AIRBORNE ROAD TRAFFIC MONITORING WITH RADAR

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ABSTRACT

To ensure mobility, future road traffic management needs actual and reliable information about the traffic over wide areas. Nowadays, outside of motorways the actual traffic situation is almost unknown due to the lack of sensor installations. Traffic monitoring with radar from high altitudes delivers a new approach which allows the capture of traffic data in wide areas and at every position in the road net. Radar can look through clouds and can operate independently of weather and sight conditions at day and night and it can detect vehicles independently of their instrumentation onboard. At the German Aerospace Center (DLR) the practical feasibility of airborne radar for road traffic management in general but also in specific situations of big events or occurred disasters is under investigation. This paper gives an overview over the actual status of project works and will present aspects for future applications of airborne radar for road traffic and disaster management.

KEYWORDS

traffic surveillance, dynamic sensors, disaster management, airborne SAR

INTRODUCTION

Maintaining of mobility is of significant importance relating to economics and it is a challenge for today's traffic management. The German automobile club (ADAC) estimates the average driver in Germany spends about 65 hours per year in traffic jams. That represents almost 40 million liters of fuel consumed daily — in Germany alone. The resulting cost to the nation's economy is between 100 and 200 billion euros (1). A detailed monitoring of road traffic and a reliable warning about traffic jam only costs a little part of this amount. However, efficient guidance systems and reliable prediction about traffic jams need comprehensive and precise traffic information covering the complete road net.

The only class of roads in Germany where roads are equipped with a high degree of stationary sensors – like overhead sensors and loops – are the motorways. But the attempt to cover the road net over wide areas also away from the motorways with traditional sensors would be too expensive and would result an extreme high effort of maintenance.

An important measure for characterizing traffic flow is the travelling time which of course cannot be focused on the motorway net alone. Presently, a first approach for wide area traffic monitoring can be achieved with FCD (floating car data). Specifically equipped cars floating with the traffic transmit their actual position and moving status via SMS to a traffic management center. The equipment of a high amount of traffic vehicles with GPS and GSM-systems and a high transmission repetition frequency is a prerequisite for a successive concept which, however, consumes a high amount of costs especially for a high frequent transmitting of SMS-messages. Keeping costs on a low level taxi-FCD – using the taxi radio link for message transmission - could be a practicable solution in agglomeration areas (2).

Only optical cameras and radar sensors on high flying platforms offer the possibility of a wide area monitoring of infrastructure as well as of the road traffic situation without the need of additional technical equipment of road vehicles. Such sensors are therefore also best suited to support managing of big events or in cases of occurred disasters e.g. for monitoring destructions or flooded areas in order to lead rescue forces to their operational areas.

AIRBORNE WIDE AREA TRAFFIC MONITORING

Traffic monitoring with radar from high altitudes delivers a new approach which allows the capture of traffic data in wide areas and at every position in the road net. Radar can look through clouds and can operate independently of weather and sight conditions at day and night and it can detect vehicles independently of their instrumentation onboard. Air- and spaceborne radar systems are able to cover wide areas on the ground. Already one single platform could support traffic planning or could operate for monitoring big events or even can be used for calibration of terrestrial sensors. Possible platforms are aircraft and satellites and even zeppelins, balloons, or UAVs (unmanned aerial vehicles) flying at high altitudes.

Figure 1 shows the typical geometry for a Synthetic Aperture Radar SAR (system on a UAV platform). In this example the illuminating beam of the side-looking radar typically covers a strip width of 20 km or more on the ground for altitudes of about 20 km. Currently, it is a big challenge to process recorded data in real time and to transmit data via a radio link to a ground station due to the huge amount of data because the resolution of produced SAR images is of the order of 1 to 2 m. Therefore, special techniques for reducing the amount of data to be processed and transmitted have to be developed and demonstrated.

For frequent traffic monitoring revisit times of the order of 20 minutes or less are necessary. A spaceborne platform version would need a system of mini-satellites to achieve this goal (3). Presently, such a scenario seams not realisable in the face of the coming Galileo satellite system and in face of the resulting costs. However, in medium terms, HALE-UAVs (High Altitude Long Endurance) circuiting at high altitudes (20-25 km) far over the general air-traffic and far over the weather could overtake such tasks for comparable much lower costs, especially, if the UAV-platform can be shared for different services. Already one single HALE-UAV would be sufficient for revisiting certain areas in short time intervals.

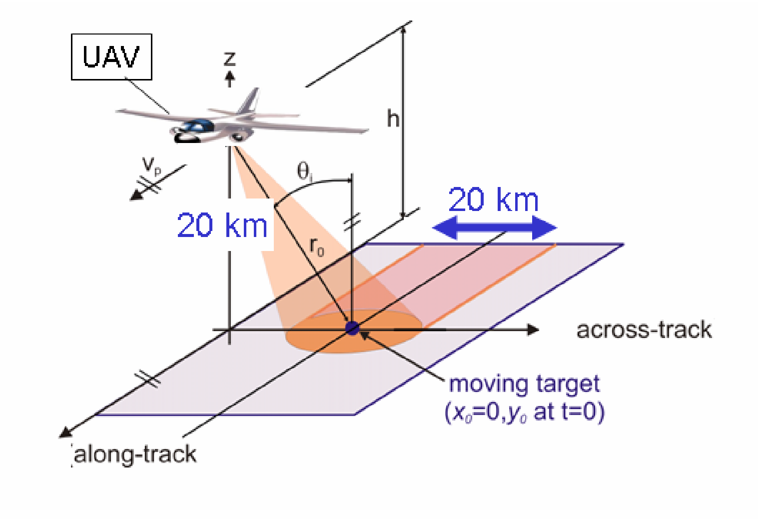

Figure 1. Example of a side-looking radar-target geometry for a SAR system on a UAV at high altitudes.

At the German Aerospace Center (DLR) the practical feasibility of airborne radar and optical sensors or also both in combination for the support of road traffic management in general but also in specific situations of big events or at occurred disasters is under investigation since several years (4), (5), (6). Optical sensors were already operationally flown in the DLR project SOCCER (9). In an other DLR project TRAMRAD (Traffic Monitoring with Radar) fundamental solutions for air- and spaceborne road traffic monitoring had been studied (4), (5), (7), (8). In a succeeding project the potential of airborne SAR operating for road traffic monitoring and especially for the support of disaster management is under investigation and is going to be demonstrated next. For this, an existing novel experimental airborne SAR system flying on a Dornier DO-228 will be used and adapted to the specific operations whereby real time processing and data transmission over a radio down link to a ground station are major goals. From made experiences in praxis, an operational compact SAR system for high flying airborne platforms is planned to be developed over the medium term which will be available then for traffic and disaster management in the future.

SAR processors deliver two-dimensional radar images from the earth surface and are suitable for monitoring stationary scenes like flooded or destroyed areas or roads. Water, for instance, scatters electromagnetic waves away from the radar sensor in case of oblique wave incidence angles and if the water surface is relative smooth. Such surfaces then appear dark in SAR images and can therefore be detected using e.g. change detection techniques.

Figure 2 shows a typical SAR image taken from an aircraft at 3000 m altitude. The different colours characterize polarisation states so that different surface states such as vegetation, moisture, or water etc. can be classified. If flooded areas are classified in a SAR image, then, for instance, in combination with GIS-data (Geographical Information System) impassable roads can be identified (see Figure 3) to support action force on-site. Such information can be derived at any daytime i.e. even in rainy and cloudy nights.

Figure 2. Fully polarimetric SAR image of Oberpfaffenhofen, including DLR facilities in image center. Composite obtained from 2 dual-polarized data takes in C-band (HH-green, HV-red, VV-blue).

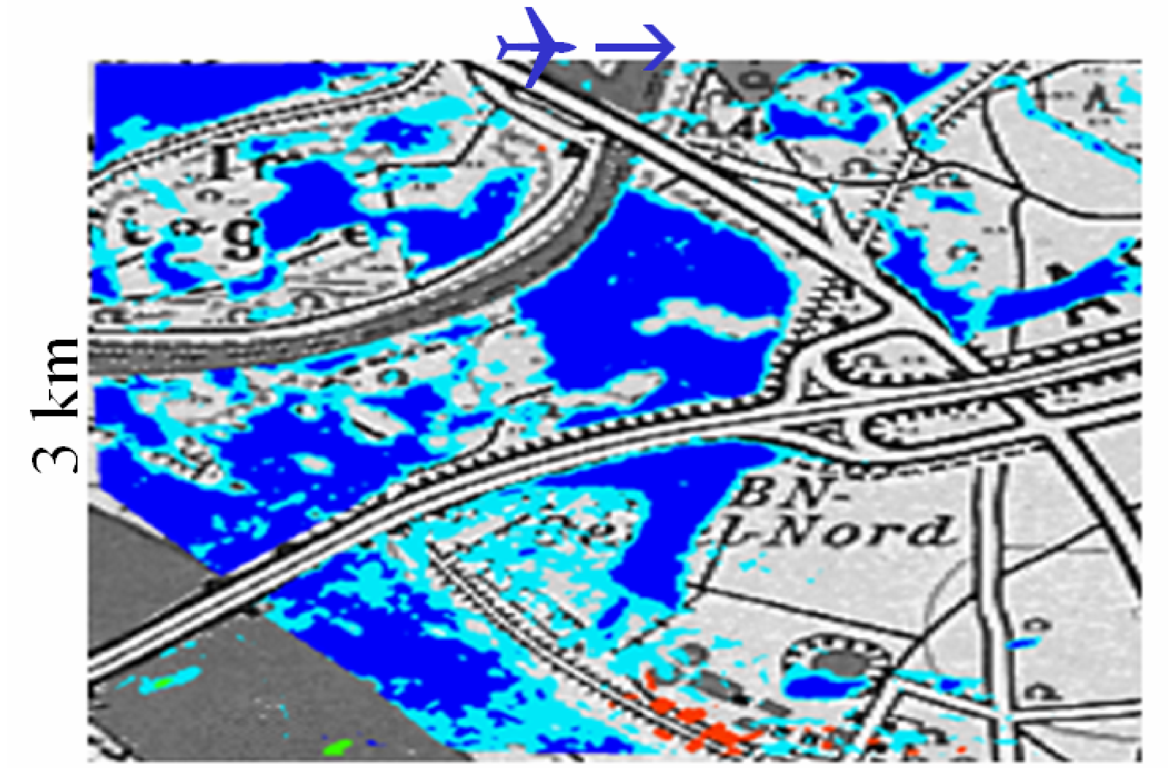

Figure 3. Rhine River during flooding in 1995, Digital map overlayed by geocoded classified DLR-E-SAR data (X-band frequency). Colours indicate changes: blue = water, red = new buildings.

A further property of radar is its capability of GMTI (Ground Moving Target Indication) i.e. the detection of moving targets against a stationary background. New techniques with respect to GMTI are currently under investigation at the DLR in order to detect traffic vehicles with a high degree of precision and reliability and to derive the moving status of road vehicles and hence major parameters for estimating the traffic flow. This capability can be used for traffic monitoring in wide areas. Information about traffic flow or travelling time in certain sections of a road net can be deduced. Figure 4 shows an example of detected traffic vehicles on a motorway. The lower velocities printed inside the marked square indicate vehicles with lower speeds which are inside a parking area as to be seen from an optical image on the right.

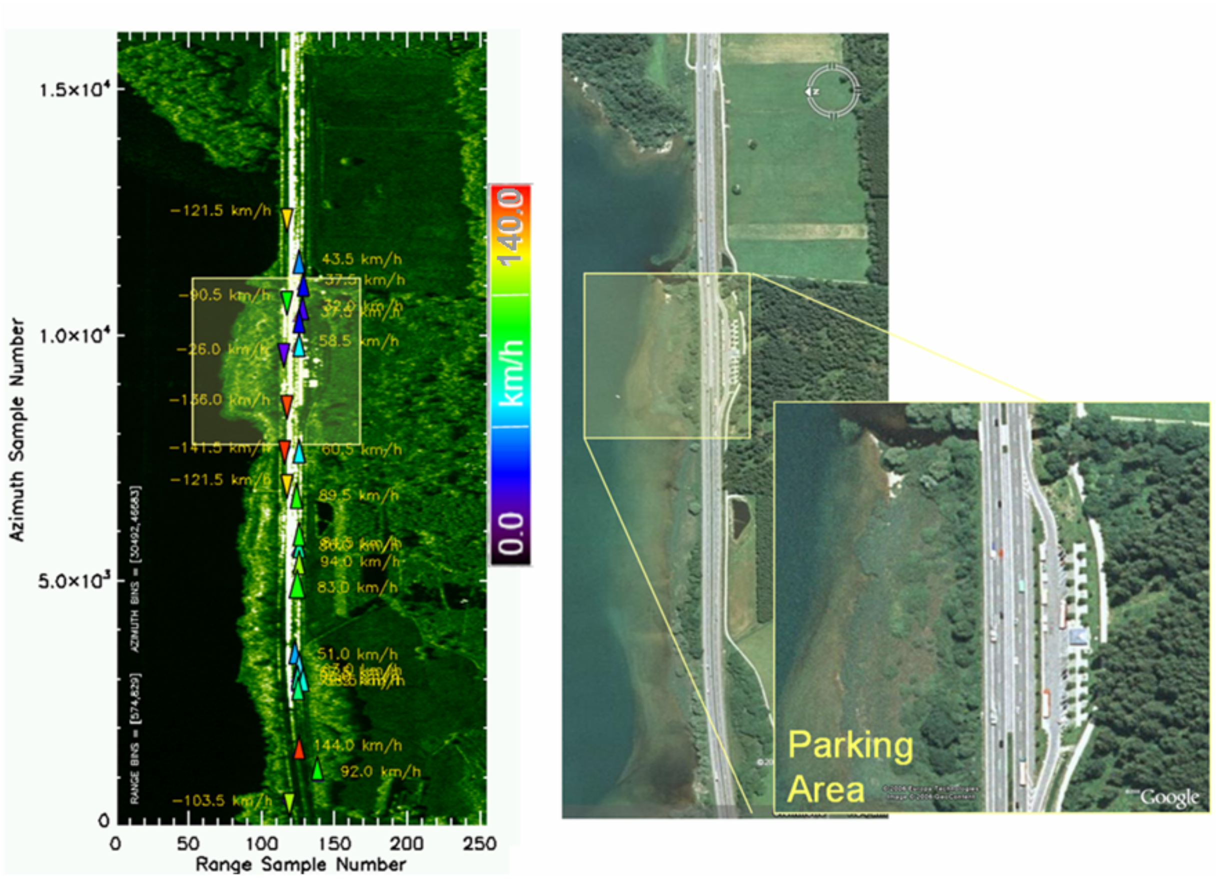

Figure 4. SAR image (left) of a motorway including detected road vehicles (triangles). For each detected vehicle the calculated corresponding speed is coloured (range 0–140 km/h). The pictures on the right are optical images (taken from Google Earth) showing the processed area.

CONCLUSIONS

As the examples shown above demonstrate, high flying radar sensors in combination with optical sensors will give complete new aspects in managing road traffic in different situations of road traffic management or disaster management. In this context, the paper presents the aims of present DLR projects and those of future project work. It further gives an outlook over the potentials of upcoming future airborne sensors supporting traffic and disaster management.

REFERENCES

(1) Trage, S, "Traffic Networking is Booming", Siemens, Pictures of the Future, fall 2005, p 27

(2) Schäfer, R-P, et al., "Analysis of travel times and routes on urban roads by means of floating-car data", European Transport Conference PTRC, Cambridge, UK, September 4-9, (2002)

(3) Fiedler, H, Krieger, G, Zink, M, "Constellation and Formation Flying Concepts for Radar Remote Sensing", in: ESA: Proceedings of the Advanced RF Sensors for Earth Observations, Advanced RF Sensors for Earth Observation (ARSI), ESA/ESTEC, The Netherlands, 2006-12-05 - 2006-12-06

(4) Hounam, D, et al., "An autonomous, non-cooperative, wide-area Traffic Monitoring System using space-based Radar (TRAMRAD)", IGARSS 2005, Harmony Between Man & Nature, International Geoscience and Remote Sensing Symposium, Seoul, July 25-29 2005

(5) Bethke, K-H, et al., "Air- and spaceborne monitoring of road traffic using SAR moving target indication - Project TRAMRAD", International Society for Photogrammetry and Remote Sensing, Airborne and Spaceborne Traffic Monitoring, 61 (3-4), Elsevier, 2006, pp. 243 - 259

(6) Reinartz, P, "Large area traffic monitoring with serial mages from airborne cameras", 13th World Congress Exhibition on Intelligent Transport Systems and Services ITS, London, UK, Oct 9-12, 2006

(7) Baumgartner, S, et.al., "Traffic Monitoring with SAR: Implications of Target Acceleration", 6th European Conference on Synthetic Aperture Radar, EUSAR 2006, 18-18 May, Dresden, Germany

(8) Gabele, M, et al., "Comparison of System Concepts for Traffic Monitoring with Multi-Channel SAR". In: European Conference on Synthetic Aperture Radar (EUSAR), VDE Verlag GmbH, S. 1 - 4, European Conference on Synthetic Aperture Radar (EUSAR), Dresden, Germany, 2006-05-16 - 2006-05-18, ISBN 3-8007-2960-1

(9) Ruhe, M, et.al., "Airborne Systems and Data Fusion for Traffic Surveillance and Forecast for the SOCCER World Cup", 86th Annual Meeting TRB - Transportation Research Board, 2007, Washington DC.