PHOTOGRAMMETRY AND GEOINFORMATION TRENDS

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ABSTRACT

Technologies are changing depending upon the development sometimes slow, sometimes very rapid. A typical example is the introduction of the digital photogrammetry which has been established in a very short period because of the obvious advantages. The development in other fields may not be so fast. A typical trend which exists just now is the introduction of digital photogrammetric cameras which started slowly up to solving the operational problems, but now it is coming very fast. Also the very high resolution satellites are entering the field of large scale mapping.

The image orientation traditionally based on bundle block adjustment is slowly changing to the combined adjustment with GPS projection centers and now also to the direct sensor orientation, determining the full exterior orientation by a combination of GPS and an inertial measurement unit. Some existing problems with this new technology are solved by a combination of the direct sensor orientation with bundle block adjustment, leading to integrated sensor orientation.

The progress of automation in object recognition is slow and still in the field of research. The few published results about real projects do show the today existing limitations, up to now the solutions are very special and cannot be transferred to other areas and similar objects.

The determination of digital elevation models (DEMs) by laser scanning for detailed and accurate data is an operational technique, only limited by the financial situation. The DEM generation by automatic image matching, especial with digital cameras, is still in use but has limitations in areas with low contrast and also in cities. There is a big progress in DEM generation by interferometric synthetic aperture radar (InSAR) airborne and also space borne, but it is only economic for covering large areas and it has limitations in cities.

Orthoimages have found a large field of application and are established. There is now a slow trend to true orthoimages, showing the object exactly in a parallel projection, that means the buildings not from the side and bridges also without deformations. But for the generation of true orthoimages a detailed 3D-model must be available together with a larger image overlap and this is very expensive, limiting the development.

1. INTRODUCTION

Today maps are not the primary results of mapping. The data acquisition will be made in a geo-information system (GIS) and maps are just a representation of the contents. In a GIS the data are available with the national coordinates, sometimes also with geographic coordinates, so there is no scale of the representation defined, but nevertheless the information contents, especially the details are related to a representation scale. By this reason usual the expression map scale is also used for a GIS. By the fact of the availability of the original data, the representation scale is not totally fixed and there is still a possibility of a small variation of the representation scale but it is not exceeding the factor 2 between the smallest and the largest scale. For a map representation the accuracy of 0.25mm in the map scale is sufficient, but for some purposes like property survey or utility systems the coordinates may have an accuracy exceeding the requirement of a graphical representation. Usually the information contents are the more limiting factor for mapping. In large scales more details are available like in small scales and in smaller scales the original information is generalized.

Generalization is not a major topic of large scales but it starts with limiting the size of building extensions which shall be included in the data base.

Between the map scale and the scale of photogrammetric images there is a relation based on experience. Under usual conditions the ground sample distance (GSD) or the distance between neighbored pixel centers projected to the ground, should be in the range of 0.05mm up to 0.1mm in the map scale. So for a map scale 1 : 2000 a GSD of 10cm up to 20cm is required. The selection of the lower or the upper figure is depending upon the area and the contents included in the GIS. So for an Indian village with small and not regular buildings a larger image scale is required like for new build up areas in the USA where the streets are wider and the buildings are very regular and larger. In addition in some countries more details are shown in the maps like in others.

The primary data source for mapping is wider like before. Digital cameras are getting a larger market share and the perspective cameras are supplemented by multiple line scan cameras.

2. PHOTOGRAMMETRIC IMAGES

2.1 Digital Array Cameras

Digital photogrammetry is the state of the art. If analogue photos are taken, they have to be scanned. This additional step in the processing chain can be avoided if digital cameras are used. We do have a very clear tendency in replacing analogue by digital cameras. Digital images are not influenced by the photographic grain, so the image quality is usually quite better. In addition the radiometric resolution is usually better, so also elements located in shadows can be identified better in images taken by digital cameras like in analogue photos. The digital cameras are more sensitive and operational also under poor light conditions. Digital cameras have to be separated between array cameras and CCD-line cameras. Line cameras have to be used in connection with direct sensor orientation equipments because the orientation of each single line has to be known while the use of digital array cameras corresponds to the use of analogue frame cameras.

Analogue cameras with an image size of 230mm x 230mm under operational conditions do have a resolution of 40 line pairs per mm (lp/mm) or even better. Based on experience one line pair corresponds to 2 pixels, so the resolution corresponds to 80 pixels/mm or over the image size of 230mm to 18400 pixels. There are no CCD-arrays available with this size, so the Z/I DMC is combining 4 arrays each with 4096 x 7168 to a synthetic image of 8000 x 14000 pixels and the Vexcel UltraCam$_D$ combines 9 CCD-arrays of 4008 x 2672 to a synthetic image of 7500 x 11500 pixels. There is a larger group of digital cameras equipped only with one CCD-array. Because of the distribution and the fixed relation to an inertial measurement unit (IMU) the Applanix DSS and because of the possible, but not fixed combination of up to 4 cameras the DIMAC camera are included in the list.

array camera	pixels	pixel size	focal length
Z/I DMC	8000 x 14000	12 µm	120mm
Vexcel UltrCam$_D$	7500 x 11500	9µm	100mm
Applanix DSS	4092 x 4077	9µm	55mm or 35mm
DIMAC	up to 4 times 4080 x 5440	9µm	60mm – 150mm

Table 1: digital array cameras

The DMC and the UltraCam$_D$ are equipped with a transfer delay and integration (TDI) function – the charge generated in the CCD-elements by the exposure can be shifted in one direction to the neighbored CCD-elements. So the forward motion can be compensated electronically and do allow a longer exposure time, leading to a better image quality. The FMC-function of these cameras is determining the mounting of the digital array cameras in the air plane – the small format size must be in the flight direction. The DIMAC camera is equipped with mechanical forward motion compensation (FMC). The DMC and the Ultra CAM$_D$ do have in addition to the large size of the synthetic image also additional optics for the color bands blue, green, red and near infrared but with a linear 4 to 5 times smaller number of pixels. By image fusion, the smaller number of color pixels can be merged with the panchromatic image to a high resolution color image. The lower information of the color corresponds to the sensitivity of the human eye which can separate more precise the grey values like the color. The Applanix DSS is using a color filter array – 50% of the pixels are sensitive for green, 25% for blue and 25% for red. Based on this, a full RGB-image is interpolated. With the removal of the IR-blocking filter and the introduction of a blue filter, the sensitivity can be changed to green, red and near infrared.

Across flight direction the DMC and the UltraCam$_D$ are not too far away from the information contents of the analogue film cameras. In the flight direction the format is smaller and the field of view corresponds to a normal angle camera, so more images have to be taken with the digital like with the analogue cameras. The smaller field of view in the base direction is leading by theory to a lower accuracy in height.

$$SZ = \frac{h}{f} * \frac{h}{b} * Spx \qquad \frac{h}{f} = scale - number \qquad \frac{h}{b} = \frac{f}{b'} \quad \text{=3.1 for DMC} \quad \text{3.7 for UltraCam}_D$$

Formula 1: vertical accuracy

For digital cameras the scale number and the standard deviation of the x-parallax can be joined together leading to:

$$SZ = \frac{h}{b} * Spx \quad \text{Spx [GSD (pixel size on ground)]} \qquad \text{formula 2: vertical accuracy}$$

Several tests have shown the excellent accuracy of the digital cameras. In block adjustments an accuracy of 0.2 pixels for the x-parallax has been reached (2.4 / 2 µm) – this is at least by a factor of 2 better like for analogue cameras. So the not so good height to base relation is compensated by the better image accuracy and a similar accuracy can be reached with the digital cameras like with wide angle analogue cameras, with the advantage of a better view to the ground also in city areas.

For digital cameras the accuracy in the image has to be expressed in fractions of the pixel size. For the geometry it does not matter if the pixel size in the image is smaller or larger because this is compensated by the focal length. Only the relation of pixel size / focal length is important. So also the horizontal accuracy should be expressed in fractions of the GSD. For targeted points 0.2 GSD can be reached.

The obvious advantages of digital cameras with better image quality, shorter turn around, avoiding film costs and at least the same accuracy is leading to a clear trend in replacing the analogue by digital cameras. The small format cameras Applanix DSS and DIMAC do have their special field of application. The combination of up to 4 original cameras in the DIMAC cannot be compared with the DMC or the UltraCam$_D$ because there is no fixed relation between the cameras and they have to be handled like independent cameras. The quite higher number of required images for covering the same ground area is leading to economic limitations for the classic bundle orientation. This is compensated by the direct sensor orientation, but still quite more flight lines are required. So the small format digital cameras do have their special field of application for example in corridor mapping of traverses and roads.

	flight direction	across flight direction	Table 2: percentage of pixels in relation to analog camera with 40lp/mm = 18400 pixels
Z/I DMC	43%	76%	
Vexcel UltraCam$_D$	41%	62%	
Applanix DSS	22%	22%	
DIMAC	22%	30%	

The technical comparison of digital with analog cameras has to respect the information contents and the object accuracy. An analog camera has an operational resolution of 40 linepairs/mm (lp/mm) corresponding to approximately 80 pixels/mm or 12.5µm/pixel. With the format of 230mm * 230mm this corresponds to 18 400^2 pixels. In the flight direction the digital cameras can compensate the smaller number of pixels with a higher number of images. Across the flight direction the difference in image quality has to be respected. The information contents of the DMC across the flight direction corresponds to a resolution of 30lp/mm and this is a realistic number for the comparison of the identification of objects, so the DMC is approximately on the same level of information contents in relation to analog images if a higher number of images are taken in the flight direction. 30lp/mm are corresponding to a pixel size of approximately 17µm. Most analog images are scanned with a larger pixel size confirming this comparison. In relation to the DMC the UltraCam_D has 82% of the number of pixels across the flight direction, so if the DMC is using 4 flight lines, the UltraCam_D has to use 5 flight lines. The Applanix DSS has to take 3.4 times and the DIMAC 2.5 times the number of flight lines like the DMC.

It is difficult to compare the geometric potential of the different digital and also analog cameras. The accuracy in the digital images in relation to analog photos cannot be used for a comparison. The best and most realistic possibility, respecting also the operational use, is to do it in relation to the strip width of the photo flight. For well defined points 1/3 of a pixel is a realistic accuracy. In the object space the expression ground sampling distance (GSD) is used, this is the distance of the centers of the neighbored pixels projected to the ground. It is independent upon an over- or under-sampling (neighbored pixels may overlap or may have a gap within between) and it appears as pixel size on the ground for the user. With an analog camera 10µm is a realistic accuracy in relation to 1/3 pixel. With both types a higher accuracy of very good defined points is possible, but it does not correspond to the operational accuracy.

	GSD	SX, SY	SX, SY in relation to analog camera	height / base	SZ	SZ in relation to analog camera
Z/I DMC	16cm	5cm	0.5	3.1	16cm	1.0
Vexcel UltraCam_D	20cm	7cm	0.7	3.7	26cm	1.6
Applanix DSS	56cm	19cm	1.9	3.7 /2.4	70cm / 45cm	4.4 / 2.8

Table 3: accuracy of digital cameras for strip width of 2.3km (1 : 10 000 scale for analog cameras) based on accuracy of 1/3 pixel in relation to wide angle analog cameras with 10µm accuracy

Table 3 does not include the DIMAC camera because of the large variety of the focal length, but like the Applanix DSS it cannot be compared with large format analog or digital cameras. These cameras may be economic for smaller projects. The DMC and the UltraCam_D do have a better horizontal accuracy like an analog camera covering the same swath width. The vertical accuracy for the DMC is on the same level like an analog camera while the UltraCam_D does not reach the same vertical accuracy; this has to be compensated with a lower flying height causing also a smaller swath width.

The digital cameras are more light sensitive, so they can be used also with less light like the analogue cameras.

2.2 Digital Line Scan Cameras

line camera	pixels	pixel size	view direction in flight direction	field of view across
HRSC	5272	7µm	+/-18.9°,+/-12,8°, nadir	11.8°
Leica ADS40	2 x 12000 staggered	6.5µm	-16°, nadir, 26°	64°
Starlabo StarImager	14400	5µm	-23°, nadir, 17°	62°
Wehrli 3-DAS-1	8032 (RGB)	9µm	-16°, nadir, 26°	42°

Table 2: digital CCD-line cameras

The CCD-line cameras cannot be compared directly with the digital array cameras. The achievable object point accuracy is dominated by the required direct sensor orientation – a combination of GPS and an inertial measurement unit (IMU), but it also can be improved by a bundle orientation. Such an improvement is required for the manual stereoscopic handling. Without bundle orientation the y-parallaxes are exceeding the tolerance level. Also with bundle adjustment, the achievable accuracy is limited to a little less than the GSD in planimetry and to a little more than the GSD in the height (Alhamlan et al 2004). The ground sample distance is depending upon the sampling frequency which has a lower limit, so also a lower flying altitude cannot improve the situation.

From the listed CCD-line cameras only the Leica ADS40 is commercially available and operational. The Starlabo StarImager is just starting with operational use. The HRSC from the German DLR can only be rented because of a contract between the DLR and Leica which was made for the support of the development of the ADS40 by the DLR. The ADS40 has two staggered CCD-lines, each with 12000 pixels.

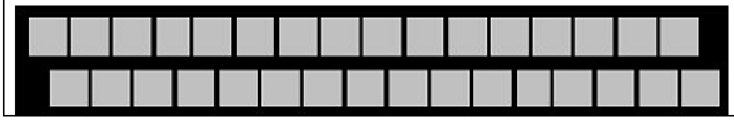


Figure 1: staggered CCD-lines

Staggered CCD-lines are shifted half a pixel one against the other (see figure 1), so by theory the resolution is improved by a factor of 2. The both CCD-lines are mounted with a small distance in the focal plane, so the combination of the staggered CCD-lines is influenced by the aircraft motion. In general the ADS40 images have to be resampled for the angular motion of the camera. This is reducing the improvement of the resolution by the staggered CCD-lines because after resampling the combination is not any more so optimal like by Theory. Becker et al 2005 have analyzed ADS40 images and have found only a resolution improvement of 8% up to 15% by the staggered CCD-lines. In addition the staggered lines are not available for the color. But nevertheless there are more CCD-elements available for the color bands of the ADS40 like for the digital array cameras leading to some advantages for object classification. For mapping by human operators this is not important.

The ADS40 has a limitation of the GSD to 10cm to 20cm. The field of application is not directly identical to the digital array cameras. Very large scale images (small GSD) can only be reached by the digital array cameras while the ADS40 has some advantages for covering large areas for topographic mapping. The better height to base relation of the CCD-line cameras in relation to the digital cameras is not leading to better height accuracies because of the excellent inner accuracy of the CCD-array cameras and the dependency of the CCD-line cameras from the direct sensor orientation, limiting the accuracy.

The digital array as well as the line scan cameras does have an advantage for the generation of orthoimages. In the case of the ADS40 the nadir view will be used having in maximum a nadir angle of 32°. If only the image part up to the center of the overlap of neighbored images in the flight direction is used, the maximal nadir angle for the DMC is 36° and for the UltraCam$_D$ it is 28°, so there is no general difference between these cameras. For an analog wide angle camera the corresponding nadir angle goes up to 41° while it is 21° for a normal angle camera.

The large digital array cameras are mainly used for large scale mapping while the ADS40 is more used for smaller scales, especially for orthoimage generation.

2.3 High Resolution Space Sensors

Very high resolution space images are available now. With QuickBird having a GSD of 62cm, IKONOS and OrbView distributed with 1m GSD, EROS A1 with 1.8m GSD and FORMOSAT-2 with 2m GSD a serious of operational space sensors are in use. As mentioned before, a GSD of at least 0.1mm in the map scale is required for a sufficient information contents. So for the map scale 1:5000 the GSD should be at least 50cm. QuickBird is very close to this and tests have been shown that the required details for mapping 1 : 5000 can be used (Topan et al 2005). IKONOS and OrbView-3 can be used for topographic maps 1 : 10 000 while EROS-A1 and FORMOSAT-2 can be used for the map scale 1 : 20 000. The very high resolution optical satellite images do not have geometric problems, with the correct mathematical model and only few control points sub-pixel accuracy can be reached

(Büyüksalih, Jacobsen 2005). The limitation for mapping is caused by the information contents; that means the GSD.

Figure 2a: IKONOS panchromatic, 1m GSD

area: Zonguldak

Figure 2b: QuickBird panchromatic, 0.6m GSD

area: Zonguldak

Figure 2c: OrbView panchromatic, 1m GSD

area: Zonguldak

The figures 2a, 2b and 2c do show the information contents of very high resolution space images. They can be compared with aerial photos with a scale 1 : 50 000 up to 1 : 80 000 based on a resolution of 12.5µm. If it will be compared with the more realistic resolution of analog photos of 20µm, respecting the photo grain, it corresponds to a photo scale 1 : 30 000 up to 1 : 50 000.

Another tool will come in the near future; the high altitude long endurance unmanned aerial vehicles (HALE-UAV). Sun energy powered automatic aircrafts shall stay over month in an altitude of approximately 20km and will take images on request (Biesemans et al 2005). The Belgian company VITO is planning to start the HALE-UAV PEGASUS which shall be able to take images with 20cm GSD. The first test flights shall be made in 2006.

3. IMAGE ORIENTATION

For photogrammetric data handling the image orientation must be known. Traditionally it will be determined by bundle block adjustment. This proven technique today is supported by tie point determination with automatic aero triangulation. Nevertheless a sufficient number of well distributed ground control points are required. The bundle block adjustment can be supported by relative kinematic GPS-positions of the projection centers. GPS has a very high accuracy potential which should be used totally by GPS carrier phases. The kinematic GPS-positioning has some limitations with the correct ambiguity solutions – the fractions of the wavelength can be determined very accurate, but the number of whole wavelength has to be estimated. During the turn around from one flight line to the next, often the connection to some GPS-satellites is interrupted, so the ambiguity has to be determined again independently for the next flight line. So systematic positional errors of the kinematic GPS-positioning cannot be avoided and they may be different from flight line to flight line. Within the flight lines a homogenous accuracy exists. The possible systematic errors can be determined by one control point at every end of each flight line – this is still a remarkable number of control points. But it is also possible to use crossing flight lines like shown in figure 3.

With such a configuration for example a block with 5100 images with a scale 1:19200 has been adjusted just using 22 control points and reaching at independent check points a positional accuracy of 25cm and a vertical accuracy of 13cm (Passini et al 2002). With larger image scale also a better accuracy has been reached.

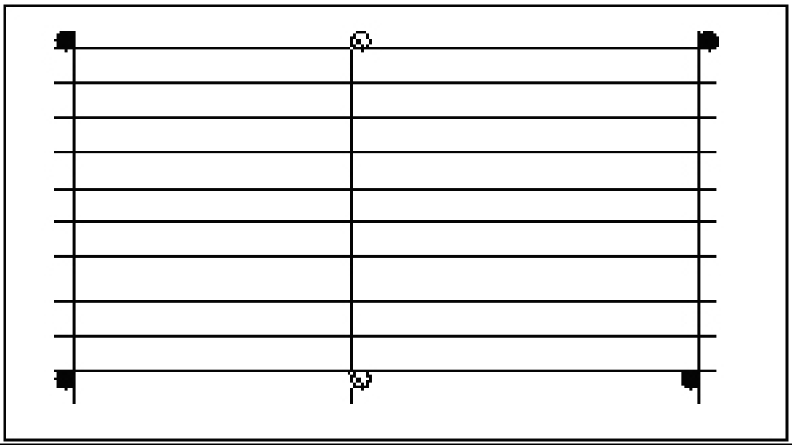


Figure 3: configuration of a combined block with GPS-projection centre coordinates

crossing flight lines every 20 – 30 base length

control points at the corners and at the end of the crossing flight lines

The combined block adjustment with GPS-positions still requires tie points, a sufficient image connection and some control points. But the exterior orientation also can be determined directly by a combination of relative kinematic GPS-positioning and an inertial measurement unit (IMU). An IMU is the basic component of an inertial navigation system (INS), but in photogrammetry it is not used for navigation, only for the determination of the exterior orientation. An IMU includes 3 gyros for the determination of the 3 rotations roll, pitch and yaw and 3 accelerometer (figure 4), which enables by a double integration of the acceleration together with the rotations the computation of coordinate differences. Today mainly fiber optic gyros are used instead of rotating dry tuned gyros. By theory the IMU is sufficient for the computation of the exterior orientation, but it has poor error propagation and only the short time accuracy is sufficient. So the IMU has to be integrated with GPS-positioning, which can guarantee the absolute accuracy with a lower frequency. By iterative Kalman filtering, the IMU- and the GPS-positioning are integrated to a full sensor orientation. IMU supports the GPS-positioning by bridging the loss of signals during the turn around and reverse GPS supports IMU by absolute positioning, avoiding the drift problems.

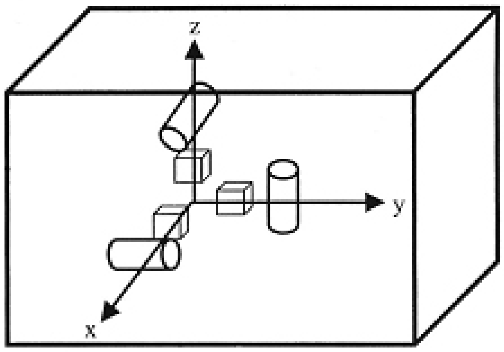
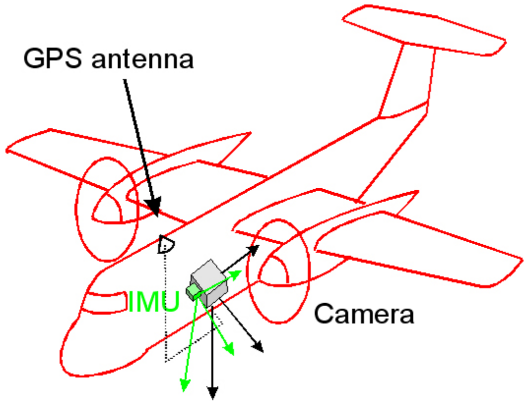
	

Figure 4: configuration of an inertial measurement unit – 1 accelerometer and 1 gyro at every axis	Figure 5: relation camera – IMU – GPS antenna

The quality of the exterior orientation determined by the combination of GPS and IMU has reached a level, sufficient for several applications. Of course such a system has to be calibrated over a test field and not only the boresight misalignment (attitude and positional relation IMU – imaging sensor, see figure 5), also the photogrammetric camera has to be calibrated under flight conditions. The laboratory calibration is not sufficient for the direct sensor orientation.

Ground point accuracy up to the range of 10cm to 20cm for all coordinate components can be reached. There are still some remaining limitations – the model set up for a stereo compilation shows larger y-parallaxes which can be solved by an integrated sensor orientation, a bundle block adjustment using the direct sensor orientation and in addition tie points which may be generated by automatic aero triangulation.

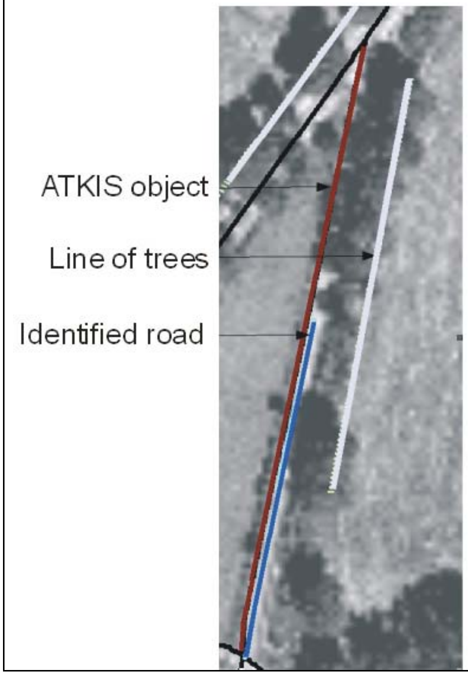
In general the direct and the integrated sensor orientation do have the advantage of a high flexibility. Control points are only required for checking purposes. Also areas where tie points cannot be determined, like water bodies, dense forest areas or deserts without any contrast can be bridged and no block configuration is required, so also isolated islands can be included without problems.

4. AUTOMATIC OBJECT RECOGNITION

A lot of research is going in the field of automatic object recognition. In large scale mapping especially the automatic reconstruction of buildings made some progress, but it is still not really operational. Also a special type of buildings like the typical German buildings with inclined roofs has been analyzed and this cannot be transferred directly to other regions.

Also with the automatic identification of the road network several limitations exists. An operational tool is under development in the University of Hannover. In a project funded by the German mapping organization BKG supported by existing information of the road network the correct location and possible changes are analyzed automatically (figure 6).

The German topographic data base ATKIS is used as pre-information for the verification of the road location. In the shown example a small offset of the road in the existing data base has been recognized and can be used for an improvement of the road location. In a similar manner also changes of the road network can be checked. This application is always used operationally, but it is limited for small scale mapping, requires the support from an existing topographic data base and a check by a human operator (Gerke 2004). In large image scales the roads are not sufficient well defined and in urban areas the roads are often partially hidden by buildings or other elements. A human operator is still able to reconstruct also an only partially visible street, but for an automatic process this is difficult. This process can be supported with a higher endlap of the images.

	Figure 6: automatic road identification based on existing information in the topographic data base ATKIS The identified road shows a small offset against the information in the data base

In the next years some progress with the automatic building reconstructions is possible, but for the other elements a solution should not be expected in near future.

5. DIGITAL ELEVATION MODELS

DEMs are basic contents of a GIS. The height information can be achieved by a human operator, but this is time consuming and not any more the state of the art. Based on stereo images the DEMs can be generated by automatic image matching. This requires a sufficient object contrast which sometimes is not available in deserts or forests. In addition the automatic image matching in build up areas sometimes is difficult especially if high buildings are available. So a combination between automatic image matching and manual measurement may be required. Because of these problems the laser scanning, also named LIDAR, made large progress. From an airplane the vector direction and the distance to the ground is measured usually by a pulsed laser. The orientation of the laser system has to be determined by direct sensor orientation described above. If the laser beam hits a tree, parts of the energy is reflected, parts may go through up to the ground. It is possible to register the so called first pulse coming from the upper vegetation level and the last pulse which may come from the ground. New systems are also able to register the full information of reflected energy from the first up to the last pulse – this may be useful for the analysis of amount of wood in a forest, but usually has no advantage for large scale mapping. The laser scanning is a proven technique, reaching accuracy between 20cm and 10cm if some reference areas are available. Like the automatic image matching, laser scanning is delivering a digital surface model (DSM) showing the height of the visible surface like buildings and dense vegetation. The DSM has to be filtered to a DEM (Jacobsen, Lohmann 2003). An example is shown in figure 7 on the left hand side – the grey value coded DEM shows the elevated objects, mainly buildings, but also some dense trees bright and the lower ground dark. An automatic filtering with the Hannover program RASCOR removed the main parts of the elements not belonging to the solid ground, but better results have been achieved after a segmentation of the objects – belonging to settlement, agriculture areas or forest.

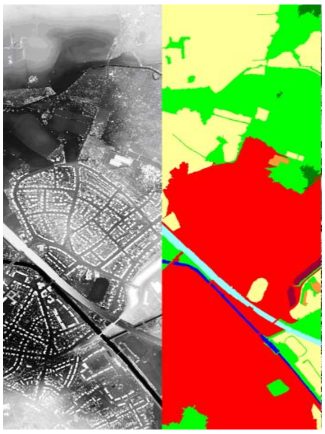


Figure 7: left: grey value coded laser scan DEM, right: segmented objects

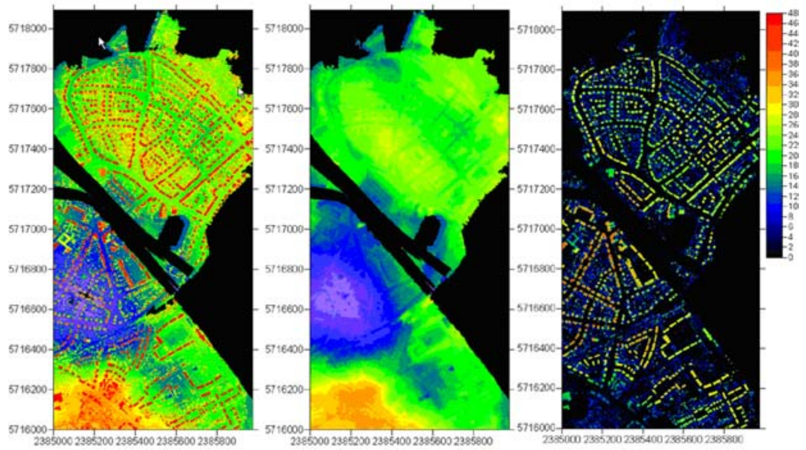


Figure 8: Left: color coded laser scan DEM
Centre: DEM after filtering
Right: extracted objects

The program RASCOR could find the required settings for the filtering more optimal separately for the different segments (build up areas, forest, rural). The finally achieved filter results are shown in the color coded DEM in the centre image of figure 8 which has not been improved by manual editing. On the right hand side of figure 8 the difference of the original DSM and the filtered DEM shows the height of the eliminated buildings, which may be useful also for different applications.

For not to high accuracy requirements also the elevation models of the Shuttle Radar Topography Mission (SRTM), available free of charge in the internet, can be used. They do have a point spacing of 3 arcsec, corresponding to 92m at the equator. The point accuracy is in the range of $4m+10m*\tan\alpha$, where α the terrain inclination (Jacobsen 2005). The C-band radar does not penetrate the vegetation, so the SRTM height model corresponds to a DSM.

6. ORTHOIMAGES

Orthoimages became standard contents of a GIS for mapping purposes. Usually orthoimages do have some geometric limitations, they do show only the elements located in the height level of the used DEM in the correct location. Buildings, not included in the DEM, are shifted with the location of the roofs depending upon the tangent of the nadir angle of the image location multiplied with the building height. So also parts of the facade can be seen (see figure 9, showing also the lines of the buildings – position on the ground, vertical building lines and roof). If the height value of the roof is included in a detailed DEM, the roof is shown in the correct position corresponding to an orthogonal map projection (figure 10). This is causing the problem that for some parts, before hidden by the roof, no information is available for the orthoimage – shown in black in figure 10.

The same problems like with the buildings exist for bridges. If the height of the area below the bridges is defined in the used DEM, the bridges are deformed (figure11). Also dams not included in the DEMs are shifted in their location visible in the example shown in figure 12 where neighbored orthoimages are matched. In the height level of the street going below the railway dam, the orthoimages are matching, but not in the height level of the railway.

These problems can be avoided with a "true orthoimage", including the height information of all details. In a true orthoimages the gaps caused by hidden objects have to be filled up with information from neighbored images (figure 11). Usually for the generation of true orthoimages a higher image overlap is used like 80% endlap and 60% sidelap. True orthoimages are becoming more popular but especially the required acquisition of all height information of the elements not belonging to be bare surface is very expensive.

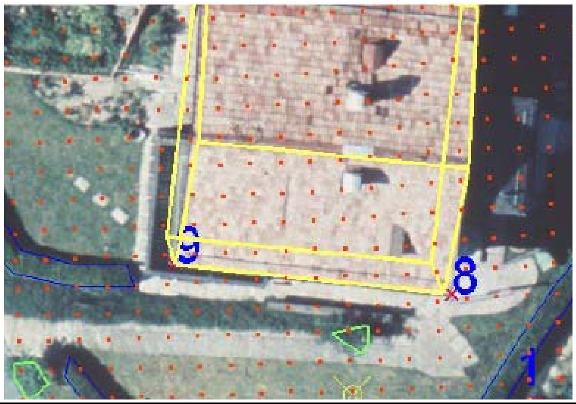


Figure 9: location of a building in a usual orthoimage based on a DEM including the bare ground

Figure 10: orthoimage with the corrected location of the building roof

Fig. 9 & 10 from Zhang and Walker 2005

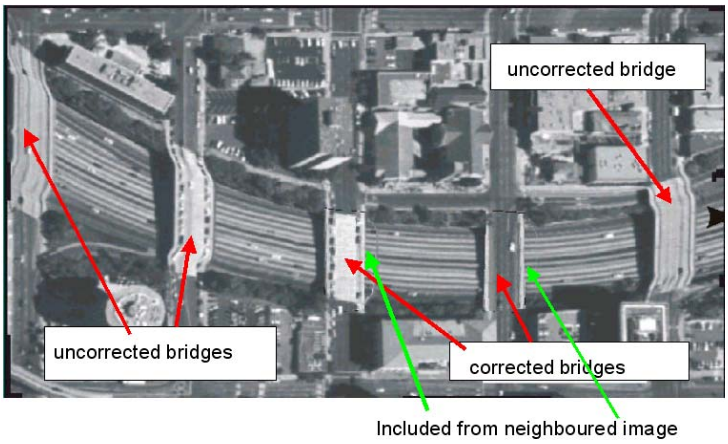


Fig. 11: location of bridges uncorrected and corrected for height differences against the road below

Fig. 12: matching of neighbored orthoimages based on DEMs not including the railway dam

CONCLUSION

Some clear trends in the development of the photogrammetry and geoinformation can be seen, some others are not so obviously today. A clear trend exists with the change from analogue film cameras to digital cameras. The use of digital line-scan or array cameras depends upon the application – for very large scales and accuracy requirements the digital array cameras do have advantages while for the coverage of large areas for medium scales the line-scan cameras may have advantages.

The bundle block adjustment for larger areas is more economic with the support of relative kinematic GPS-positions of the projection centers. There is also a trend to the direct sensor orientation, which has reached a high accuracy level.

The automatic object recognition is still in the level of research and development. It may be supported in the near future by digital images with a higher overlap.

Digital elevation models for large scale are generated more and more by laser scanning, having some advantages for the generation of 3D-city models. With digital images the automatic image matching is simpler like with analogue images; this is also supported by the larger height to base ratio of the digital cameras, making the matching more easily, having advantages in city areas and not loosing accuracy. The DEMs generated by laser scanning and also by automatic image matching do show the visible surface, if the height model of the bare ground is requested, the data have to be filtered. This can be made automatically by program avoiding the time consuming editing or reducing it to a minimum.

True orthoimages do have some advantages, they are used more and more, but the generation of the required detailed height information is still expensive.

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