Urban Green Space Management Information

Processing and Use of Remote Sensing Images and Scanner Data

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Abstract

Information on urban greenery is vital for planning, design and maintenance of the urban environment. This paper describes the monitoring of phytotopes in Vienna for the management of urban greenery using remote sensing methods. The present use of infrared images and the potential of digital images for whole city inventories is discussed.

Starting with the background of the BIOTOPMONITORING VIENNA program, the processing chain of air-borne, multi-spectral scanner data is outlined. Especially the geo-referencing of scanner data records with it's important spatial impact on the following steps is discussed in closer detail. Additional information on applications of BIOTOPMONITORING and from the COST E12 Action "Urban Forests and Trees", provide an insight in the latest development of monitoring methods in European cities.

1 Information regarding Green Urban Areas

Almost in all cities accurate and detailed maps of streets and the built environment are available. Only in few cities overall information on urban greenery exists and information on green areas with data on species, state, distribution and development of vegetation are accessible for the public administration.

To gather city-wide information on urban green and free space in great detail with the aim of environmental protection, the work program BIOTOPMONITORING VIENNA[3] was launched in 1991. Since then, an information system has been developed, to provide in depth information on Vienna's green areas and their development. The collection of data was based on remote sensing methods supported through ground truth inventories. On the basis of three aerial surveillances, the results of BIOTOPMONITORING provide an overview of changes and the present state of 35.400 vegetation areas between 1991, 1997 and 2000 in the city of Vienna.

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[3] Commissioned by the Municipal Department „Environmental Protection" (MA 22 – Umweltschutz), Vienna. URL: http://www.magwien.gv.at/ma22/pool/biomon.htm

2 Monitoring methodology

In the three surveying flights over Vienna, aerial colour images and air-borne multi-spectral scanner data were taken simultaneously over the whole city area (413 km^2). During each flight the entire city area was depicted on colour infrared 23x23 cm aerial pictures with a scale of 1:7.800. These 2.440 infrared photos were used for the visual image interpretations of green areas and free space. The scanning of images led to a digital aerial image archive (Fig. 1).

Fig. 1:
Digital image archive

In comparison to ground-truth inventories, infrared images with a resolution of 0,2 m (Fig. 2 left) permit a precise observation, classification and measurement of green areas in an economical manner. Stereoscopic interpretation enables interpreters to identify and describe e.g. biotope type, vegetation stock, number and crown condition of trees and surface type (vegetation covered, sealed, built-up area etc.).

Within BIOTOPMONITORING scanner data were recorded, to improve the cost efficiency through automation-supported identification of green urban areas. The multispectral air-borne scanner data of Daedalus AADS 1268 provide the basis for the evaluation of the operational application of these data. Recorded from the same flying altitude, the geometric resolution of 2,5 m of the Daedalus scanner data (Fig. 2 right) is about 12 times lower compared to the infrared images; but the radiometric information in 11 separated spectral bands is significantly higher. Therefore scanner data enables the identification of green areas more efficiently than visual interpretation if - for classification purposes - additional information is available. Hyperspectral sensors with very high resolution provide further improved features for semi automated change detection in green urban areas.

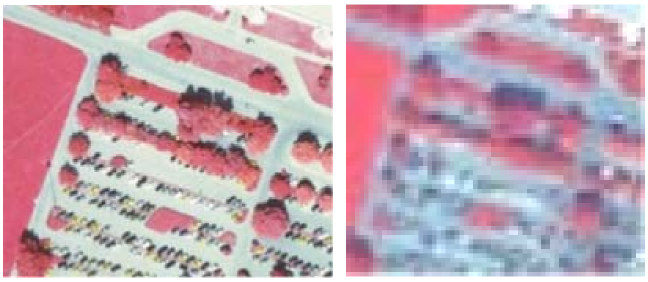

Fig. 2: Resolution comparison of an infrared image (left) and scanner data (infrared simulation right)

By now BIOTOPMONITORING data from visual interpretation include the attributes of the investigation areas (Fig. 3) in a 51 x 21.100 matrix for the densely built-up area and in a 10 x 14.300 matrix for the peri-urban region. These two matrices form the main database for the Geographic Information System (GIS), which is from now on used in the intranet of the municipal government in Vienna.

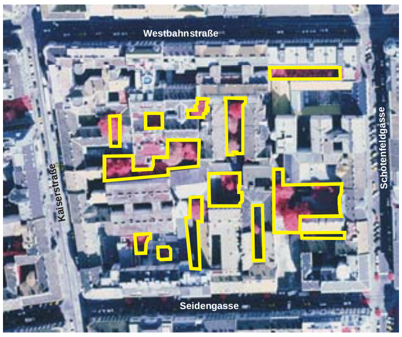

Fig. 3: Investigation areas in a block of houses in the densely built up city

3 Processing Chain of Air-borne Multi-spectral Scanner Data

Scanner data are suitable for identification and classification of forests and green areas. For change detection high requirements upon geometric accuracy exist, especially for urban areas. Sufficient computer capacity (speed, memory) and geo-referenced pixel data are prerequisites for inventories of green areas.

An overview of the image processing steps for air-borne scanner images is given in Fig. 4. After the data acquisition some pre-processing steps have to be performed, like radiometric and atmospheric corrections and geometric rectification (i.e. geo-referencing). Subsequently, data analysis with multi-spectral and textural classification can take place. The obtained results can be the basis for a post-classification analysis and the final result can be visualised in maps or introduced into a GIS. If scanner data of two or more epochs are available a multi-temporal analysis and change detection can be performed.

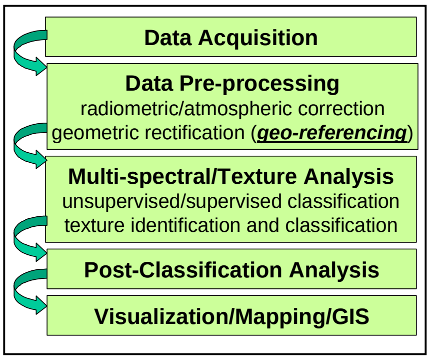

Fig. 4: Image processing chain

Within data pre-processing the geometric rectification of scanner images influences substantially the quality of all subsequent steps for green area identification and change detection. Therefore geo-referencing is discussed in closer detail.

3.1 Geo-referencing of Air-borne Multi-spectral Scanner Data

3.1.1 Principles of Geo-Referencing

A geo-reference can be defined as a global or regional object coordinate system to which sensors or spatial object data are related. Hence, the process of geo-referencing image data denotes the transformation of an image into the object coordinate system. The result is an orthoimage or a geo-referenced image. Geo-referencing an image is a "2-step-process": firstly the parameters of the transformation are determined and secondly the resampling of the image into the object coordinate system is performed. The term geo-referencing – per se – does not define which of the various possible mathematical models is used for the transformation. For example, for geo-referencing of a satellite image a two-dimensional polynomial rectification based on a few identical points is often applied. In the following we present the process of geo-referencing of air-borne multi-spectral scanner images based on sensor orientation (Fig. 5). The input for the subsequent resampling method are the scanner images, the related sensor orientation parameters as well as a digital terrain model.

Sensor orientation includes the determination of the so-called exterior orientation (position and attitude of the imaging sensor with respect to the object coordinate system) at the time of data acquisition as well as of relevant geometric system calibration parameters (Heipke et al., 2002). According to the technology applied, we can distinguish between various methods of sensor orientation:

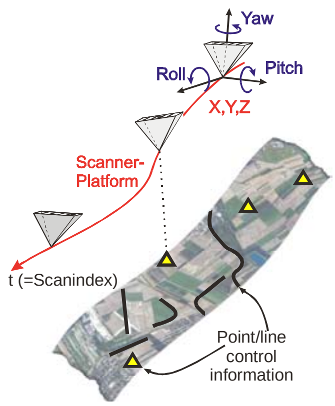

Fig. 5: Modelling the exterior orientation

- *Indirect sensor orientation* (comparable to traditional photogrammetric aerial triangulation) is based on an adjustment, in which image coordinates of tie points and image as well as object coordinates of control points are used as observations for the *indirect* determination of the unknown exterior orientation parameters and – if necessary – system calibration parameters (like the interior orientation of the scanner).
- *Direct sensor orientation* is based on direct observations of the exterior orientation along the flight path provided by a combined GPS/IMU-system (Global Positioning System/Inertial Measurement Unit). A GPS/IMU-system allows the measurement of the exterior orientation along the flight path with frequencies of 50 Hz and higher. In this case no ground control points are used, hence all system calibration parameters have to be determined in a separate step beforehand. This includes the calibration parameters of each sensor (e.g. the interior orientation of the imaging sensor) and parameters relating to the individual sensor observations in space and time to a common geo-reference.
- *Integrated sensor orientation* uses all available information, like tie points and control points as well as GPS/IMU-observations in a simultaneous hybrid adjustment for determining all relevant sensor orientation parameters.

3.1.2 Geo-referencing of Scanner Data of BIOTOPMONITORING VIENNA

The geo-referencing of the scanner data of BIOTOPMONITORING VIENNA of the flight 2000 was carried out by the Institute of Photogrammetry and Remote Sensing (I.P.F.) of the Vienna University of the Technology[4]. The whole city area of Vienna was recorded in 24 north-south strips with a side-overlap of about 40%. Further geometric characteristics of the Daedalus scanner and the surveying flight are: flying altitude ~2000 m, field of view = 42,96°, instantaneous field of view = 1,25mrad, 716 pixel per scan and pixel-size on the ground in nadir ~2,5 m.

For the surveying flight 2000 a GPS/IMU-system was in operation. The rapid development of GPS/IMU-systems within the last few years lead to a break through of air-borne multi-spectral scanner systems for various applications. With GPS/IMU-systems the task of sensor orientation is feasible in an operational manner by direct or integrated sensor orientation. Direct sensor orientation bears still some risks like undetected datum defects or erroneous system calibration parameters which can decrease the quality of the geo-referenced image. At present, for high accuracy and reliability demands, integrated sensor orientation is a good tool for detecting and correcting possible datum defects and other erroneous effects.

For geo-referencing of the data of the flight 2000, an integrated sensor orientation based on a hybrid adjustment was used. In the adjustment a mathematical model of the time variant exterior orientation of the scanner image has to be available. At the I.P.F. an algorithm was developed which uses a six-dimensional vector of spline functions (here called “orientation spline”) for modelling the six parameters of the exterior orientation along the flight path. The orientation spline can be determined with the help of direct observations of the exterior orientation provided by GPS/IMU and/or by ground control and tie information.

The GPS/IMU-data were introduced into the adjustment as observed models, which can be shifted and rotated with respect to the object coordinate system via control information. This way a datum correction is performed, which should be sufficient, if all systems work properly, but during this process some drift phenomena within the GPS/IMU-data were detected. The geo-referenced images of about 50% of the flight strips showed a very good quality with random deviations not larger than 2,5 m (1 pixel) in relation to a reference map (the digital multipurpose map MZK of Vienna 1:5000), whereas other flight strips had in some parts a lower geometric accuracy with systematic deviations up to 4-5 pixel (~10-12 m). From the flight 2000 in Fig. 6 the original GPS/IMU data from a strip with low geometric accuracy were depicted on the left, and a cut-out of the image after geo-referencing in comparison with the MZK is shown top right.

[4] The research and practical works on geo-referencing at the I.P.F. were supported by the Austrian Science Fund FWF (research project P-13432-MAT).

For quality improvement the drift phenomena of the affected strips were modelled in the hybrid adjustment by splitting the GPS/IMU-model of one strip into several parts and/or introduction of additional parameters for modeling of higher order disturbances; simultaneously additional control and tie information had to be provided for the determination of the additional unknowns in the hybrid adjustment (Ries et al., 2002a and 2002b). In case of un-revealed higher order disturbances in the orientation data, in few local limited regions deviations up to 4-5 pixel (total accuracy) may occur. In general after successful drift modelling the geo-referenced scanner images show a high quality with deviations not larger than about one pixel (~3 m) in relation to the MZK (see Fig. 6 bottom right). With this result, a further important step in the work program of BIOTOPMONITORING VIENNA towards an economic applicable change detection of urban green areas using multi-spectral scanner images has been accomplished.

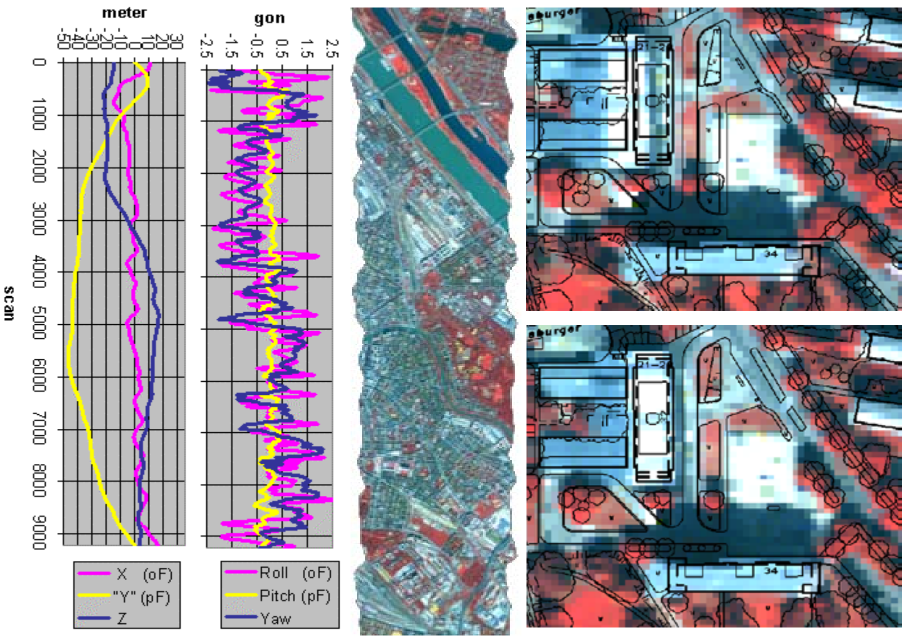

Fig. 6:

Left: Original GPS/ IMU-data (oF: orthogonal to flight direction; pF: parallel to flight direction; "Y": deviation from a uniform motion)

Middle: geo-referenced scanner image (part from scan 3300 to 6800)

Right: detail of the geo-referenced image before (top) and after (bottom) drift-modelling overlaid with MZK 1:5.000.

4 Green Area Management in a European Perspective

In the city development different forces determine the townscape. One of them is the management for urban green areas. It is guided through local (political) goals including public opinion, availability of financial resources, personal means, climate conditions etc. A legislative basis and fundamental information about the state and the development of green areas are prerequisites for an effective management.

In the Study “Tree preservation legislation in Europe” (Schmied, Pillmann 2002) a comprehensive survey on ordinances for the protection of green areas and their practical implementation in 34 large European cities has been elaborated. In the course of this study, also questions about methods and tools for monitoring green urban space were incorporated. As depicted in Tab. 1, the cities which answered the questionnaire uses advanced information technology and remote sensing methods for mapping and controlling their green environment.

City	Vienna	Brussels	Bern	Geneva	Prague	Copenhagen	Lyon	Marseille	Berlin	Essen	Frankfurt	Hamburg	Hannover	Karlsruhe	Stuttgart	Milan	Amsterdam	Warsaw	Bratislava
Country	A	B	CH	CH	CZ	DK	F	F	D	D	D	D	D	D	D	I	NL	P	SL
Observation	yes	yes	no	yes	no	yes	yes	yes	yes	no	yes	yes		yes	yes	yes	yes[3]	no	yes
Remote sensing	yes	yes[1]	no	no	yes	yes	yes	yes	yes	no	yes	yes	yes	[2]	yes	yes	yes	no	no
B/w aerial images											x	x	x		x	x			
IR aerial images	x	x			x			x	x		x		x		x		x		
scanner data					x	x	x												
satellite images		x			x	x													
Computer assisted	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes [2]	yes	yes	yes[4]	no	no
Inventory software			x					x			x	x	x		x	x	x		
GIS	x	x	x	x	x	x	x	x	x		x	x	x				x		
Databases software	x	x		x	x	x		x	x		x	x	x	x		x			
Web address	yes	yes	yes	no	[2]	[2]	no	yes	yes	yes	yes		yes		yes	yes			no

[1] only for street trees; [2] under development; [3] without trees; [4] in some districts

Tab. 1: Remote sensing application and computer assistance in European cities for urban green management (Schmied 2002)

Inventories of urban forests, parks, street trees and other greeneries were indispensable for the high-quality management of the urban environment. For a sustainable city development, the planning period have to cover 10 to 20+ years and should include the long-term perspective of preservation and nature conservation. Basic strategies, tools and good practice cases were available and were under further development in research programmes. Examples for these were COST E12 “Urban Forests and Trees”, COST C11 “Greenstructures and Urban Planning”, URGE “Development of Urban Green Spaces”, MOLAND “Monitoring Land Use/Cover Dynamics” and

GREENSCOM "Communicating Urban Growth and Green", mostly accessible through the Web (addresses see Par. 6).

5 Further perspective

Scanner data and image processing methods can be used for change detection to support green area management. The goal in the further development of monitoring methods will be an improvement of the cost efficiency of repeatable inventories. Since July 2002, a geo referenced multi-spectral scanner image is available[5] with a resolution of 2,5 m in 11 spectral bands for further use in change detection over the whole city of Vienna. The data basis presently available out of BIOTOPMONITORING could provide an excellent basis for the evaluation of semi automated inventories. In the future, high resolution satellite images with primary multi-spectral sensor resolution of around 2 m and less promise to be a usable data source.

6 Bibliography and Web references

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Schmied A., Pillmann W. (2002): Baumschutz in Europäischen Städten. Österreichisches Bundesinstitut für Gesundheitswesen, Report, Wien 2002

COST C11	Greenstructures and Urban Planning	www.map21ltd.com/COSTC11/
COST E12	Urban Forests and Trees	www.fsl.dk/cost_e12/
Greenscom	Communicating Urban Growth and Green	www.greenscom.com
MOLAND	Monitoring Land Use/Cover Dynamics	http://moland.sai.jrc.it
URGE	Development of Urban Green Spaces	www.urge-project.org/

[5] At ÖBIG, „Österr. Bundesinstitut für Gesundheitswesen" (Austrian Health Institute)