NEW QUALITY STANDARDS FOR DIGITAL IMAGES

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ABSTRACT:

With the transition from analytical to digital photogrammetry digital image data has become more important. Today digital image data acquisition is mainly based on scanned aerial film. The user is facing the problem to appraise the radiometric and the geometric quality of digital image data. If a scanning service provider will be mandated with the film scanning, a detailed specification of the project is requested.
The German bureau of standards is currently working on a new set of standards for photogrammetric products. (DIN 18740) A new standard " Requirements for scanned aerial images" is available as a draft. It describes on which technical parameters of photogrammetric scanners the user has to pay attention. This can have a big impact on the image quality. Furthermore it is described on how then user can specify and check the radiometric and geometric image quality.
An attachment with a template for bidding of scan contracts is available for the user. This form can be used to specify the scan parameters, the data format, the meta data and quality reports.
A second standard about the quality of digital images acquired directly with digital aerial cameras is currently in preparation. This standard will cover line sensors and frame sensor cameras.
This papers reflects some ideas and fundamental knowledge concerning these standards and their usage.

ZUSAMMENFASSUNG:

Mit dem Übergang von der analytischen zur digitalen Photogrammetrie wuchs die Bedeutung von digitalem Bildmaterial. Bis heute war die Gewinnung digitaler Bilddaten vor allem durch das Scannen von Luftbildern auf Filmbasis gegeben. Der Benutzer steht vor dem Problem die Qualität solcher digitaler Daten zu beurteilen. Falls ein Anwender das Scannen von Bildmaterial beauftragt, ist eine detaillierte Spezifikation solcher Projekte gefordert.
Der deutsche Normenausschuss erarbeitet im Augenblick einen Satz von Normen für verschiedene photogrammetrische Produkte (DIN 18740). Eine neue Norm mit dem Titel "Anforderungen an das gescannte Luftbild" ist als Entwurf verfügbar. Die Norm beschreibt die technischen Parameter die der Anwender von seinem photogrammetrischen Scanner fordern kann. Dies hat eine große Bedeutung für die Bildqualität. Weiter wird beschrieben, wie der Anwender die Einhaltung der radiometrischen und geometrischen Qualität nachprüfen kann.
Im Anhang der Normen werden Formblätter mitgeliefert, die der Anwender zur Beauftragung von Scanprojekten benutzen kann. Damit können Scan Parameter, Datenformat, Umfang der Metadaten und Qualitätsberichte festgeschrieben werden.
Eine zweite Norm, welche sich mit der Qualität digitaler Bilddaten von digitalen Luftbildkameras beschäftigt ist in Vorbereitung. Diese Norm wird Zeilensensoren und Flächensensoren einschließen.
Dieser Vortrag soll Überlegungen zu diesen Papieren und ihren Anwendungsbereichen zusammenfassen.

1. INTRODUCTION

A digital image in photogrammetry has to reproduce or objects on earth as accurate as possible.

More exactly these are images of two dimensional planes, which intersect earth's surface.

Different natural influences and technical features of the used systems determine the accuracy of this imaging and measurements within these images.

We always have to keep in mind, that the measurement is done within an image and not at the object directly.

The main aspects of image quality image are:

- Geometry,
  with all aspects of the optical systems and sensors
- Radiometry,
  which includes
  - grey values within a certain dynamic range and
  - colours, when more spectral ranges are overlapped to produce different colour output images.

So called digital images mainly can be produced in two different manners.
These two possibilities are discussed in this paper:

- Analogue systems, which use a standard film based cameras for image exposure and a scanner to digitise the stored image information.
- Digital cameras, based on line sensors or array sensors, which are able to store digital data directly during the flight.

Digital images produced with one of both methods have two important common features:

- Discrete spatial information. The spatial information is sampled and stored in a fixed pattern array, determined by pixel size and pixel number. Compared with film, it is a strongly periodical equidistant array. The array is produced by the sensor of the digital camera or the sensor and mechanical system of the scanner.
- All grey values are digitised. On the sensors themselves the images are available as analogue values, even on CCD or CMOS sensors. A/D conversion always is made after image capture. The only difference between systems is the point, when this conversion it is done and where.

Images can be digitised, after they have been stored on film, or after they have been stored in a CCD or a CMOS array.

Image quality can be defined by the determination of the system component's quality. The quality definition has to be independent from image information.

The question cannot be "What is a good image" but "What is a system, that produces images with minimum difference to the physical objects"

2. IMAGE QUALITY, INFLUENCES AND DETERMINATION

Within the following text the process, starting with light reflection on the ground to the digital information storage will be analysed. Most of these steps can be controlled and optimised by the user, in order to get optimum imaging quality.

Each step will be explained with all influences and minimum requirements for used system will be announced. For most of these steps above mentioned DIN standards define objective criteria and limits.

We do not want to publish these definitions and limits here, but want to enhance the understanding for their importance.

In all cases we have to look for geometrical effects, which change dimensions of an object and radiometric effects, which influence the grey values.

2.1 Procedures of film and scanner based imaging

When a film based camera and a scanner are used, the steps of information transfer from an object to its image are:

- Illumination with sun light
- Light reflection and diffraction at the object
- Information transfer using light, through the atmosphere
- Optical transformation by means of a lens system
- Optical filtering
- Storage on film, including
    - exposure control
    - mechanical treatment of the film
- Chemical development process
- Scanning
    - Illumination within the scanner
    - Optical transformation with scanner lens system
    - Spatial sampling with photo diodes or CCD line elements
    - Mechanical transportation of the film
    - A/D conversion for digital storage
- Data compression

2.2 Procedures of digital cameras

Digital cameras and scanners use more or less the same processes for grabbing images into a digital storage device. In case of digital cameras the storage media are transported with the camera and connected for online storage during flight mission.

So all steps for image storage on film are not needed. Now there is no influence from mechanical film transportation, chemical development process and optical influences from the scanner illumination an lens onto quality of the end product .

On the other hand available CCD sensors are smaller than film, so lines sensors or smaller array sensors have to be combined to form a large sized image. These cameras use one ore more mechanical shutters for exposure control. This combination of smaller images gives an additional step in image processing and may influence the quality of the image.

The process steps for "digital cameras" are:

- Illumination with sun light
- Light reflection and diffraction at the object
- Information transfer using light, through the atmosphere
- Optical transformation by means of a lens system
- Optical filtering
- Spatial sampling with photo diodes or CCD elements
- A/D conversion for digital storage
- Combination of camera heads, built with two dimensional arrays or lines.
- Data compression

2.3 Geometrical and radiometric quality criteria

2.3.1 Natural influences

The first three steps, "Illumination with sun light", "Light reflection and diffraction at the object", "Information transfer using light, through the atmosphere" are the physical circumstances which are given by nature.

They depend on the weather and on the time during the day, and also on the season.

Here the size of the shadows, the existence of clouds and the turbulence in the air influence the geometry and grey value distribution within the images.

All these parameters are defined in DIN 18740, part 1. Herein the preconditions for an aerial flight are defined.

2.3.2 Geometrical correction of the lens

Optical lens systems have geometrical errors, like distortion and astigmatism While astigmatism can be corrected to a minimum, distortion always has to be considered.

Therefore the lens systems have to be calibrated. In case of film based cameras this calibration has to be repeated in a certain time frame e.g. every two years. This calibration data set is used to correct the images after the scanning process.

In case of a digital camera, like Z/I imaging's DMC, the geometrical correction is applied during the post processing step, where the images from eight camera heads are combined to one large image.

The accuracy can be tested on special test fields with known position of test objects.

2.3.3 Radiometric correction of the lens systems

Because of mostly used wide angle lenses in photogrammetry a relatively high apodisation can be detected. For film based cameras special grey filters are used to compensate this effect. This is the only possibility to do it, because of the relatively low dynamic range of film.

With digital imaging a reference image can be exposed and stored in order to correct the image digitally. This possibility can be used based on a wider dynamical range of CCD elements.

In combination with apodisation correction the pixel sensitivity correction is done, which is mentioned later.

2.3.4 Resolution of the lens

On film based cameras and scanners two different lens systems are used during image production.

The first lens system is used in the camera itself, the second within the scanner. For both systems resolution criteria have to be fulfilled.

The pixel size of the sensor determines the edge frequency of the so called MTF curve. The variable of this curve is the spatial frequency in line-pairs/mm. It determines the number of line pairs (black/white), which can be resolved in the image.

The highest value fits with the pixel raster, when the change of white and black lines in the test grid have the same distance as the pixels of the sensor. So the edge frequency (EF) is defined as:

$EF = 500 / PX$ where PX is the pixel size in µm

For example a CCD sensor with 12µm pixel size has to be combined with lenses resolving about 42 LP/mm..

In case of digital cameras these criteria have to be fulfilled by the camera lens only.

2.3.5 Compensation of sensors effects and defects

No technical sensor array, either line sensor or two dimensional array, has a totally identical sensitivity for each sensor element.

Film has the same effect, but because of the change of film material from picture to picture, this effect cannot be compensated. It is a statistical effect, called grain noise, that depends most of all on the material characteristics of the used film. The conditions of the chemical development process are important too.

A compensation can be done and must be done for digital sensors.

It is nearly the same process for scanners and digital cameras. A reference image of an object with totally homogenous light density distribution is stored and produces a data set for image correction.

This correction data set has to be delivered with each digital camera or with each scanner.

Within this data set the different sensor errors, like hot spots, dark pixel errors and columns defects are registered and compensated.

This calibration process has to be repeated in case of the scanner in certain time frames.

In case of digital cameras there is no experience until now, if this radiometric calibration has to be repeated.

For our opinion it has to be done only once during production. This statement has to be proven within the next years, when cameras work out in the field.

2.3.6 A/D Conversion

This step influences the radiometric accuracy only. Here the producer of the camera or scanner has to guarantee his specifications.

Scanners should have a dynamical range of 10 bit minimum.

Digital cameras usually work with a dynamical range 12 bit.

2.3.7 Combination of multiple camera heads

In case of digital cameras more than one camera heads are combined, using identical cameras to increase the field of view and cameras for different spectral ranges.

Cameras which cover the whole spectral range produce panchromatic images: These images more ore less determine the spatial resolution of the overall system.

As an overlay for colour information called multi - spectral cameras are used. Depending on the camera system these colour cameras use less resolution than panchromatic cameras.

The relation between pixel size in panchromatic images and pixel size of colour overlay images should not exceed 1:5.

When images are combined to one larger image The maximum grey value difference at the seem line has to be specified and guaranteed by the producer.

If more than one lens system and more than one shutter is used, the difference between two panchromatic or two multi spectral cameras has to be less than +/- 5%. That means less than +/- 20 grey values for 12 bit images.

2.4 Test possibilities for the end user

The scanner can be tested very easily, using defined reference cards in case of radiometry.
Glass plates with exactly positioned test structures are used to test scanners and certify accurate geometry.

The geometrical accuracy for the overall process, including film based camera and scanner or digital cameras, can be tested by flying across test fields. These fields contain reference objects with exactly known geometrical positions. The measurement within the images prove the accuracy of the system.

To test the overall process for exactly radiometric results is not so easy to handle, either with film based cameras and with digital systems.
If reference cards with defined grey values or colours are used, you cannot overcome the influence of the air between reference object and camera. Reliable test methods for radiometry are under investigation.

REFERENCES

Diener S., Kiefner M., Dörstel C., 2000. Radiometric Normalisation and Colour Composite Generation of the DMC, IAPRS Vol. XXXIII, Amsterdam 2000

Fraser, C. Digital camera self-calibration. ISPRS Journal of Photogrammetry and Remote Sensing. 1997; 52(4):149-159.

Hinz, A. ; Dörstel, C, Heier, H., 2000. DIGITAL MODULAR CAMERA: System Concept and Data Processing Workflow, Proc. IAPRS Vol. XXXIII, Amsterdam, 2000

Hinz, A., Dörstel, C, Heier, H., 2001, DMC – The Digital Sensor Technology of Z/I-Imaging, Photogrammetric Week 2001, Eds D. Fritsch / R. Spiller, Wichmann, Heidelberg pp 93 - 103.

Talley, B.B., 1938. Multiple-Lens Aerial Cameras, in Engineering Applications of Aerial and Terrestrial Photogrammetry, Pitman Publishing Corporation, New York & Chicago

Graham, L., 2001, Workflow Oriented Sensor Management Systems,
Photogrammetric Week 2001, Eds D. Fritsch / R. Spiller, Wichmann, Heidelberg pp 25 - 33.