Annual Report 2018

Institute of Engineering Geodesy (IIGS)

1. Members of Staff

Head of Institute:	Prof. Dr.-Ing. habil. Volker Schwieger	
Secretary:	Elke Rawe Ute Schinzel	
Scientific Staff:	M.Sc. Alexandra Avram	GNSS
	M.Sc. Laura Balangé (since 01.12.2018)	Quality Modelling
	M.Sc. Urs Basalla (since 15.10.2018)	Terrestrial Laser Scanning
	M.Sc. Marko Gasparac	GNSS and Digital Map
	M.Sc. Aiham Hassan	Monitoring
	Dipl.-Ing. Patric Hindenberger	Location Referencing
	M.Sc. Gabriel Kerekes	Terrestrial Laser Scanning
	Dipl.-Ing. Otto Lerke	Machine Guidance
	M.Sc. Philipp Luz (since 01.11.2018)	Digital Map
	Dr.-Ing. Martin Metzner	Engineering Geodesy
	M.Sc. Dung Trung Pham	Kinematic Positioning
	Dipl.-Ing. Annette Scheider (until 31.03.2018)	Kinematic Positioning
	M.Sc. Annette Schmitt	Multi-Sensor-Systems
	M.Sc. Martin Wachsmuth	Kinematic Positioning
	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 Faculty 6 “Aerospace Engineering and Geodesy“ within the University of Stuttgart. Prof. Schwieger holds the chair in “Engineering Geodesy and Geodetic Measurements”. Since 2017, he is the 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, the IIGS is involved in the Center for Transportation Research of the University of Stuttgart (FOVUS). Thus, the IIGS actively continues the close collaboration with all institutes in the field of transportation, especially with those belonging to Faculty 2.

Since 2011, Prof. Schwieger is a full member of the German Geodetic Commission (Deutsche Geodätische Kommission – DGK). Furthermore, he 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.

In 2018 the Cluster “Integrative Computational Design and Construction for Architecture” (IntCDC), for which the university has applied for a grant as part of the excellence strategy to strengthen top-level research in Germany, has been awarded funding for the next seven years. The cluster IntCDC aims to harness the full potential of digital technologies in order to rethink design and construction, and enable groundbreaking innovations for the building sector through a systematic, holistic and integrative computational approach. As a member of the cluster (IntCDC), the institute research in the field of new construction methods is intensified in cooperation with architects, civil engineers, computer scientists, production engineers and other scientists from the university.

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 modelling. 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. Automated Multi-sensor Early Warning System on the Three Gorges Dam - DAAD PPP China

The Project-Based Personal Exchange between the Institute of Engineering Geodesy (IIGS) at the University of Stuttgart and the School of Geodesy and Geomatics (SGG) at the University of Wuhan is supported by the DAAD (German Academic Exchange Service) and the CSC (China Scholar Council). The aim of this project is to realize an automated multi-sensor early warning system near the Three Gorges Dam. The sensors used for this purpose are GNSS, Ground Based Synthetic Aperture RADAR (GB-SAR) and Terrestrial Laser Scanner (TLS). Based on the GNSS and GB-SAR data gathered in the first measurement campaign performed in September 2017, an integration concept between both techniques was proposed. Furthermore, the atmospheric influence on the GB-SAR data was analyzed and the available correction methods were tested. The results of those tests showed that GB-SAR data are more sensitive against variation of humidity and temperature and less sensitive against variation of air pressure. The atmospheric correction of these data using Ground Control Points (GCP) is more efficient compared to the correction by means of atmospheric models based on meteorological observations gathered at the measurement site. The analysis of the displacement time series (Figure 1) at the measurement site showed no significant displacement during the measurements. The results of those investigations were published in a joint paper, written by all participants, in the FIG congress in Istanbul 2018.

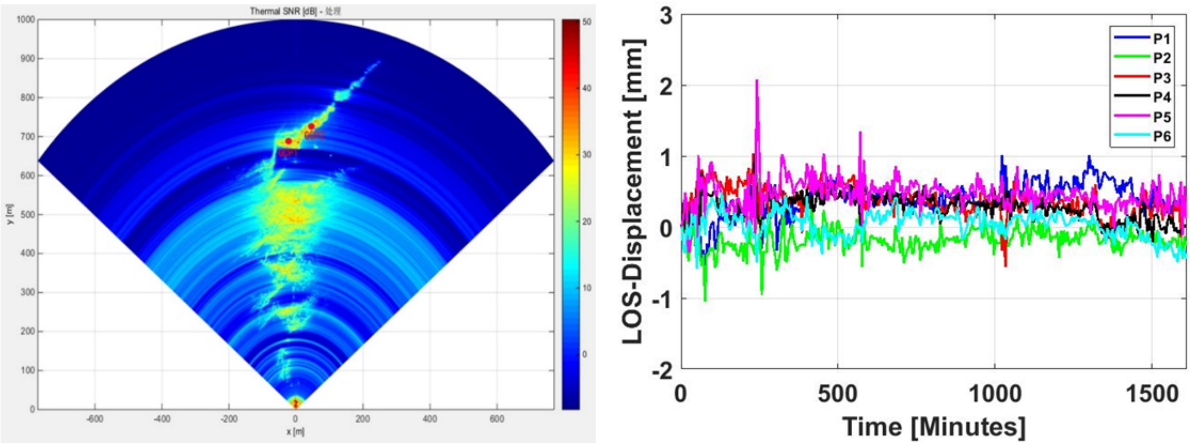

Figure 1 SAR Thermal SNR image and selected GCPs for the atmospheric correction (left) and Line of sight (LOS) displacement time series for some pixels after atmospheric correction using GCP (right)

In order to include TLS in the integration concept, a Bachelor thesis at the IIGS discussed the efficiency of available Laser Scanning software regarding the geodetic deformation analysis.

Prof. Volker Schwieger, Li Zhang, Annette Schmitt and Aiham Hassan visited the SGG in March 2018 and went to the Three Gorges area for the second measurement campaign. Besides the GB-SAR and GNSS measurement, TLS and low cost GNSS measurements were performed in this campaign. Within this visit, the extension of the project was discussed.

Furthermore and in order to optimize the selection of measurement configuration for the GB-SAR, a simulation was performed and the accuracy of the 3D-displacement, which can be extracted from the measured 1D LOS-displacement through a transformation involving further measurements, was analyzed under different measurement configurations. This analysis showed that the main influence factor on this accuracy is the angle between the LOS- and the real displacement directions. The results of the simulation were then approved using empirical data from the second measurement campaign. The results of this investigation were published at the GeoPreVi 2018 international symposium in Bucharest, Romania. Finally, it should be mentioned that DAAD and CSC approved the extension of the project for one year.

3.2. Adaptive Control for Guidance of Tracked Vehicles

The automatic control may be established by designing a closed-loop system, where the process respectively the plant follows a reference variable, respectively a set point. The main disadvantage of conventional controllers (3-point-, PID-, or Fuzzy- controllers) is that during changes in the environment (or the process) the controller parameters need to be retuned and reset to keep the control quality at a desirable level. To overcome this drawback, an adaptive controller can be used which automatically adjusts in particular alternating operating conditions in order to match the set requirements on control quality.
Among different adaptive controller schemes, the self-tuning regulators and controllers (STR/ STC) have been chosen for guidance of a tracked UGV.
The starting point is an ordinary closed-loop system, where the feedback signal is processed within a controller in order to minimize the control deviation. This feedback control loop is now extended by an additional functionality, which identifies the controlled process by the use of its input and output. The extension estimates the process parameters and subsequently calculates the controller settings, respectively its parameters.
The online parameter estimation, related to the identification step, is based on a linear model, expressed as linear difference equation in the shape of an ARMAX model (autoregressive moving average model with auxiliary or exogenous input).

$$y(t) + a_1 y(t-1) + \cdots + a_n y(t-n) = b_0 u(t-k) + b_1 u(t-k-1) + \cdots$$
$$\ldots + b_m u(t-k-m) + c_0 \xi(t) + c_1 \xi(t-1) + \cdots + c_n \xi(t-n) + d(t) \qquad (1)$$

y – controlled variable, u – regulating variable, a_i, b_i, c_i – model parameters, ξ – stochastic noise, d – disturbance variable (not measured).

After the process model parameters have been estimated, the calculation of suitable controller settings for control action must be performed. The minimum variance control law can be derived by rearrangements and simplifications of equation (1) in order to obtain the regulating variable (Seborg et al. 1986):

$$u(t) = \frac{1}{\beta_0}\left(\alpha_1 y(t) + \cdots + \alpha_n y(t-n+1)\right) - \beta_1 u(t-1) - \cdots - \beta_l u(t-l) \qquad (2)$$

Exemplarily, four driving experiments have been conducted, whereas two of them have taken place in laboratory and two under outdoor conditions. The achieved results are satisfactory, while showing the control quality of the STC at a comparable level to the conventional PID controller under laboratory conditions (Table 1). The outdoor experiments show a better performance of the STC (Table 2).

Table 1: RMS values for the laboratory experiments

Trajectory	Self-tuning controller (STC)	PID controller
1 (oval)	*0.0023 m*	*0.0018 m*
2 (eight)	*0.0037 m*	*0.0028 m*

Table 2: RMS values for the outdoor experiments

Trajectory	Self-tuning controller (STC)	PID controller
3	*0.0089 m*	*0.0131 m*
4	*0.0072 m*	*0.0086 m*

The greatest advantage of adaptive controllers is the non-necessity of excessive, time-consuming tuning procedures and the indicated better performance in outdoor driving environments.

3.3. Optimization of the Positioning of Adaptive Supports

At the university of Stuttgart, the first adaptive double curved plane load bearing structure was developed. This structure is called Stuttgart SmartShell. It has got a base area of about 100 m² and a thickness of 4 cm, made of multilayer wood. Resting on three adaptive supports and one static support, the Stuttgart SmartShell offers the investigation of possibilities to reduce stress and structural vibration, while the weight of the structure is reduced drastically. Figure 2 shows the Stuttgart SmartShell.

In a former investigation, laser scanning data from 2012 were compared with a data set from 2015 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 laser scanning data.

The optimization of the position of the adaptive support due to environmental influences is the main task of this project. The deviations due to the environmental influences are investigated by laser scanners. To detect the significant deviations it is necessary to know the 3D-point error of the measured points. This error is calculated for a complete scan of the Stuttgart SmartShell by using the synthetic variance covariance matrix from IMKAD. In the next step, an algorithm to compute the deformation analysis is developed based on the 3D – point errors and the law of error propagation.

Figure 2: Stuttgart SmartShell (© Bosch Rexroth)

3.4. Quality assurance for wooden pavilion

For the Bundesgartenschau 2019 in Heilbronn, the Institute for Computational Design and Construction (ICD) has planned a wooden pavilion. Similar to the pavilion of the Landesgartenschau 2014 in Schwäbisch Gmünd, it is constructed with many wooden elements. These wooden elements, called cassettes, are made of spruce wood glued together. For this pavilion, the plan is that the cassettes fit with small tolerances, meaning the cassettes are milled to the true form and not smaller. The aim is to investigate how precise the milling process of the cassettes is. Therefore it is planned to take measurements with the API laser tracker along the edges that are in contact with other elements. These measured edges will then be compared to the CAD model of the equivalent cassette (Figure 3). In December, two measurements took place and further measurements are planned. Furthermore, scanning of the whole pavilion is planned in three stages: after constructing, midterm and before deconstructing.

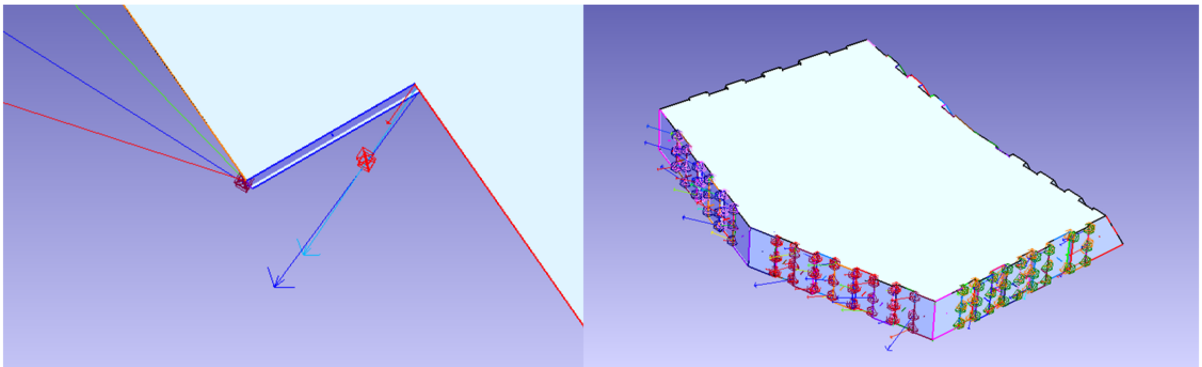

Figure 3: CAD model of a wooden cassette with laser tracker measurements.

For the Remstal Gartenschau 2019, the ICD has planned a wooden tower. Half of the wooden elements will be constructed in Switzerland. These wooden elements will be constructed with curved wood bilayers. The approximately 30 curved wood bilayers will be scanned at the factory “Blumer-Lehmann” in Gossau (CH) to obtain the radii. In a next step, the wood bilayers will be glued into two fifteen meter long elements. These will be scanned as well at the factory. Of these larger elements the finished components will be milled out and scanned again at the factory. The plan is to build the tower near Urbach and have it scanned every six months for monitoring purposes. The tower is planned to be on site for five years.

3.5. Hybrid model for GNSS multipath simulation

Errors in the GNSS receiver Delay-Locked Loop (DLL) and Phase-Locked-Loop (PLL) are mainly caused by multipath biased phase and code measurements. These influence the positioning algorithms and induce errors in the final coordinates. In order to analyse the receiver tracking error for a specific environment with a GNSS (Global Navigation Satellite System) signal generator, a combination between a deterministic and a statistic model is used. A deterministic model is appropriate when the system is well known, whereas a statistic one describes the unknowns in terms of probabilities. Considering that GNSS multipath errors are influenced by many factors, a combined model is appropriate to describe the system accurately.

The Fresnel-Kirchhoff formula is implemented to model the diffraction in 2D. Given the satellite elevation angle, building coordinates, antenna position and height, the signal fading characteristics are modelled. Diffuse multipath is added to the time series to take into account the random scattering. For this purpose, a Rayleigh fading channel using Gaussian distributions in quadrature is implemented. The 2D environment is modelled and the signal fading is simulated for a satellite at 35° elevation.

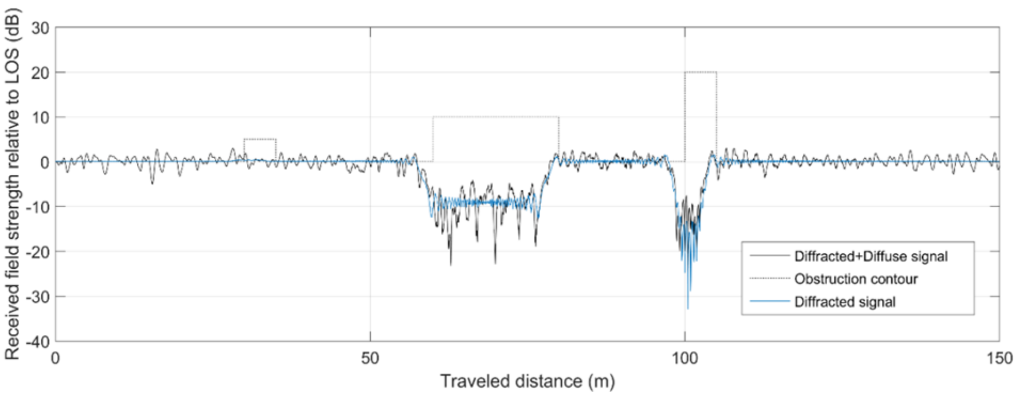

Figure 4 – MATLAB simulation of the 2-dimensional environment and the corresponding multipath series for one satellite at 35° elevation. The receiving antenna is simulated along a trajectory parallel to the three buildings

Figure 4 shows the three buildings, which are modelled. The corresponding multipath fading is outlined with the black line along the trajectory, whereas the blue line represents the diffraction. It is visible that the higher the building, the more affected is the signal. This approach is appropriate for multipath simulations, where a specific environment has to be considered.

3.6. Integrated space-time modelling based on correlated measurements for the determination of survey configurations and the description of deformation processes (IMKAD II)

Gefördert durch
DFG Deutsche Forschungsgemeinschaft

The previous DFG (Deutsche Forschungsgemeinschaft) project IMKAD I focused on functional modelling of point clouds, stochastic modelling of terrestrial laser scanners' (TLS) error sources and analyzing survey configurations for space-continuous monitoring. The advances obtained during the IMKAD I project, but also the drawbacks of different measurements are subject to deeper research in the current proposal.

In recent years, B-spline curves and surfaces became popular within engineering geodesy due to their suitability in representing point cloud information. However, if geometry is functionally modeled through local B-spline and global Bézier surfaces without stochastic information about the control points, this may lead to unrealistic surface estimations. The approach developed in collaboration with the Austrian partner Research Group Engineering Geodesy (RGEG) from TU Wien foresees the use of a synthetic covariance matrix to stochastically model TLS point clouds. This is further used as weighting information in the B-spline model:

$$\boldsymbol{\Sigma}_{ll} = \sum_{k=1}^{p} \boldsymbol{D}_k \cdot \boldsymbol{\Sigma}_{\delta\delta,k} \cdot \boldsymbol{D}_k^T + \boldsymbol{F} \cdot \boldsymbol{\Sigma}_{\xi\xi} \cdot \boldsymbol{F}^T + \sum_{h=1}^{q} \boldsymbol{G}_h \cdot \boldsymbol{\Sigma}_{\gamma\gamma,h} \cdot \boldsymbol{G}_h^T$$

With $\boldsymbol{p}$ matrices $\boldsymbol{D}_k$ for non-correlating errors, one matrix $\boldsymbol{F}$ for functional correlating errors, q matrices $\boldsymbol{G}_h$ for stochastic correlating errors. $\boldsymbol{\Sigma}_{\delta\delta,k}$ the covariance matrix for the non-correlating errors, $\boldsymbol{\Sigma}_{\xi\xi}$ the covariance matrix for the functional correlating errors, $\boldsymbol{\Sigma}_{\gamma\gamma,h}$ the covariance matrix for the stochastic correlating errors. Until now, this model was developed for a phase-based panoramic scanner (Leica HDS 7000) and not validated through real-world measurements. The future steps imply the creation of an extended synthetic covariance matrix with an improved functional model for the phase-based scanner and a new model for a pulse-based scanner (Riegl VZ-2000). Furthermore, validation experiments are planned for objects that range in dimension from 30 cm (laboratory conditions) up to 300 m (water dam). As regards findings, we expect to achieve a realistic stochastic model for point clouds and determine optimal scanning parameters for deformation analysis based on B-spline surface estimation.

3.7. Ghosthunter - Telematics System against Ghost Drivers using GNSS

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

The aim of the Ghosthunter II research project is to develop a detection system to extend current car navigation systems detecting ghost drives on motorways and their ramps and warning both the ghost drivers themselves and other road users. This project is carried out in cooperation with the Institute of Space Technology and Space Applications at the University of the Federal Armed Forces Munich and the companies NavCert and TomTom.

In a first step, the algorithms developed in the previous project must be ported and optimized with regard to the lower performance of the target hardware. The TomTom Bridge navigation system based on Android was selected as the target hardware.
In order to ensure the real-time capability of the algorithm, changes have been made. Especially the search functions and the data structure have been improved. Thus it was possible to reduce the time to match a GPS position from 1460 ms to 400 ms. Furthermore, an Android app was developed to visualize the digital map as well as the results of the map matching and to allow an operation in the car (Figure 5).

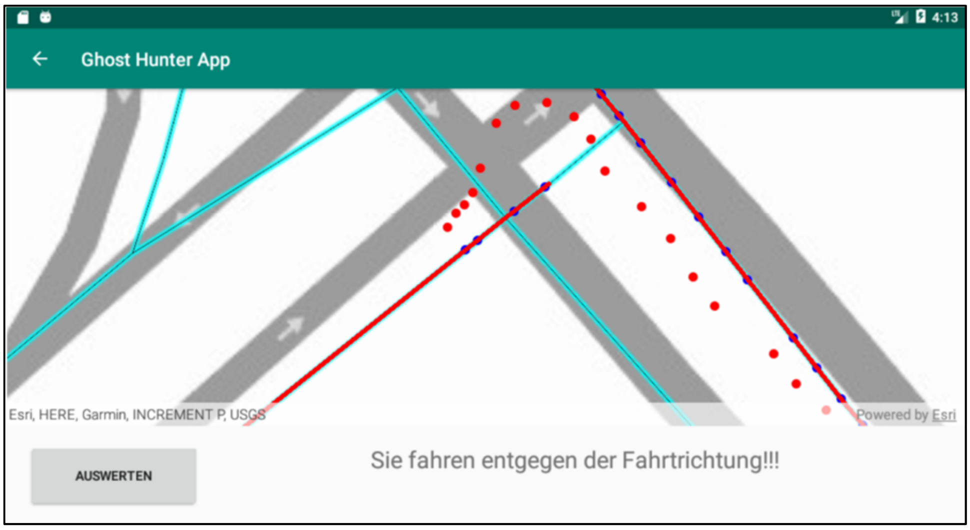

Figure 5: Interface of the Android App "Ghosthunter"

The next steps include the integration of traffic flow data and the adaptation of the algorithm to lane exact ADAS maps. In addition, the integrity of the system will be analyzed.

3.8. TransSec - Autonomous Emergency Manoeuvering and Movement Monitoring for Road Transport Security

With the rise of truck-based terror attacks in European countries (like in Nice and Berlin), a new form of transport security is necessary to help prevent such incidents. For this purpose, a European Project TransSec (Autonomous emergency manoeuvering and movement monitoring for road transport security) is funded by the European Commission within the program Horizon H2020 for three years. This project was started in February 2018 and its goal is to design and implement such an intelligent positional monitoring and manoeuvering system to prevent terror attacks.

European Commission

European Global Navigation Satellite Systems Agency

The Institute of Engineering Geodesy (IIGS) at the University of Stuttgart is one of the five partners involved in the TransSec project. The IIGS has the task to design, develop and implement a prototype of map including the static environment as well as an electronic horizon provider for the vehicle based on a map aiding algorithm. Finally, a local dynamic map will be created using the information of the current acquired situation from the sensors like cameras and laser scanners, so that the dynamic objects like vehicles, pedestrian around the trucks can be detected.

And the other task of IIGS is to get the precise positioning of the trucks by integrating the data from GNSS and other additional sensors like odometer, gyroscopes and accelerometers, cameras and Lidar, etc.

In 2018, map data availability and quality analysis was done. The first demonstration of positioning system (based on GNSS only) with map preview was successful. The next step is the extension of the static map and multisensor integration.

3.9. Dynamic Location Referencing: Probability and Fuzzy Logic based decision systems

Dynamic Location Referencing is a well-known methodology to transfer geoobjects from one digital road map to another in such cases where no common databases and/or common structures are available and are typically used to share traffic information. The key issue in dynamic Location Referencing is to find the correct geoobject in the target map which corresponds to the geoobject in the source map. So far, in nearly all methods an analytical (deterministic) algorithm is implemented to perform this. Given the fact that geodata as well as the matching procedure for geodata has some uncertainty, it is obvious to research uncertainty-based algorithms.
For this, two different uncertainty-based approaches were picked up and investigated in detail. Firstly, a probability-based approach, for which a corresponding decision algorithm was formulated using the already estimated probability distributions for a given set of criteria (geometrical, topological, syntactical and semantical). Secondly, a fuzzy-based approach by defining the fuzzy sets for the input criteria (same set of criteria like for probability-based) and the output criterion (grade of correspondence), specifying the rule base, fuzzy inference system and defuzzification strategy. For the latter, various optimizations were carried out to determine the best methods (fuzzy logical operations, defuzzification method).

To evaluate the performance, a QGIS-based module has been developed implementing these two approaches and extended by the well-known analytical OpenLR-algorithm to compare the results between the uncertainty-based and determined concepts. A first evaluation has been done by using real live traffic situations in the city of Stuttgart and selecting the underlying edges in the digital maps of TomTom and HERE. These selected edges have been transferred from TomTom to HERE and vice versa to compare the results for the specific mapping direction based on the same traffic situation. As a result, the probability-based and fuzzy-based approaches show similar results with an average hit rate up to 90% (nearly equal for both mapping directions) and improve the results of OpenLR in average by 12 percentage points.

In conclusion, the uncertainty-based algorithms deliver an adequate performance and thus offer an alternative to the analytical algorithms, promising a significant improvement of the results in an expected range of 10 percentage points.

3.10. Selection of a filter algorithm non-linear problem definition

For the estimation of trajectories a suitable non-linear filter algorithm (Extended Kalman Filter, Unscented Filter, Particle Filter) shall be applied. The optimal filter can be evaluated according to different criteria, whereby the easiest way to evaluate the optimal algorithm is to use the difference between a true and an estimated trajectory. However, since the true trajectory is usually not available, alternative approaches are used to assess the quality of the filter. In a study, an optimal filter algorithm was selected on the basis of a nonlinearity measures.
By means of examples for the selection of the filter algorithm it becomes clear that nonlinearity provides a criteria approach for the selection of an optimal filter model.

3.11. Position Determination of a Moving Reflector in Real Time by Robotic Total Station Angle Measurements

Angle readings from Robotic Total Stations (RTS) can be acquired with a higher update rate in comparison to distance measurements. For short ranges, these readings can be considered more accurate than the distance measurements. The currently presented system combines measurements from two Leica RTS (TS30 and TS16) that have Automatic Target Recognition (ATR) sensors. This helps at identifying and tracking the reflector. Both RTS are stationed in the same coordinate reference frame and controlled by a central computer running a LabVIEW program. It retrieves the angle measurements via GeoCOM protocols and computes the current position of the moving reflector based solely on angle intersection principles, similar to a Theodolite Measurement System (TMS) (Figure 6). This increases the positioning frequency of the RTS system to 20 points/second, which is twice as fast as the normal tracking mode of these specific RTS. A miniature railway and trolley are used to move the studied reflectors in laboratory experiments with ranges of up to 6 m.

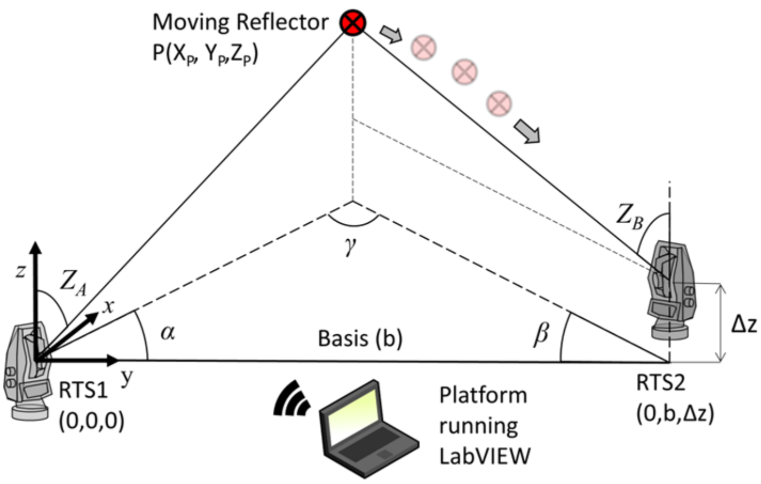

Figure 6: System components with measured and computed values

Firstly, different angle based positions of each reflector are compared to positions that result from measurements of angles and distances for the same points while the trolley is stationary. The differences are under 1 mm, confirming that the implemented mathematical model is correct. Further experiments present the achieved positions in kinematic mode (at slow speeds) by means of lateral deviations to a reference line. Results show an average lateral deviation of 2.1 mm for the two 360° reflectors and 3.3 mm for a normal reflector (Figure 7). Here, synchronization of the two RTS readings is the most significant factor.

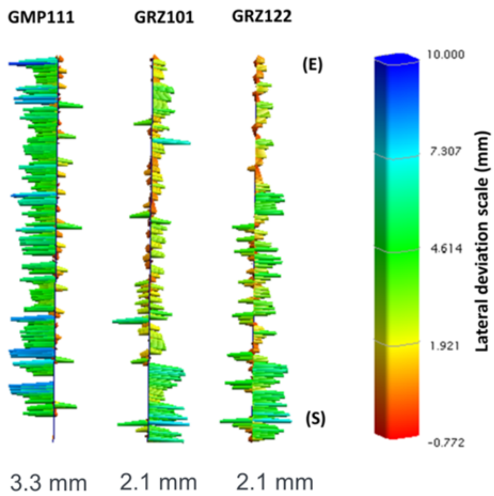

Figure 7: Reflectors on trolley (from left to right - GMP111, GRZ101, GRZ122); lateral deviation for each scenario/reflector (right)

3.12. Kinematic Positioning in a Real Time Robotic Total Station Network System

A network of Robotic Total Stations (RTSs) facilitates continuous tracking of a moving reflector even when obstructions interfere with the line-of-sight. Further on, a representative system comprised of two Leica RTSs (TS30 and TS16) is presented. These are stationed in the same coordinate frame and track one 360° reflector in a synchronized manner. If one line-of-sight is interrupted, the specific RTS is set to a passive state and will continue to ''blindly'' track the reflector until a new line-of-sight is available. In guidance and control applications, having one RTS limits the positioning accuracy to the instrument's technical specifications and narrows down the area of use. Multiple networked RTSs (Figure 8 left), on the other side, enhance the accuracy through an optimal measurement configuration and assure a non-interrupted tracking process. A central computer establishes multidirectional data flow between each RTS with the help of the Leica GeoCOM Protocol and a LabVIEW based program. During the active tracking phase, each calculated position is stored and simultaneously made available for all other instruments in the network.

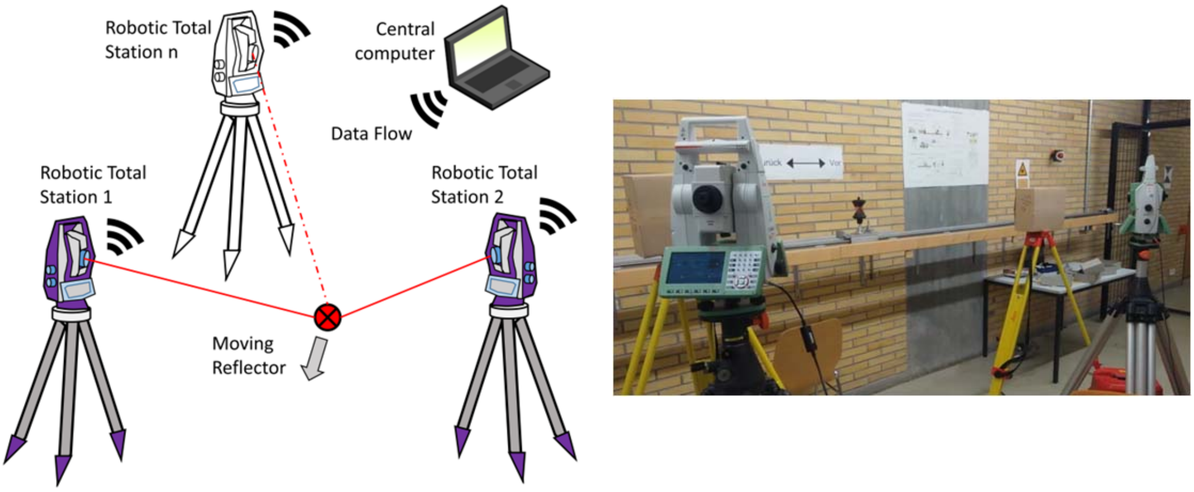

Figure 8: Real Time Robotic Total Station Network System (left), experimental setup (right)

To verify the system's performance, a reflector is fixed on trolley and measured while travelling with constant speed on a calibration rail (Figure. 8 right). The boxes interrupt the line-of-sight for each RTS in a controlled manner, thus creating areas where both or only one RTS are either in active or passive state. The rail serves as line of reference with coordinates determined by a laser tracker. Lateral deviations to this line are considered quality indicators for the tracking process.

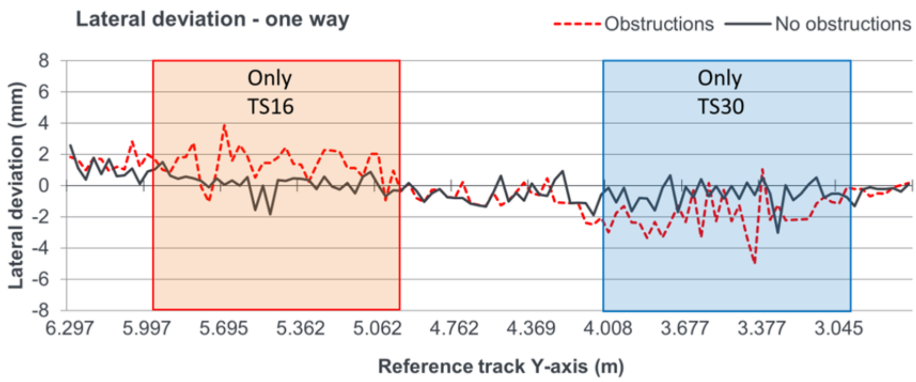

Figure 9: Lateral deviation of the 360° reflector position with respect to a reference line (0)

As briefly shown in Figure 9, the RTS network system reduces the lateral deviation (middle area and continuous line), improves the positioning accuracy in tracking mode and generally increases reliability.

4. Publications

Refereed Publications

Abdallah; A.; Schwieger, V: Improving Hydrographic PPP by Height Constraining. FIG Congress 2018, Istanbul, Turkey. May 06-11, 2018.

Aichinger, J., Schwieger, V.: Influence of scanning parameters on the estimation accuracy of control points of B-spline surfaces, Journal of Applied Geodesy, 12 (2), pp. 157-167, deGruyter, Berlin, 2018.

Avram, A.; El Gemayel, N.; Schwieger, V.: Assessment of the Delay-Locked Loop error due to multipath models regarding a deterministic-stochastic channel and a GPS L1 receiver model for kinematic trajectories. Proceedings of the 31st International Technical Meeting of the Satellite Division of the Institute of Navigation (ION GNSS+ 2018), September 24 - 28, 2018.

Hassan, A., Xu, J., Xing, C., Schwieger, V. (2018): A contribution to variance analysis of 3D-displacement extracted from GB-SAR measurements. In: GeoPreVi International Symposium, 29-30 October 2018, Bucharest, Romania.

Kerekes, G., Schwieger, V.: Kinematic Positioning in a Real Time Robotic Total Station Network System. 6th International Conference on Machine Control and Guidance. In Bornimer Agrartechnische Berichte Heft 101, ISSN 0947-7314, p. 35-43, Berlin, Germany.

Kerekes, G., Schwieger, V.: Position Determination of a Moving Reflector in Real Time by Robotic Total Station Angle Measurements. GeoPreVi International Symposium, 29-30 October 2018, Bucharest, Romania.

Lerke, O., Schwieger, V.: Adaptive Control for Guidance of Tracked Vehicles. 6th International Conference on Machine Control and Guidance. In Bornimer Agrartechnische Berichte Heft 101, ISSN 0947-7314, p. 83-94, Berlin, Germany.

Zhang, L.; Ionescu, I.-M., Schwieger, V.: Monitoring of the church tower in Herrenberg with Low-Cost GNSS. GeoPreVi International Symposium, 29-30 October 2018, Bucharest, Romania.

Non-Refereed Publications

Hassan, A., Xu, J., Zhang, L., Liu, G., Schmitt, A., Xing, C. Xu, Y., Ouyang, C., Schwieger, V.: Towards integration of GNSS and GB-SAR measurements: Exemplary monitoring of a rock fall at the Yangtze River in China. In: FIG CONGRESS 2018, Istanbul, Turkey.

Hindenberger, P.; Schwieger, V.: Probability Based Location Referencing Method – Statistical Evaluations and Estimated Probability Distributions. 14th Conference on Location Based Services (LBS), Zurich, Switzerland, January 15-17, 2018.

Wang, J.; Wachsmuth, M.; Metzner, M.; Schwieger, V.: Die digitale Karte als Sensor. 176. DVW-Seminar Multisensortechnologie: Low-Cost Sensoren im Verbund (MST 2018), Hamburg.

Monographs, books and book chapters

Schwieger, V.; Beetz, A.: Baumaschinensteuerung – der ingenieurgeodätische Beitrag, pp. 283-318. In: Schwarz, W. (Hrsg.): Ingenieurgeodäsie, Springer, Berlin, 2017.

Wieser, A.; Kuhlmann, H., Schwieger, V., Niemeier, W.: Ingenieurgeodäsie – eine Einführung, pp. 1-22. In: Schwarz, W. (Hrsg.): Ingenieurgeodäsie, Springer, Berlin, 2017.

5. Presentations

Schwieger, V.: Integrated Monitoring of a Rockfall at the Yangtse River. Interexpo GeoSiberia 2018, Novosibirsk, Russia, April 24-26, 2018.

Schwieger, V.: Positioning for Autonomous Driving. FIG Congress 2018, Istanbul, Turkey. May 06-11, 2018.

Schwieger, V.: Punktwolken – warum, wie und wofür? 12. GeoMessdiskurs, Jena, 28.06.2018.

Schwieger, V.: Automatisiertes Fahren und Geodäsie. Tübingen, Wildermuth Gymnasium, 28.09.2018.

Schwieger, V.: Geodesy for Smart Construction. GeoPreVi 2018, Bucharest, Romania, October 29 – 30, 2018.

Schwieger, V.: Map Matching Applications. Seminar SE 3.05 " GPS/INS-Integration und Multisensor-Navigation", Carl-Cranz-Gesellschaft e.V., Oberpfaffenhofen, 22.11.2018.

Zhang, L.: Monitoring of Rock Fall at Yangtze River with Low-Cost GNSS receiver. Second workshop of DAAD Thematic Network Modern Geodetic Space Techniques for Global Change Monitoring, 24.-28. 07 2018, Luxembourg.

Zhang, L.: Low-Cost GNSS for geodetic applications. FIG Congress 2018, 06.-11.05.2018, Istanbul, Türkei.

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

Volker Schwieger

- Dean of the Faculty of Aerospace Engineering and Geodesy, University of Stuttgart
- Full member of the German Geodetic Commission (Deutsche Geodätische Kommission – DGK)
- Member of the section „Engineering Geodesy“ within the German Geodetic Commission (DGK)
- 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

- Co-Chair of FIG Commission 5 (Positioning and Measurement), Working Group 5.6 – Cost Effective Positioning
- Member of Working Group III „Measurement Methods and Systems“ of Deutscher Verein für Vermessungswesen (DVW)

7. Doctorates

Glabsch, Jessica: Konzeption und Realisierung kosteneffizienter GNSS-Monitoring -Systeme für ingenieurgeodätische Überwachungsmessungen Hauptberichter: Prof. Dr.-Ing. Otto Heunecke, Mitberichter: Prof. Dr.-Ing. habil. Volker Schwieger

Kemper-Böninghausen, Rolf: Entwicklung automatisierter Messverfahren für Vortriebskontrollen beim Rohrvortrieb Hauptberichter: Prof. Dr.-Ing. habil. Wolfgang Niemeier, Mitberichter: Prof. Dr.-Ing. habil. Volker Schwieger

8. Master Theses

Abuwarda, Amgad: Performance Analysis of a Topological Weight-Based Map-Matching Algorithm with Real Vehicle Positioning Data (Wang)

Basalla, Urs: Zielverfolgung mittels von Leica TS16 erfassten Objektbildern (Kerekes)

Bolocan, Alin: Investigation of the behaviour of Terrestrial Laserscanner beams due to wood (Schmitt)

El Ankh, Salih: Development of availability forecasts for GPS visibility along railway tracks (Metzner)

Fuchs, Florian: Realisierung einer Gridmap basierend auf Sensordaten zur Verifizierung der Umfelderfassung (Metzner)

Ionescu, Iuliana-Madalina: Monitoring of the church tower in Herrenberg with GNSS (Zhang)

John, Jelin: Implementation of an Inertial Measurement Unit for Determining the Orientation within the Control Algorithm of a Model Dozer (Lerke)

Liu, Zhixin: Implementation of real-time map-matching algorithms with a Windows based C++ development environment (Wang)

Luz, Philipp: Positionsbestimmung und Navigation mittels bildverarbeitender Tachymeter (Lerke)

Mahr, Sabine: Nick- und Wankwinkelschätzung des Eigenfahrzeugs für radarbasierte Assistenzsysteme (Lerke)

Mendoza, Kevin Para: Displacement and deformation detection of a model structure simulated by a mechanical actuator using the Leica HDS7000 laser scanner (Kerekes)

Ren, Wenhao: Untersuchung von Odometern auf Eignung als Positionssensoren zur Überbrückung von Messunterbrechungen des Tachymeters aufgrund von Sichtbehinderungen (Lerke)

Schneider, Patrick Entwicklung einer Koppelnavigation für den Nutzfahrzeugbereich (Gasparac, Metzner)

Stilling, Niclas: Erstellung und Umsetzung eines prototypischen Kalibrierkonzepts und Justagekonzepts für Radarsensoren an Agrar- und Baumaschinen (Schwieger)

Zhao, Yuzhe: Bestimmung einer GNSS Kombinationslösung aus mehreren individuellen GNSS-Messungen für die Absteckung hoher Türme (Zhang)

9. Bachelor Theses

Ganesharatnam, Marien: Analyse der Wertschöpfungskette im kombinierten Flurneuordnungsverfahrens Uttenweiler (B 312) (Helfert, Metzner)

Hörz, Joachim: Reaktivierung innerörtlicher Flächen zur Senkung des Flächenverbrauchs (Helfert, Metzner)

Rahn, Anne: Analyse der Eignung verfügbarer Laserscanning-Softwarepakete für die geodätische Deformationsanalyse natürlicher und künstlicher Objekte (Hassan)

Keller, Philipp: Untersuchung des Messverhaltens der Lineareinheit des IIGS (Schmitt)

Tsao, Wen-Ning: Optimierung von Messkonzepten für Deformationsanalyse mittels JAG3D (Schmitt)

Wang, Rui: Deformationsanalyse einer Staumauer mit GNSS (Zhang, Lerke)

10. Education

SS18 and WS18/19 with Lecture/Exercise/Practical Work/Seminar

Bachelor Geodesy and Geoinformatics (German):	
Basic Geodetic Field Work (Wachsmuth, Kanzler)	0/0/5 days/0
Engineering Geodesy I (Schwieger, Kerekes)	4/2/0/0
Geodetic Measurement Techniques I (Metzner, Wachsmuth)	3/1/0/0
Geodetic Measurement Techniques II (Schmitt)	0/1/0/0
Integrated Field Work (Kerekes, Metzner)	0/0/10 days/0
Methods of Measurements and Analysis in Engineering Geodesy (Schwieger, Kerekes)	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, Kanzler)	1/1/0/0
Land Development (Eisenmann)	1/0/0/0
Monitoring Measurements (Schwieger, Basalla)	1/1/0/0
Monitoring Project (Schmitt)	0/0/2/0
Terrestrial Multisensor Systems (Zhang, Lerke, Kerekes)	1/1/0/0
Thematic Cartography (Zhang, Lerke)	1/1/0/0
Transport Telematics (Zhang, Luz)	2/2/0/0

Master GeoEngine (English):

Integrated Field Work (Kerekes, 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, Basalla)	1/1/0/0
Transport Telematics (Metzner, Luz, Balangé)	2/1/0/0
Terrestrial Multisensor Systems (Zhang, Schmitt)	2/1/0/0

Bachelor and Master Aerospace Engineering (German):

Statistics for Aerospace Engineers (Zhang, Hassan)	1/1/0/0

Master Aerospace Engineering (German):

Industrial Metrology (Schwieger, Schmitt, Kanzler)	1/1/0/0
Transport Telematics (Zhang, Luz)	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, Hassan)	2/1/0/0
Transport Telematics (Zhang, Luz)	2/1/0/0

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