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Traffic monitoring with serial images from airborne cameras

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Abstract

The classical means to measure traffic density and velocity depend on local measurements from induction loops and other on site instruments. This information does not give the whole picture of the two-dimensional traffic situation. In order to obtain precise knowledge about the traffic flow of a large area, only airborne cameras or cameras positioned at very high locations (towers, etc.) can provide an up-to-date image of all roads covered. The paper aims at showing the potential of using image time series from these cameras to derive traffic parameters on the basis of single car measurements. To be able to determine precise velocities and other parameters from an image time series, exact geocoding is one of the first requirements for the acquired image data. The methods presented here for determining several traffic parameters for single vehicles and vehicle groups involve recording and evaluating a number of digital or analog aerial images from high altitude and with a large total field of view. Visual and automatic methods for the interpretation of images are compared. It turns out that the recording frequency of the individual images should be at least 1/3 Hz (visual interpretation), but is preferably 3 Hz or more, especially for automatic vehicle tracking. The accuracy and potentials of the methods are analyzed and presented, as well as the usage of a digital road database for improving the tracking algorithm and for integrating the results for further traffic applications. Shortcomings of the methods are given as well as possible improvements regarding methodology and sensor platform.

Keywords: Aerial images; Image series; Traffic monitoring; Geocoding; Velocity estimation; Road database

1. Introduction

Traffic research and planning require a vast quantity of detailed information about traffic dynamics, statistics and behavior. Empirical studies, measurements, modeling attempts, and simulation programs are numerous and diverse. The challenge is to develop robust methods for predicting, visualizing and modeling of complex traffic events (Brockfeld et al., 2004). Only on the basis of reliable data, the simulation, control and planning of traffic systems can be optimized and, thereby, contribute to the efficient use of existing infrastructure, the reduction of emissions, and the increase of transport safety.

Merely equipping the streets with conventional stationary measurement systems such as induction loops, radar sensors or cameras does not provide an adequate supply of suitable data. The challenge is to develop innovative solutions that augment the information from existing individual measurement sites, thereby closing the gaps in the traffic picture. Traffic research counts on so-called large area data collection to achieve a considerably improved data basis. New approaches currently under investigation include the recording of data by means of mobile measurement units, which flow with

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the traffic (floating car data, FCD, Schaefer et al., 2002). The big advantage of the remote sensing techniques presented here is that the measurements can be applied everywhere and do not depend on any third party infrastructure.

Due to very sparse measurement sites especially in areas beyond city and town limits obtaining an area-wide picture of the traffic situation is difficult. On German freeways and national roads, for instance, numerous accident-prone sites exist for which the precise cause of accidents is not well known or adequately documented. Besides this, it is also important to further study how traffic congestions develop and how vehicle velocity reduces at the tail end of a jam or in response to speed limits. Reliable ways to estimate the travel time through these dense traffic situations is also a matter of interest. Stationary camera systems near ground level are only of limited use for these purposes, as they only allow the detailed analysis of the traffic situation within a small area. Their shallow observation geometry prevents data acquisition for area-wide traffic analysis.

In contrast to that, satellite and aircraft sensors are able to provide area-wide observations of a whole road network. However, a continuous observation of traffic based on satellite data is impossible due to various reasons: i) because of the high orbit altitude satellites in geostationary earth orbits do not provide suitable image resolution. ii) Satellites in a low earth orbit have a high rotational speed (~7 km/s) and can only supply snapshots of a momentary traffic scene, or several within a few minutes (Toth et al., 2003). Their typical revisit time is in the order of a couple of days. iii) Optical sensor data from high altitudes are only applicable during good weather conditions.

Radar sensors as, e.g., mounted on the upcoming German TerraSAR-X satellite allow to monitor traffic situations worldwide and independently of weather and daylight (Runge et al., 2004). However, severe problems are expected in inner city areas due to the inherent side-looking geometry of radar.

A technology that combines the advantages of satellites and aircrafts for traffic monitoring is provided by autonomous unmanned aircrafts permanently positioned in the stratosphere. These High Altitude Long Endurance (HALE) platforms are more flexible than satellites and allow permanent observation of large areas on a regional scale.

The benefit of aircraft optical data from both the visible (Shastry and Schowengerdt, 2002; Stilla et al., 2004; Toth and Grejner-Brzezinska, 2004) and thermal infrared (Ernst et al., 2003; Hinz and Stilla, 2006) part of the spectrum for vehicle detection has been studied using many different approaches. However, there are not many investigations on optical time series recorded by satellite, aircraft or other sensors with a large field of view (Mirchandani et al., 2002; Toth et al., 2003; Pötzsch, 2005). Image sequences of large areas taken at intervals of seconds or less are however easy to acquire with airborne sensors. The high sample rate of such data is well suited for the derivation of parameters relevant for traffic analyses, such as individual vehicle and vehicle group velocities, vehicle type, distance, traffic density and travel times.

With an image time series it is possible to record the entire traffic dynamics for a given area and to analyze, for example, overtaking maneuvers, merge and exit behavior, as well as traffic jams for a certain time span. Such results are highly relevant input data for traffic modeling and simulation programs, for testing the efficacy of traffic control measures and for GIS systems for traffic monitoring (Ernst et al., 2005). First results on this topic have been shown in Reinartz et al. (2005).

The paper shows, beside visual interpretation, some improved methods for the automatic evaluation of serial image data using single vehicle tracking and describes comparisons and error estimations in combination with other methods for measuring the velocity of vehicles. The influence of image frequency is shown as well as the benefit of digital vector data of the road network. Automatic vehicle tracking is compared with results of visual interpretation, and mandatory preprocessing methods like geocoding and image matching are discussed. Finally, an outlook is given on possible applications for large area traffic monitoring. The main scope is to show the potential of airborne serial image data, mainly from commercial non-calibrated frame cameras for monitoring traffic situations.

2. Aerial image data and ground reference

The data acquisition of serial images for these investigations was performed using two different cameras:

1. ZEISS RMK A30/23 film camera (image frequency ~1/3 Hz) — case 1.
2. Canon Camera EOS 1D Mark II 8 MPixel digital camera (image frequency 3 Hz) — case 2.

The analog aerial images were recorded in October 2004 with the ZEISS camera mounted on a DLR aircraft. The regions covered are along the A99 and A9 freeways north of Munich, Germany and along another part of the A9 freeway south of Nuremberg. The time difference between two consecutive images is about