USE OF GIS METHODOLOGY FOR ONLINE URBAN TRAFFIC MONITORING

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ABSTRACT:

Main goal of traffic management is the optimisation of traffic flow. This aim is based on possession of precise traffic describing data and parameters. Two dimensional traffic data acquisition becomes a research emphasis of German Aerospace Center (DLR)s Institute of Transport Research to improve these data basis. Data sources are ground based like floating car data as well as airborne remote sensing data and the developed procedures are appropriate to support traffic management effectively.
A preliminary real time system for airborne traffic monitoring (ATMS) was already successful proved to collect traffic data on demand. The whole chain of the system extends from the sensor technology - including a stabilized platform and image processing, via the data transmission to the ground - to a traffic center for the further processing of images in which the information will be refined with prognosis tools. An open interface ensures a multi-facetted utilization of the information by multiple user groups. The data processing is based on a commercially available digital map. Practical tests showed that the quality of traffic flow data extraction will increase significantly by improving the digital map basis. The aim of the work presented here is to use heterogeneous image data, especially high resolution satellite data (Quickbird, Ikonos) to extend the a priori knowledge for implementation into the monitoring system. In parallel the image data from ATMS can be evaluated in focus of problems of description and assessment of the urban space. Consequently a GIS platform seems to be an adequate tool to implement, process, analyse and visualise the actual geodata. Special GIS data products are available for simulations or analysis and merge of sociodemographic and socioeconomic structure data (people and pixels),and the methodology can be adopted for for real-time applications like ATMS. Additionally the GIS System offers the opportunity to implement and manage the historical traffic flow data generated and derived from all data collecting systems (terrestrial, airborne and spaceborne sensors).
In front of this background the paper will present the analysis of existing Satellite and ATMS data for the region of Berlin. As a first step the application of a vegetation detection algorithm will be shown. This results in an information layer concerning structures of trees at or near street areas and will eliminate an essential disturbance factor at real time airborne data collection and will therefore enhance the validity of the derived data.
Since at the moment the digital map will not account for parking areas, high resolution remote sensing data will be analysed to extract accordant information layer for future applications. The implementation of the extended a priory knowledge into both the ATMS as well as the GIS will be presented and the improvements will be demonstrated.

1. INTRODUCTION

“The three biggest problems in modern traffic management are 1. data, 2. data and 3. data.” [1] and additionally intelligent transport systems require a new kind of data acquisition methods. Prediction of traffic, dynamic routing, off board navigation and standardisation of traffic flow parameters are the challenges we are faced with. With this situation in mind, several scientific institutes and companies are developing new approaches and methods for traffic data acquisition. Airborne systems are well suited to fit these demands. They offer spatial availability, broad variety of extractable parameters and the speed of collection. Beside these advantages, however, in general a time gap between collecting and processing the data exists. The highly dynamical system of transport undoubtely requires real time processing of traffic data due to its extremely high time dependency.
On the basis of innovative sensor technology which is now available, a system for the air-supported recording of the traffic situation was designed, realized, and demonstrated as a tool to provide integrated solutions addressing issues of traffic monitoring, fleet management and emergency services support, e.g. for the organization of large scale events. Its main feature is the coverage of a certain area of interest for a longer time. The central technological challenges were located in the software area, i.e. in the development of suitable image processing procedures and the already above mentioned traffic simulation and prognosis tools. The prognosis plays a key role and serves the bridging of inevitably occurring time-gaps in the recording by the aircarrier. It thus contributes considerably to added value and the acceptance of air-supported monitoring.
Geoinformation systems (GIS) form an appropriate and intelligent communication platform to figure spatial georeferenced information, derive traffic data products, model and visualize transportation events. They account for data source synergies as well as for system extension.

2. SYSTEM DESCRIPTION

Figure 1 gives a system overview. The entire system consists of an onboard unit, a transmission system and ground facilities for the derivation of traffic relevant parameters and their implementation into traffic prognosis and a transportation related GI System.

DLR used its competence on the field of opto-electronic systems and applied a number of different camera systems in or-

[1] Cit.: Prof. R.Kühne (German Aerospace Center, Institute of Transport Research)

der to evaluate their parameters and to define configurations being able to satisfy user specified tasks (Kührt et al. 2001). In

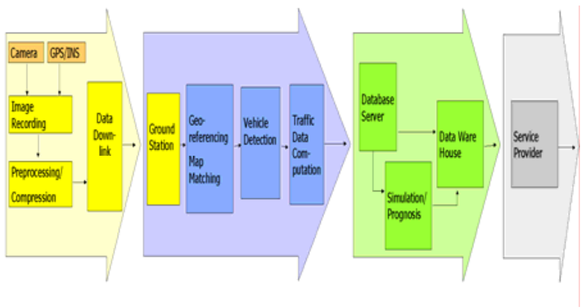

Figure 1: Airborne traffic monitoring system overview

our configuration a high resolution camera in the visible range of the electromagnetic spectrum was used. Anyway a combination of different sensors seems to be very promising and will be realised in future systems.

Due to the realtime requirements of the system onboard georeferencing is needed. This implies that all six parameters of the so-called exterior orientation (three translations, three rotations) of the camera for each snapshot have to be determined. Depending on the desired accuracy of data products, these parameters have to be measured with an accuracy in the order of one ground pixel distance and one instantaneous field of view. The system consists of an Inertial Measurement Unit (IMU) LN200 and a control unit with an integrated time synchronised D-GPS receiver and provides real time output of position and orientation with an absolute accuracy of 0.5 to 2 meters for position and of 0.015 to 0.05 degree for attitude (E. Lithopoulos et al., 1999, F. Scholten et al. 2001).

The data transmission rate to the ground is one of the most limiting factors for real time airborne systems. It defines the maximum possible image acquisition rate. Focusing on freely accessible radio frequencies commercially downlink systems were chosen. They deliver data rates up to 5 Mbps.

3. DATA PROCESSING

During the measurement flights, real time orientation data, misalignment angles and interior orientation define a transformation from image space to object space and vice versa. Assuming a medium terrain height, the position of the vehicles can be estimated. Consequently, for each pixel of interest a (x,y)-tuple can be determined and each real world object corresponds to an equivalent pixel in the image. Assuming a known interior camera geometry, for an observed point P the following equation describes the relation between image space and object space for Illustration see fig. 2

$$P^m = C^m + (P - C)^m = C^m + \alpha \cdot dp^m \qquad (1)$$

$$dp^m = C_g^m C_b^g(\Phi,\Theta,\Psi) C_c^b C_i^c \begin{bmatrix} x_P \\ y_P \\ -f_P \end{bmatrix}^i , \qquad (2)$$

where

x_P , y_P are coordinates of P in image frame (i)

f means focal length of the camera,

C is the camera projection centre,

Φ,Θ,Ψ (Roll, Pitch, Heading) are Euler angles for the transformation from navigation frame (b) to geographic frame (g).

C_k^l describes an appropriate rotation for transformation from frame (k) to frame (l).

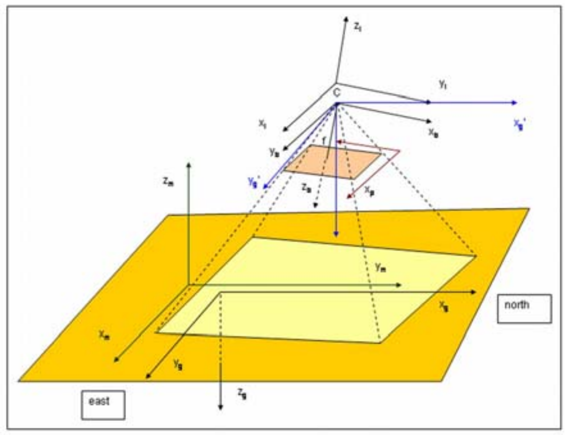

Figure 2 Illustration of projection geometry with directions of used coordinate frames

Thus it is possible to project an image (i) to the digital map frame (m) in a world coordinate system and vice versa.

After deriving the relations between object space and image space, relevant traffic objects have to be detected in the image data. The implemented approach (Ernst et al. 2003) bases on a digital road map (NAVTEQ) and a digital terrain model. Using the a priori knowledge about roads (e.g. nodes, directions) images can be masked considering a margin depending on the accuracy of different data (etc. GPS/IMU data quality, maps). The vehicle detection is done on the masked image where the sizes of the expected vehicle in the image space are dynamically adapted to the current navigation data values (height over ground, attitude of the aircraft). The vehicles have a variety of appearances in the captured images depending on sensor type, object properties and environmental conditions (e.g. illumination, temperature). Most of the traffic objects can only be recognized as coarse rectangular shapes to be more or less in contrast to the background. Therefore the algorithm searches for characteristic contours (of suitable sizes) in edge images retrieved by applying edge detection operators, e.g. Sobel. The vehicle recognition algorithm delivers rough size estimation so that accepted car hypotheses can be divided into a number of length classes. Using three classes has proven to be very practical; a larger number reduces the exactness of the classification. Thus essential shapes of cars, vans and long vehicles can be detected. The traffic data extraction within the airborne traffic monitoring projects is done per image and road segment first.

Evaluating the number of vehicles per scene gives a measure for traffic density. High frame rates allow the determination of velocities. Densities and/or velocities are calculated for each vehicle class from the obtained vehicle numbers and positions. The extracted data for single images are combined for completely observed road segments using size and position of the scanned streets. The calculated averages per road segment of the digital map and per timestamp can be provided to a central processing computer and can be used now as input data for simulation and prognosis tools.

4. OPERATIONAL SERVICE EXPERIENCES AND PRELIMINARY RESULTS

We found as a preliminary result for arterial city roads that 61 % of all cars were detected correctly by the automatic detection system. Only 20% were falsely counted cars, i.e. cars that do not exist. Moving cars can easier be identified than parking cars. If we exclude parking cars, the automatic detection rate increases to about 75% for the traffic parameter measurements. For this case exclusion of parking car is tolerable because they do not contribute to the traffic flow. Only 8 % falsely counted cars are then found for arterial roads.

Since we wanted to achieve the real time feasibility first, also the recognition rate is not too poor. However, there are still several opportunities to tune the algorithm.

As already mentioned excluding parking cars increases the recognition rate significantly. The discrimination between parking cars and vehicles only standing in right lane will be one challenge for the next future.

The quality of detection strongly depends on the quality of the digital map. The algorithm accounts for street information like number of lanes or directions of polygons to create the best possible extraction of the streets in the images. Any inconsistency in the map information leads to systematic errors in calculation of the traffic parameters.

After numerous test flights we find that the reality is not in every case fitted by the digital map. Especially for broadways, freeways and other arterial roads the stored geometry of the map is well suited for our purposes and with additional map attributes and road making rules the street width can be reconstructed very accurately. Unfortunately for smaller roads nevertheless being of great importance as main traffic axis the given map precision is partly unsatisfactory. The information concerning lane numbers is insufficient and especially at the sorting area near crossroads simply false. For the usual map application as basis for car navigation systems these information are not relevant and therefore the map companies will not deliver that kind of information. Regrettably for a system that exploits the map information as basis for optimised image processing the precise knowledge of lane numbers is essential. The definition of traffic related areas via the existing map attributes is not sufficiently accurate, especially the marking of parking slots or lanes , bus lanes or similar. The missing or existence of constructional separation of opposite directions is sometimes inconsistent over a block. For this reasons the vehicle detection takes place at the roadside or in the other case not at all lanes. Both cases avoid the derivation of realistic values for the traffic flow describing parameters.

Another number of problems of automated airborne traffic data acquisition result from the sensors.

One reason for not finding all cars correctly is that the distances between cars standing at a light signal are some small that they might be below the pixel resolution of the camera. New versions of the algorithm will account for that.

On the other hand possibilities of the optical cameras used here are restricted due to the opacity of objects in the radiation path. Non registered railway bridges, traffic signs or trees will disturb the signals significantly and lead to a decrease of accuracy. Partly tree covered roads extend the difficulties for ATMS since on the one hand vehicles become more or less invisible and on the other hand tree shapes often will be interpreted as cars hypotheses. Dependent on the illumination conditions one has to account for shadow effects and flares too.

5. REALTIME SERVICE SYSTEM REQUIREMENTS AND IMPROVEMENTS

The operational use of of the system allows only algorithms ensuring image processing of 5 to 8 frames per second as the necessary prerequisite for sufficiently precise derivation of vehicle velocities. For the further improvement of the real time vehicle recognition rate therefore the consequential utilisation of all available background information is essential. As previously pointed out a digital map and terrain model are already in use in the data processing unit.

To avoid the above mentioned mismatches is a realistic aim of system optimisation. One possible way is the development of improved image processing algorithms. On the basis of texture information contained in the images traffic relevant areas and vegetation will be separated and the algorithms will be implemented in the online processor. The main advantage of this method is the usage of the real images at the moment of acquisition. Newly built roads, vegetation variation due to seasons, tree cut down or other changes compared to historical data can be neglected. On the other hand the existence of only one (or few) spectral channel and the limited calculation time restrict the success rate significantly.

One way to improve the validity of the data basis is the use of additional map information for example ATKIS[2]. In general they offer archive information concerning land use and crop of trees. Other maps are potentially available from public transport organisations and local authorities.

Another way is the derivation of additional information from historical data and existing images covering the test site. The preparation of a supplementary layer for the digital map projecting the crop of trees in the region of interest especially at the edges of traffic relevant areas must be one first aim. The following integration of the resultant tree mask into the online processing system allows the fast generation of a vegetation mask for the actual image. In parallel and addition to the real time algorithms the vegetation mask provides information about the expected trees resulting in the separation and exclusion of non visible regions. For partly covered image regions the lesser reliability of the calculated traffic parameters is indicated.

6. GENERATION OF A SATELLITE BASED CROP OF TREES GIS LAYER

Besides images of historic airborne measurement campaigns optical satellite image processing becomes of enormous importance for the (semi)automatic generation of tree maps. They do not only cover the entire area of interest at one time, they are also equipped with several spectral channels and are therefore well suited for the estimation of vegetation indices. The dis-

[2] official german topographic and cartographic information system

crimination of sealed and non sealed zones is from the application point of view the most important one in urban space.
For the analysis of land use classes seasonal and spatial variable scenes of Quickbird satellite images covering Berlin city and its freeways were used. Areas of interest have been extracted for detailed investigations for both multispectral and highly resolved pan data. Due to the different data formats and resolution image to map – see fig. 3 and image to image rectification was applied.

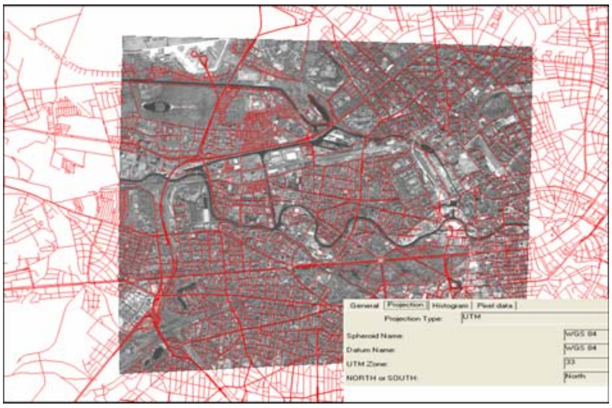

Figure 3 Quickbird panchromatic image projection into map layer

The test site vegetation classes have to be clearly assigned, thus an unsupervised classification of the multispectral pixels is followed by allocation to thematic classes. The first assignment permits the separation of vegetation and anthropogenic areas. This results after combination with the NAVTEQ map in a simplified mask only describing traffic related areas– fig. 4.

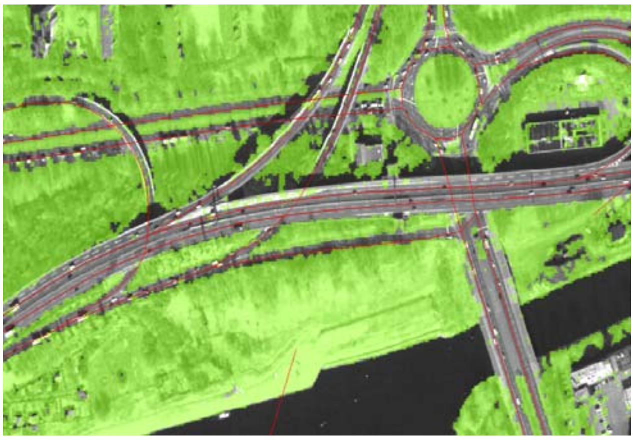

Figure 4 satellite based vegetation raster layer

Implementation in the real time processing system necessitate the conversion of the GIS generated raster layer to a vector layer . Only backtransformation and projection to both the digital map and the terrain model allows the implementation into the ATMS. In the end an additional vegetation map on the single image basis is available for the real-time processing, dynamically adopted for illumination, flight and acquisition parameters.

7. OUTLOOK

For the improvement of online airborne systems the GIS methodology was proved to be adopted. GIS combines a- priory knowledge and parameter driven features to extend the reliability of online traffic data derivation. First steps demonstrate the promising potential of this approach. Further improvements require better trustworthiness and accuracy of recognition of urban classes. Endeavors will be focused on the combination of multispectral classification and texture information. Multitemporal analysis will decrease the number of mismatches due to seasonal vegetation changes. Post processing of online images will enhance the precision and quality of the GIS based urban layers. Exclusion of problematic region will be simplified and discrepancies between pre- and online processing will be attended, resulting in advices for data interpretation.
Last but not least the integration of all data sources into a transportation GIS will led to a better understanding of traffic sources, goals and demand relations.

8. ACKNOWLEDGEMENTS

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