Annual Report 2016

Institute of Engineering Geodesy (IIGS)

1. Members of Staff

Head of Institute:	Prof. Dr.-Ing. habil. Volker Schwieger	
Secretary:	Elke Rawe Ute Schinzel	
Emeritus:	Prof. Dr.-Ing. Dr.sc.techn.h.c. Dr.h.c. Klaus Linkwitz	
Scientific Staff:	Dr.-Ing. Ashraf Abdallah (until 31.03.2016)	GNSS Positioning
	M.Sc. Bara' Al-Mistarehi (until 31.03..2016)	Construction Process
	M. Sc. Alexandra Avram (since 01.10.2016)	GNSS
	M.Sc. Marko Gasparac (since 01.01.2016)	GNSS and Digital Map
	M.Sc. Aiham Hassan	Monitoring
	Dipl.-Ing. Patric Hindenberger (since 01.08.2016)	Location Referencing
	Dipl.-Ing. Stephanie Kauker	Monitoring
	Dipl.-Ing. Otto Lerke	Machine Guidance
	Dr.-Ing. Martin Metzner	Engineering Geodesy
	Dipl.-Ing. Annette Scheider	Kinematic Positioning
	M.Sc. Pham Trung Dung	Kinematic Positioning
	M.Sc. Annette Schmitt	Multi-Sensor-Systems
	Dr.-Ing. Rainer Schützle (until 30.06.2016)	Location Referencing
	M.Sc. Jinyue Wang	Map Matching
	Dr.-Ing. Li Zhang	Monitoring
Technical Staff:	Andreas Kanzler Martin Knihs Lars Plate	
External Teaching Staff:	Dipl.-Ing. Jürgen Eisenmann	Geschäftsbereichsleiter Landratsamt Ostalbkreis,– Geoinformation und Landentwicklung
	Dipl.-Ing. Christian Helfert	Fachdienstleiter Flurneuordnung im Landkreis Biberach
	Dipl.-Math. Ulrich Völter	Geschäftsführer der Fa. Intermetric
	Dr.-Ing. Thomas Wiltschko	Daimler AG, Mercedes-Benz Cars; Research and Development

2. General View

The Institute of Engineering Geodesy (IIGS) is directed by Prof. Dr.-Ing. habil. Volker Schwieger. It is part of the Faculty 6 "Aerospace Engineering and Geodesy" within the University of Stuttgart. Prof. Schwieger holds the chair in "Engineering Geodesy and Geodetic Measurements". In 2016 he was elected Dean of Faculty 6.

In addition to being a member of Faculty 6, Prof. Schwieger is co-opted to Faculty 2 "Civil and Environmental Engineering". Furthermore, IIGS is involved in the Center for Transportation Research of the University of Stuttgart (FOVUS). So, IIGS actively continues the close collaboration with all institutes in the field of transportation, especially with those belonging to Faculty 2.

Since 2011 he is a full member of the German Geodetic Commission (Deutsche Geodätische Kommission – DGK). Furthermore, Prof. Schwieger is a member of the section „Engineering Geodesy" within the DGK. He is head of the DVW working group 3 "Measurement Techniques and Systems" and chairman of the FIG Commission 5 "Positioning and Measurements" in the period from 2015 to 2018.

The institute's main tasks in education focus on geodetic and industrial measurement techniques, kinematic positioning and multi-sensor systems, statistics and error theory, engineering geodesy and monitoring, GIS-based data acquisition, and transport telematics. Here, the institute is responsible for the above-mentioned fields within the curricula of "Geodesy and Geoinformatics" (Master and Bachelor courses of study) as well as for "GEOENGINE" (Master for Geomatics Engineering in English). In addition, the IIGS provides several courses in German for the curricula of "Aerospace Engineering" (Bachelor and Master), "Civil Engineering" (Bachelor and Master), "Transport Engineering" (Bachelor and Master) and "Technique and Economy of Real Estate" (Bachelor). Furthermore, lectures are given in English to students within the master course "Infrastructure Planning". Finally, eLearning modules are applied in different curricula.

The current research and project work of the institute is expressed in the course contents, thus always presenting the actual state-of-the-art to the students. As a benefit of this, student research projects and theses are often implemented in close cooperation with the industry and external research partners. The main research focuses on kinematic and static positioning, analysis of engineering surveying processes and construction processes, machine guidance, monitoring, transport and aviation telematics, process and quality modeling. The daily work is characterized by intensive co-operation with other engineering disciplines, especially with traffic engineering, civil engineering, architecture, and aerospace engineering.

3. Research and Development

3.1. Improving the Quality of Low-Cost GPS Receiver Data Using Temporal Correlations

The investigations on low-cost single frequency GPS receivers at the Institute of Engineering Geodesy (IIGS) show that u-blox LEA-6T GPS receivers combined with Trimble Bullet III GPS antennas containing self-constructed L1-optimized choke rings can already obtain an accuracy in the range of millimeters which meets the requirements of geodetic precise monitoring applications. However, the quality (accuracy and reliability) of low-cost GPS receiver data, particularly in shadowing environment, should still be improved, since the multipath effects are the major error for the short baselines. The multipath effect is changing continuously with the time, i.e. it is temporally correlated. The temporal correlation of the multipath effect is used to improve the quality of low-cost GPS receiver data.

The multipath effect is periodic and a so-called multipath frequency of the carrier-phase can be modelled, if the geometric relationship between satellites, antenna and reflectors is known exactly, normally this is unknown in practice. Many satellites and reflectors are in the vicinity of the antenna, so that the multipath effect of the position is a mixture of the effects of the different pseudo ranges. The other problem is that the multipath frequency is changing with time because of the satellites also changing their positions constantly.

The idea is to calculate the precise multipath frequencies $f_{\delta\varphi,j}$ (compare equation (1)) within a short time period and to reduce these periodic effects in the GPS time series.

$$x_i = \sum_{j=1}^{q} a_j \cdot \sin\left(2\pi \cdot f_{\delta\varphi,j} \cdot t_k\right) + b_j \cdot \cos\left(2\pi \cdot f_{\delta\varphi,j} \cdot t_k\right) \qquad (1)$$

The precise multipath frequencies $f_{\delta\varphi,j}$ can be calculated in two steps:

- The value of the multipath frequencies $f_{\delta\varphi,j}$ will be estimated roughly from the periodogram (step1).
- Since the frequencies in the periodogram are discrete, the precise multipath frequencies $f_{\delta\varphi,j}$ will be estimated in the neighborhood of the found frequencies from the step 1 by adjustment. The frequencies $f_{\delta\varphi,j}$ will be calculated iteratively until there are no more significant harmonic oscillations which are caused by the multipath effect.

The accuracy (standard deviation) of the low-cost GPS measurement can be improved by approx. 50% using this method.

3.2. Positioning of a Survey Vessel: Improved System Model for an Filter Algorithm

The HydrOs system focuses on the supply of precise positions and orientations on inland waterways. For this purpose, an evaluation software including an Extended Kalman Filter (EKF) was implemented and the measurements of a multi-sensor system are used as input (l_k at epoch t_k). Such a multi-sensor system was installed on the survey vessel "Mercator" of the WSA Duisburg.

An EKF algorithm consists of two computation steps: The prediction step which is expressed by the system model and the update step with an observation model.

To achieve further improvements of the resulting positions and orientation angles, the system model and consequently the filter algorithm is expanded as a dynamic system (with memory effect).

It is assumed that accelerations being caused by the vessel propulsion, current, and wind can be modeled if the proper regulating variables are captured. In these cases, a delayed reaction to effective changes in acting forces is observed. So, a term describing a time-delayed proportional response characteristic can be used to model current accelerations, especially in the horizontal velocity components.

Other acting forces (caused by waves, vessel engine, passing ships, etc.) are not included in this deterministic model. They influence especially the roll rate ω_x, the pitch rate ω_y as well as the vertical velocity v_z and the corresponding accelerations. By looking at the measurement details, it is obvious that they include oscillations. For the integration of these remaining, non-modeled accelerations, a geometric prediction is chosen. Therefore, the resulting oscillation characteristics must be investigated, especially the occurring frequencies. For this purpose, Short Time Fourier Transform (STFT) and Continuous Wavelet Transform (CWT) are applied. In the second case, a transfer into the frequency domain is implemented.

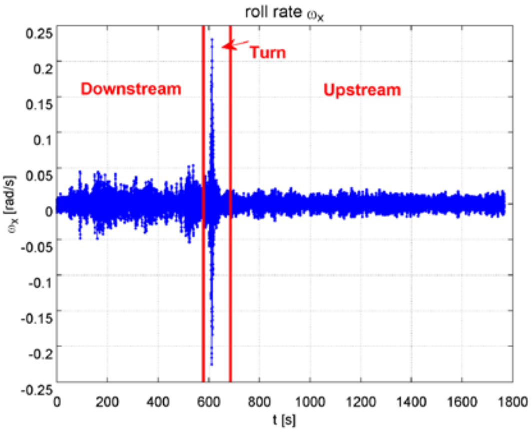

Figure 1: Measured roll rates

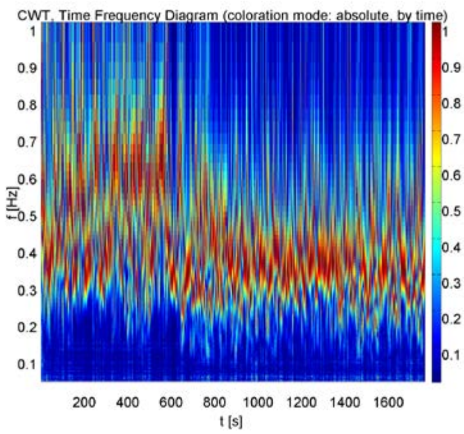

Figure 2: CWT Time Frequency diagram of $\boldsymbol{\partial \omega_x / \partial \Delta t}$ (absolute values, coloration by time epoch)

The results of the analyzed roll rates (see Figure 1) / roll accelerations are shown in Figure 2. Oscillations in the three parts (downstream - turn - upstream) vary with regard to their amplitudes and the occurring frequencies. Therefore, it is necessary to model oscillations locally. The local oscillation parameters are computed by using the Gauß-Markov model for observations at epochs $(\mathrm{t}_{\mathrm{k-n}}, \mathrm{t}_{\mathrm{k}})$. The estimated parameters at epoch t_{k} permit an approximation of the accelerations which are inserted into the the EKF. Hence, the prediction of the state variables $\bar{\mathrm{x}}_{\mathrm{k+1}}$ can be improved (see Figure 3), which is visible in reduced innovations $\mathrm{d}_{\mathrm{k+1}}$,

$$\mathrm{d}_{\mathrm{k+1}} = \mathrm{l}_{\mathrm{k+1}} - \mathrm{a}_{\mathrm{k+1}}(\bar{\mathrm{x}}_{\mathrm{k+1}}),$$

where $\mathrm{a}_{\mathrm{k+1}}(\bar{\mathrm{x}}_{\mathrm{k+1}})$ are the observation equations.

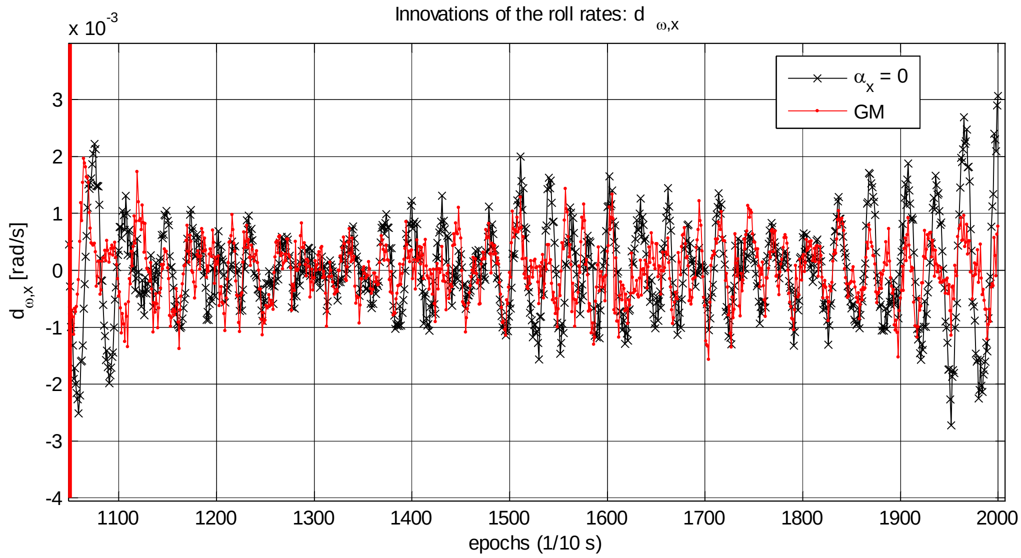

Figure 3: Innovations $\boldsymbol{d_{\omega,x,k}}$ of the roll rates for a model without angular accelarations ($\boldsymbol{\alpha_x} = \mathbf{0}$) and with approximated angular accelerations, which are computed by using the estimated oscillation parameters (GM). (Measurements of Kongsberg MRU5+)

The improvements can be expressed numerically by comparing the Root Mean Square (RMS) values of the innovations resulting from the previous prediction model with those of the extended dynamic system model. Table 1 shows the percentage reduction of these RMS values for the velocity components of the state vector.

Velocity component	ω_x	ω_y	ω_z	v_x	v_y	v_z
Improvement	53 %	42 %	5 %	35 %	13 %	14 %

Table1: Percentage reduction of the RMS values of the innovations for the filter approach with a dynamic system extension compared to the old model

3.3. Evaluation of the Control Quality for Tachymetric Controlled Vehicles

The control quality of a model truck in the scale 1:14, which is part of the construction machine simulator that has been developed at the Institute of Engineering Geodesy, University of Stuttgart, is investigated. The simulator system allows to test and evaluate the performance of different sensors or sensor combinations, as well as filter and control algorithms. In the present configuration, the simulator is able among others to perform lateral control of the model truck which moves automatically along a predefined reference trajectory. A robot tachymeter is the controlling sensor. For the evaluation, the laser tracker *API Radian* is used in combination with an active target as an external measurement system (s. Figure 4 and Figure 5).

Figure 4: Laser Tracker API Radian and Active Targe (Automated Precision Inc., 2014)

The IIGS simulator system comprises a control computer, a robot tachymeter Leica TCRP1201 in combination with a 360° prism GRZ101, an A/D converter, a remote control and the mentioned model truck. The control of the model truck is realized by a closed-loop-system. The loop performs as follows: the tachymeter measures the position of the prism *y(t)*, mounted on the truck at the center of gravity and sends it to the control computer. The computer calculates the perpendicular distance / lateral deviation *e(t)* between the truck position and the reference trajectory. Based on this information, the algorithm calculates the best steering angle *u(t)* to guide the truck back on the reference trajectory as fast as possible. This sequence is executed 8 to 10 times per second. This rate is mainly depending on the kinematic measurement ability of the used robot tachymeter.

The distance measurement accuracy of the used laser tracker is 250 times better than that of the tachymeter. The angle measurement accuracy for both devices is at the same level. The active target has the ability to permanently align with the tracker’s laser beam and thus always keep the line of sight, independently of the platform orientation. The use of this accurate external device allows to separate the control quality and the measurement accuracy from the resulting perpendicular distance, respectively lateral deviation *e(t)*. In consideration of the fact that *e(t)* consists of the two quantities to be separated, we can define this value as combined measure.

Figure 5: Target Device Combination: Active Target and 360° Prism GRZ101

The minimization of *e(t)* within the system is carried out by a PID controller. The control quality of a given controlled system mainly depends on the choice of the controllers and is described as the remaining control deviation. Hypothetically, this value must reach zero. One definition of control quality is the root mean square (RMS), stated as follows:

$$RMS = \sqrt{\frac{\sum_{i=1}^{n} {e_i}^2}{n}}, \qquad (2)$$

e - lateral deviation, *n* - number of measurements.

The quality parameters can be derived from the consideration of the differences between the reference trajectory, the recorded tachymeter trajectory and the recorded laser tracker trajectory. Thus, the following specifications for quality parameters can be defined: the RMS between the reference trajectory and the recorded tachymeter trajectory is defined as combined measure, containing the control quality and the measurement accuracy. The RMS between the reference trajectory and the recorded laser tracker trajectory represents the control quality and the RMS between the tachymeter and the laser tracker trajectory represents the measurement accuracy.

In the test scenario, two different trajectories in the shape of an “oval” and an “eight” were driven. Both trajectories contain the route design elements, like clothoides, circle arcs and straights. A PID controller, with empirically determined parameters, has been used. The data acquisition mode of the laser tracker was set to temporal discretization with a rate of 10 Hertz. The tracker was run simultaneously to the closed-loop of the tachymeter and vehicle operations. Table 2 depicts the achieved results.

	Combined Measure [m]	Control Quality [m]	Measurement Accuracy [m]
“Oval”	*0.0029*	*0.0031*	*0.0028*
“Eight”	*0.0028*	*0.0031*	*0.0029*

Table 2: Resulting RMS for the Quality Parameters

Reconsidering the definition for quality parameters, where the combined measure partly consists of the control quality and the measurement accuracy, it can be expected that the quadratic sum of these two RMS values must result in the RMS of the combined measure. Obviously, that is not the case. The consequential assumption is that unknown systematic effects affect the measurements. These effects could not be revealed yet, only by observing the combined measure. For the first time, this procedure of separating control quality and measurement accuracy allows to detect such effects, which is one of the benefits of the presented laser-tracker based evaluation system.

3.4. Impact of Terrestrial Laser Scanning Error Sources

This work is part of the project IMKAD, which is funded by the Deutsche Forschungsgemeinschaft (DFG) and realized in cooperation between the Institute of Engineering Geodesy, University of Stuttgart, and the Department of Geodesy and Geoinformation, Vienna University of Technology.

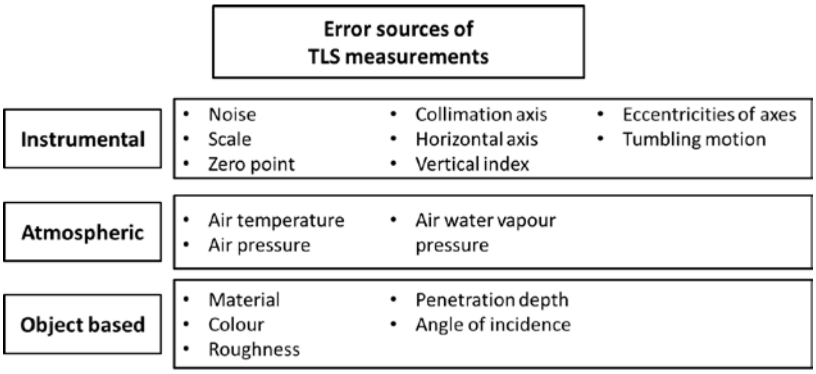

Figure 6: Error sources of terrestrial laser scanning measurements

A synthetic covariance matrix allows to investigate correlations within a point cloud. This matrix contains variances and co-variances based on the functional models of the main influences on measurements, e.g. a terrestrial laser scanning (TLS) point cloud. Figure 6 presents the error sources and their grouping into the three main parts for laser scanning measurements: instrumental errors, atmospheric errors and object-based errors.

In order to compute the correlations, these error sources must be classified into non-correlating, functional correlating, and stochastic correlating groups. The latest is the most challenging part, since the errors show complex relations between surface characteristics and incidence angles. Since the functional relation of these impacts cannot be separated completely, their correlations are computed by assuming an exponential curve as correlation function. For simulation, different data sets are generated, e.g. a grid with the size of 30 cm x 25 cm at 5 m distance (dataset 1) and a grid with the size of 65 m x 55 m at 50 m distance (dataset 2).

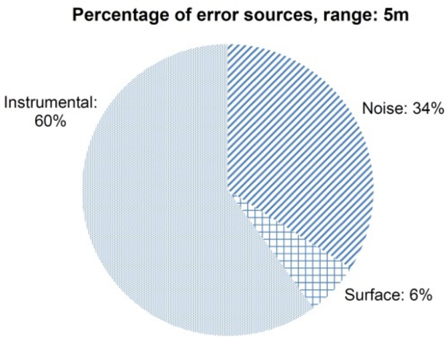

Figure 7: Percentage impact on 3D positional error, dataset 1; mean 3D positional error: 0.6 mm

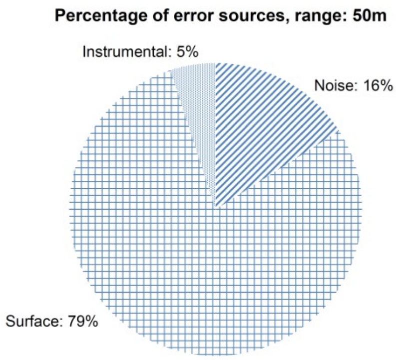

Figure 8: Percentage impact on 3D positional error, dataset 2; mean 3D positional error: 19 mm

By determining the synthetic covariance matrix to dataset 1 and dataset 2, the impact of each error source can be evaluated. In figure 7, dataset 1 is presented. In this case, 60% of the impacts on the three-dimensional positional error are caused by the instrumental error sources which affect the range measurements substantially. The mean error of position is up to 0.6 mm. With respect to the spatial correlations, the biggest impact is up to 90% which is caused by functional correlated range errors. In case of dataset 2, shown in figure 8, the three-dimensional positional error is affected essentially by the impact of the object-based errors due to bigger incidence angles. This group of errors also causes the main impact on the spatial correlations which is up to 95%.

As result, a synthetic covariance matrix might be considered for terrestrial laser scanning in order to take into account essential impacts. For future work, the investigations will focus on computing general correlation functions which might be valid for several datasets.

3.5. Geodetic Control of FEM-Model from Plane Load-Bearing Structures

Stuttgart Smartshell is a double-curved plane load-bearing structure with a base area of about 100 m² and a thickness of 4 cm, made of multilayer wood. Stuttgart SmartShell is resting on four supports. One of these supports is static, while the other three are mobile. The main reason to develop a structure like Stuttgart SmartShell is to investigate possibilities for constructions which offer an active manipulation in order to reduce structural vibrations and stress. In the same time the weight of the structure is reduced drastically. Figure 9 shows Stuttgart SmartShell.

Figure 9: Stuttgart SmartShell (© Bosch Rexroth)

The mobile supports of Stuttgart SmartShell could be moved in the three directions X, Y and Z. For the investigation with the Laser Scanner Leica HDS 7000, all supports are moved sequentially, in all three directions. After each measurement the support is moved back to the initial position. The movement is 20 mm in each direction.

The comparisons between the initial position and the different movements show results as expected by comparison to the FEM-Models. More interesting is the comparison between the FEM-Model and the scans in each position, because the scans show the actual measured state and the simulation shows the model state. For this comparison, the scans are transformed with a classical 3D-Helmert-Transformation to the coordinate system of the FEM-Model. The transformation parameters are determined once in the initial position and used for all other positions, too. Multiple statistical tests are made for all positions. Due to this test, there are no significant deviations, but the results are not realistic, because the deviations of more than 33 mm occur. One reason for the fact that these deviations are non-significant may be the correlations between the measurements.

In another step, laserscanning data from 2012 was compared with the current data set of the initial position. The two data sets were transformed as well and compared. This comparison shows significant deviations at one support. Reasons for those deviations could be the ageing of the structure and the influence of the weather. These deviations led to a fracture of the structure. After fixing the structure, a new CAD model was created from laserscanning data.

The next steps should be the integration of influences due to weather, waterproofing and grinding into the FEM-Model. For further scans, the scanner errors should be investigated in detail and considered in the tests.

3.6. Ghosthunter - Telematics System Against Ghost Drivers Using GNSS

After the data quality evaluation of four different digital road maps (HERE, TomTom, OpenStreetMap and ATKIS-Basis-DLM) had been conducted, a weighting-function based map-matching algorithm was developed and implemented within the research project Ghosthunter that is cooperation with the University of the Armed Forces Munich (UniBwM) and the company NavCert in Brunswick. A map-matching algorithm is utilized to localize and to allocate the measured vehicle position based on GNSS signals on the most probable road link in a given digital road network database. In the preliminary studies, various criteria in terms of similarity between the vehicle trajectory and the matched digital road link are employed for an unambiguous correct identification of the correct road link on which the vehicle is travelling. As similarity criteria, heading, proximity (closeness) and link connectivity are chosen in this work.

The heading criterion describes the difference between the heading angles of the vehicle and a certain road link, which can be expressed as a cosine function (see Equation (1)). Thus, the less the $\Delta\alpha$, the higher the weight $f(\Delta\alpha)$ will be:

$$f(\Delta\alpha) = \cos(\Delta\alpha), \tag{3}$$

where the difference $\Delta\alpha$ between these two headings is defined as the angle between two 2D vectors, the directional vectors v_1 and v_2 respectively:

$$\Delta\alpha = \begin{cases} \arccos\left(\dfrac{\mathbf{v}_1 \cdot \mathbf{v}_2}{|\mathbf{v}_1| \cdot |\mathbf{v}_2|}\right), & 0° \le \Delta\alpha \le 90°; \\ 180° - \arccos\left(\dfrac{\mathbf{v}_1 \cdot \mathbf{v}_2}{|\mathbf{v}_1| \cdot |\mathbf{v}_2|}\right), & 90° < \Delta\alpha \le 180°. \end{cases} \tag{4}$$

Besides the heading criterion, the proximity criterion depending on the distance from a point to a line in 2D, which is calculated as follows:

$$D = \frac{x_3(y_1 - y_2) - y_3(x_1 - x_2) + x_3(x_1 y_2 - x_2 y_1)}{\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}}, \tag{5}$$

where (x_3, y_3) are the coordinates of a measured vehicle position, the points (x_1, y_1) and (x_2, y_2) are the start point and the endpoint of a road link, respectively.

The last criterion considered in the proposed algorithm is the link connectivity that is denoted as,

$$X = \begin{cases} 1 & \text{with connectivity;} \\ 0 & \text{without connectivity.} \end{cases} \tag{6}$$

Using the above introduced similarity criteria, the corresponding weighting-function is expressed as:

$$TWS_i = \begin{cases} H_w \cos(\Delta\alpha) + D_w \left(\frac{\sqrt{2}b - D}{\sqrt{2}b} \right), & i = 2; \\ H_w \cos(\Delta\alpha) + D_w \left(\frac{\sqrt{2}b - D}{\sqrt{2}b} \right) + C_w X, & i \geq 3; \end{cases} \quad (7)$$

where the total weighting score (TWS) for the i-th measured vehicle position is determined from the weight coefficients H_w, D_w and C_w as well as the parameters $\Delta\alpha$, D and X related to heading, proximity and link connectivity criterion in Equation (2), (3) and (4); the variable b is used to define the buffer size. As the second point of the vehicle trajectory has no previous matched road link, the coefficient C_w is set to be zero for i = 2. Additionally, it is suitable for H_w, D_w and C_w to take the values in the following equations:

$$\begin{aligned} &H_w = 0.5, D_w = 0.5, && i = 2, \\ &H_w = \frac{1}{3}, D_w = \frac{1}{3}, C_w = \frac{1}{3}, && i \geq 3. \end{aligned} \quad (8)$$

For testing the correctness of the proposed map-matching algorithm, 35 real-world trajectories datasets and 37 simulated ones were generated und utilized. As illustrated in the figures below, the vehicle positions are completely correctly (100%) matched to the corresponding road segments. It can be demonstrated quite satisfactorily that the developed map-matching algorithm in this work is capable to provide highly correct map-matching results. For each vehicle position, the maximum time consumed by the map-matching process is less than 100 milliseconds. Thus, this map-matching algorithm has been found to be accurate and efficient to locate the vehicle position in the digital road map data, and it is very promising to be applied for the proposed wrong-way driving detection.

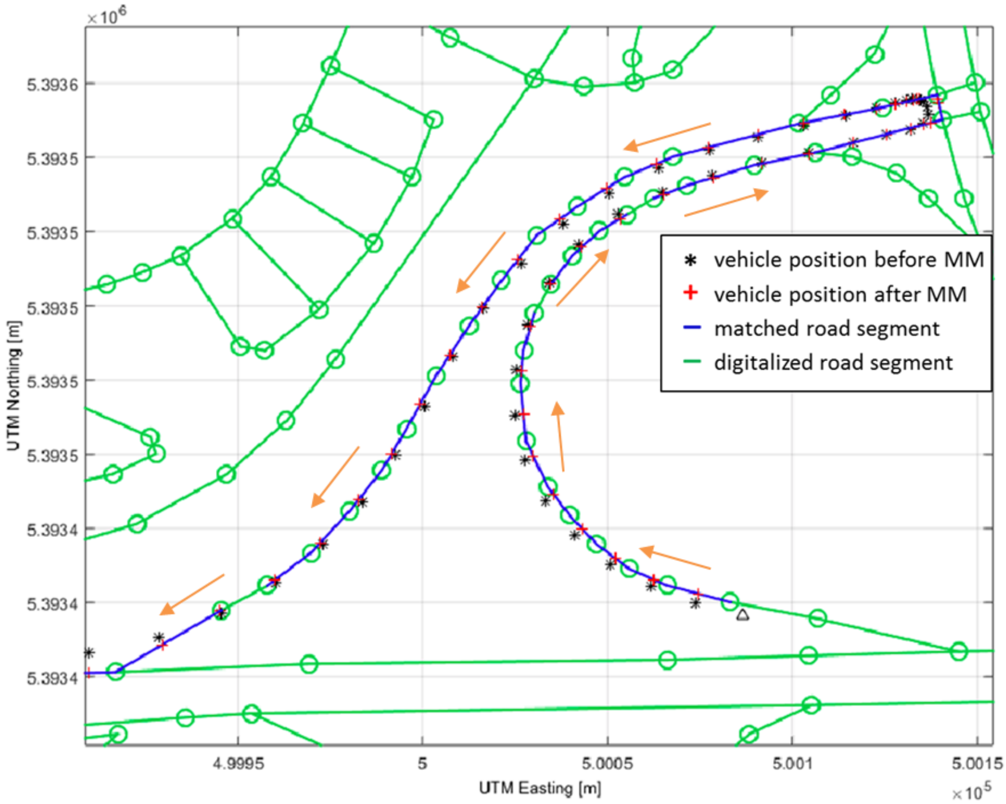

Figure 10: Map-matching results using GNSS-based real-world trajectory data

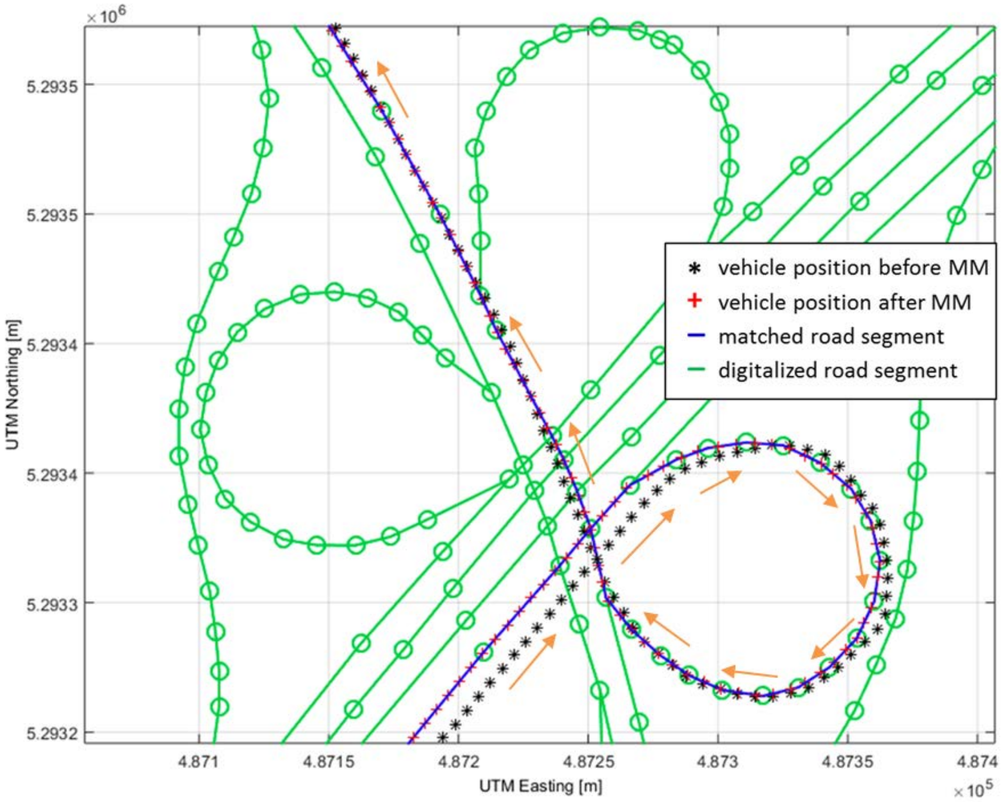

Figure 11: Map-matching results using simulated trajectory data

This work results from the research project Ghosthunter, which has been granted and funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) and the German Aerospace Centre (DLR) under grant number 50 NA 1524.

4. Publications

Refereed Publications

Abdallah, A., Schwieger, V.: Static GNSS Precise Point Positioning Using Free Online Services for Africa. Journal of Survey Review, 47 (346), pp. 61-77, Taylor & Francis, Bristol, United Kingdom.

Harmening, C., Kauker, S., Neuner, H., Schwieger, V.: Terrestrial Laserscanning - Modeling of Correlations and Surface Deformations. FIG Working Week 2016, 02-06.05.2016, Christchurch, New Zealand.

Kauker, S., Holst, Ch., Schwieger, V., Kuhlmann, H., Schön, S.: Spatio-Temporal Correlations of Terrestrial Laser Scanning. Allgemeine Vermessungsnachrichten, 6/2016, S. 170-182, Wichmann Verlag im VDE VERLAG GMBH, Berlin.

Kauker, S., Schwieger, V.: First Investigations for a Synthetic Covariance Matrix for Monitoring by Terrestrial Laser Scanning. In: 3rd Joint International Symposium on Deformation Monitoring (JISDM), 30.03-01.04.2016, Vienna, Austria.

Poptean, S., Jocea, A., Schmitt, A., Schwieger, V., Heidingsfeld, M., Sawodny, O.: Applications of Terrestrial Laser Scanning for Deformation Analyses of an Adaptive Supporting Structure. In: 3rd Joint International Symposium on Deformation Monitoring (JISDM), 30.03-01.04.2016, Vienna, Austria.

Wujanz, D.; Holst, C.; Neitzel, F.; Kuhlmann, H.; Niemeier, W.; Schwieger,V.: Survey Configuration for Terrestrial Laser Scanning. Allgemeine Vermessungsnachrichten, 6/2016, S. 158-169, Wichmann Verlag im VDE VERLAG GMBH, Berlin.

Zhang, L.; Schwieger, V.: Improving the Quality of Low-Cost GPS Receiver Data for Monitoring Using Spatial Correlations. In: Journal of Applied Geodesy 2016, 10(2): pp 119-129, De Gruyter, Germany.

Zhang, L.; Schwieger, V.: Improving the Quality of Low-Cost GPS Receiver Data for Monitoring Using Spatial Correlations. In: 3rd Joint International Symposium on Deformation Monitoring (JISDM), 30.03-01.04.2016, Vienna, Austria.

Non-Refereed Publications

Abdallah, A.; Schwieger, V.: Performance of IGS Final Satellite Data for Kinematic PPP Solutions Using Bernese Solutions and CSRS-PPP Online Service. GeoSiberia 2016, 20.-22.04.2016, Novosibirsk, Russia

Al-Mistarehi, B.; Schwieger, V.: Automatic Classification for Pavement Cracks for Mobile Mapping Data. FIG Working Week 2016, 02-06.05.2016, Christchurch, New Zealand.

Artz, T., Scheider, A., Breitenfeld, M., Brüggemann, T., Schwieger, V., Wirth, H. (2016): Improved Positioning of Surveying Vessels on Inland Waterways with HydrOs. Hydrographische Nachrichten (HN 105), 11/2016, S. 34 - 38; und HYDRO 2016, Rostock-Warnemünde, 08.-10.11.2016

Frankl, K., Beckmann, H., Wang, J., Metzner, M., Schwieger, V., Eissfeller, B.: Preconditions for a Reliable & Robust Detection of Wrong-Way Driving on Highways with GNSS and Autonomous Sensors. 29th International Technical Meeting of the Satellite Division of The Institute of Navigation ION GNSS+ 2016, 12.-16.09.2016, Oregon Convention Center, USA.

Scheider, A.; Hassan, A.; Schwieger, V.; Breitenfeld, M.; Brüggemann, T. (2016): Erweiterte Echtzeit- und Postprocessing-Verfahren zur Optimierung der GNSS-Ortung in Abschattungsbereichen an BWaStr. (Projektabschlussbericht HydrOs II) BfG-Bericht BfG-1892

Wang, J., Metzner, M., Schwieger, V.: Überprüfung und Bewertung der Datenqualität von digitalen Straßenkarten – Kartenvergleich zwischen HERE, TomTom, OSM und ATKIS-Basis-DLM, DGON-Symposium POSNAV, Berlin.

5. Presentations

Lerke, O., Schwieger V.: Evaluation of the Control Quality for Tachymetric Controlled Vehicles; MCG 2016 – 5th International Conference on Machine Control & Guidance, 5./6.10.2016; Vichy, France.

Pham, D.; Schwieger, V.: Comparison of filtering algorithms in vehicle positioning by using low-cost sensors. MCG 2016 – 5th International Conference on Machine Control & Guidance, 5./6.10.2016; Vichy, France.

Schwieger, V.: Low-Cost GPS for Monitoring - Improvement by Using Spatial Correlations. 16.05.2016, Chinese Academy of Surveying and Mapping; 18.05.2016, Wuhan University; 20.05.2016, Tongji University, China.

Schwieger, V.: Introduction on Faculty of Aerospace Engineering and Geodesy as well as Institute of Engineering Geodesy. 16.05.2016, Chinese Academy of Surveying and Mapping; 18.05.2016, Wuhan University; 20.05.2016, Tongji University, China.

Schwieger, V.: First Investigations for a Synthetic Covariance Matrix for Monitoring by Terrestrial Laser Scanning. First Workshop of DAAD Thematic Network "Modern Geodetic Space Techniques for Global Change Monitoring", 20.–22.07.2016, Stuttgart, Germany.

Schwieger, V.: Qualitätssicherung in der Ingenieurgeodäsie - ein Überblick. 153. DVW Seminar Qualitätssicherung geodätischer Mess- und Auswerteverfahren, 23./24.06.2016, Hannover, Germany.

Schwieger, V.: Construction Machine Guidance. 31.10.-02.11.2016, Technical University of Construction Bucharest, Romania.

Schwieger, V.: Low Cost GNSS. 31.10.-02.11.2016, Technical University of Construction Bucharest, Romania,

Schwieger, V.: Terrestrial Laser Scanning. 31.10.-02.11.2016, Technical University of Construction Bucharest, Romania.

Map Matching Applications. Seminar SE 3.05 " GPS/INS-Integration und Multisensor-Navigation“, Carl-Cranz-Gesellschaft e.V., Oberpfaffenhofen, 24.11.2016.

6. Activities at the University and in National and International Organisations

Volker Schwieger

- Dean of Faculty of Aerospace Engineering and Geodesy, University of Stuttgart
- Chair of FIG Commission 5 "Positioning and Measurement"
- Head of Working Group III „Measurement Methods and Systems“ of Deutscher Verein für Vermessungswesen (DVW)
- Chief Editor of Peer Review Processes for FIG Working Weeks and Congresses
- Member of Editorial Board Journal of Applied Geodesy
- Member of Editorial Board Journal of Applied Engineering Science
- Member of Editorial Board Journal of Geodesy and Geoinformation

Martin Metzner

- Member of the NA 005-03-01 AA "Geodäsie" at the DIN German Institute for Standardization

Li Zhang

- Vicechair of Administration of FIG Commission 5 "Positioning and Measurement"
- Member of Working Group III „Measurement Methods and Systems“ of Deutscher Verein für Vermessungswesen (DVW)

7. Doctorates

Abdallah, Ashraf Talaat Mohammad: Precise point positioning for kinematic applications to improve hydrographic survey. Hauptberichter: Prof. Dr.-Ing. habil. V. Schwieger, Mitberichter: Prof. Dr. sc.-techn. W. Keller. Online Publikationen der Universität Stuttgart http://dx.doi.org/10.18419/opus-9026

Schützle, Rainer: Entwicklung und Evaluierung eines formgestützten Location Referencing Verfahrens München 2016, ISBN 978-3-7696-5193-5, Hauptberichter: Prof. Dr.-Ing. habil. V. Schwieger, Mitberichter: Prof. Dr.-Ing. L. Meng, Prof. Dr.-Ing. D. Fritsch. Online Publikationen der Universität Stuttgart: http://dx.doi.org/10.18419/opus-8971 und Bayerische Akademie der Wissenschaften, Verlag C. H. Beck, DGK, Reihe C, Nr. 776

Zhang, Li: Qualitätssteigerung von Low-Cost-GPS Zeitreihen für Monitoring Applikationen durch zeitlich-räumliche Korrelationsanalyse München 2016, ISBN 978-3-7696-5188-1, 170 S., Hauptberichter: Prof. Dr.-Ing. habil. V. Schwieger, Mitberichter: Prof. Dr.-Ing. O. Heunecke, Prof. Dr.-Ing. habil. L. Wanninger. Online Publikationen der Universität Stuttgart: http://dx.doi.org/10.18419/opus-8940 und Bayerische Akademie der Wissenschaften, Verlag C. H. Beck, DGK, Reihe C, Nr. 781

8. Diploma Theses and Master Theses

Friedrich, Janina: Geodätische Aufnahme des Flughafens Friedrichshafen zur Zertifizierung

Piesch, Simon: Programmierung einer Android-App zum Einrichten einer Referenzstation

Pricӑ, Iulia-Mihaela: Investigation of the deformations of a timber plates pavilion (in cooperation with Technical University of Construction Bucharest)

Schirmer, Isabella: Geodätische Aufnahme des Flughafens Friedrichshafen zur Zertifizierung

Trusca, Sandra: Optimization of 2D and 3D Geodetic Networks (in cooperation with Technical University of Construction Bucharest)

Wenk, Maximilian: Untersuchung verschiedener Ansätze zur kinematischen Georeferenzierung für terrestrische Laserscanner

Zhang, Lifan: Accurate Geo-Referencing for Deformation Analysis by TLS

9. Study Theses and Bachelor Theses

Kohler, Stefan: Untersuchung einer optimalen Aufnahmekonfiguration für Laserscanner

Kokenbrink, Jana: Erstellung eines 3D CAD-Modells der Stuttgarter Smartshell durch Vermessung der Ist-Geometrie (In Zusammenarbeit mit dem Institut für Leichtbau Entwerfen und Konstruieren - ILEK)

Mayer, Lucas: Bewertung und Analyse der innerörtlichen Flurneuordnung zur Beseitigung ungeregelter Verhältnisse und Reaktivierung von Ortskernen

Ren, Wenhao: Qualitätsvergleich von SmartNet- und SAPOS-Dienst

10. Education

SS16 and WS16/17 with Lecture/Exercise/Practical Work/Seminar

Bachelor Geodesy and Geoinformatics (German):	
Basic Geodetic Field Work (Schmitt, Kanzler)	0/0/5 days/0
Engineering Geodesy in Construction Processes (Schwieger, Hassan)	3/1/0/0
Geodetic Measurement Techniques I (Metzner, Schmitt)	3/1/0/0
Geodetic Measurement Techniques II (Schmitt)	0/1/0/0
Integrated Field Work (Kauker, Metzner)	0/0/10 days/0
Methods of Measurements and Analysis in Engineering Geodesy (Schwieger, Hassan, Kauker)	2/2/0/0
Reorganisation of Rural Regions (Helfert)	1/0/0/0
Statistics and Error Theory (Schwieger, Wang)	2/2/0/0
Master Geodesy and Geoinformatics (German):	
Causes of Construction Deformation (Metzner, Wang)	1/1/0/0
Deformation Analysis (Zhang)	1/1/0/0
Industrial Metrology (Schwieger, Schmitt)	1/1/0/0
Land Development (Eisenmann)	1/0/0/0
Monitoring Measurements (Schwieger, Wang)	1/1/0/0
Monitoring Project (Lerke)	0/0/2/0

Thematic Cartography (Zhang, Kauker)	1/1/0/0
Transport Telematics (Metzner, Scheider)	2/2/0/0
Master GeoEngine (English):	
Integrated Field Work (Kauker, Metzner)	0/0/10 days/0
Kinematic Measurement Systems (Schwieger, Lerke)	2/2/0/0
Monitoring (Schwieger, Wang)	1/1/0/0
Thematic Cartography (Zhang, Kauker)	1/1/0/0
Transport Telematics (Metzner, Scheider)	2/1/0/0
Terrestrial Multisensor Systems (Zhang, Lerke)	2/1/0/0
Bachelor and Master Aerospace Engineering (German):	
Statistics for Aerospace Engineers (Zhang, Hassan)	1/1/0/0
Master Aerospace Engineering (German):	
Transport Telematics (Metzner, Scheider)	2/2/0/0
Bachelor Civil Engineering (German):	
Geodesy in Civil Engineering (Metzner, Hassan)	2/2/0/0
Master Civil Engineering (German):	
Geoinformation Systems (Metzner, Lerke)	2/1/0/0
Transport Telematics (Metzner, Scheider)	1/1/0/0
Bachelor Technique and Economy of Real Estate (German):	
Acquisition and Management of Planning Data and Statistics (Metzner, Kanzler)	2/2/0/0
Bachelor Transport Engineering (German):	
Statistics (Metzner, Kanzler)	0.5/0.5/0/0
Seminar Introduction in Transport Engineering (Schmitt)	0/0/0/1
Master Infrastructure Planning (English):	
GIS-based Data Acquisition (Zhang, Schmitt)	1/1/0/0