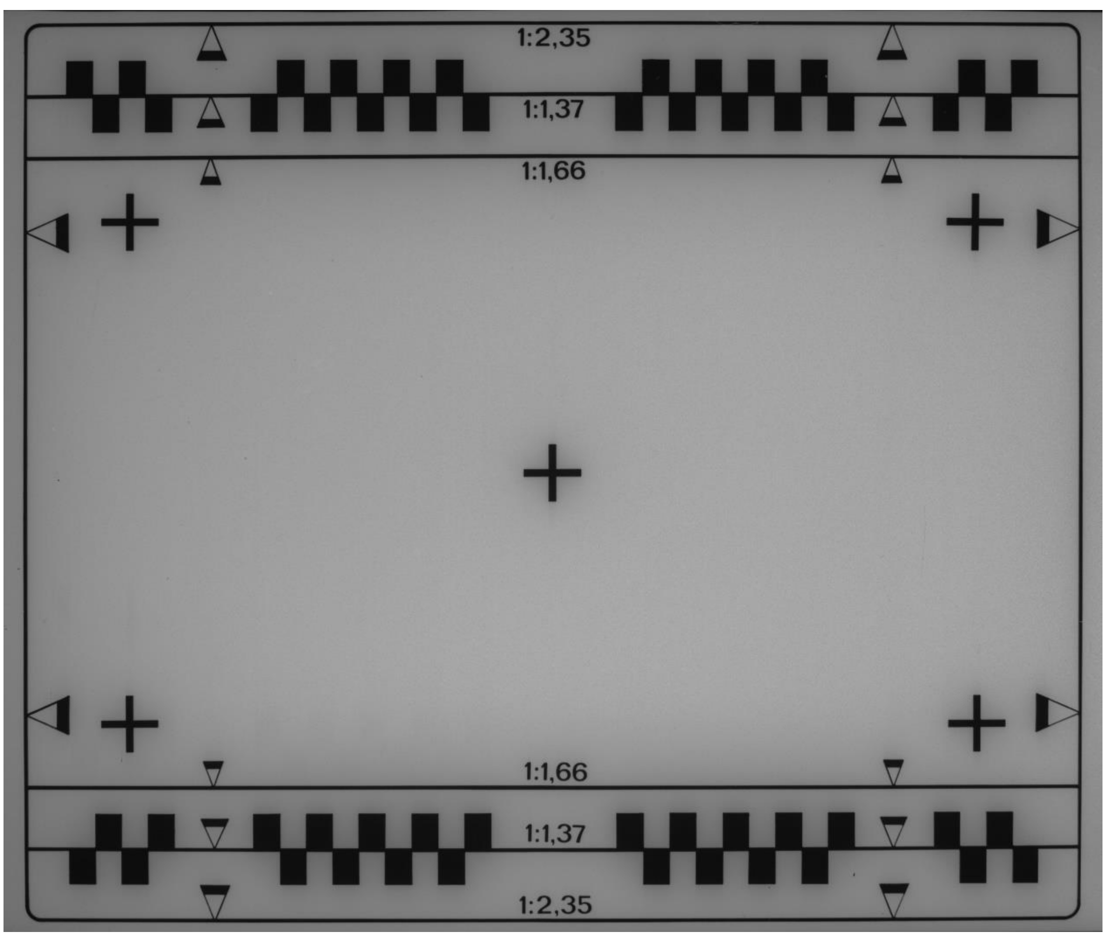
Primally this research is studding 10-60 Positive VUZORT sample (pic.4.2). This exemplar was scanned with NorthLight2 in 2K, 4K and 8K resolutions, and with ScannStation in 2K resolution.

Similar but Negative 10-60 VUZORT Test sample (pic.4.2.1) was scanned with NorthLight 2 in 2K, 4K and 8K resolutions, and with ScannStation in 2K resolution.

Third participant in the study is film designed to test uniformity of distribution of the luminance across the screen in cinemas (pic.4.2.2). This test was scanned by both stations in just 2K resolution and would be used to confirm scanners ability to provide same level of quality in every area of the frame.



Pic.4.2.1 - 10-60 Negative VUZORT resolvometric test



Pic.4.2.2 - VUZORT sharpness homogeneity test

4.2.1. Positive

Original scanned film contains eight identical frames. Due to the old age of the film and storage in inappropriate conditions the whole filmstrip worn out and scans contain undesirable additional details – scathes, abrasions and chemical spots. Out of the eight scanned frames I chose the cleanest one to run the test program on.

4.2.2. Negative

Negative film contains only two frames which makes it more difficult to choose a clean version. This filmstrip was produced in the same year and was subject to the same damages as Positive. It is possible that filmstrip had out worn over the time, but physical existence of frequency range up to 60[lp/mm] on both (Positive and Negative) test film was subjectively proven using x160 zoom microscope.

4.2.3. Sharpness of crosses

This test subject was not scanned in every possible resolution and will be used only as detector for possible distortions caused by scanners optic system. Designed for a person who is not schooled in this topic. The filmstrip is projected onto the canvas and of all 5 crossed do not look alike in terms of sharpness, then service need to be called.

4.3. Results

The preliminary stage was a simple survey. I have shown nine measured charts to 20 different people and asked if they can tell which one have better quality in terms of contrast on their subjective opinion. Comparing 2K resolution scans no one has put one chart over another within same scanned frame. But general impression is that NorthLight2 shows better result than ScannStation. However, NorthLight's image appears to be more pleasing, people still were able to identify bar patterns as "distinguishable" at a same level of 30-40[lp/mm]. Same level of details was spotted on 4K resolution scan from NorthLight2.And 8K format improved this number up to "distinguishable" 50[lp/mm].

But from subjective assessments to objective merriments.

As it was mentioned before, to properly calculate MTF input contrast values are needed. Every VUZORT test sample contains "I" segment originally (pic.4.3.1) intended for reference of color density originally stored on film.

So, this leads to logical first step in every measurement: Evaluate the input value from "I" segment and use as a reference.

Pic.4.3.1
Contrast reference segment

4.3.1. NorthLight 2

I have evaluated one scan of 10-60 Positive VUZORT test in each resolution (2K, 4K, 8K) with Matlab program and record every relation of lightness on spatial frequencies. Every single output graph might be found labeled as "Apendix.4" in Thesis folder.

Knowing the equation, I have calculated MTF values corresponsive with present frequencies and stored them in excel file. In spreadsheet listed further are values representing center bar pattern chart. Where 2K – tab.1; 4K – tab.2; 8K – tab.3.

NorthLight 10-60 Positive VUZORT test film

Frequency [lp/mm]	MTF[-]
VERTICAL	
10	0.980489582
15	0.89749702
20	0.732054841
25	0.541287174
30	0.372100747
HORIZONTAL	
20	0.755048434
30	0.36811829
40	0.178490862
50	0.061411183
60	0.015258688

Tab.4.3.1.1 - 2K

Frequency [lp/mm]	MTF[-]
VERTICAL	
10	0.99357319
15	0.942055245
20	0.820831464
25	0.670730526
30	0.497829273
HORIZONTAL	
20	0.829452993
30	0.503553779
40	0.219999299
50	0.095864732
60	0.05136331

Tab.4.3.1.2 - 4K

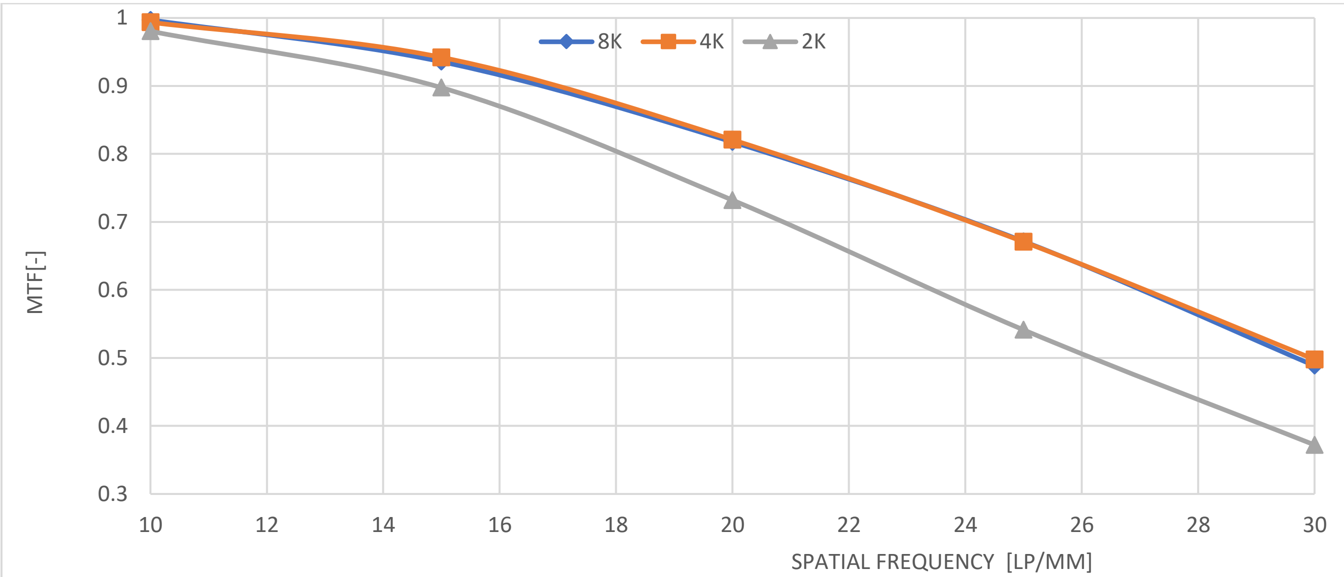
Frequency [lp/mm]	MTF[-]
VERTICAL	
10	0.997118186
15	0.935627937
20	0.817561405
25	0.671452157
30	0.488528839
HORIZONTAL	
20	0.835277289
30	0.520949121
40	0.261598717
50	0.101643449
60	0.044103929

Tab.4.3.1.3 - 8K

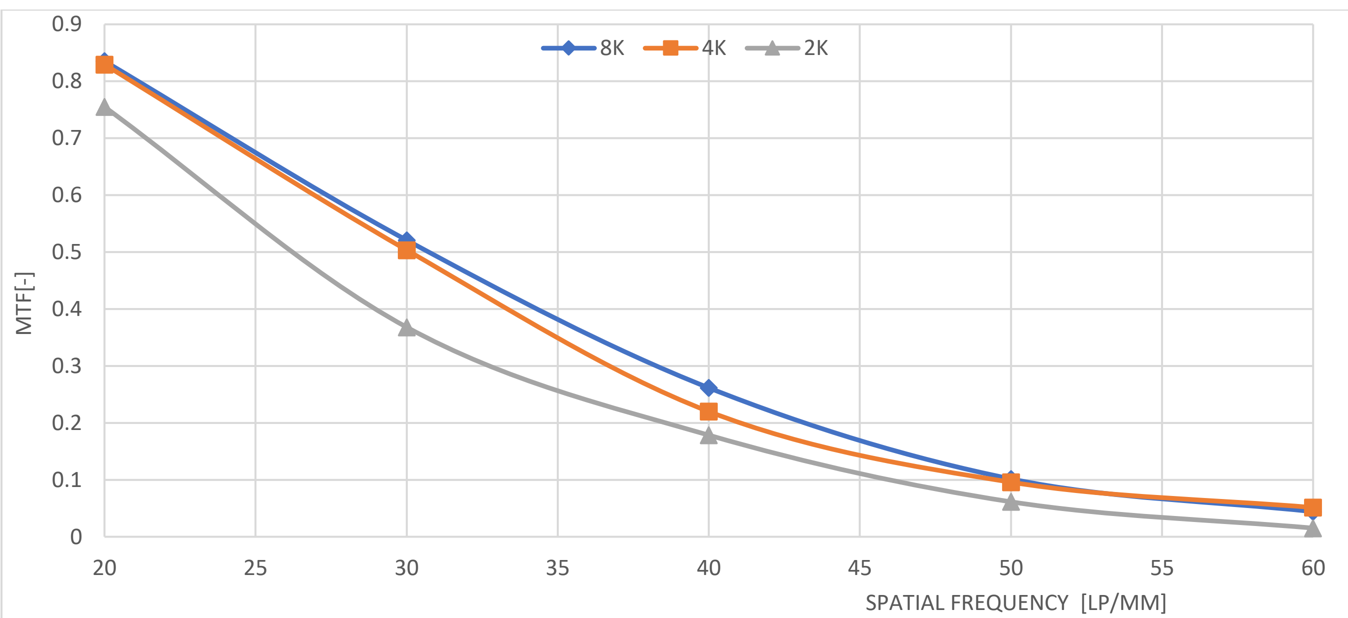
Full list of lightness values, MTF values is stored as "Apendix.2" in Thesis folder.

Comparing the outputs on each chart from different resolutions it is noticeable, that 4K and 8K shows very close results whereas 2K image significantly drops in quality in terms of sharpness.

From this spreadsheet I have created graphs comparing MTF function of each resolution. Values obtained from Vertical segment of chart – Graph.1; from Horizontal segment of chart – Graph.2



Graph. 4.3.1.1 – Vertical frequencies (NorthLight 10-60 Positive VUZORT test film)



Graph. 4.3.1.2 – Horizontal frequencies (NorthLight 10-60 positive VUZORT test film)

The graphs show the drop of the MTF curve under 30% on the about 37[lp/mm] for 4K and 8K resolutions and about 33[lp/mm] for 2K.

On 10-60 Negative VUZORT test I have evaluated middle raw of test charts in each resolution (2K, 4K, 8K). Center chart for primary data, left and right to register possible distortions, such as barrel roll distortion or motion blur. Every output lightness/spatial frequencies graph from this test is stored as "Apendix.5".

Calculated MTF values of center test chart for each resolution are shown further.

NorthLight 10-60 Negative VUZORT test film

Frequency [lp/mm]	MTF[-]
VERTICAL	
10	0.921059808
15	0.742676325
20	0.511189809
25	0.320728744
30	0.175326076
HORIZONTAL	
20	0.362223995
30	0.060020968
40	0.054130313
50	0.035042424
60	0.009995024

z

Tab. *4.3.1.4* - 2K

Frequency [lp/mm]	MTF[-]
VERTICAL	
10	0.941169701
15	0.804124233
20	0.576269805
25	0.402087774
30	0.22154638
HORIZONTAL	
20	0.397091151
30	0.070390459
40	0.083580519
50	0.048596312
60	0.042303

Tab. 4.3.1.5 - 4K

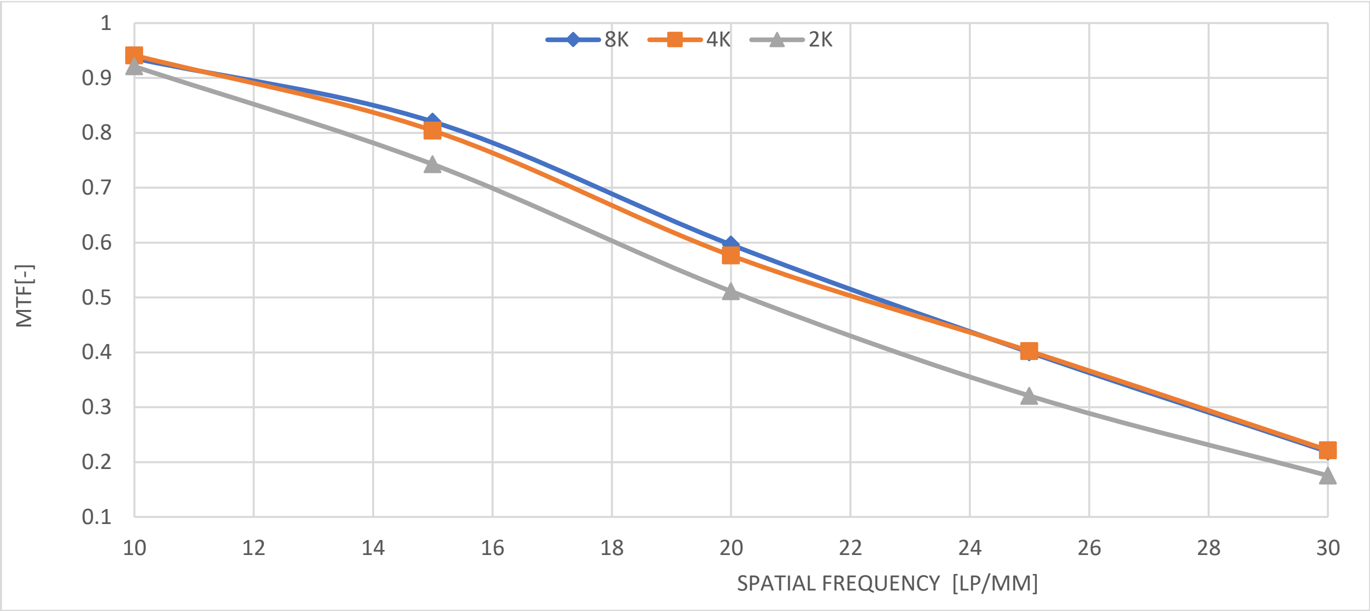
Frequency [lp/mm]	MTF[-]
VERTICAL	
10	0.935756842
15	0.82034718
20	0.596073027
25	0.400016705
30	0.218835707
HORIZONTAL	
20	0.423149482
30	0.083603687
40	0.105069549
50	0.07139489
60	0.04591231

Tab. *4.3.1.6* - 8K

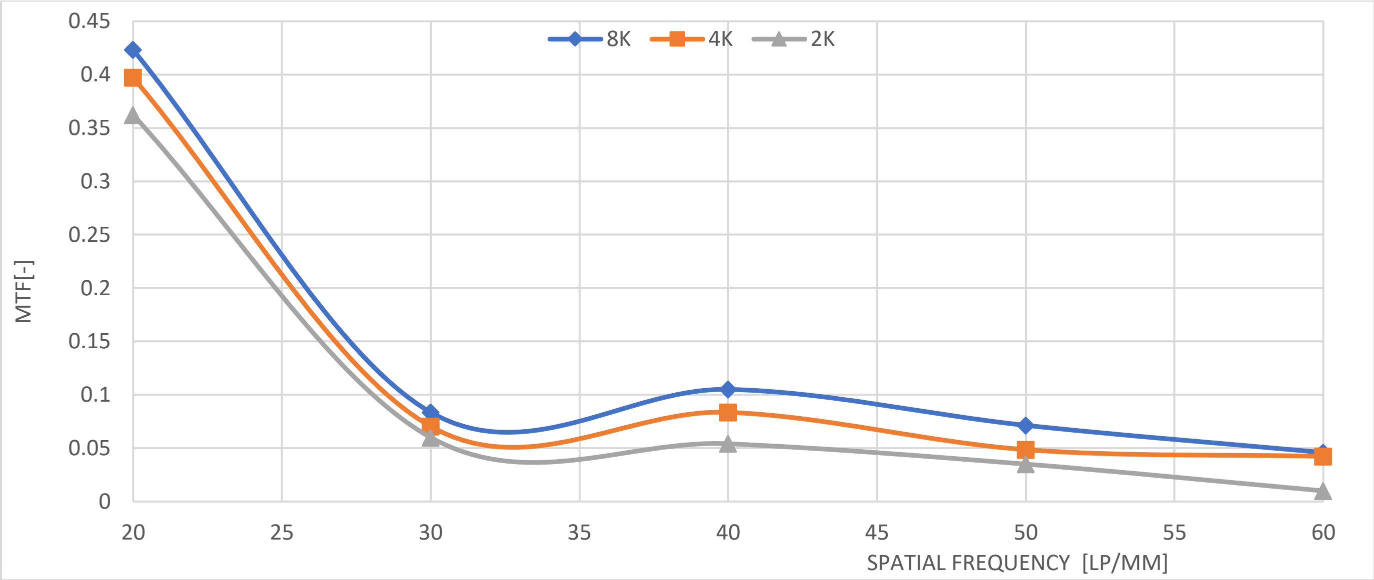
Full list of lightness values, MTF values is stored as "Apendix.3" in Thesis folder.

Outputs from Negative scan have degraded compared with Positive one. As expected 4K scan show better contrast values than 2K, and worse than 8K.

Comparing of MTF function of each resolution is available further. Values obtained from Vertical segment of chart – Graph.3; from Horizontal segment of chart – Graph.4



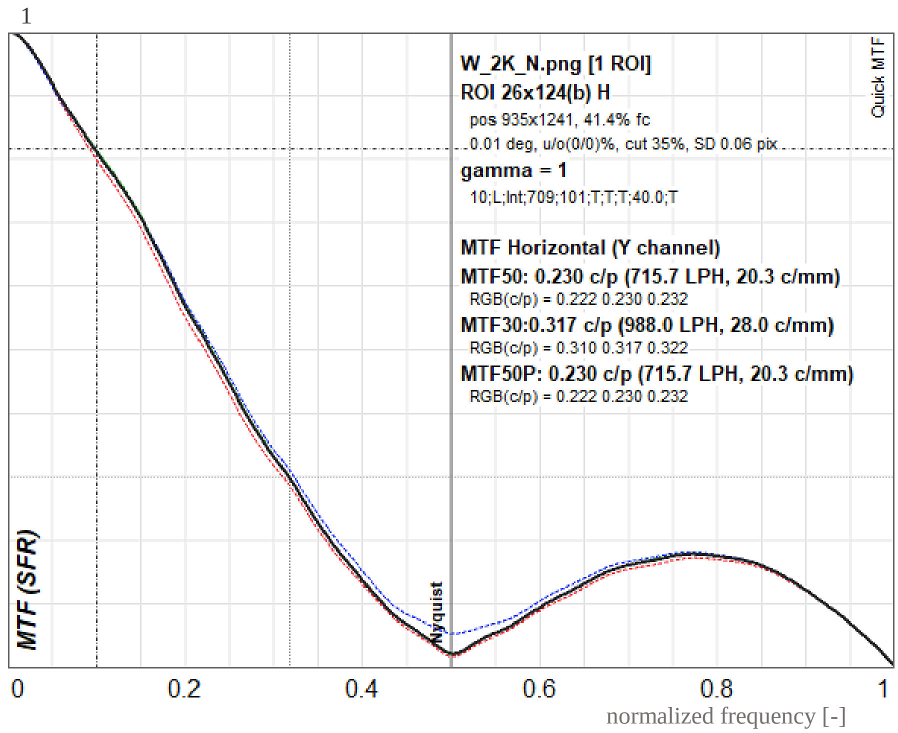
Graph. 4.3.1.3 – Vertical frequencies (NorthLight 10-60 Negative VUZORT test film)



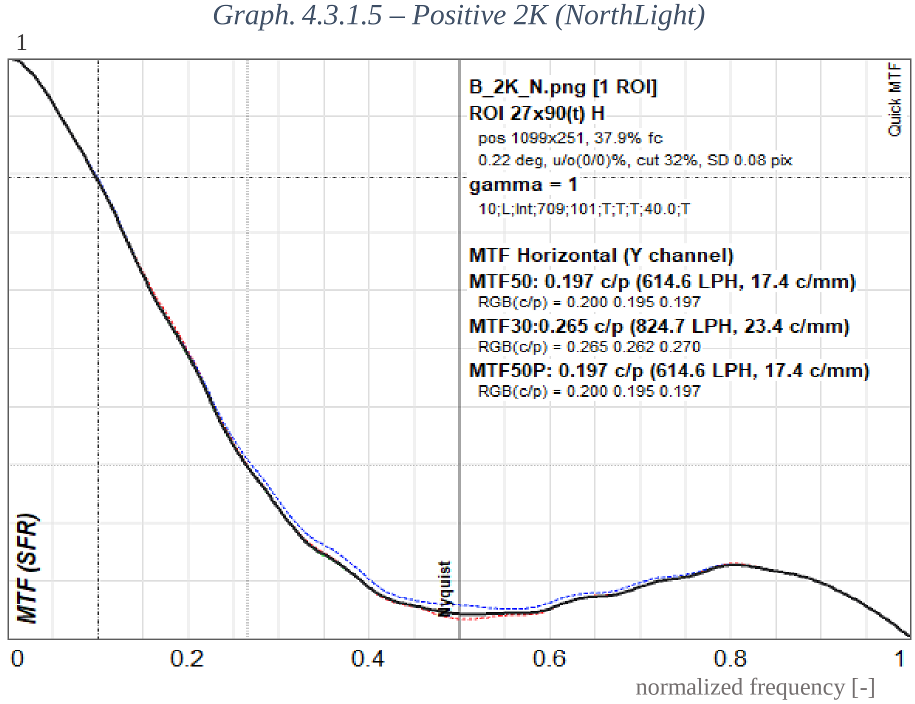
Graph. 4.3.1.4 – Horizontal frequencies (NorthLight 10-60 Negative VUZORT test film)

The graphs show the drop of the MTF curve under 30% on the about 34[lp/mm] for 2K, 4K and 8K resolutions.

Also, same scans were evaluated with Quick MTF program. MTF was measured using edge response method. Program has resolved 40[lp/mm] for 8K; 36[lp/mm] for 4K; 28[lp/mm] for 2K in Positive test film, and 29[lp/mm] for 8K; 27[lp/mm] for 4K; 23[lp/mm] for 2K in Negative test film.



Graph. 4.3.1.5 – Positive 2K (NorthLight)



Graph. 4.3.1.6 – Negative 2K (NorthLight)

Next follows the spreadsheet with result of evaluation test subject “Sharpness of crosses”.

	Position				
	Up Left	Buttom Left	Center	Bottom Right	Up Right
MTF[-]	0.8789	0.8812	0.8914	0.8791	0.881

Tab. 4.3.1.7 - Sharpness of crosses (NorthLight)

According to the values this scanner does not meet the requirement of high-end performance.

Full data from edge response method, as well as valuation of “Sharpness of crosses” is stored in “Apendix.7”

4.3.2. Lasergraphics ScannStation

Exact same steps were taken to evaluate output from ScannStation, except only 2K resolution scan is available.

10-60 Positive VUZORT test scanned with ScannStation was measured with Matlab program and lightness/spatial frequencies output stored in “Appendix.6”.

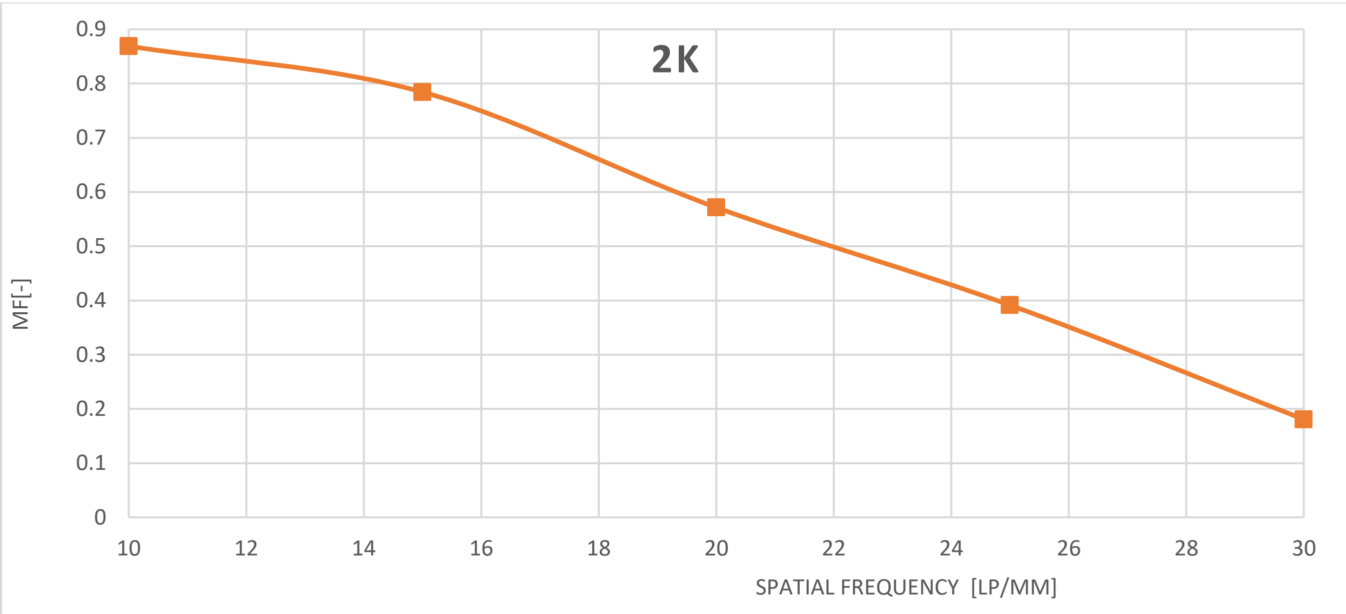
Calculated MTF values for center test chart are in spreadsheet below.

ScannStation 10-60 Positive VUZORT test film

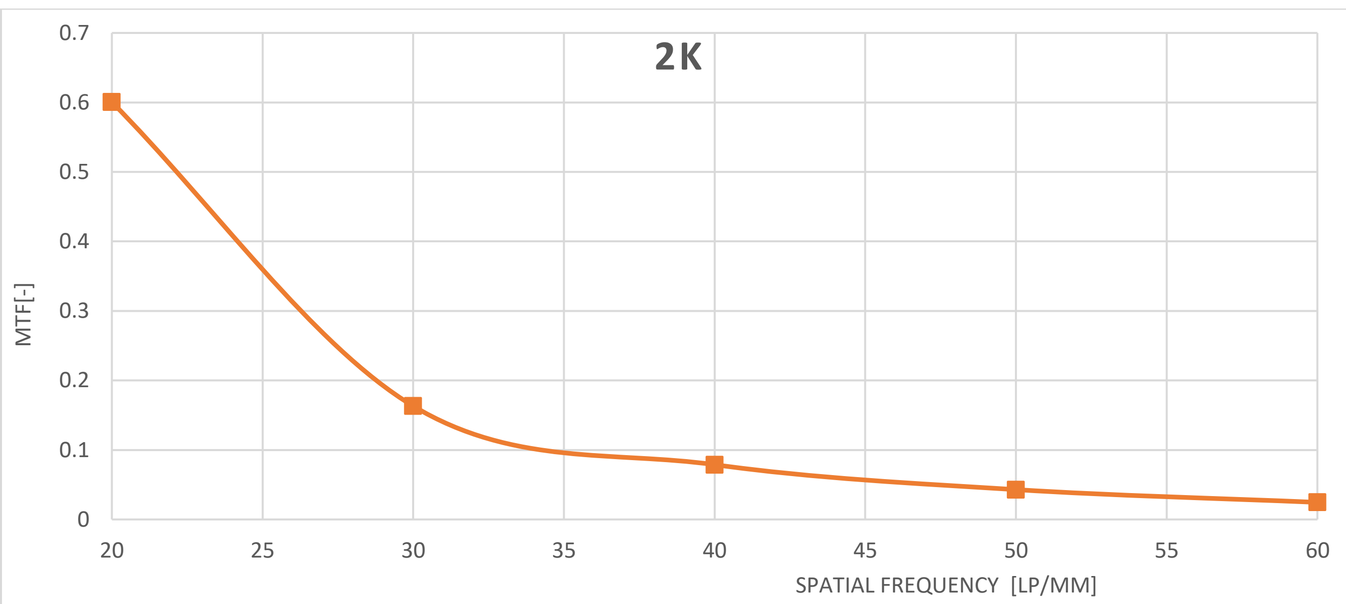
Frequency [lp/mm]	MTF[-]
VERTICAL	
10	0.869012277
15	0.78440367
20	0.571506065
25	0.391338588
30	0.18082826
HORIZONTAL	
20	0.600518718
30	0.163085057
40	0.078768569
50	0.042877268
60	0.024578305

Tab.4.3.2.1 - 2K

Using values from this table I have created representative graphs.



Graph. 4.3.2.1 – Vertical frequencies (ScannStation 10-60 Positive VUZORT test film)



Graph. 4.3.2.2 – Horizontal frequencies (ScannStation 10-60 Positive VUZORT test film)

The graphs show the drop of the MTF curve under 30% on the about 27[lp/mm] for 2K output form Lasergraphics ScannStation.

Once again processing 10-60 Negative VUZORT test film scan I have evaluated only middle row of test charts. Center chart for primary data, left and right to register possible distortions. lightness/spatial frequencies outputs are in “Apendix.6”

Calculated MTF values for center test chart are in spreadsheet below.

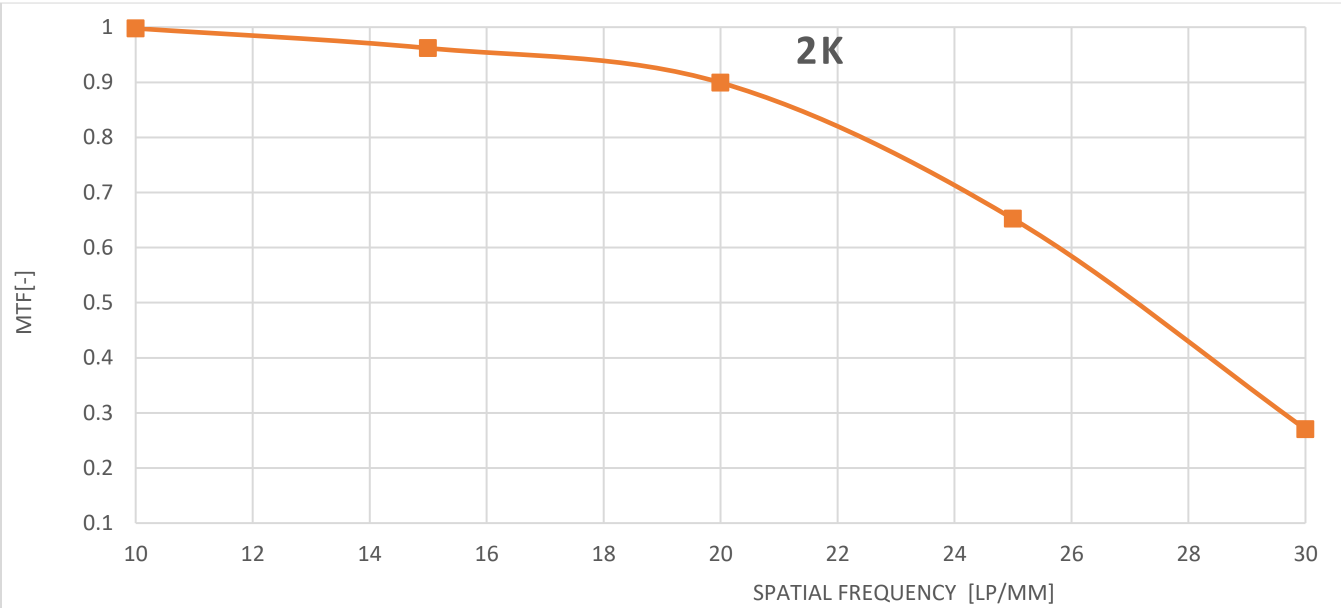
ScannStation 10-60 Negative VUZORT test film

Frequency [lp/mm]	MTF[-]
VERTICAL	
10	0.997808272
15	0.961900936
20	0.899315497
25	0.652127485
30	0.270447279
HORIZONTAL	
20	0.983925475
30	0.444341767
40	0.113610111
50	0.109951624
60	0.053531196

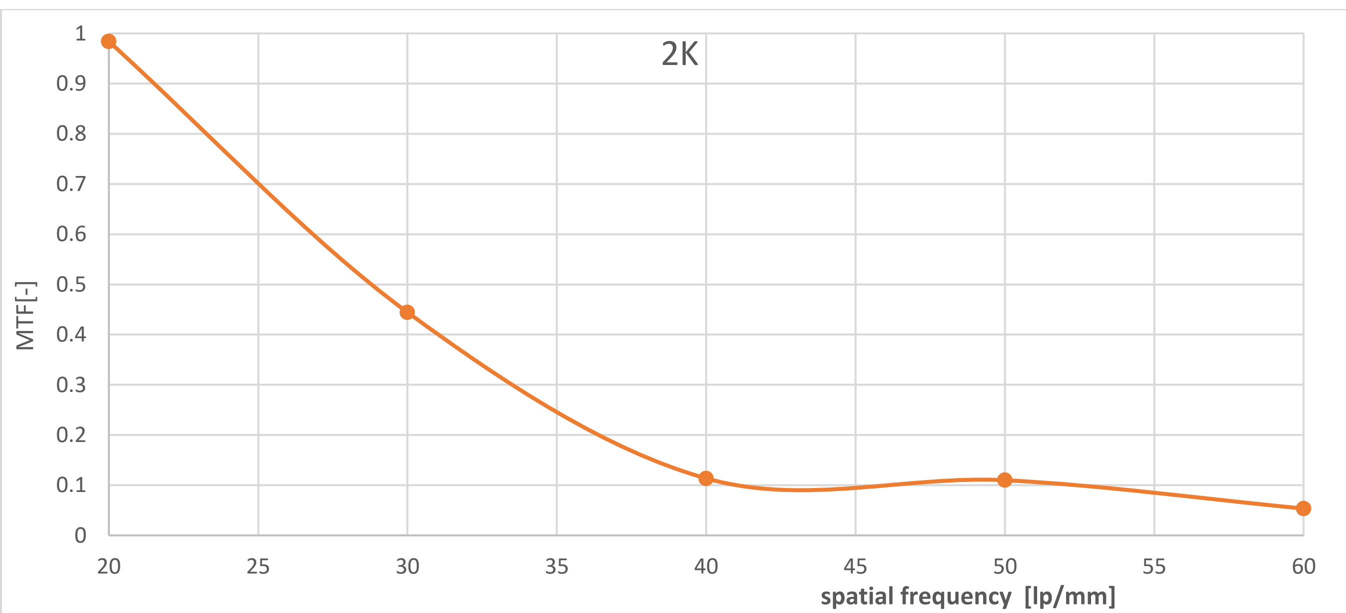
Tab. 4.3.2.2 - 2K

Comparing results of evaluating scanned with ScannStation I have found out that Negative test film scan have better quality than Positive, unlike it was with NorthLight.

Using values from this table I have created representative graphs.



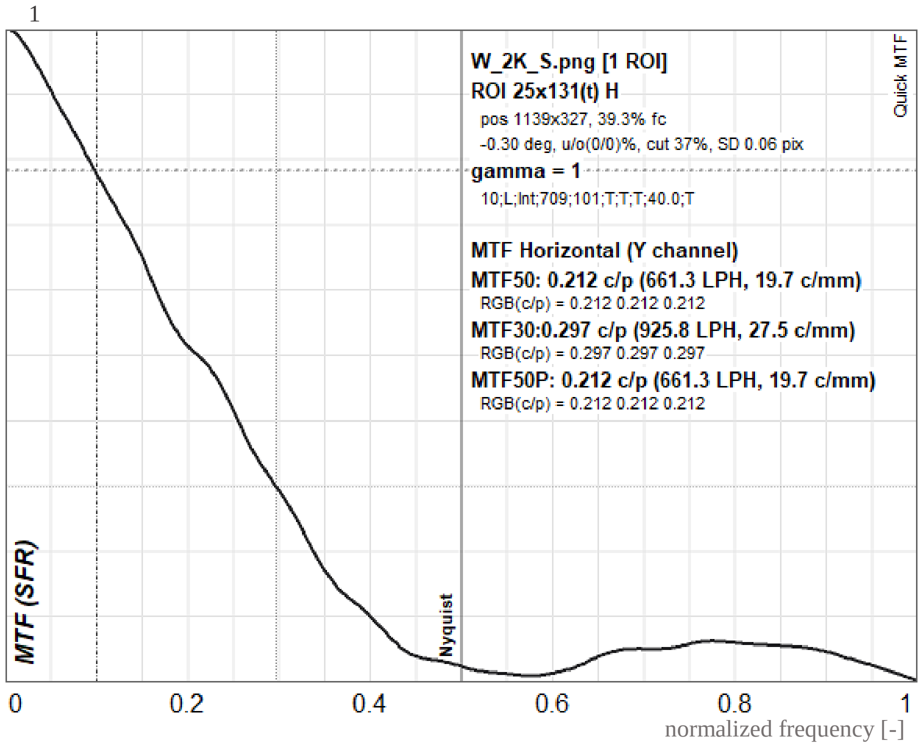
Graph. 4.3.2.3 – Vertical frequencies (ScannStation 10-60 Negative VUZORT test film)



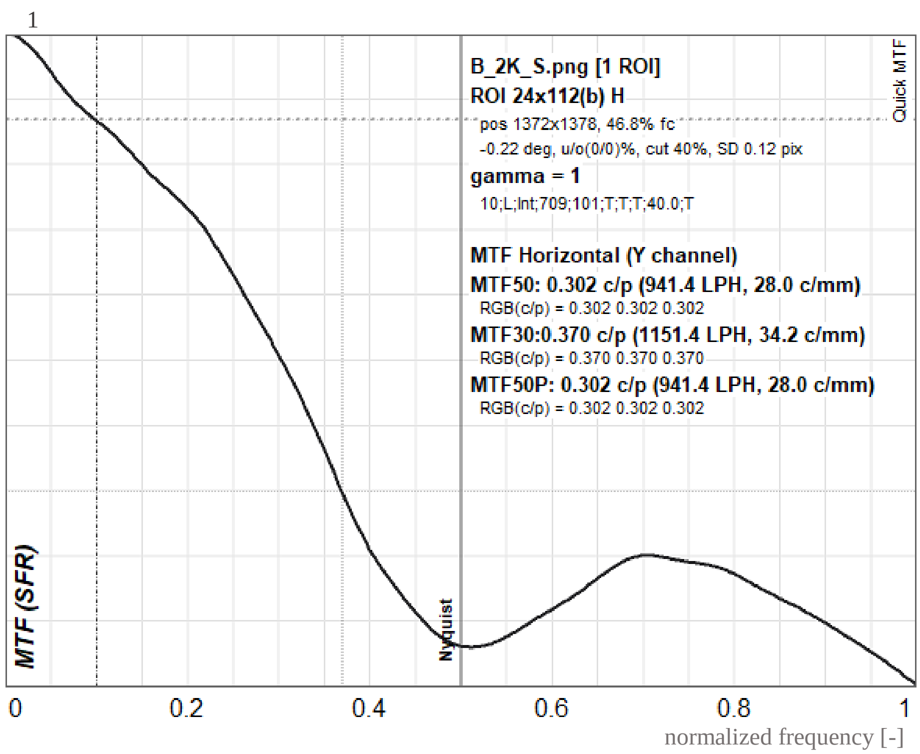
Graph. 4.3.2.4 – Horizontal frequencies (ScannStation 10-60 Negative VUZORT test film)

The graphs show the drop of the MTF curve under 30% on the about 33[lp/mm] for 2K output form Lasergraphics ScannStation.

Quick MTF program using edge response method rated resolution at 27[lp/mm] for 2K in Positive test film, and 34[lp/mm] for 2K in Negative test film.



Graph. 4.3.2.5 – Positive 2K (ScannStation)



Graph. 4.3.2.6 – Negative 2K (ScannStation)

Next follows the spreadsheet with result of evaluation test subject “Sharpness of crosses”.

	Position				
	Up Left	Buttom Left	Center	Bottom Right	Up Right
MTF[-]	0.7727	0. 7698	0.8263	0.7712	0.7735

Tab. 4.3.2.3 - Sharpness of crosses (ScannStation)

According to the values this scanner does not meet the requirement of high-end performance.

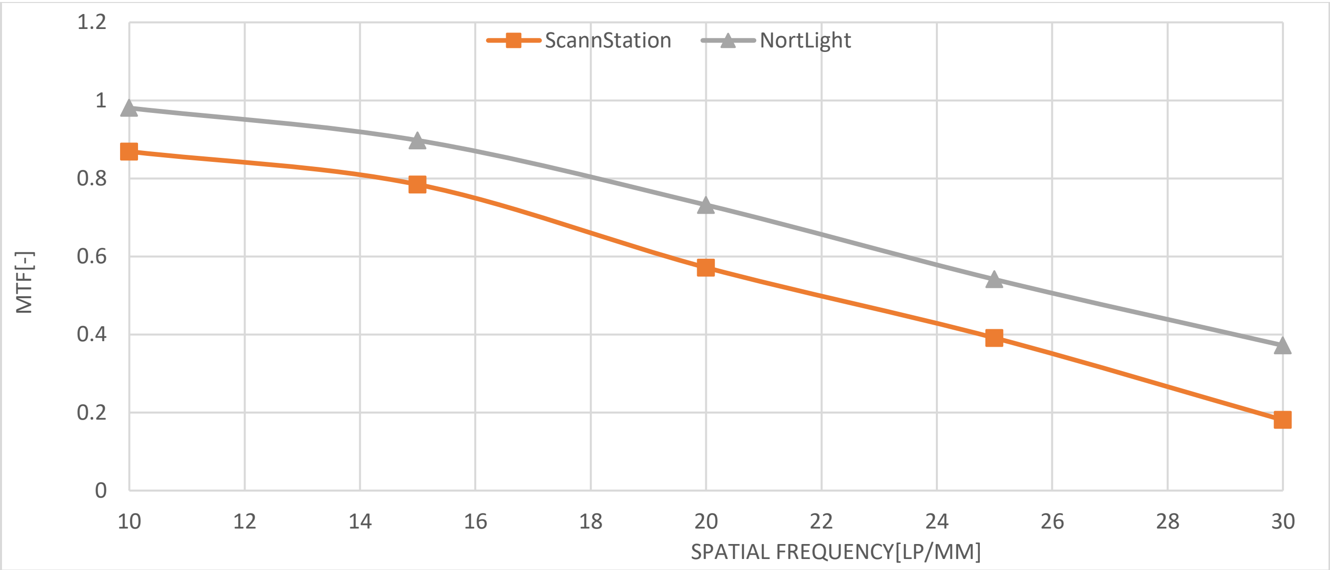
Full data from edge response method, as well as valuation of “Sharpness of crosses” is stored in “Apendix.7”

4.3.3. Comparison of used scanners

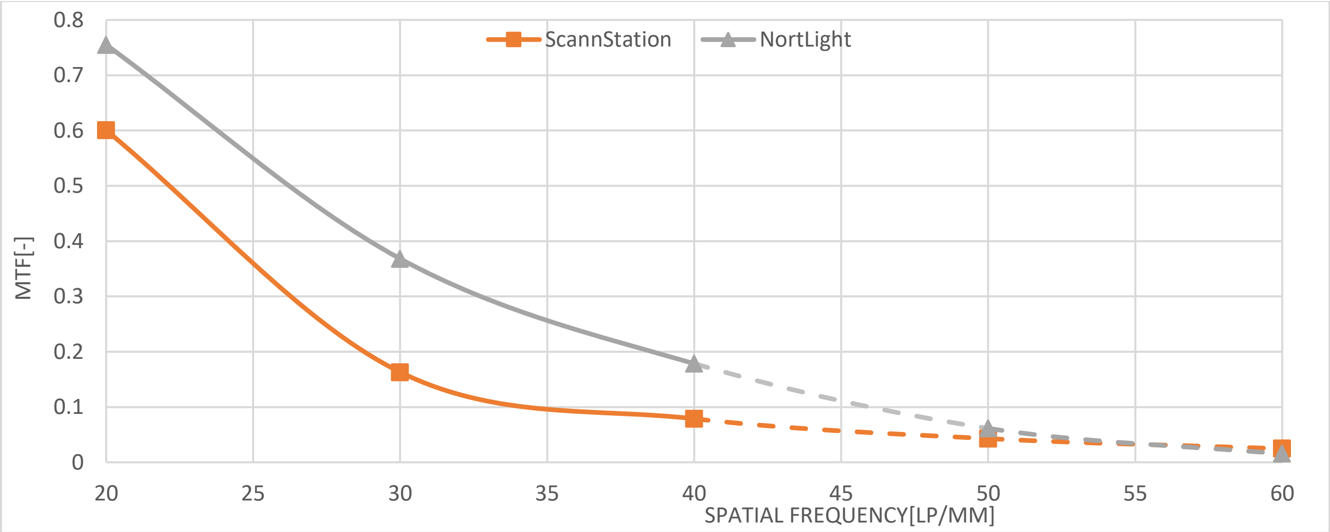
Since output from Lasergraphics ScannStation only available in 2K, comparison might be conducted in this particular resolution.

As first it should be noted, that MTF values obtained on bar pair frequencies over 40[lp/mm] cannot be calculated within 15% error and therefore will not be taken into account. This means I will compare 10, 15, 20, 25, 30, 40[lp/mm].

For clarity I have grated graphs containing MTF.



Graph.4.3.3.1 – Vertical Positive 2K comparison



Graph. 4.3.3.2 – Horizontal Positive 2K comparison

Overall measurements on test image show better quality on NorthLight 2 scanning machine. Values obtained from measurement with edge response method supports this result. MTF drops under expectable 30% level on 33[lp/mm] using NorthLight, while ScannStation does not hold over 27[lp/mm]. These results are far from requirements to be classified as “Good” and does not correspond with values specified by the manufacturer.

Subjectively evaluating output images this machine also shows better result in color accuracy relative to the source image.

Measurement aimed to control homogeneity of sharpness across all surface of scanned image shows same results for both scanning stations. Difference in sharpness in between center and cornered charts varies from 6 to 9%. This indicator meets the minimum requirements.

5. Conclusion

The purpose of this work was to evaluate the quality of the scanner and decide whether it is suitable for the purposes of the film fund. Main quality factor for digital image is sharpness and its level is directly connected to a contrast. Modulation Transfer Function(MTF) is a fair representative of contrast level.

Two programs were used to evaluate level of MTF: Matlab code is attached as Appendix.1, and Quick MTF application might be found online.

35 mm film samples were produced in year 1959 by VUZORT and originally designed to test optical system of projectors in a cinema. Positive and Negative films contain 15 charts with different frequencies in two angles of rotation. 10 15 20 25 30 in vertical direction and 20 30 40 50 60 in horizontal. Sharpness of crosses was designed to be projected onto the center and corner of canvas and establish if optic system distribute image evenly across the screen.

Minimal requirement for “Good” output resolution is 0.3 MTF on 80 line pairs per millimeter spreaded across image within deviation of 15%.

MTF measurement of NorthLight 2 scanner output established average sharpness level 32[lp/mm] for 8K and 4K resolution, and 28[lp/mm] for 2K resolution. This level differs between the center and the edge charts within 7%. Edge response method measurement shows similar numbers: 34[lp/mm] for 8K, 31[lp/mm] 4K resolution, and 26[lp/mm] for 2K resolution. Subjective visual assessment confirms the absence of a difference between 8K and 4K resolutions. In order to reasonably use available digital space, it is better to use 4K resolution since 8K output from this particular scanner does not provide significant advantages.

MTF measurement of Lasergraphics ScannScation scanner output established average sharpness level 24[lp/mm] for only available 2K resolution. This level differs between the center and the edge charts within 8%. Edge response method measurement once again shows similar numbers: 26[lp/mm] for 2K resolution.

Competing objective output values NorthLight proves to be only slightly better than ScannStation in terms of sharpness. Subjective image evaluation puts NotrhLight quality as more pleasing and color accurate.

Neither of these devices are suitable for professional digitization process and can probably only be used in amateur purposes, where there is no intention to project scanned image on large-sized HD screen. Machines do not meet either common minimal requirement or even own claimed level for the sharpness and should not be used for preservation of cultural heritage.

6. Bibliography

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