MULTISPECTRAL ANALYSIS OF DIGITAL IMAGE DATA IN ARCHITECTURAL PHOTOGRAMMETRY

Robert Godding
Institut für Photogrammetrie
und Bildverarbeitung (IPB)
Technische Universität Braunschweig

Giesbert Sacher
Meßbildstelle, Gesellschaft für
Architekturphotogrammetrie mbH
Dresden

Gunnar Siedler
Institut für Photogrammetrie
und Fernerkundung (IPF)
Technische Universität Dresden

Germany
Commission V

ABSTRACT

A combination of the digital methods of close range photogrammetry for the determination of object geometry and remote sensing for a multispectral determination of object attributes by using classification algorithms is useful for various applications. The image data can be recorded directly with a digital device, for example with a low resolution CCD-camera or the high resolution Réseau-Scanning-Camera. Additionally, an analogous recording on film with a later digitisation is possible. The different spectral bands are selectable by using different filters during the image recording.
First results of a multispectral and multisensor data acquisition and evaluation in an architectural application will be presented.

Key Words: digital multispectral image data, image acquisition systems, filters, classification

1. INTRODUCTION

Multispectral image analysis allows the determination, localisation and quantitative recording of object attributes by analysing their special emissions and reflections with multispectral recording systems.
The main application of multispectral image analysis is the wide field of remote sensing. The idea of terrestrial use was derived from geological applications. Terrestrial multispectral data recording has been applied since 1980 for open cast mining and other geological sample sites.
Then, first analysises of buildings were effected where the distinction of different building materials was the major field of interest. Simultaneously, the experiences made in the field of painting analysis were of use in this sector. Photos in different spectral ranges were taken for damage anaysis although the data material was mainly evaluated visually.
At present, the spectrum used in close range applications reaches from X-rays to the thermal infrared light. In most applications, spectral information from 350nm to 2000nm is applied. The improvement of digital image processing methods together with the availability of different kinds of digital sensors for the image acquisition and more powerful computers allow a wide range of new applications and the development of new methods.
In the following, some possibilities of digital multispectral image acquisition and evaluation as well as results of a survey of an architectural object will be presented.

2. RECORDING AND EVALUATION SYSTEMS

2.1 Cameras and Scanners

The recording of digital images is possible with CCD-cameras on-line, or by digitising analogous photos off-line.
The on-line usage of usual CCD-sensors with approximately 768 x 512 pixel is restricted to applications which only require a low resolution. Digital cameras with larger solid state sensors and a higher resolution are very expensive or are not available on the civil market [Luhmann, 1991].
For this reason, the realisation of higher resolutions and larger image formats is reached by using different techniques, which in most cases are based on the recording of parts of an entire image with a moving sensor. The precise orientation of the partial images relative to the entire image can be achieved mechanically (for example with a piezo-unit at the micro-scanning camera) or optical and numerical by using the réseau technique (réseau-scanning) [Wester-Ebbinghaus, 1989].
For the digitising of analogous photos, several instruments are available on the market. Here as well, different scanning techniques are known. Most scanners work with a CCD-line or with a CCD-matrix sensor and the required accuracy can be reached with a high precision mechanism or with optical and numerical methods as used in réseau-scanning.
For the image acquisition of photos, the use of metric cameras or middle-format réseau cameras is most efficient.

2.2 Filters

For the recording of special object attributes, different ranges of the electromagnetic spectrum can be selected by using the corresponding filters. With this method, it is possible to obtain independent images of the different spectral regions with high contrast.
To reach optimal results, it is necessary to use filters with steep edges and a limitation of the transmission on both sides. These conditions are given in metal interference filters with a transmission range of 20 to 40 nm. In the infrared region (>800nm), the half-wave breadth of the transmission is even larger.
A reduction of the half-wave breadth for a better selection of object attributes is limited by the decreasing transmissivity and is only efficient if spectral characteristics of different object attributes are well known.
In the field of art analysis for example, extensive measurements of spectral reflections of pigments and binding materials with defined artificial illumination were investigated, which resulted in the exact knowledge of the spectral behavior [Asperen de Boer, 1970]. With this knowledge, it is possible to select these spectral ranges, most useful for defining particular object characteristics. In architectural applications, especially in the recording of buildings, in most cases it is impossible to reach similar constant conditions because of the changing illumination situtation.

2.3 Evaluation Systems

For the evaluation of multispectral image data, a wide range of software systems is offered, often in combination with a link to geo-information systems. Most systems are outlined for the evaluation of remote-sensing data. The software packages which are either PC- or workstation-based, are able to convert different image data formats and allow various image manipulations such as image enhancement, image filtering and geometric transformation. Additionally, different algorithms for unsupervised and supervised classification are implemented in most cases. These algorithms are well known from different publications [e. g. Haberäcker, 1989], and will not be described here.

Fig.1 Recorded Building

3. EXAMPLE OF A MULTISPECTRAL ANALYSIS OF A BUILDING

3.1 Description of the Object

The present recording object is the building of the "Hochschule für Grafik und Buchkunst" in Leipzig (Fig. 1). For this university building, a restoration concept is being developed at present. This analysis forms part of an complete documentation of the building's condition. A part of the Northern front with different building materials and typical damages was chosen for the examination.

3.2 Object Recording

For the survey of the building, three different recording systems were selected. Two systems are on-line systems: on the one hand the low resolution CCD camera Rollei CS1 with an Valvo CCD-sensor NXA 1010 with 604 * 576 Pixel (Fig. 2), on the other hand the high resolution Rollei Réseau Scanning Camera (RSC) with approximately 4200 x 6250 pixel [Riechmann, 1990] (Fig. 3).

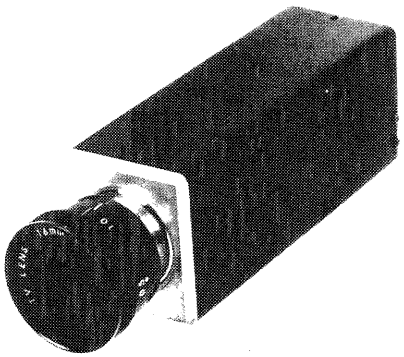

Fig.2 Rollei CCD-Camera CS1

The third system is an off-line system, using a Rolleiflex 6006 metric for an analogous film recording and a Rollei RS1 réseau-scanner for digitising (Fig. 4, Fig. 5) With these systems, two different parts of the building were recorded with different resolutions, image formats and filters as shown in Tab. 1. The digital image acquisition with all systems was done with a PC-AT386 and software packages, which had been developed at the IPB.

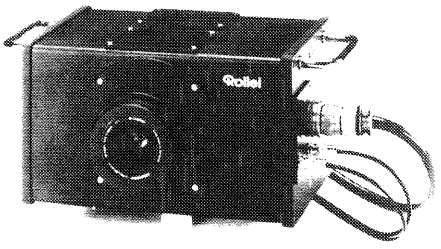

Fig.3 Rollei Réseau-Scanning-Camera

Fig. 4 Rollei 6006 metric

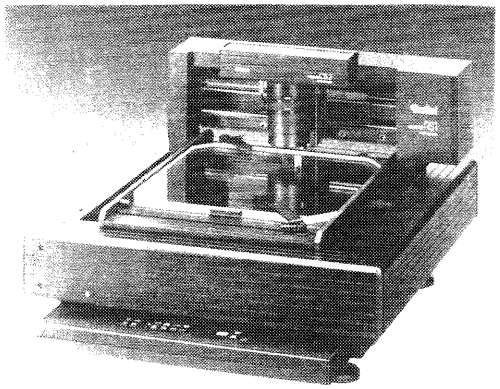

Fig.5 Rollei RS1 Réseau-Scanner

Due to the fact that there was no a-priori knowledge about the spectral behavior of the different materials, no special part but a wider range of the spectrum was selected.

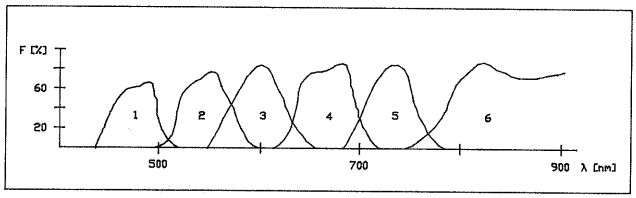

Fig. 6 Transmission curvature of MKF6 filters (from [Kronberg 1985])

In general, metal interference filters taken from the multispectral camera MKF6 of Carl Zeiss Jena, which mainly had been developed for remote sensing in geology, were used, replenished by some ORWO gelatine filters. Fig. 6 shows the transmission curvatures of the used MKF6 filters. It was tried to record images in the UV- region (315nm - 380nm), the visible spectrum (380nm - 780nm) and the near infrared (680nm - 1200nm).

Given that the CCD-sensors are less sensitive in the UV-region, with the RSC and the CS1, only the acquisition of images in the visible and in the near infrared was possible. By using different films for the Rolleiflex 6006 metric, it was possible to obtain images that covered the whole spectrum. Altogether, 11 different filters were used with the different cameras.
During the survey, favourable constant diffuse illumination with little shadow prevailed.

Recording System	Area	Image Format [pixel]	Pixelsize image [µm]	Pixelsize object [mm]	Spectral Range [nm]
RSC	1	2048 x 2048	15	6	400-1150
6006/ RS1	1	512 x 512	80	24	ORWO VF-45
		1024 x 1024	40	12	330- 730
	2	512 x 512	80	55-80	ORWO I-750
		1024 x 1024	40	20-30	680- 800
CS1	1	768 x 512	8	21	400-1150
	2	768 x 512	8	26-36	

Table 1: Image Acquisition Conditions

3.3 Image evaluation

The multispectral image evaluation was effected with the software package ERDAS(c), which was originally developed for the evaluation of remote sensing data. The software is implemented at a SUN-workstation of the IPF at the Technical University Dresden.
In a first step all corresponding images were geometrically transformed to a common basis. In order to reduce the amount of data, principal component transformation was effected with the 7 - 8 original bands; for further evaluation, the first four synthetic channels were used.
The spectral behaviour of the observed material was unknown and a determination of training-areas for a supervised classification became difficult. Therefore, for a first analyse a minimum distance operator was used for an unsupervised classification of the images.

3.4 Results

3.4.1 Handling of the Recording Systems

The low resolution camera Rollei CS1 is a low cost camera which is easy to handle. The arising amount of data (approx. 0.4Mbyte per image with a resolution of 768 x 512 pixels) can easily be processed with a PC. The image acquisation with this camera was done in short time (approx. 30 seconds per image incl. filter changing, adjusting focus and aperture and image storing.) A disadvantage can be seen in the low resolution which only allows a detection of coarse structures.
With the RSC, the size of the scanned pixel is selectable from 10µm to any lower resolution. An additional advantage is the possibility of focussing without the necessity of changing the interior orientation, especially when further photogrammetric evaluations have to be effected with these images. The RSC thus allows a very flexible selection of parameters (aperture, sensor-gain, focus, pixelsize, size of the scanned area) for every application. A disadvantage of the RSC, which is also true for other systems using a scanning sensor, can be seen in the relatively long time necessary for receiving images. For this time constant illumination conditions are required.

Advantages similar to the RSC are given for the digital images, which originate from the scanning of photos acquired with the Rolleiflex 6006 metric. Also with the réseau scanner RS1, a digitisation with a selectable pixel size is possible. Film deformations can be taken into account by measuring the réseau crosses [Sinnreich 1989]. From the same photo, digital images with different resolutions could be derived, a fact which is highly useful for studying the impact of resolution on the evaluation quality. A disadvantage must be seen in the difficult image acquisition which cannot be controled in the on-line mode. Further disadvantages are the delay between image acquisition and evaluation as well as the relatively high costs for the entire system. Nevertheless, the best results were obtained with exactly this system.
Advantageous for a successful evaluation was the possibility given with the on-line systems to control the results of image acquirement directly. It was thus easily feasible to react very flexibly on changing illumination and the different filter reactions. With the film camera, it is very difficult to find the right adjustment of aperture and exposure time for the different filters.

3.4.2 Multispectral Analysis

Until now there was only a evaluation of parts of the data. So the derived results are partly preliminary and allow no generalization. Results of sooner investigations can be confirmed [Grunicke et al., 1990]. The following conclusions can be drawn:

- It is possible to distinguish between different building materials.

- For the different materials, a classification of damages was possible, the correlation of the determined classes to other materials is not possible.

- On account of correlations between the images a selection of some filters well distributed over the examined spectral band leads to similar results as the evaluation of the synthetic channels of a principal component transformation from all channels.

- For the examined object, a target size of 2 cm x 2 cm was sufficient for the evaluation.

- Classification results of the digitised analogous photos and of the CCD-Cameras are well comparable.

- The results from the evaluation of both recorded areas of the building are comparable.

4. CONCLUSION AND FUTURE ASPECTS

The results of the multispectral image recording allow different conclusions and lead to further studies.

- The use of simple CCD-Cameras for multispectral image recording is suitable for a wide range of applications.

- It is possible to distinguish between different building materials and to determine damages.

For the improvement of the method, further studies have to be made:

- A detailed analysis of characteristics of different materials, comparable to similar analysis in remote sensing, seemes to be useful for the determination of applicable combinations of filters and sensors.

- Radiometric calibration of the used sensors or radiometric corrections of the digital images seem to be helpful if the illumination changes.

- An extension of the applicable spectrum into others (for example the thermal infrared or the microwave region) gives more information.

- The algorithms for the image processing, especially for the classification of the data, have to be adapted and optimised for the special requirements of close range applications.

In general, the facilities of digital multispectral image acquisition and evaluation offer a large potential of applications. Especially in combinations with the photogrametric methods of geometric evaluation the digital multispectral image data will become more and more useful for a complete analysis of the quality and geometry of an object.

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