DIGITISATION AT THE CROSSROADS
DIFFERENCES AND PARALLELS BETWEEN DIGITISATION OF PHOTOGRAPHS WITH SCANNERS AND PHOTOGRAPHIC EQUIPMENT FROM AN ARCHIVES' PERSPECTIVE

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It is late 2018 and long ago full-frame digital cameras have become a household name for mainstream digitisation around the world. Cultural heritage institutions, private subjects, as well as numerous societies and fundations strive for the highest digital image quality possible and in their efforts they reach out for the kind of equipment that boasts with unmatched specifications, unparalleled productivity, fastest performance, while still providing for the safety of original documentation. Oftentimes the equipment of choice is a digital camera system either with a full-frame camera body of up to 50 MP or a medium format digital back of up to 100 MP, a set of interchangeable lenses and state-of-the-art advanced LED lamps. On the margin are smaller subjects, which in their digitising activity rely solely on budget scanners.

Is it really the case however and do scanners only cater to small, underfunded entities? Certain manufacturers, especially in the likes of HASSELBLAD and EPSON, still produce and sell quality professional appliances for the digitisation of photographs which compete with contemporary photographic means and sometimes even outperforming them in terms of productivity-to-quality ratio. Such scanners cater to both smaller and larger subjects and are compliant to internationally recognized standards, namely *Metamorfoze Preservation Imaging Guidelines*[1] and Federal Agencies Digital Guidelines Inititiative's *Technical Guidelines for Digitizing Cultural Heritage Materials*[2].

However, everything comes at certain price with photography scanners, repro cameras and digital camera systems. The aim of this paper is to display and to discuss vast array of gains and trade-offs, benefits and sacrifices, conveniences and niuances, standards and workflows of contemporary digitisation of photographs with scanners and photographic devices – a digitisation from an archives' perspective.

Nowadays numerous institutions seem to regard scanners as a thing of the past. Not all scanners of course, since scanning appliances for textual records, newspapers, cartography and prints are doing quite well. Companies in the likes of SMA and Zeutschel have established their brands long ago and still continue to supply broad scope of subjects with quality devices. On the other hand well-acclaimed manufacturers of scanners aimed at digitisation of photographs like Kodak and Nikon have long since discontinued the production of their once

popular and highly demanded models such as iQsmart[3] and Super CoolScan LS-9000 ED respectively. Only a handful of photography scanners remain in production to date, although some of them seem to cater to a different market, other target group if you will, be it privately owned small photography and printing studios, press agencies or individual users. Such subjects view digitisation or preservation of photographs unevenly, sometimes quite contradictory to cultural heritage institutions, which produce digital images in a highly standardized and formal fashion. From an archives' perspective in particular the quality of each digital capture is assessed with numerous norms and standards.

Given broad array of guidelines both international and domestic and the fact that various proven scanning appliances pretty much belong to a landfill, a question remains – are there any scanners for photography left in production that would have met rigorous requirements of modern audiovisual archives? The answer is positive. There are such solutions available on the market. In fact, one such scanner had been purchased by National Digital Archives not so long ago – in December 2017. This particular appliance and the results of its testing at National Digital Archives shall be discussed in later part of the paper.

First off, it is important to outline certain specifications of scanning appliances which make these devices an attractive alternative for an audiovisual archives in particular and cultural heritage institutions in general. Obviously, scanners for photographs come fairly cheaper than digital camera systems and their derivatives in the likes of scanner cameras and repro cameras. Currently HASSELBLAD Flextight X5 photography scanner costs ca. 34 000 € including batch scan feeder and twenty holders for mass digitisation of 35 mm and 120mm film strips, a digital camera system based on PHASE ONE XF body, PHASE IQ3 80 MP digital back and both 80 mm and 120 mm macro Schneider-Kreuznach Blue Ring lenses along with a column, tables for transparent and reflective materials and two lamps costs ca. 47 000 € and a high-end system Zeutschel ScanStudio with a table for transparent materials, a book cradle for reflective materials of up to A1 format, both 70 mm and 100 mm Rodenstock lenses and PHASE ONE IQ3 100 MP digital back costs roughly 140 000 €[3].

Photography scanners do not require special environment for their operation in form of a large photography studio or a dark room and they are quick for implementation in terms of staff training. It is not difficult to take photography scanners' performance paired with simplicity and ease of use for granted, but as soon as one starts working with a digital camera system things begin to complicate especially in dimension to the frequency of calibration and profiling, depth of field and image sharpness control including *Spatial Frequency Response* evaluation, resolution calculation, light uniformity control, as well as avoiding numerous image distortions. In fact, same variables are either taken care of or non-existent for photography scanners. It does not matter whether a scanner is situated in a darkroom or a studio or located in plain office. Photographs are scanned in a sealed space and should meet the requirements anyway.

Lamps which are mounted inside the scanner are precisely leveled and symmetrical so there is no risk for the lack of light uniformity. The surface is smooth and even so no spatial distortion should occur.

As far as calibration and profiling are concerned at National Digital Archives our older flatbed photography scanners Kodak iQsmart^3 had been pre-profiled by the manufacturer, whereas white calibration is fully automated. Both focus and white calibration of HASSELBLAD Flextight X5 scanner are semi-manual. An operator only puts either white balance sheet or focus calibration chart to proper holders and rest of the process is done by FlexColor software. These actions are performed once every three months due to a large number of scans produced with this device. This scanner had also been pre-equipped with its ICC profile by the manufacturer, however an operator is able to create new ICC profile for the device using Coloraid.de IT 8.7/1 transparent reference charts on 35 mm color slide film medium. Such reference charts used at National Digital Archives bear the characteristics of Kodak and Fuji films which were pretty much most common mediums for film photography back in the day.
Before the purchase of HASSELBLAD Flextight X5 scanner National Digital Archives' annual digitisation output of 37 500 scans of photographs had been achieved with four scanners already out of production: three Kodak iQsmart^3 and one Nikon Super CoolScan LS-9000 ED. Enter HASSELBLAD and more than 45% of the production of digital images has been transferred to this appliance. HASSELBLAD Flextight X5 is a powerhouse of a scanning solution, paired with batch feeder it is capable of mass digitisation of up to 60 frames of 35 mm film and 30 frames of 60x60 mm on 120 mm film in continuous process with 6300 PPI optical resolution that is nearly 8900x5900 pixels and 48-bit RGB within just a little over half an hour. A single exposure takes 1.5 minutes with abovementioned parameters, which is shorter than usual 3-6 minutes for other scanners i.e. EPSON Perfection V850 Pro, Kodak iQsmart^3 not to mention the resolution (amounting to 8000 PPI for 35 mm film in horizontal orientation), and scanner cameras (7 minutes of exposure), but the degree of automation along with automated frame recognition is what makes digitisation with this appliance so productive.

The automation of scanning is at heart of digitisation process with scanners. On the contrary digital cameras, although having faster exposures, still do not allow for the same automated control. They do however provide for the kind of versatility and modularity that is unmatched by photography scanners. The flipside is that if a particular cultural heritage institution digitises only one sort of archival material or if that subject's collection is comprised of uniform objects like film negatives with small degree of photo prints, then there is virtually no need for versatile systems with interchangeable components. In such terms either flatbed, film or virtual drum scanners perform just as good as digital cameras and repro systems at much lower costs.

At National Digital Archives 35 mm and 120 mm film strips account for nearly 85% of its entire collection. Only a minor portion of National Digital Archives' archival stock is comprised of glass plates, antique photographs (i.e. daguerreotypes and ambrotypes) and photo prints. The choice of HASSELBLAD Flextight X5 as main scanning tool for photographs at National Digital Archives is linked to the composition of its collection. HASSELBLAD Flextight X5's strongest potential for high quality and high productivity digitisation is only achievable with the batch feeder, which had been purchased along with the scanner as first such item in Poland. As a result of all Polish institutions, and there are five such subjects in Poland that use this model, only National Digital Archives is able to fully benefit from the device's capacity for automated, large-scale digitisation of 35 mm and 120 mm film strips. By the rate of it's daily production of digital images it would shorten the digitisation of overall National Digital Archives' stock by approximately 111 years[4], moreover with far better technical parameters than formerly used appliances.

Time-wise, as mentioned on previous page, Hasselblad Flextight X5, needs only 1.55 minutes for a single exposure for a single frame of 35 mm with 8000 PPI resolution, 1.25 minutes for a single frame of 35 mm film with 6300 PPI resolution and 1.10 minutes for a single 60 mm frame with 3200 PPI resolution all with 48-bit RGB[5]. That means it takes merely 75 minutes for scanner to digitise 60 frames of 35 mm film and 33 minutes to digitise 30 frames of 60 mm height, adding extra time to fill holders with materials. By comparison flatbed photo scanners like Kodak iQsmart[3] have digitised same amount of 35 mm frames within 7 hours – in line with PENTACON SCAN7000 scanner camera which took 7 minutes exposures.

In terms of productivity-to-quality ratio HASSELBLAD Flextight X5 can only compete with full-frame digital camera systems and their repro and all-in-one counterparts and by no means does not fall short, as 8000 PPI is more less equivalent to 80 MP. Obviously digital cameras and repro cameras win in dimension to shutter speeds, however such appliances are capturing digital images one after the other or one film strip after the other, whilst HASSELBLAD Flextight X5 scans multiple frames and film strips in continuous process and what is more – with abovementioned automated frame detection. Another characteristics that distinguishes HASSELBLAD Flextight X5 from its competitors on the contemporary scanning market is unparalleled optical density of 4.9[6]. Such D_{max} is equivalent to a dynamic range of 16 *f*-stops[7]. Currently digital back for HASSELBLAD H6D camera system is able to achieve the dynamic range of 14 *f*-stops and PHASE ONE IQ3 100 MP digital back has the dynamic range of 15 *f*-stops and these two sit on the very top of high-end full-frame digital photography market.

The scanner is comprised of several parts – a fixed focal length Rodenstock lens with fixed aperture of *f*=8, a photo-sensitive sensor which has three layers of 8000 photo-sensitive points or pixels, two fluorescent cold cathode lamps by OSRAM which generate high quality light and what is interesting - available at numerous stores with household equipment, and a virtual

drum underneath the sensor. The only issue with the device's mechanics that have ever occurred at National Digital Archives was when it pulled a holder inside and could not return it, however scanner operators managed to retrieve it on their own.

HASSELBLAD Flextight X5 has the capacity for fine and quality digitisation of prints, albeit the process is not as automated and does not include as many multiple photographs as in case of scanning film strips. On one hand its specifications exceed both tonal range and resolving power of original objects, on the other without its batch feeder there really is no automation and productivity that are so essential for National Digital Archives' annual production plans. It is basically too inconvenient for an operator to change material every 2-5 minutes, as such person spends more time loading new photo prints into the holder than scanner needs to capture all images

Therefore National Digital Archives has been scanning only transparent photographs with this appliance both 35 mm and 120 mm negative films and color slide films at all times having mounted batch feeder. AT National Digital Archives' disposal are two sets of holders. First set of ten holders is used to digitise sixty 36x24 mm frames and the second set of another ten holders is used to scan thirty 60x60 mm frames. Each frame, either 36x24 mm or 60x60 mm is captured in portrait orientation with maximum 6300 PPI or 3200 PPI respectively and with 48-bit RGB. Automated frame detection is available only with 3F scanning mode which basically means the image is preserved in an FFF file (*Flexible File Format*) – a quasi-RAW file that is essentially an enhanced TIFF with IPTC metadata and high quality preview. The image itself is captured with sensor only and no tonal adjustment or any other alternation to colors or contrasts by software's algorithms ever occurs. Flexcolor – an operating software dedicated to this appliance – offers numerous settings with which the scan can be exported to TIFF giving an operator a great deal of versatility and control, limiting the extent of further post-processing with Adobe Photoshop. Scanning process with 3F format alone takes no longer than 75 minutes, but additional time has to be considered for putting the materials inside all ten holders. Overall daily digital image production amounts to 210 copies with this device alone. That means the scanner exceeds twofold the production of digital copies on both Kodak iQsmart[3] flatbed appliances and nearly four times the production of digital images with PENTACON SCAN7000 scanner camera that have been considered productive in their own right. Added 48-bit color depth and a raw negative image registration, an operator is able to capture greatest amount of detail without losing too much information in both shadows and highlights due to imperfect software algorithms.

Likewise to photographic equipment scanners also have the technical capability of capturing raw images, however information is not preserved in a proprietary file format , but as a genuine TIFF file which in case of Flexible File Format only requires a free Photoshop plug-in to have been read.

At National Digital Archives post-processing raw digital images is quick with both Flexcolor and Adobe Photoshop. An FFF file is exported to generic TIFF file with either GrayGamma 2.2 grayscale or AdobeRGB1998 color space, 16-bit color depth and ca. 6500x4300 resolution as well as neatly cropped. Then, using operations in Photoshop color image is inverted with special Curves preset, then black point is readjusted using black framing around the picture, levels are corrected by finding light and dark colors and that is all. Grayscale scans are even faster to process – they are likewise inverted with same Curves preset, then only levels are readjusted. Usually it takes less than 20 seconds to fully post-process an image according to National Digital Archives rules and about 5 minutes to export sixty FFF images to generic TIFF files.

One may argue that such array of actions dispels any kind of productivity and slows down the entire process, however operations in Photoshop and preset settings in Flexcolor provide for efficient and quick post-processing which extent is already limited anyway in order to avoid any retouch. Overall daily post-processing of digital images produced by scanners at National Digital Archives falls somewhere between 150-200 copies, depending on the condition and characteristics of the original material.

Usually productivity is due to digitising technique, digitising mode with which digital images are created (16-bit grayscale or 48-bit RGB, positive or negative, JPEG or TIFF etc.), their parameters as well as the length of sensor's exposure to light. National Digital Archives does not yet have a legitimate digital camera digitisation system. However as of December 2017 the institution had purchased a very unique high-end device for digitisation of spatial and flat objects which is a kind of hybrid between a scanner and photographic equipment based on the technology of an advanced merger of aforementioned two – Zeutschel ScanStudio. This appliance came as a replacement for PENTACON SCAN7000 scanner camera which although providing for an excellent optical resolution was indeed pretty slow in terms of productivity.

The idea behind this purchase had evolved through many stages – from a simple full-frame camera body in the likes of either Nikon or Canon with proprietary fixed focal length lenses, then Book2net X71 repro camera system, followed by HASSELBLAD X1D-50C mirrorless medium format digital camera with 50 MP CMOS sensor, HASSELBLAD XCD 45 mm 1:3.5 lens along with separate repro column, table and lamps building up to final competition between PHASE ONE XF digital camera system with IQ3 80 MP CCD sensor of 13 *f*-stops dynamic range and resolving power of 10328x7760 pixels, Schneider-Kreuznach Blue Ring 80 mm 1:2.8 LS lens and Schneider-Kreuznach Blue Ring 120 mm Macro 1:4 LS lens and HASSELBLAD H6D-50C digital camera system with 50 MP CMOS sensor, HASSELBLAD HC 80 mm 1:2.8 lens, HASSELBLAD HC 120 mm Macro 1:4 lens along with KAISER rePRO setup. National Digital Archives had established few essential requirements for the equipment to meet, among them were compliance to both *FADGI* and *Metamorfoze*

standards for bound volumes, rare and special materials, unbound documents, oversize items, prints and photographs, an ability to digitise objects of A1 format in a single shot with at least 300 PPI optical resolution, light uniformity of no more than 1 EV difference and ΔE_{00} below 2. In wake of this purchase Zeutschel ScanStudio has been bought and it came in the following setup: PHASE ONE IQ3 100 MP (not Trichromatic) digital back with medium format full-frame CMOS sensor achieving optical resolution of 11608x8708 pixels and dynamic range of 15 *f*-stops, Rodenstock HR Digaron-W 70 mm 1:5.6 lens (for A1 and larger objects), Rodenstock HR Digaron-S 100 mm (for A6 to A2 objects), advanced ergoLED lamps with luminance of 500-4500 lux and two tables: transmissive light source table and Zeutschel OT180H50 scanner table. It was at the time of the purchase and remains to date the only such device in Poland and only one of a number in the entire world. Also the Zeutschel OT180H50 scanner table for A1 and larger objects is the only one table of that size in Poland.

The rationale for the purchase of Zeutschel ScanStudio was to provide for both National Digital Archives and all state archives in Poland an appliance that would cope with currently the safest and the highest quality digitisation achievable of most valuable archival materials in Poland – not only photographs, but especially oversize objects like historical maps or medieval parchment books. IQ3 100 MP medium format full-frame sensor is capable of high optical resolution as well as noise under the *FADGI* 4-star threshold, because its physical size of 54x40 mm allows for less tight positioning of all pixels, whilst each pixel is 4.5 micron size and RGB filters do not overlap each other too much so the color capture is more accurate and easily below ΔE_{00} value of 2. The issue of overlapping RGB filters along with imperfect algorithms often occurs with scanners resulting in too yellow-ish, too green-ish or too blue-ish images when scanning directly to positive. Also lamps mounted in Zeutschel ScanStudio provide for excellent light uniformity and color capture. Still they are not fully synchronized with the machine's mechanics leaving certain margin of flexibility to an operator.

The workflow with Zeutschel ScanStudio is significantly different from *modus operanti* of HASSELBLAD Flextight X5. There are of course certain actions that have to precede both scanning and shooting digital images which are identical, for example both appliances have to be fully calibrated, profiled and configured before the production is commenced, but right after that numerous differences begin to emerge.

For instance, both devices come with already embedded equipment ICC profiles. The process of assembly of Zeutschel ScanStudio took three days straight and one day was meant for complete calibration and configuration of the entire setup. Operators of either HASSELBLAD Flextight X5 and Zeutschel ScanStudio have the ability to embed their own equipment ICC profiles, however it is faster and easier to create such profile for the scanner using simply IT 8.7/1 transparent reference chart and *i1Profiler* software given full automation of the device, continuous and fixed light as well as uniform materials that will have been

scanned. It is also suggested to perform white calibration although no more than once every 4-6 months for HASSELBLAD Flextight X5. Much to the contrary with Zeutschel ScanStudio and its digital back white calibration for fine tuning must be performed every 50-100 scans and anytime new materials are photographed which is very likely to occur quite frequently given the versatility of the device. Such calibration has to be made in the event of even a minor change to device's surrounding and settings, like new aperture value. This is a bit easier than in case of a digital camera since for a camera system each change of aperture value, shutter speed and ISO calls for new ICC profile and calibration. For every extraordinary kind of the material an equipment ICC profile has to be created either using x-rite ColorChecker Passport (both with 24 patches and 140 patches), *i1Photo* spectrophotometer and *i1Profiler* or certain open source software like *Argyll* which is not as precise. An equipment ICC profile can also be generated via *delt.ae* webpage, however it is not recommended since such profiles are not as accurate due to *ie.* mean colorimetric values. Then there is also the possibility for the creation of ICC profile using *ColorChecker* software yet it is only compatible with Adobe Photoshop and Adobe Lightroom. Furthermore an LCC profile is generated during brightness calibration which provides for software compensation of over- or underexposure and light non-uniformity. Each equipment ICC profile has to be controlled for its precision using for instance open source *ICC Profile Inspector*[8]. Furthermore an operator needs to check if the lens is in perfect vertical axis. That control is possible using for instance a laser collimator and a laser spirit level. For a digital camera an operator has also to control the depth of field, however in case of Zeutschel ScanStudio this issue is pretty much eliminated since the system automatically positions the lens on proper height according to the size of the document. Color temperature of the lamps can be measured with spectrophotometer and BabelColor's *Color Translator & Analysis*[9] software (since LED lighting may require certain amount of time to warm-up and attain proper color temperature of 5500K to 6500K). Finally light uniformity can be controlled with *delt.ae* webpage, however it is time consuming, or with basic lightmeter like the SEKONIC L-308S-U used at National Digital Archives in order to achieve no more than 1 EV difference on the entire surface of the table. On the other hand our analysis of Zeutschel ScanStudio's lighting performed with both abovementioned lightmeter and BabelColor *CT&A* had shown that its LED lamps achieve correct color temperature nearly immediately after turning on.

What makes Zeutschel ScanStudio different from classic digital camera system is that it operates through document profiles or presets stored within its software – *OmniScan* 12. These profiles contain lamp position and aperture value guidelines, lens calibration and height settings, ISO and shutter speed values, among other things. Each document profile is programmed only with *OmniScan* which virtually controls every aspect of the system's operation.

Working with Zeutschel ScanStudio teaches in fact a lot about the technology behind holistic systems combining scanner and digital camera capabilties and how such appliances differ from regular digital camera setups. Digital cameras in particular have been praised for their versatility, modularity and manual control over the entire configuration of the system, thus the whole digitisation process. Especially in case of medium format DSLRs an operator can swap interchangeable lenses and digital backs at his or hers own convenience and in order to achieve desired effects. An operator can also manually set ISO, aperture and shutter speed. When it comes to Zeutschel ScanStudio lenses are also interchangeable having their distinctive mount, digital backs can also be replaced, however certain functions have been automated to simplify its workflow and for the sake of productivity. An aperture value can be chosen manually and *f*=5.6 is optimal, whereas ISO and shutter speeds are set during calibration process. Different positions of lamps have been calculated by the manufacturer and saved within document presets. These presets save time that would have otherwise been spent on searching proper depth of field and light uniformity due to already programmed camera stand settings.

Photographers who work with classic digital cameras often shoot with ISO 100 and 1/100 of a second shutter speed, sometimes using flash to avoid the loss of sharpness due to micro vibrations caused for example by passing vehicles. Lamps are mounted on separate tripods allowing for manual adjustments of the distance from the photographed object since the power of light diminishes to the distance square. Zeutschel ScanStudio operates with ISO between 200 and 400 and shutter speeds of 1 second to 1/30 of a second. Lamps are attached to the main column and one can adjust their height as well as angles of brackets and boxes. Lamps are more less facing in a forward direction and when taking a photo light intensifies for a brief moment. Both light intensity and flash delay can be adjusted manually. According to National Digital Archives' measurements with BabelColor *CT&A* however the quality of light does not exceed *FADGI* 4-star level and luminance uniformity ΔL does not exceed the value of 1.7.

As far as post-processing goes it is much faster with Zeutschel ScanStudio than the scanner since *OmniScan* software allows for automated cropping, rotating and leveling an image right after taking a photo. Both prints and black and white glass plates are scanned in color and with *OmniScan* version 12.2 with 48-bit AdobeRGB1998. Virtually post-processing is pretty much non-existent for photo prints. Software automatically crops an image leaving about 2 mm of black frame around it, then levels it and rotates, so no further actions in Adobe Photoshop are needed. Glass negatives are only converted to Gray Gamma 2.2. grayscale and inverted to in Adobe Photoshop. Zeutschel ScanStudio is highly productive, generating approximately 30 images per hour – a result comparable with HASSELBLAD Flextight X5, however at National Digital Archives an operator spends only four out of eight working hours at photographic equipment in order to let his or hers eyes rest from the continuous exposure

to light of the lamps in a sealed dark room. As a result daily production with this system amounts to 160-170 digital images of photographs depending on the condition and uniformity of the material.

In terms of equipment's technical requirements and parameters of digital images both HASSELBLAD Flextight X5 and Zeutschel ScanStudio meet the standards followed by the National Digital Archives exponentially, so in order to identify any sort of difference between scanners, repro and digital camera systems as well as wholesome scanner/camera systems one has to consider certain factors that contribute to the quality of an information captured on the digital image by either of those appliances. For photographic means numerous factors add to the quality of such information: focal length of the lens and sensor size, distance between the lens and the object, quality of light generated by lamps, freshness and number of lamps and their positioning, precision of equipment ICC profiles, frequency of calibration. For scanners and for all-in-one devices (but to certain extent) the number of contributing factors is fairly smaller. Scanners have only one optics and fixed light situation. They do not require as often calibration as digital backs and full-frame bodies. Therefore all-in-all mostly sensor characteristics matter as well as freshness of fluorescent lamps. Holistic systems use interchangeable lenses and photographs are taken with at changing lamp positions. They require much frequent calibration and depending on the material as well as due to an open surrounding they may need changing ICC profiles more often, so they are more complexed to handle and more variables have to be included for achieving the best content presentation on the digital image.

Among aforementioned factors that have an impact on the quality of the content captured on the image lens characteristics play significant role, especially in attaining proper depth of field[10]. This is especially important for medium format digital backs which have a larger point of confusion than 35 mm full-frame digital bodies and thus a shallower depth of field. Furthermore the greater the focal length of the lens and shorter distance from the object the better the resolution but shallow depth of field. Much to the contrary to scanners like HASSELBLAD Flextight X5 which operates at automatically adjusted distance between the lens and the object and therefore with uniform resolutions like 600 PPI, 1200 PPI up to 6300 PPI and 8000 PPI, photographers working with lenses of different fixed focal lengths have to spend more time finding proper depth of field, sometimes trading some resolution by increasing the distance from the spatial object in particular for better sharpness of the image. A good example that illustrates the difference between depth of field of a 35 mm full-frame camera and medium format digital back is one out of digitisation branch. A photographer takes two portrait pictures of the same model of 1.7 meters height during a slight overcast – first with 35 mm full-frame camera and the second with medium format digital camera with a digital back of 54x40 mm sensor size. He only wants to show her figure from her face on top of the frame to the

middle of the stomach on the bottom using both devices. Both cameras have mounted 100 mm prime lenses and the aperture on both has been set to 5.6. In order to achieve identical effects on both appliances the photographer has to take a picture of the model in a horizontal orientation from approximately 2.02 meters with a 35 mm full-frame digital camera. At such distance the total depth of field with 100 mm fixed lens and at 5.6 *f*-stop will be equal to 12.5 cm. Using a medium format digital camera he has to take a horizontally oriented picture of the model from more or less 1.19 meters, because the lens and the sensor are larger and would have otherwise captured more of the background with smaller figure. At such distance the total depth of field with 100 mm fixed lens and at 5.6 *f*-stop will be equal to 6.5 cm – only a half of the depth of field attained with 35 mm full-frame. This example might seem odd from an archives' perspective, however in order to achieve proper quality of the digital image of an archival material an operator has to mind the percentage of sensor coverage by that object in order to provide sufficient number of pixels to capture all detail. As a result resolutions of digital images captured with digital cameras are less uniform – 682 PPI, 984 PPI etc. At National Digital Archives camera operators try to keep more or less 70% sensor coverage by the object when working with PENTACON SCAN7000 scanner camera which provides for manual distance adjustment. It is important to note that considering best depth of field-resolution ratio one has to mind that each lens, inspite of the focal length or its manufacturer has only one optimal aperture with which images are the sharpest, often between 5.6 to 8 or 11. Obviously each lens is also sharpest in the center, therefore if an archival object fills nearly too much of the optics its digital image may lose the sharpness on its borders. In order to avoid such flaw an operator has to take a shot of SFR or *Spatial Frequency Response* control charts positioned on four corners of the area as seen through the lens and measure this parameter for example with *delt.ae* website before proceeding to digitisation. For the control of image sharpness at National Digital Archives a *Universal Test Target* reference chart and *delt.ae* website are used when configuring photographic equipment.

What is essential for classic digital camera systems are lamps – mainly in terms of their number and positioning. Basic and most frequent setups are comprised of two lamps which cast light evenly on the entire surface where archival materials are photographed. When specifying digital camera system one can establish the norm for light uniformity either using *FADGI* or *Metamorfoze* guidelines or naming highest accepted value of light non-uniformity measured in EV units. For National Digital Archives 1 EV difference on the entire table is satisfying and easily achieved with Zeutschel ScanStudio, however in case setups which include greater number of lamps that are not directly connected to the main table or column, light uniformity does matter and has to be checked every time wheter new materials are photographed or new light sources are added. Lamps mounted on separate tripods can be used with softboxes or light diffusion transparencies depending on desired results as well as

characteristics of photographs like for instance glossy medium which requires softer and dispersed light. Each lamp configuration calls for a different equipment ICC profile so every time an operator arranges lamps in different fashion he or her needs to spend additional time on that procedure. Additionally for every new lamp configuration new white calibration is necessary. In case of a system like Zeutschel ScanStudio equipment ICC profile is already embedded for all document formats and only frequent brightness calibration along with white calibration with QPCard 101 chart are mandatory since this appliance does not require neither softboxes nor light-diffusing transparencies.

All-in-all by comparison scanner operators do not have to mind broad array of time consuming actions that photographers have to take. To a certain degree photography scanners are already pre-configured leaving only a handful of activities to have been done manually and with lesser frequency. Digital cameras and repro cameras take longest time for complete calibration and configuration which include numerous variables that have to be taken care of manually and frequently by qualified operators whereas merging systems like Zeutschel ScanStudio fall somewhere in the middle having many features automated by their manufacturers and yet still necessitating for manual control over certain aspects like lamp positions and frequent white calibration.

Having examined the characteristics of scanners, digital and repro cameras as well as merging systems let us draw some conclusions. Digital camera setups are fully modular as nearly each part is interchangeable. They are precise, flexible and provide for full manual control over the entire setup and thus the quality of digitisation if paired with high-end lamps. Their drawbacks are however time needed for complete system configuration as well as very frequent necessity for equipment calibration and profiling due to an open surrounding that is a photo studio and vast array of factors that impact on the final outcome of digitisation. These numerous variables require qualified staff to be taken care of and greater number of standards to meet. Their derivatives in likes of repro cams, although cheaper can be paired with top-of-the-notch digital backs and on one hand provide for high quality digital images and on the other – follow similar constraints and obligations.

Finally, the creation of a full-fledged photo studio for cultural heritage digitisation does not end with the purchase of a high-end digital camera system. What makes such setup versatile is a set of expensive lenses which although do not have to be bright for the closed environment of a photo studio must have fixed focal lengths of at least 80 mm, 100 mm and 120 mm macro and must be aspherical as well as apochromatic. One has to buy numerous accessories accommodating for various sorts of photographs like softboxes and light diffusion transparencies for glossy photo prints or antique photographs in glare frames, velvet cover for the table which absorbing the light provides for a very aesthetic pitch black framing around the digital image, foam book supporting wedges for old family photo albums, as well as vacuum

table, laser collimator and laser spirit level for precise positioning of the lens and table, a spectrophotometer and a lightmeter, different reference charts for calibration and profiling, for calibration control and to be included to digital image among other things. The studio in and of itself has to be properly arranged with black ceiling, matte grey walls and matte floor, it should also be of proper height accommodating higher columns and last but not least it must be completely dark either with no windows or with metal shutters. Generally speaking the decision on using photography equipment in digitisation implies a really big investment not only in the infrastructure but also in highly qualified staff. On the other hand either flatbed, film or virtual drum photography scanners can function successfully in whatever environment available, even one next to the other, whereas putting two digital cameras close to one another would have resulted in unwanted light interference so that they could not have worked simultaneously.

In case of all-in-one digitisation system like Zeutschel ScanStudio it certaintly requires a separate room due to its sheer size which must also have matte walls and matte floor, but on the other hand it is all-inclusive as it comes equipped with whatever is needed for autonomous calibration and calibration quality control. Equipment ICC profile can be created using Coloraid.de IT 8.7/1 transparent reference chart and ColorChecker PassPort SG whilst the quality of calibration is assessed with *Universal Test Target* (European equivalent to Image Science Associates *Device-Level-Target*). White calibration is performed with QPCard101 chart and there is a separate white sheet for brightness calibration. All these charts are provided with the appliance. The only accessories that have been purchased separately were the velvet for photo prints and foam book support wedges for old family photo albums.

An issue of essential importance to digitisation from digital archives' perspective is productivity. Due to abovementioned numerous variables that have to be taken into account when working with digital cameras productivity is pretty much non-existent. The extent of both calibration and configuration of the equipment in the event of any changes to working environment, replacing setup components or digitising new materials simply eliminates any large-scale production of digital images.

Although digital cameras and repro cameras are excellent at digitising film photographs in terms of resolution, sharpness, contrasts and tones, color rendering and color depth they usually fall short in terms of pace. In a continuous process one can digitise a single frame with highest optical resolution, because 120 mm macro lens will only get us so far. The process of course can be faster with wider angle lens however at the expense of pixels.

Scanners on the other hand are made for productivity by design – it only matters how many photographs can a particular device digitise in a continuous process. High-end photo scanners provide for large resolutions of digital images. They produce sharp images with properly matched contrasts and colors meeting both MTF and ΔE requirements as established in both *FADGI* and *Metamorfoze* standards. On the other hand their versatility is highly

constrained. Scanners which operate with holders for reflective and transparent photographs will not digitise neither glass plates nor three dimensional objects like photo albums. Appliances which lamps have been positioned precisely only for negatives on film and reflective photographs will not cope with glass plates either. Only flatbed scanners which scan all materials put directly on the glass surface can digitise such objects if a particular subject does not have a digital camera. On the other hand flatbed scanners are not recommended for digitisation of photo albums in terms of their safety. Even most capable film photography scanner will not be flexible unless one is willing to pay for additional holders and even if a subject is equipped with numerous holders for all sorts of strips and frames still there is an issue of film rolls which cannot be cut to strips for the safety of their preservation. Finally photo scanners do not digitise large format photo prints above A3.

Digital cameras as well as digitising systems like Zeutschel ScanStudio compensate perfectly for scanners' shortcomings. Both are best for safe digitisation of three dimensional objects like family photo albums and antique photographs, both cope excellent come digitisation of glass plates and film rolls. With Zeutschel ScanStudio family photo albums are photographed using a foam book supporting wedge which holds one cover of the book and following pages in a safe opening angle. Film rolls are digitized frame by frame, but still faster than with a flatbed scanner which exposure takes up to 6 minutes per picture.

Last but not least let us examine the issues of how either scanner, digital camera or all-in-one digitisation system is both future-proof and fool-proof. When it comes to upgradeability a scanner is pretty much a one-time buy. An operator cannot swap scanner components for the better on the other hand there is no real need for that since already scanners provide for excellent resolutions, accurate color capture and generate 16-bit images. In terms of preventive maintenance service providers can replace exploited sensors or fix broken mechanics, which are not prone to malfunction often, whereas due to ease of accessibility an operator can usually unmount used fluorescent lamps and attach new ones as well as clean the interior autonomously. The only risk is linked to availability of new scanners as well as spare parts on the market. Currently it is difficult to estimate how long will contemporary photography scanners remain in production and for how long can an institution prolong their lifespan buying spare parts.

Digital camera and repro camera setups as well as holistic systems like Zeutschel ScanStudio are more future-proof. LED lamps, digital backs, lenses, camera bodies can be swapped with newer models provided compatible mounting. There is no need for the wholesome device replacement, rather particular components can be changed at lower costs. Certain procedures belong to service support only, but more simple actions can be performed autonomously on daily basis.

Obviously scanners are more fool-proof than digital cameras since they are more automated and less of a human factor contribute to the overall digitisation outcome, but appliances that aim at combining characteristics of both prove well in this field either due to the extent of their automation.

Although each cultural heritage subject has more or less developed its own workflows and guidelines which result from distinctive collections and their condition, digital appliances in use and number of staff as well as causes and purposes of digitisation. This paper aims to show that all these workflows virtually fall into two main categories. Either an organization bares resemblance to the factory, producing digital images on industrial scale, going as far as to generate tens of thousands high quality images compliant to particular norms in an annual cycle or operates in similar fashion to a fine art studio focused on high quality digitisation usually of difficult spatial objects yet less compliant to annual production norms and to the greatest extent interested in the quality of visual representation of each original material in accordance to sophisticated standards and meticulous quality control. Such approach follows the premise that digital images have to be first captured with raw format in fully controlled environment and in the most precise way possible, displaying even most subtle colors, gradients as well as complete characteristics of the medium or original material without any flares, shadows, unwanted reflections and any other artifacts. To achieve this effect sophisticated setup is created, precise calibration and configuration are performed as well as meticulously checked with numerous parameters and various tools like reference charts, spectrophotometers among other things. Digital images are captured with high resolutions, large color depth and with specific reference charts. Eventually employees responsible for digitisation spend most of the time preparing the entire surrounding and equipment, then capturing number of images of the same object and choosing the best one. Upon obtaining such image other employees do extensive editing on the access copy for that image before it is made available to the general public. Factories demand appliances of greatest productivity and fastest, automated performance before high-end specifications, whereas fine arts photo studios strive for top-of-the-notch specifications and full manual control, modularity and versatility.

In order to fully understand the nature of National Digital Archives' activity on the field of digitisation let us dive deeper into the workflow of National Digital Archives' Digitisation Department. Ever-since its inception in 2008 National Digital Archives conducts large-scale digitisation of photographs. Its collection exceeds 15 872 497 of pictures mostly on uniform mediums – 35 mm and 120 mm film strips. Annually 37 500 thousands of photographs are digitised at National Digital Archives which to date had digitised over 427 870 pictures[11], that is 2.69% of the whole collection. For a number of years digitisation of photographs was conducted on three Kodak iQsmart[3] flatbed scanners running nearly 14 hours daily and one

PENTACON SCAN7000 scanner camera. Since late 2017 one Kodak iQsmart[3] scanner has been replaced with one HASSELBLAD Flextight X5 virtual drum scanner with batch scan feeder for 35 mm and 120 mm film strips which is able to produce over 1 400 TIFF digital copies within one week with ca. 8900x5900 pixel optical resolution, 16-bit color depth and either GrayGamma 2.2 grayscale or AdobeRGB1998 color space. Additionally, PENTACON SCAN7000 was replaced with Zeutschel ScanStudio for reflective photographs, photo albums, A2 and larger prints as well as other valuable material out of National Digital Archives' stock with a production norm of 30 high quality RAW images per hour with ca. 11608x8708 pixel optical resolution exported to 16-bit RGB and AdobeRGB1998 color space TIFF files.

Given such characteristics it is safe to assume that National Digital Archives is a factory with a touch of a fine arts studio, striving for both productivity and high quality of digital images. This may change in the future provided the creation of Central Digitisation Studio for State Archives of Poland at National Digital Archives and the need for a legitimate photo studio.

Different approaches to digitisation may result in different guidelines that are followed. National Digital Archives relies on standards as established within the framework of the Ordinance no. 14 of the General Director of State Archives in Poland dated 31st of August 2015 which is due to be updated in the following year. These guidelines pertain to both scanners and photographic appliances and include: resolution between 3000 PPI for smallest photographs below 24 mm on shorter border up to 600 PPI for larger images above 131 mm on shorter edge, 16-bit color depth for both grayscale and RGB, TIFF 6.0. file format for the master copy and finally GrayGamma 2.2. grayscale and AdobeRGB1998 color space for RGB. Such set of guidelines is simple and yet quite basic that is why in case of devices which operate in an open space with external lighting and to the greater extent are subjected to environmental impact operators at National Digital Archives also take advantage of international standards such as *FADGI* and *Metamorfoze* in order to assess the precision of equipment calibration and profiling as well as general quality of digital images. Both *FADGI* and *Metamorfoze* guidelines are more elaborate and contain specific norms for both equipment and environmental factors contributing to digital capture. In case of *FAGDI* standards operators at National Digital Archives use ColorChecker PassPort SG and *delt.ae* website paying special attention to luminance uniformity and noise, MTF10 and MTF50, sharpening and color accuracy (mean ΔE_{00}), whereas in case of *Metamorfoze* using again *delt.ae* website and *Universal Test Target* – to white balance, exposure tolerances, noise and illumination. Although both sets of guidelines are not mandatory in Poland they are frequently applied in Polish cultural heritage institutions especially on photographic side of digitisation and provide for fast, accurate assessment of equipment configuration. When digitising with Zeutschel ScanStudio in particular results at full *Metamorfoze* and at least 3-star *FADGI* levels are satisfying.

Scanners on the other hand are sealed systems with fixed lighting and minimal environmental impact therefore do not require any more complexed standards than of resolution, color depth and color accuracy (mean ΔE_{76} below 3 at the moment) as well as color space. Any aberration to light uniformity, color rendering or sharpness can be assessed by means of visual control and corrected with either the creation of a new equipment ICC profile or through the replacement of exploited parts.

Due to abovementioned differences between digitising appliances resulting in different workflows and approaches to guidelines and quality control it is common for numerous cultural heritage institutions in Poland to divide the digitisation process on two collateral paths – the path of photography and the path of scanning – having their own guidelines, quality assessment and equipment configuration tools as well as distinctive objects to have been digitised.

From an archives' perspective standards are more general since there are not many state archives in Poland which use photographic equipment – only The Central Archives of Historical Records in Warsaw, State Archives in Wroclaw and the National Digital Archives. However those who do use such appliances seem to regard more complexed guidelines as tell-tale tools for quality digitisation. Compliance to more restrictive standards determines smaller production norms and provides for higher quality digital images however neither the choice of guidelines does not determine the purchase of equipment nor conversely. It is only a matter of person's decision whether a photograph is scanned with the scanner or with the digital camera and according to whichever rules so long as they provide for an accurate digital resemblance of the original source and allow for its multipurpose use. On the other hand of course more precise guidelines extending to numerous factors that determine the quality of a digital image help to sort out the digitisation process. That is why upcoming update of the ordinance of General Director of State Archives in Poland pertaining to the digitisation of archival stock will on one hand simplify the issues of resolution (all digital images will have had at least 4000 pixels of height) and include new norms for digital copies of photographs: sharpening (MTF max.), luminance uniformity (ΔL), dynamic range for digital cameras and color accuracy (mean ΔE_{00}).

Different paths of digitisation are represented also in the issue of RAW vs. TIFF. The competition between these two file formats seems to be regarded as somewhat scanner vs. digital camera question or to be more precise – scanner vs. everything else, since digital camera solutions had evolved so much so that have become parts of different types of appliances. Apart from obvious differences in size and software support between both two formats they show scanners' and cameras' capability.

A RAW file is not a graphics format, it merely is a record of impulses taken by camera sensor without neither compression, software processing nor color management. The

interpretation of color occurs later when exported to another file format like TIFF and given its own ICC profile. Capturing an image directly with TIFF is rather unlikely for digital cameras but it also risks the loss of precise color control since such file will have ICC profile assigned from the very beginning. On the other hand while exporting RAW file to TIFF file an operator can embed whatever ICC profile is needed according to the particular usage of that image. The number of exports to different files and with distinguished profiles is vitually limitless. To the contrary during the scanning process a TIFF file has already ICC profile embedded either chosen by the operator or the equipment ICC profile attached automatically by the device. The color space of that ICC profile can only be converted to a different color space but with already pre-determined colorimetric values. In other words scanner simply interprets colors, half-tones, contrast etc. This interpretation is identical for all captured images because the light is fixed and at all time continuous. However an option can be chosen within scanner software not to embed an ICC profile at all. This is particularly useful when capturing an image of a negative on film directly by scanner sensor as a raw color negative rather than in its automated positive inversion. New professional photography scanners offer such possibility among other modes of operation like creating a TIFF file with embedded profile of a popular and frequent color space for example sRGB or Adobe RGB or like scanning with equipment ICC profile. No color management whatsoever is better at the scanning stage although an operator will have to embed a profile manually later on, because it allows for greater control over the colors. An operator is able to then create a separate precise ICC profile and assign it to a raw image with a graphics program every time the digital image is used for a different purpose. This is how close scanners can get to photography equipment and as a result the notion of whether TIFF vs. RAW is really about scanner vs. digital camera is not so much the case. The quality of both files is high only the RAW offer certain wider flexibility in terms of managing ICC profiles.

At National Digital Archives both flatbed scanners as well as virtual drum scanner are able to capture an image directly with the sensor and either with or without embedded ICC profile. Photographs are scanned with 48-bit RGB either transparent negative for glass plates and film photography or reflective positive for prints however at all time without automated invert to readable image. Later AdobeRGB1998 color space profile is embedded for color negatives and color slide films or GrayGamma 2.2 grayscale for black and white photos. Upon the assignment of ICC profile the image is inverted with special curves preset as mentioned before.

In case of all-in-one digitisation system which at National Digital Archives captures digital images of mostly reflective material all such prints both black and white and color are photographed in either 24-bit or 48-bit RGB and AdobeRGB1998 color space. There is no procedure revolving around long-term preservation of RAW data, but for exceptionally valuable objects RAW images are created and preserved as well. For other institutions in Poland in likes

of National Museums or the National Library of Poland some of them keep RAW data and preserve it in data centers others simply delete it upon the conversion to TIFF files.

Upon the examination of numerous issues and factors linked to scanners and cameras as well as various instances of how their methods of operation have an impact on digitisation process the question emerges whether digitisation of photographs is really at its turning point – at symbolic crossroads when scanner era is ending while more and more digital cameras are taking over. From a certain point of view that would be the case given for example narrowing availability of photography scanners on the market, however the importance of scanners is still recognized by institution in the likes of National Digital Archives which relies on these devices as main pillars of digitisation of more than 15 million photographs. The automation, productivity and workflow simplicity of a scanner is both appreciated by archivists and implemented by manufacturers of all-in-one digitisation systems. On the other hand it would have been unreasonable not to benefit from the modularity, versatility, resolution and quality of color accuracy provided by digital cameras especially with medium format backs. Therefore the final conclusion would be that rather sooner than later digital cameras and their derivatives will have dominated digitisation market but as long as there are cultural heritage subjects that see the characteristics of scanners fit to their archival photography collections the demand for scanners will not disappear and their place in digitisation process will be secure.

Notes:

1. Hans van Dormolen, *Metamorfoze Preservation Imaging Guidelines. Image Quality, version 1.0.* (The Hague: Koninklijke Bibliotheek, 2012), 16-38.
2. Thomas Rieger, *Technical Guidelines for Digitizing Cultural Heritage Materials* (Federal Agencies Digital Guidelines Initiative, 2016), 33-41.
3. Prices of these appliances had been taken from purchases made by National Digital Archives in late 2017.
4. Taking into account overall number of photographs preserved at National Digital Archives, annual production norm for the digitisation of photographs as well as number of appliances in use total estimated time for digitisation of the rest of National Digital Archives' photography collection amounted to little over 388 years. Having one Kodak iqSmart[3] flatbed scanner replaced with one virtual drum HASSELBLAD Flextight X5 scanner the production of digital copies with one device has doubled and the total estimated time to scan all photographs at National Digital Archives' stock has shorten to approximately 277 years.
5. Numbers had been achieved during tests performed at National Digital Archives.
6. Such D_{max} was only comparable to Nikon Super CoolScan LS-9000 ED, which boasted 4.8 optical density. However Nikon ceased production of that once high quality device.
7. Cambridge in Colour, *Dynamic Range in Digital Photography*. The article is available at https://www.cambridgeincolour.com/tutorials/dynamic-range.htm.
8. *ICC Profile Inspector* tool is no longer developed. However it is still available for free download at http://www.color.org/profileinspector.xalter.
9. More information regarding BabelColor *Color Translator & Analysis* software is available at http://babelcolor.com/index.htm.
10. For archivists that have not yet had a contact with the issue of the depth of field there is a mathematic formula for this parameter which for the sake of this paper is presented in a simplified way:

$$in\ front\ of\ subj.DoF = \frac{distance \text{ x } (focal\ lenght)^2}{(focal\ lenght)^2 + (apperture \text{ x } distance \text{ x } circle\ of\ confusion)}$$

$$behind\ subject\ DoF = \frac{distance \text{ x } (focal\ lenght)^2}{(focal\ lenght)^2 - (apperture \text{ x } distance \text{ x } circle\ of\ confusion)}$$

$$Total\ DoF = (distance - in\ front\ of\ subject\ DoF) + (behind\ subject\ DoF - distance)$$

11. Data taken from the *Annual Report on the Activities of the National Digital Archives* dated 31st of December 2017.