DATA FUSION AND DATA INTEGRATION OF RASTER AND VECTOR DATA

Dr.-Ing. Manfred Wiggenhagen, Institute for Photogrammetry and Engineering Surveys,
University of Hannover, Germany

Commission VI, Working Group 1

KEY WORDS: Education, Training, Fusion, Format, Method, Mosaic, Software

ABSTRACT:

This paper presents methods and algorithms for data fusion and data integration of digital raster and vector data. In education and training it is very important to explain the differences of standard image file formats, the necessary transformation methods and practical solutions for image processing on personal computers and workstations. Principally two different data types have to be considered. Raster formats of digital satellite and digitized aerial photographs as well as vector formats for all additional interpretations can be handled by most of the known standard and individual software packages. It is shown that standard hardware and software components on modern personal computers are sufficient for image interpretation and image processing in education. To enlarge the acceptance of potential applicants new individual image processing software has been developed which will be described in this paper. With this software geometric image correction, rectification, digital image mosaicing and radiometric correction of digital images can be carried out in education and training.

KURZFASSUNG:

Dieser Beitrag beschreibt Methoden und Verfahren zur Datenverknüpfung und -integration digitaler Raster- und Vektordaten. Innerhalb der Lehre und Weiterbildung ist es sehr wichtig den Auszubildenden die Unterschiede zwischen Standardbildformaten, notwendigen Transformationsansätzen und praktische Lösungen für die Bildverwaltung auf Personal Computern und Arbeitsstationen aufzuzeigen. Es müssen grundsätzlich zwei unterschiedliche Datentypen berücksichtigt werden. Standard- und Individualprogramme verarbeiten Rasterformate der digitalen Satelliten- und Luftbilder ebenso wie Vektorformate aus zusätzlichen Interpretationen. Es wird gezeigt, daß Standardhardware- und Softwarekomponenten auf modernen Personal Computern für die Ausbildung ausreichen, um Bildverarbeitung und Bildinterpretation durchzuführen. Um die Akzeptanz der Software durch mögliche Anwender zu erhöhen, wurde neue Individualsoftware entwickelt, die in diesem Beitrag beschrieben wird. Mit dieser Software können innerhalb der Ausbildung geometrische Bildkorrekturen, digitale Entzerrung, digitale Mosaikbildung und radiometrische Korrektur digitaler Bilder durchgeführt werden.

1. INTRODUCTION

In the field of scientific education and training it is very important to use standard hardware and software components. Although operational processing tools are installed on UNIX-based workstations, the application of modern PC based systems is necessary to reduce costs and to enlarge the software acceptance of students and applicants. Therefore several PC-based software tools have been developed at the Institute for Photogrammetry and Engineering Surveys of the University of Hannover (IPI).

1.1 General Requirements

For digital data fusion different standard image formats have to be considered. On UNIX-based SUN workstations the SUN rasterfile format is one of the most common image formats.
It is used for image storage as well as for the storage of digital elevation models.
To enter the field of PC-based applications all digital data sets have to be converted to the usual PC image formats PCX, BMP or TIF. Most of the digitized aerial photographs include additional translations, rotations and scalings. The orientation and the resolution of these images and digitized maps have to be matched before final data integration steps can be carried out. In the mentioned educational software modules different orientation angles will be calculated from two up to four tiepoints. Image resolution and map scaling are also calculated by two measured tiepoints.
To enable operational data access an overall map scale has to be fixed before serving as a base map. For remote sensing applications a map scale between 1 : 25 000 and 1: 200 000 is recommended. In the field of terrestrial photogrammetry scaling is set to 1 : 150 up to 1 : 20. For the rectification of remote sensing images, topographic maps or base maps will be digitized with a flatbed scanner and are used as raster images for the later data fusion and mosaicing process. In the case of terrestrial applications, existing line drawings will be digitized or vector data sets will be used for the following registration and interpretation steps.

Both data types have to be displayed and edited by the visualization and measuring software.

1.2 Education Goal

Digital photogrammetric methods require knowledge of the image data sets, the annotation data and all necessary algorithms to produce the digital output.
Therefore the candidates or students have to learn how digital data sets have to be processed in order to reach good quality and accuracy in the processing results.
This is shown by digitized aerial photographs, satellite images and digitized maps. Additional ground control points are calculated with location in image coordinates and geographic or cartographic coordinates.
The dependencies between high and low resolution, necessary high and low data storage requirements and the resulting accuracy will be outlined in the lectures and exercises.
To enable follow on training all image processing steps will be shown on PC-based systems under MS-Windows.

1.3 Experience after completion of Training

After training with typical photogrammetric examples the students should possess experience in following areas:

- conversion of image formats,
- image transfer between different hardware and software systems,
- application of flatbed scanners and digitizers or onscreen digitizing tools,
- application of rectification programs,
- application of image enhancement methods,
- calculation of geocoded or georeferenced digital image data sets,
- data fusion results for later data integration applications.

2. HARDWARE AND SOFTWARE EQUIPMENT

In addition to the well known analog and analytical photogrammetric equipments the computer software and hardware plays a growing role at IPI. To fulfill educational and research requirements additional individual software for image processing and adjustment has been developed in the past.

2.1 Hardware Requirements

Until 1988 operational image processing systems have been implemented on VAX (VMS) mini computers and SUN (UNIX) workstations. Depending on research projects additional individual software has been developed on both platforms. To enlarge the students' acceptance of image processing tools it was very important to integrate new functions also on personal computers.
Therefore a large number of modules has been converted to C-language operating under MS-DOS and MS-Windows since 1985.

Today powerful PENTIUM PCs with two or three Gbyte disc storage are installed. But most of the students work under following hardware conditions:

- CPU 486/66 Mhz,
- 500 Mbyte disc,
- 16 Mbyte RAM,
- 1,44 Mbyte floppy disc,
- CD-ROM
- Mouse,
- Ink-Jet Printer,
- 15" or 17" color monitor.

Of course there are always new hardware modules with more powerful CPUs and better peripherals, but for educational purposes a running system under above mentioned conditions is more recommended because a running stable system is much better than a state of the art system with unknown bugs and internal problems which prevents the user from working.
Additional peripheral devices are necessary to enable data exchange, image processing and digital video applications:

- Ethernet board,
- SCSI Interface and Flatbed scanner,
- backup streamer tapes,
- digitizer or digitizing pad,
- graphic board with variable resolution (480x640 up to 768x1024 pix) in 256 colors (32768 or 65535),
- frame grabber board.

2.2 Software requirements

For operational purposes or industrial applications a lot of very powerful but also expensive software systems are installed. Tools like ERDAS, EASY/PACE, MGE or for example IDL/ENVI are well known in the areas of remote sensing, image processing and digital photogrammetry. For education and training very often low costs systems are preferred. Therefore public domain tools like KHOROS or GRASS are installed at the Institute. In addition standard PC-based software in combination with individual software is used at IPI, Hannover.
To enable analog to digital conversion of photographs and maps scanning software is required. For this purpose the scanning software of the HP Scanjet IIcx is sufficient. On PCs this software is accomplished by drawing and low-level image processing software like ALDUS-Photostyler or Photoshop. To meet all requirements of education and training contents additional individual software has been developed at the Institute. The modules enable following processing steps:

- image format conversion, digital filtering,
- geometric correction,
- onscreen digitizing,
- mosaicing.

To connect ARISTO or Summagraphics Digitizers standard software as well as individual drivers are used.

2.3 Individual Software Tools

For data fusion, image visualization and data integration several individual software tools have been developed. The program VIEWPL allows image coordinate measurements with the graphical mouse on the PC screen. It displays raster images in BMP-image format.
A very simple on-screen digitizer with additional graphical overlay function is realized in the module LINEPL.
With the on-screen digitizing tool ONSCRE up to ten classes can be measured and saved onto disc. This is done with additional geolocation information and in standardized database format (dBase).
The rectification program BPROTRA is based on an eight parameter projective approach. It is used for all required resampling purposes dealing with image to image registration in flat terrain (Albertz, Kreiling, 1980).
The mosaicing of edited satellite images, for example ERS-1 radar images, will be carried out with the data fusion software MOSES.
Image conversion software has been implemented to handle SUN rasterfile format and MS Windows BMP-formats. The functions are SUNTOBMP and BMPTOSUN.
To immediately start the on-the-job training it is recommended to use also standard PC-software which is always present on PCs.
For image display and painting the MS-Windows program PBRUSH is used. If the candidates have to edit ASCII textfiles or coordinate files the NOTEPAD editor is always sufficient.
Very important to handle MS-DOS applications under MS-Windows is the PIFEDIT module. This function is not necessary under MS-Windows '95 any longer.

3. SOFTWARE DESIGN

Depending on institutional software requirements the above mentioned tools have been developed in C-programming language under MS-DOS and MS-Windows.

3.1 MS-DOS Software

To ensure batch ability and to be independent from any graphical user interface (GUI) the following modules have been developed in C-language:

- BPROTRA,
- MOSES,
- SUNTOBMP,
- BMPTOSUN.

Most of the software developers know the problems with memory management under MS-DOS.
Caused by the 65 kByte border it is impossible to work with large image arrays stored in the main memory area. To avoid these complications and to work without additional memory DOS extenders all mentioned modules work line-oriented in direct access to the image files stored on disc.

3.2 MS-Windows Software

Most of the modern software tools work under graphical user interfaces like X11, Motif or MS-Windows. To use all the built-in features of MS-Windows all new software modules have been developed under this user interface programmed in C or C++ language.
The GUI allows multiwindow application, access to several preinstalled device drivers and additional peripheral equipment.
To enable fast image display and simple image coordinate measurement in images and maps at the same time the modules VIEWPL, LINEPL and ONSCRE are inplemented under MS-Windows.
All programmes are menu-driven with file-I/O functions and graphical mouse support.
The above mentioned DOS modules are called from these tools by system calls using program interface files (PIF).

3.3 Implementation

To show some of the training steps the detailed implementation of the additional software is outlined now.
In most of the digital image processing applications the first steps will be the image display, the measurement of tiepoints in digital images and the rectification of the image to a given map reference.
All these functions are covered by VIEWPL, which loads 8-bit raster images and displays them with 256 colors or greyvalues. A roam function is realized to handle images which exceed the monitor dimensions. The measurement of image coordinates is carried out by the pointing device (mouse cursor).
The measured coordinates and image dimensions are stored on ASCII files for further calculations. To compare original and reference image location the program can be started simultanously with both images at the same time.
Input data for the program are raster images and digitized maps, output data sets are two text files with corresponding image coordinates for the following rectification process.
The projective transformation is calculated with the programm BPROTRA, which stands for Bytewise PROjective TRAnsformation.
The perspective distortions are corrected in a straight approach with four measured tiepoints. Without any adjustment this approach uses the eight transformation coefficients for the indirect resampling of the digital input image (Brandstätter, 1995). The corrected output image will be stored in 8-bit and also 24-bit BMP raster image format.
A very important processing step is the quality control of the rectified image. For this task the programmes LINEPL and ONSCRE have been implemented. Both modules are able to visualize raster images on screen and to add graphical overlays derived from vector data sets.
The vector information can be edited, deleted and updated with the pointing device. The onscreen digitizer ONSCRE additonally offers functions to generate database interface files and a mosaic control file for the following mosaicing software (Wiggenhagen, 1993). With this tool the user can define regions of interest which will

be matched in the calculation of image mosaics. The database exchange file can be converted with CLIPPER database software to dBase standard format.
This interface is important for the data integration into GIS. With this link object and attribute collections can be included into ARCVIEW (Buhmann, Schaller, Bachhuber, 1996; Wiesel 1996).

4. EXAMPLES

Most of the following image examples are used in education and training at IPI, Hannover.
To reach better throughput they are limited to image dimensions up to 1024x1024 pix. This is only to get fast results while the education is going on. The programmes normally have no limitation in the image dimensions.

4.1 Digitized aerial photographs

To show the large amount of details in a vertical aerial photograph, an image of the Great Royal Garden in Hannover has been digitized with a resolution of 150 dpi (Fig.1).

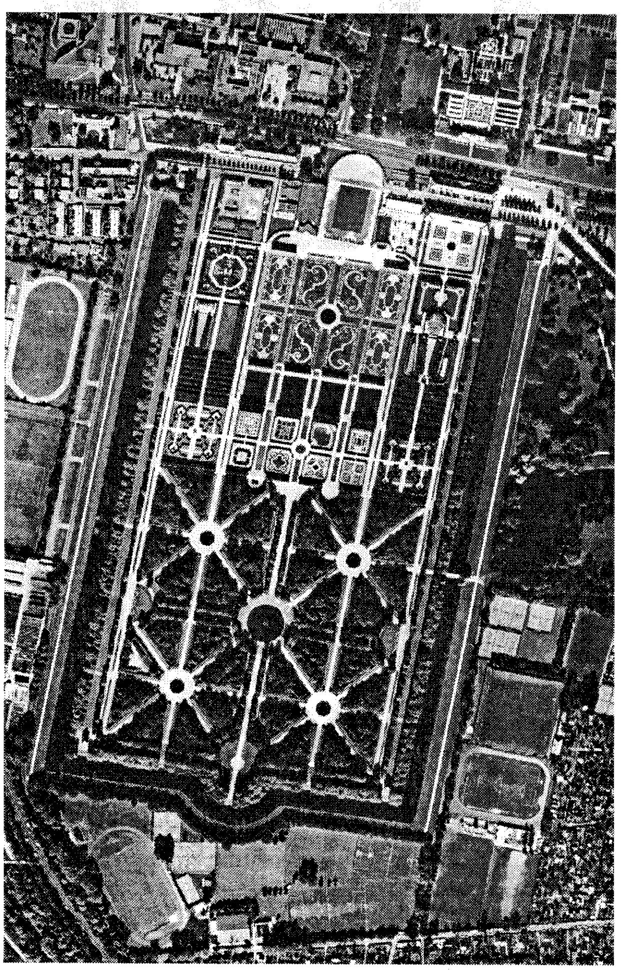

Fig.1, Digitized aerial photograph

To get all details it is recommended to scan with 600 up to 1200 dpi, but for educational purposes it is a good compromise to reduce the required amount of disc space by using a reduced resolution.
In comparison to this image an oblique amateur photograph has been digitized.
This is used to demonstrate the effect of perspective transformation in the image to image registration (Fig.2).

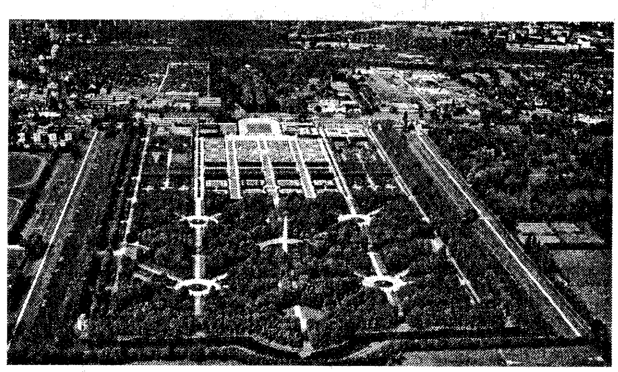

Fig.2, Oblique photograph

4.2 Digitized maps

For quality control purposes a digitized city map in the scale 1 : 20.000 is used (Fig.3).

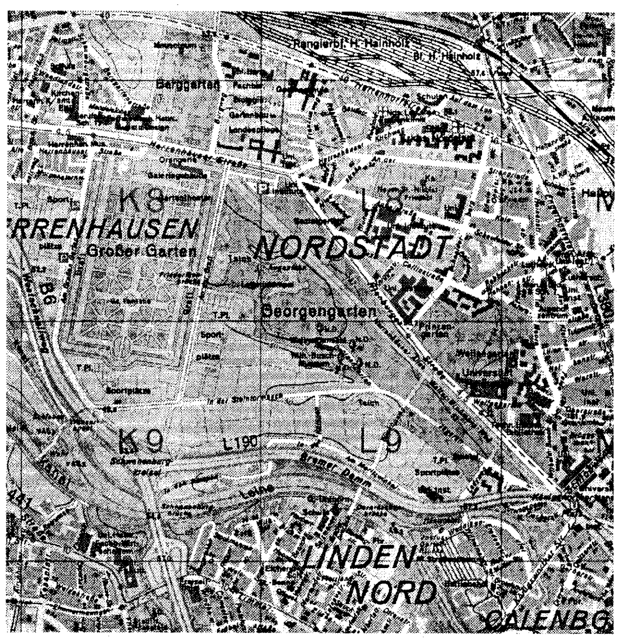

Fig.3, Digitized city map

For the registration of satellite images a topographic map in the scale 1 : 100.000 has been digitized.
With the program ONSCRE several objects in vector presentation are measured in the digital image. This vector information can be superimposed with the rectified aerial image. This is a fast approach for a first visual quality control.
For the final quality control tiepoints in image and map have to be measured and residuals can be calculated and displayed with additional software.

4.3 Satellite images

From actual remote sensing projects three ERS-1 GTC images have been combined to a RGB-composite (Fig.4) (Lotz-Iwen, Göbel, Markwitz, 1995).

Fig.4, ERS-1 radar image

This image will be matched with the topographic map (Fig.5).

Fig. 5, Digitized topographic map

The data fusion between map and radar image is very important for the advanced interpretation of the radar image. A visual quality control is also possible, but generalization effects in the map have to be considered.

4.4 Terrestrial photographs and line drawings

To show that the software is not only applicable for spaceborne and airborne images there are also examples from terrestrial applications. Under the condition that all tiepoints have to be measured in one flat area, parts of a building can be rectified (Fig.6).

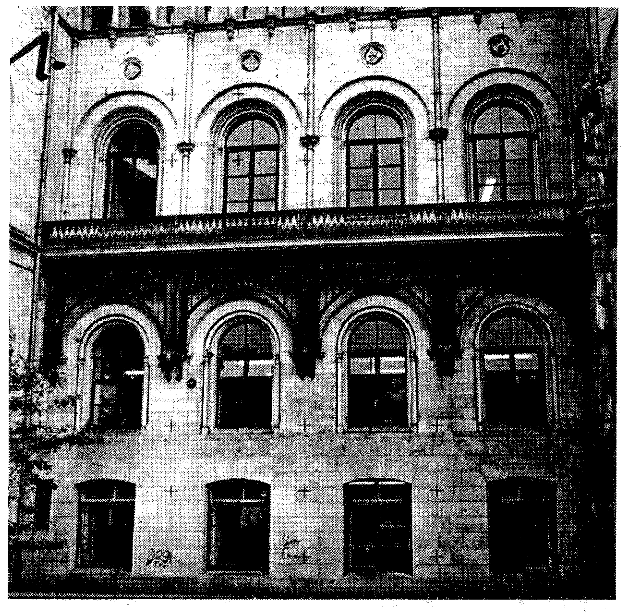

Fig.6, Architectural photograph

As reference serve local coordinates, which have been measured with an electronic tachymeter or existing line drawings, which have been digitized on a flatbed scanner (Fig.7).

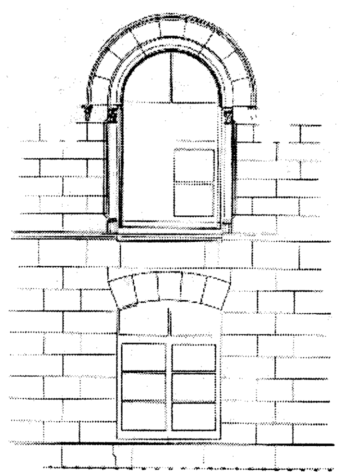

Fig.7, Digitized line drawing

With the geolocation function of the program ONSCRE digital monoplotting can be carried out (Frick, 1995; Heipke, 1995). Measured objects can be stored in local coordinates and image coordinates, too. This tool in combination with BPROTRA is used for student education at IPI every year.

5. FUTURE DEVELOPMENTS

All described software is still under development. This is an advantage, because all user requests and also critical functions in education and training can be considered in the last upgrade.

5.1 Functionality

Based on user requests the projective transformation BPROTRA will be converted to MS-Windows. During the education there were some problems fixed with the display tool VIEWPL. The new version will be extended with functions for subpixel measurements, new zoom and roam functions and on-line rectification methods.
The on-scren digitizing tool ONSCRE will contain additional functions for object attribute definitions and accumulating mosaicing functions.

5.2 Conclusions

Today it is always advisable to develop individual software for image processing and digital photogrammetry. Only then it is possible to include all features a user requests. A growing modular software will lead educational projects as well as research projects to good results.
Of course, there exist a lot of commercial software installations for operational production, but with standard software not all problems can be solved.
A toolbox which can grow with the requirements of a project is the best solution. This task can be covered by individual software and by flexible processing systems, which are open for the integration of additional own modules.

6.LITERATURE

Albertz, J., Kreiling, W., 1980, Photogrammetrisches Taschenbuch, pp. 43,44, Wichmann Verlag.

Brandstätter, G., 1995. On a Most Uncomplicated Method of Projective Normal Case Transformation. Photogrammetrie und Fernerkundung, ZPF, 5/95 pp.189 - 198.

Buhmann, Schaller, Bachhuber, 1996. ArcView, GIS-Arbeitsbuch. ISBN 3-87907-281-7, Wichmann Verlag.

Frick, W., 1995. Digitale Stereoauswertung mit der ImageStation. Photogrammetrie und Fernerkundung, ZPF, 1/95 pp. 23 -29.

Heipke, Ch.,1995. Digitale photogrammetrische Arbeitsstationen - die Photogrammetrischen Auswertesysteme der Zukunft. Photogrammetrie und Fernerkundung, ZPF, 1/95 pp. 2 - 3.

Lotz-Iwen,Göbel,Markwitz, 1995. ISIS - Fernerkundung für jedermann. ISBN 3-87907-286-8, Wichmann Verlag.

Wiesel, J., 1996. Praktischer Einsatz von Geoinformationssystemen, GIS-Arbeitsbuch. ISBN 3-87907-280-9, Wichmann Verlag.

Wiggenhagen, M., 1993. Development of Preparation Tools for Mosaicing of ERS-1 Geocoded Image Data. ISPRS Working Group IV/2, Proceedings of workshop and conference „International Mapping from Space“ , Volume 15, IPI Hannover.