Annual Report 2022

Institute of Engineering Geodesy (IIGS)

1. Members of Staff

Head of Institute:	Prof. Dr.-Ing. habil. Dr. h.c. Volker Schwieger	
Secretary:	Elke Rawe Désirée Schreib	
Scientific Staff:	M.Sc. Sahar Abolhasani (since 01.01.2022)	Sensor Fusion
	M.Sc. Laura Balangé	Quality Modeling
	M.Sc. Urs Basalla (until 30.06.2022)	Terrestrial Laser Scanning
	M.Sc. Rudolf Frolow (since 15.07.2022)	Sensor Fusion
	Dipl.-Ing. Lyudmila Gorokhova	Kinematic Positioning
	Dipl.-Ing. Susanne Haußmann (until 30.06.2022)	Kinematic Positioning
	M.Sc. Gabriel Kerekes	Terrestrial Laser Scanning
	Dr.-Ing. Otto Lerke (until 30.06.2022)	Machine Guidance
	M.Sc. Philipp Luz	Digital Map
	Dr.-Ing. Martin Metzner	Engineering Geodesy
	M.Sc. Christoph Sebald	GIS for Climate Data
	Dr.-Ing. Li Zhang	Engineering Geodesy
Technical Staff:	Dipl.-Ing. (FH) Andreas Kanzler Martin Knihs, Mechanikermeister Dipl.-Geogr. Lars Plate	
External Teaching Staff:	Dipl.-Ing. Jürgen Eisenmann	Geschäftsbereichsleiter Landratsamt Ostalbkreis, Geoinformation und Landentwicklung
	Dr.-Ing. Frank Friesecke	Prokurist der STEG Stadtentwicklung GmbH
	Jonas Stadler M. Eng.	Landratsamt Alb-Donau-Kreis Flurneuordnung der Landkreise Alb-Donau-Kreis und Biberach
	Dipl.-Math. Ulrich Völter	Geschäftsführer intermetric - Gesellschaft für Ingenieurmessung und raumbezogene Informationssysteme mbH
	Dr.-Ing. Thomas Wiltschko	Daimler AG, Mercedes-Benz Cars; Research and Development
PhD Students:	M.Sc. Julia Aichinger	Terrestrial Laser Scanning
	Dipl.-Ing. Patric Hindenberger	Location Referencing
	M.Sc. Yu Li	Digital Map
	M.Sc. Annette Schmitt	Multi-Sensor-Systems
	M.Sc. Tobias Schröder	Automation of Production Process
	M.Sc. Yihui Yang	Multi-Sensor-Systems
	M.Sc. Christian Bader	Kinematic Laser Scanning

2. General View

The Institute of Engineering Geodesy (IIGS) is directed by Prof. Dr.-Ing. habil. Dr. h.c. 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”.

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, since 2020 he is head of the section „Engineering Geodesy“ within the DGK..

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, IIGS is responsible for the above-mentioned fields within the curricula of “Geodesy and Geoinformatics” (Master and Bachelor in German) and 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 and Master). Furthermore, lectures are given in English to students within the Master course “Infrastructure Planning”.

The cluster “Integrative Computational Design and Construction for Architecture” (IntCDC), which is part of the excellence strategy to strengthen cutting-edge research in Germany, was awarded funding in 2018 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 ground breaking innovations for the building sector through a systematic, holistic, and integrative computational approach. As a member of the cluster (IntCDC), the institute’s research in the field of new construction methods is intensified in cooperation with architects, civil engineers, computer scientists, manufacturing engineers, and other scientists from various research institutions within and outside the University of Stuttgart.

The current research and project work of the institute is expressed in the course contents, thus always presenting the current 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 geodetic processes and construction processes, machine guidance, monitoring, transport 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. AI-supported Collaborative Control and Trajectory Generation of Mobile Manipulators for Indoor Construction Tasks

Gefördert durch DFG Deutsche Forschungsgemeinschaft

IntCDC CLUSTER OF EXCELLENCE

For the automation of indoor construction tasks specifically in existing buildings, mobile robots offer great flexibility and provide digital support for time-consuming tasks such as the positioning of building elements. Within the framework of the Cluster of Excellence IntCDC, the research project RP 26 focuses on collaborative path and trajectory generation for a heterogeneous group of collaborating mobile robots. These robots, which are depicted in Figure 1, are equipped with sensors including cameras, LIDAR, IMU and different manipulator arms and operate under Robot Operating System (ROS). In this project three institutes from Stuttgart University cooperate: Institute of System Dynamics (ISYS), Institute of Photogrammetry (IFP) and Institute of Engineering Geodesy(IIGS).

Simultaneous Localization and Mapping (SLAM) is a special form of Structure-from-Motion (SfM), focused on real-time accurate tracking of robot trajectories while simultaneously building a map of the respective environment. The main goal of IIGS is to use the capability of robot total stations (RTS) in seamless absolute positioning to improve SLAM methods to reach the high accuracy levels necessary for automatic assembly or manipulation.

Figure 1: Robots Overview (© IIGS/Abolhasani)

To initiate the tracking and positioning of robots with RTS a test case was arranged by placing a prism on the sensor robot in IntCDC Laboratory for Large-Scale Construction Robotics (LCRL). Using a GPS receiver, a NTP time server was developed to synchronize the total station with other sensors. Having compared the results with those of SLAM, developed by IFP, in the next step the absolute coordinates resulting from sensor fusion are to integrate in SLAM.

Supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany’s Excellence Strategy – EXC 2120/1 – 390831618.

3.2. CYBER-PHYSICAL ON-SITE CONSTRUCTION PROCESSES USING A SPIDER CRANE ROBOTIC PLATFORM

In a frame of the Cluster of Excellence IntCDC, the research project cyber-physical construction had been improved and further developed. The project itself deals with development of a cyber-physical construction (CPC) instrumentation platform, including two types of robotic cranes (see Figure 2), for the automated or partly automated assembly of building components, where the accurate position of the platform has to be provided by a network of total stations. The position of the being developed platform can be achieved using different opportunities, for example: by tracking the prism, installed on the platform, or by tracking the object itself, using it's images. Based on it, the whole research project can be divided on two parts, which are being connected to each other.

In the first phase of the project, from July 2019 until June 2022, a real time robotic image assisted total station (IATS) network was realized, which was capable of calculating and transmitting the pose seamlessly to the mini crane. Additionally, in order to evaluate the performance of the network two criteria of reliability and accuracy were taken into consideration in simulation and real-world tests leading to satisfactory results. Furthermore, in a period since July until December 2022, the first version of the completed system had been additionally tested out in respect to the internal uncertainties and errors. The local geodetic network, being used for positioning of the cranes, had been measured again and the coordinates of the network points had been examined in respect to its stability.

After the successful implementation of the first part of the project, the second had started from July 2022. The aim of it is to use the whole potential of the robotic total stations, by usage of the integrated camera for the absolute tracking and positioning purposes via image-processing techniques. It requires at first to calibrate the robotic total stations in order to provide the accurate tracking algorithm. The development of the proper calibration procedure is in process in order to realize the correct conversion from a pixel-based image coordinate system into metric IATS coordinate system. The robotic total stations, being already involved in developed on the first step of the project network, had been checked in respect to the quality of the integrated cameras and its possible further usage in the project. It is planned to integrate the calibration procedure on all robotic total stations, which are used in the network.

Figure 2: Example of the cooperation between two cranes for the automated/partly automated construction

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3.3. Holistic Quality Model for Existing Buildings - Social, Environmental, Technical and Economic Integration

As part of the cluster of excellence Integrative Computational Design and Construction for Architecture (IntCDC), the research project "Holistic Quality Model for IntCDC building systems" is concerned with the development of a holistic quality model. This is done in close cooperation with the Institute of Acoustics and Building Physics (IABP) for the environmental quality and the Institute of Social Sciences (SOWI) for the social quality. The objective of the IIGS here is to consider the technical quality.

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In the final phase of the first research period the focus of the interdisciplinary work was to detect and map the dependencies of quality characteristics between the different disciplines. Special attention was paid to the interpretation of the agent-object dependencies between the quality characteristics of different disciplines.
For the disciplinary work the focus of the IIGS was the development of a quality assessment concept for the application of coreless filament winding. Therefore, algorithms for the autonomous detection of fiber segments from laser scanner point cloud are developed and implemented. Also the mapping of the data to the available fiber syntax was one of the main challenges. In addition, investigations of the calculation of the fiber cross-sections were carried out by using different methods (see Figure 3).

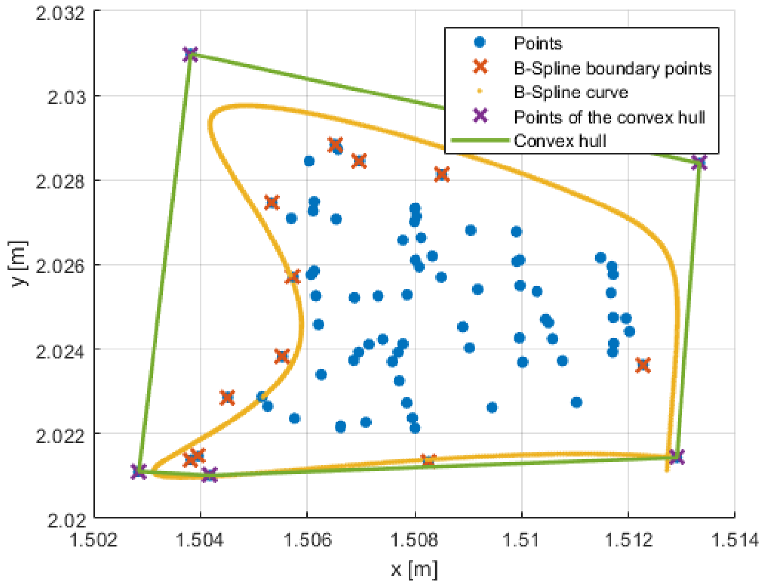


Figure 3: Computed boundary of fiber segments using convex hull and B-spline approach.

With the start of the second project phase in the middle of the year, another dimension was added to the quality model. Since July, the Institute for Construction Management (IBL) has been part of the project, which integrates besides the social, environmental and technical components now also the economic component into the model to assess the economic life cycle, cost efficiency as well as flexibility and adaptability of IntCDC building systems. Another focus of the second project phase is to not only assess the quality of new buildings, but also the quality of existing buildings. Therefore, in a first step different measures for the building stock extension are defined and investigations are carried out about the social, environmental, economic and technical drivers for the building stock extension.

Supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy – EXC 2120/1 – 390831618.

3.4. Automated Assembly of a Wooden Pavilion

Monitoring the geometry is of major importance in the construction industry. Since automation is becoming more and more important and many processes are carried out robotically, determining the position of the construction robots is also of crucial importance in addition to monitoring the geometry of the building itself. In the framework of the FIT construction project (FIT - Freiburg Center for Interactive Materials and Bioinspired Technologies), which is a timber pavilion built with 127 individual wooden cassettes. The project is a cooperation between the two clusters of excellence livMatS at the University of Freiburg and IntCDC at the University of Stuttgart. For IntCDC the project serves a building demonstrator.

The geodetic contribution to the FIT Pavilion consists of two main parts: Geodetic control of the construction robots and geometric quality assurance. Regarding the first part, initially a three-dimensional coordinate system was defined as a frame of reference for subsequent observations and geometry calculations, followed by bringing the cranes according to the desired alignment at precisely predefined points inside and outside the pavilion. Subsequently with the aim of integration of geodetic techniques for localization and control of the construction robots a highly accurate real-time total station network consisting of four total stations was developed. Two total stations determined the position of one construction robot and the two remaining total stations that of the second one. From this fully automatic real-time measuring system, which is depicted in Figure 4, the positions of the reflectors were transmitted to control the construction robots. The goal was an accuracy in the range of a few millimeters.

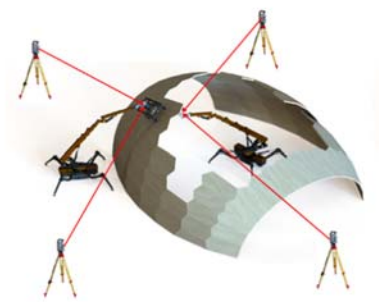


Figure 4: Configuration of total station Network

Figure 5: TLS measurements of timber shell

In order to be able to guarantee a fluent assembly of complex buildings with double-curved shells, quality assurance is of major importance. In the following, special emphasis is placed on the geometric quality of the components and the construction. The aim was to accompany a previously defined number of components through the manufacturing process in order to be able to detect possible changes in the geometry. For this purpose, 3D point clouds of the selected cassettes were generated using a terrestrial laser scanner, which could then be compared with the nominal geometry from the planning. These measurements were carried out after production in Blaustein, on the construction site in Freiburg before assembly, as well as in the installed state (see Figure 5). In order to be able to carry out a final geometric quality assurance, a scan of the finished shell was also taken in order to finally evaluate the geometry.

Supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy – EXC 2120/1 – 390831618.

3.5. Patch-based M3C2: Towards Lower-uncertainty and Higher-resolution Deformation Analysis of 3D Point Clouds

Multitemporal acquisitions of 3D point clouds for geomonitoring tasks allow the quantification and analysis of geometric changes of monitored objects by advanced processing algorithms, further revealing the underlying deformation mechanism. Among numerous approaches proposed in the geoscientific domain for point cloud-based deformation analysis, the Multiscale Model-to-Model Cloud Comparison (M3C2) is the most widely applied for distance quantification between two point clouds with high surface roughness. Small-magnitude deformations under complex topographies, however, are still challenging to be accurately quantified and analyzed by a statistical significance test when using standard M3C2, for (1) average positions may deviate from the actual surface in cylindrical neighborhoods and (2) empirical uncertainties represented by local roughness are overestimated in highly variable areas. Besides, the resolution of derived deformation is limited by original point densities and algorithm limitations. In this contribution, an extended alternative called patch-based M3C2 is proposed, which inherits the basic framework of standard M3C2 for its simplicity. This novel approach does not need surface meshing and identification of semantic or instance correspondences for point clouds. Lower uncertainty is achieved by generating locally planar patches and projecting measurements on associated patch planes, allowing better detection of small deformations in complex 3D topographies. Besides, the patch-based M3C2 could assign a deformation value to any position located within the overlapping areas, enabling a higher resolution of deformation analysis. The proposed method is demonstrated and evaluated on three datasets. The experimental results indicate that patch-based M3C2 exhibits higher accuracy and lower uncertainties on distance computations between two surfaces. Figure 6 shows the general workflow of patch-based M3C2.

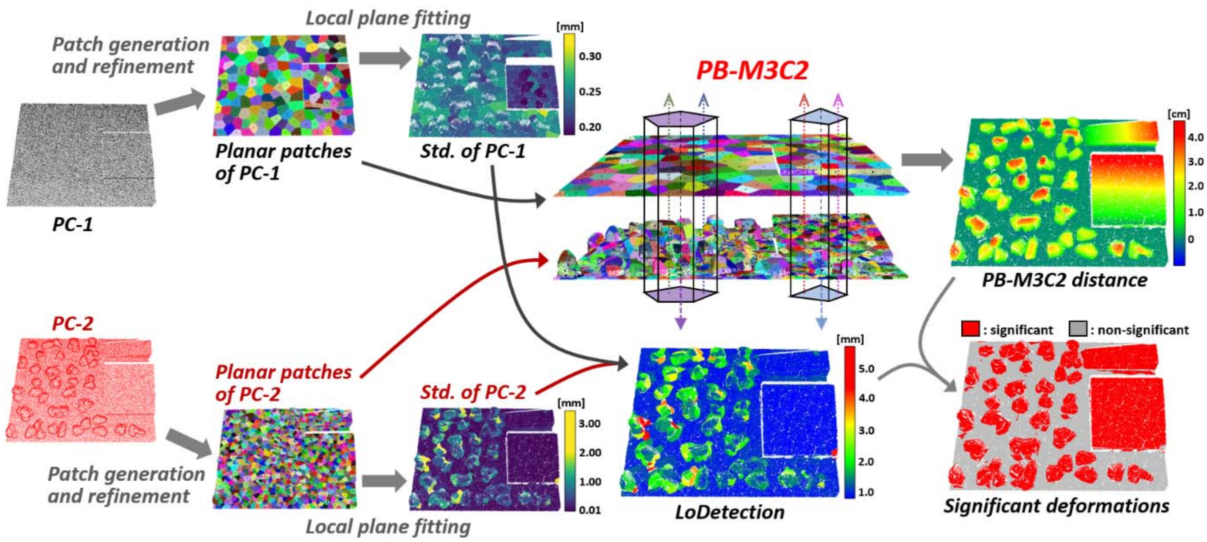


Figure 6: The workflow of patch-based M3C2 (*PB-M3C2*)

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

Gefördert durch DFG Deutsche Forschungsgemeinschaft

The report for the DFG (Deutsche Forschungsgemeinschaft) IMKAD II was completed in 2022. To sum up the main objectives, the project addressed the analysis of deformation processes with high spatial-temporal resolution. The intended applications are related to monitoring of civil engineering buildings and constructions with complex shapes. The project was carried out together with a partner, the Department of Geodesy and Geoinformation of the Vienna University of Technology. Several study cases show this, out of which the Urbach Tower (Figure 7 left) is shortly presented.

The scanned object is a unique double curved wooden 14 m tall tower, called the Urbach Tower, designed and constructed in 2018 with new self-shaping processes. Since it has complex façade geometry, it is an interesting and challenging object for B-spline modeling and Terrestrial Laser Scanning (TLS) deformation analysis.
A novel method, which allows the statistically based deformation analysis using the epochal and space-continuous estimated B-spline surfaces, was developed. The surface parameters define the point correspondences on different B-spline surfaces. Using these correspondences, a RANSAC-approach is implied to estimate the parameters of the rigid body movement. The resulting consensus set initially defines the non-distorted areas of the object, which are extended and statistically verified in a second step. Distorted regions can be reliably detected and the parameters of the rigid body movement can be simultaneously determined if the appropriate stochastic model is considered. In this project, the synthetic variance-covariance matrix (SVCM) defines the stochastic model. The results show that by stochastical and B-spline surface modeling, the measurement noise is reduced and distorted regions are detectable in a statistically correct way even in mm level (Figure 7 middle & right).

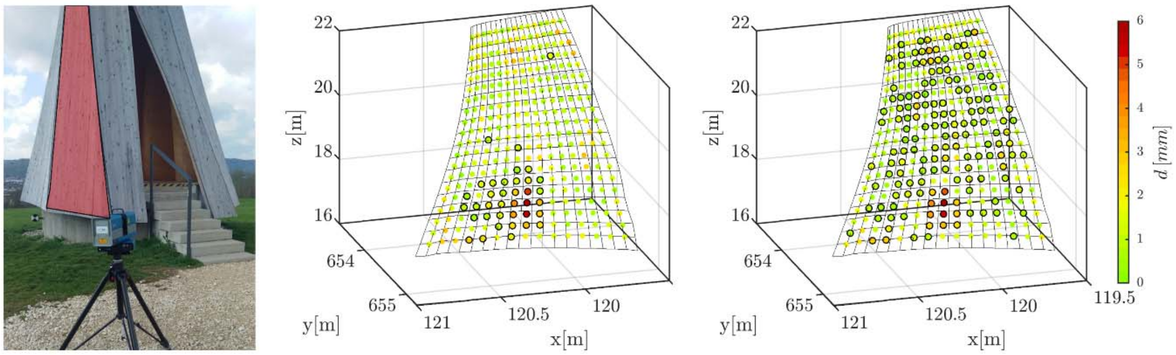


Figure 7: left: Urbach Tower façade element (red);
middle: statistically identified deformation area (circled points) with fully-populated SVCM;
right: falsely identified deformation areas with diagonal SVCM.

This research was funded by DFG (German Research Foundation), SCHW 838/7-3 and the Austrian Science Fund (FWF), I3869.

3.7. Studies on deformation analysis of TLS point clouds using B-splines

High-resolution point clouds of terrestrial laser scan measurements present advantages for epoch-wise comparisons of deformation analyses. However, since there are no identical points between the epoch-wise laser scans, modeling by means of B-splines offer an opportunity to superimpose the B-spline surfaces using feature-based methods and to identify deformations. Compared to current methods, the generation of the B-spline surfaces is based on a direct use of control points for the first time. In many current methods, the B-splines are generated via a control point estimation. The novel approach, in which control points are used directly, currently consists of a mapping method that ensures a superposition location of two B-spline curves based on the ranks of curvature values in combination with the determination of rank correlation functions in order to calculate coordinate differences. A stochastic model based on a variance-covariance propagation is used in parallel to this procedure and allows the performance of a significance test for each curve point to determine possible deformations.
On the basis of the developed fundamentals, this novel method is to be applied to B-spline surfaces. Here, a preparation of the control point grid structure by a knot insertion algorithm to create a uniform grid using Boehm's algorithm is necessary. A mapping algorithm to determine the superposition location of B-spline surfaces from different epochs is to be developed.

3.8. Achieving Road Boundary Detection in a Neural Network based Semantic Segmentation Pipeline

To achieve vehicle autonomy, road boundary detection is one essential component in the environment perception stack. The precise detection of the road geometry not only improves the vehicle localization, but also facilitates the motion planning task, thus the vehicle control efficiency. LiDAR sensors have been widely used for this task. Existing rule-based detection approaches still require handcrafted filters to achieve rational result. Usually, it is hard to adapt these handcrafted filters on different sensor models, and the diverse road conditions pose additional challenges to this problem. To overcome these issues, the semantic segmentation technique that is based on convolutional neural network provides another possible solution.

In the first step, the unordered 3D point cloud is converted into an efficient data representation, so that the power of convolutional neural network can be leveraged. In our experiment, both the Bird's Eye View (BEV) and Cylindrical Projection (CP) are used as the LiDAR representations. Then, a semantic segmentation neural network with the standard encoder-decoder architecture is utilized to accomplish the inference task. There exists a variety of mature network designs for semantic segmentation task, such as U-Net and ENet. With the runtime and storage efficiency in mind, the comparison of existing networks in terms of their inference performance and the computational efficiency is realized. In addition, the influence of the network size on the inference result is investigated. Finally, as the output of a semantic segmentation network, an inferred binary mask image, where pixel value 1 stands for road boundary point and 0 for background, is received. The overall pipeline can be seen in Figure 8.

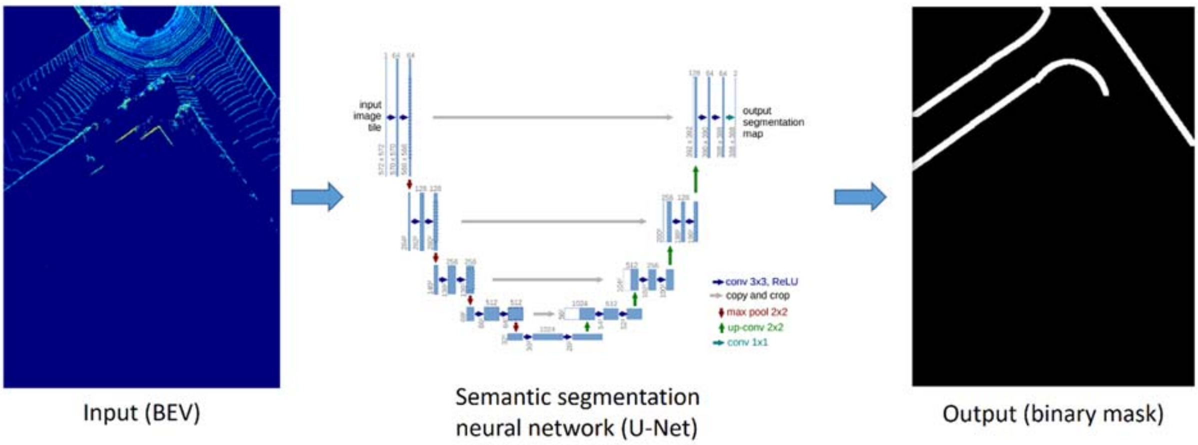


Figure 8: Overview of road boundary detection in a semantic segmentation pipeline

3.9. Dynamic Location Referencing: Probability- and Fuzzylogic based decision systems

To share geoobjects between digital maps, location referencing is a well-known methodology typically used for exchanging traffic information such as traffic jams, road works etc. In some cases, there are no common databases between the systems (maps) being exchanged. For this, dynamic (on-the-fly) methods are developed to share Location References (LR, digital-map based geoobjects) between different maps in such particular cases where no common databases and/or common structures are available.

Generally, Location Referencing Methods follow a one-dimensional three step process of encoding the LR in the sender system, transfer and decoding the LR in the receiver system without any iterations and typically limited bandwidth. Given the fact, that there are no dedicated links/common data structures between the maps, the key issue for Dynamic Location Referencing is to find the correct LR in the target map which corresponds to the LR in the source map (see Figure 9).

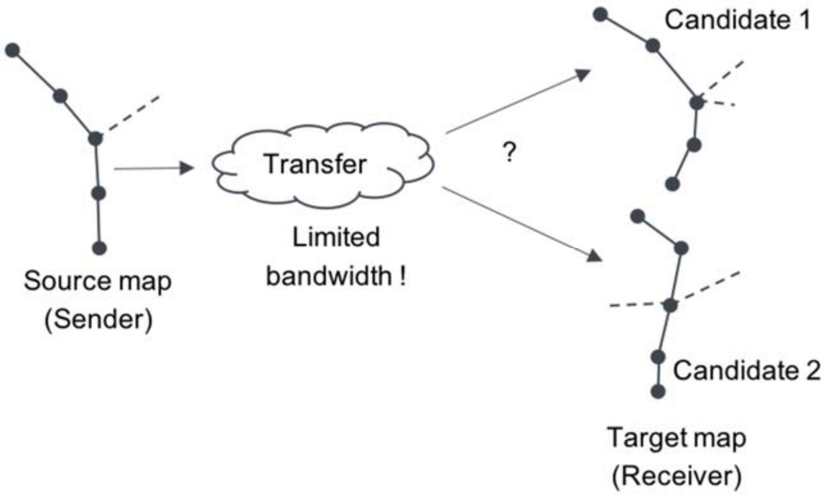


Figure 9: Identification of Location Reference

So far, deterministic algorithms have been defined and implemented. Based on the fact, that there is uncertainty in matching procedures for geodata, uncertainty-based decision systems are in process of research. That means in specific, a probability-based and a fuzzy-based approach as two different uncertainty-based concepts were specified and investigated in detail. For both, a set of decision criteria (geometrical, topological, syntactical and semantical) were defined and the decision algorithms formulated. Both approaches were implemented in an evaluation system and analyzed.

As a result, the probability-based and fuzzy-based approaches show similar results with an average hit rate up to 90% and improve the results of a comparable deterministic approach (OpenLR) in average by 12 percentage points.

As pointed out in the last report, new principles have been developed to validate the previous results and provide a broader basis. Most of these topics are done, specified and implemented in the existing evaluation system. Some first pre-tests show successful results, so the previous results are confirmed. In the course of the year this will be continued and brought to a final stage.

3.10. Ghosthunter III

The aim of the Ghosthunter III project (s. Figure 10) is to develop an app for Android smartphones that will help to reliably detect wrong-way drivers on freeways and their slip roads and warn the wrong-way drivers themselves as well as the other road users in the surroundings. This app, including the server infrastructure will be certified with regard to its functionality. The search for a future operator of the system will finalize the project. 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 company NavCert GmbH.

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

A key component of the app is the digital map on the basis of which the map matching is performed. Since the app is to be provided free of charge, this map must be based on freely available open source data. For this purpose, a program was developed that filters the OSM (Open Street Maps) data according to its necessity for our use case and then creates an SQLite data-

Figure 10: Ghosthunter III project logo

base from it. This way of storing the map information allows efficient access in the app with only a small memory footprint. Based on this database, the map matching algorithms used were adapted to ensure interoperability with them.

The Ghosthunter III research project is funded by the German Federal Ministry of Economic Affairs and Climate Action (BMWi) and the German Aerospace Center (DLR) under grant number 50 NA 2109.

3.11. The CoKLIMAx Project

Supported by:

Federal Ministry for Digital and Transport

on the basis of a decision by the German Bundestag

The CoKLIMAx project started in November 2021. It deals with the use of COPERNICUS data for climate-relevant urban planning by the example of water, heat, and vegetation. The project consortium consists of four project partners. The project lead is with the City of Konstanz, supported by the Institute of Engineering Geodesy (IIGS) at the University of Stuttgart, the Konstanz University of Applied Sciences for Technology, Economics and Design (HTWG) Konstanz, and the Climate Service Center Germany (GERICS) at the Helmholtz Center Hereon.

The use of climate date in municipal administrations is not common these days. Municipalities and their respective administrations, their specific divisions involved in city planning are increasingly interested to learn more and integrate the added value gained from climate data in their daily routines for better decision making. This is especially true because the data is now publicly available, via the Copernicus Climate Data Store. However, it remains a challenge for these administrative entities to simply use the data. This is mostly due to the lack of hardware and software, but also of expertise. Hence, it remains a challenge and it is difficult for municipal users in these administrative bodies, to identify and put the relevant data to effective use, since the sheer amount of data and its complexity must be known, understood and tackled. Having said that, it also depends very much on the available technology (e.g. hardware, software) and specific know-how available. Without the right tools or specialist expertise in place, the resource that most municipalities lack, it is about impossible to succeed and put the data to good use for better decision making. In this context it becomes clear that urban planning in cities requires rather practical tools that are easy to handle by staff. These are needed and shall help to assimilate Copernicus data with local (in situ) data, and to further process and use the results in municipal planning activities.

CoKLIMAx continues to develop new procedures and products for municipal users. A more practice-oriented approach for technical tools and applications is needed to derive and process data from some Copernicus services, and combining these with various local data. Thus, the project persists to develop an Advanced Municipal Climate Data Store toolbox (AMCDS Toolbox). The project members are currently working on the exemplary implementation, which is based on actual local needs of the city of Konstanz. New data products ought to be developed, implemented, applied and validated for better decision-making applications, for the respective study area and municipality.

2022, especially the first half year, was mainly dominated by continuous configuring and fine-tuning the numerous GIS Server software components of the distributed GIS Enterprise system on the CODE-DE server infrastructure. The initial setup of the installed system took place back in December 2021. After all, the GIS Enterprise system, installed on the Code-de IT infrastructure, required more attention, care and devotion as initially anticipated and planned. While the project partner from GERICS started to make use of many preinstalled applications available, the backend setup and configuration was ongoing. By the end of 2022, a myriad number of extra hours had to be invested into additional troubleshooting and system checks to make the system run smoothly. Meanwhile, ETL (extract, transform and load) processes were developed and tested to derive data from the CDS, and other sources.

In May 2022, the first consortium meeting took place in Konstanz. The first results were shared with colleagues from the Federal Ministry of Digital Affairs and Transport. The meeting was also a great opportunity for a dialogue with stakeholders from Constance and other participating partners form different cities, and the swords project Urban Green Eye. In June 2022, IIGS staff and the project were invited and presented at the “National Forum for Remote Sensing and Copernicus 2022” in Berlin with the guiding slogan "Copernicus.Digital.Sustainable". In the technical session E.1 "Designing the city of the future with Copernicus" the project titled "CoKLIMAx: Using COPERNICUS data and services for climate-resilient urban planning with municipal application potentials using the example of the city of Konstanz" were presented. In November 2022, the project CoKLIMAx was once again invited to Berlin, in order to present at the “10th German GeoForum”. The event is an annual networking event hosted by the German Association for Geoinformation. The slogan of the event was "Geoinformation for a sustainable future". The forum draws together stakeholders from science, industry, government and municipal administrations. The presentation on the CoKLIMAx project was well received by the audience and the subsequent discussion made it clear that one of the biggest challenges is the consolidation of climate services within municipal administrative structures.

The CoKLIMAx research project is funded by the German Federal Ministry for Digital and Transport (BMDV) and the German Aerospace Center (DLR) as part of the "Climate Adaptation Strategies for Municipal Applications in Germany" under grant number 50EW2103C.

3.12. Advanced Automated Gap and Flush Measurement Assisted by a High Flexible and Accurate Robot System

A modular measurement system that is characterized by its hardware and software components is presented (s. Figure 11). Due to requirements, such as higher cars with more measurement points and complex surfaces (glass, chrome and painted plastic), a new sensor unit is necessary. The new sensor unit uses the ultraviolet wavelength to profit from the block layers in automobile materials. In addition, the performance of the system has been formally demonstrated through a measurement system analysis according to VDA (2021) and it is already being used in series. Furthermore, it is aimed to further flexibilize the composition of components into an overall system in order to eliminate the limitations in the implementation and adaptation of components. The modular referencing system showcased in this report is an important development in the field of measurement and positioning. It allows the use of components with significantly higher tolerances regarding their positioning accuracy (in the order of several centimeters), while still ensuring the required positional accuracy of ±4 mm of the overall system. This provides an advantage in terms of efficiency and cost savings, as components with higher tolerances can be used for the same results. Further information can be found in DVW Band 101/2022.

Figure 11: SME-SL for automated gap- and flush measurement

3.13. Multi Sensor Multi Object Tracking using the GM-PHD Filter and Sensor Models

Modern vehicles with advanced driver assistance systems (ADAS) fuse the detections of different sensors to obtain a comprehensive environment detection. This is often done by a Kalman filter, which requires data association as well as a track management to add or remove tracks. In order to eliminate error sources by the data association and the track management, filters of the random finite set (RFS) family can be used. These estimate both the states themselves and the number of states by using a random set variable. Thus, no explicit data association procedure and no direct track management is necessary. Both setups are shown schematically in the Figure 12 below.

The Gaussian Mixture Probability Hypothesis Density filter (GM-PHD) is a filter from the RFS family, which can achieve real time capability. To enable a fusion of several sensors with the GM-PHD filter, which have different field of views and different measurement properties, sensor models are developed. These model the parameters of the GM-PHD filter, such as the clutter density and the detection probability depending on the state space. The figure exemplary shows the detection probabilities' dependency of the distance in x- and y-direction.
Using the Karlsruhe Institute of Technology and Toyota Technological Institute (KITTI) data set, the performance of the Kalman filter setup is compared with that of the GM-PHD setup. Detections from camera and Lidar are fused and evaluated using the Higher Order Tracking Accuracy (HOTA) metric on the KITTI multi object tracking benchmark. The Kalman filter achieves a HOTA of 73.56%, while the GM-PHD filter achieves 77.11%, with runtime doubling in comparison.
When using modern electronic control units (ECUs) with increasing computation power, the use of RFS filters, such as the GM-PHD filter shown here, can therefore achieve improved environment perception.

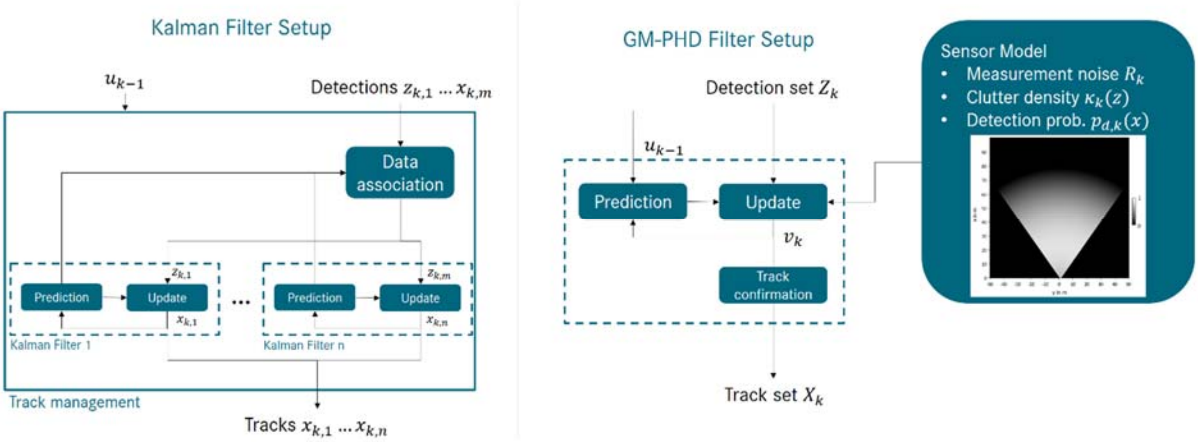
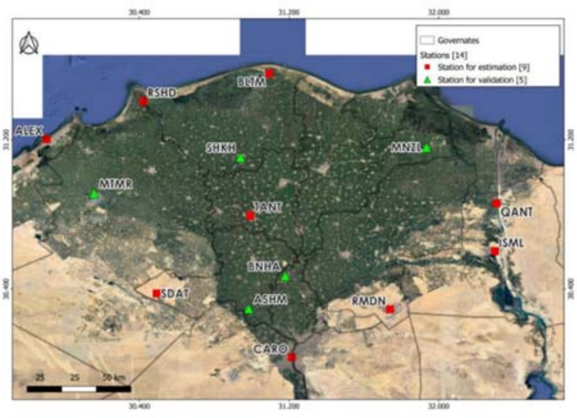


Figure 12: Comparison of Kalman filter and GM-PHD filter setup

3.14. Regional Ionosphere Model (RIM) for Single Frequency GNSS PPP Solution using Bernese GNSS Software - Case Study: Egyptian Nile Delta



Egypt is quickly constructing many infrastructures such as roadways and railways. Due to the spare coverage of the international GNSS service (IGS) network in North Africa, in January 2012, the Egyptian surveying authority (ESA) established the first permanent Egyptian continuously operating reference stations (CORS) network. This network is covering the Nile valley and its delta. In this study, a developed regional ionosphere model (RIM) is modeled in obtaining a single-frequency precise point positioning (SF-PPP) solution for the Nile delta. This solution is compared with the solution obtained using the Global Ionosphere model (GIM). A data set of six consecutive days 202-207/2019 of the ESA-CORS permanent stations was involved in the study. Nine stations were considered for RIM estimation and five stations are used for model validation. Bernese GNSS V. 5.2 software is used to model the regional ionosphere by using a geometry-free linear combination for code observation data (P4)
Bernese GNSS v. 5.2 software developed at the Astronomical Institute of the University of Bern (AIUB), Switzerland is used to model the regional ionosphere and estimate the SFPPP solution.

The estimated accuracy of the SF-PPP solution using the modeled RIM model shows an average error for all stations of 0.06 m - 0.07 m (SD = 0.06 m - 0.07 m) in the east direction. For the north, the solution displays an approximate average error of 0.1 m (SD = 0.03 m - 0.04 m). Based on the results presented in this table, the height average error shows approximately 0.3 m (SD = 0.05 m - 0.10 m). Generally, the SF-PPP solution using the RIM model shows an average 2D accuracy of 0.13 m and a height of 0.30 m. In addition, the solution provides an average 3D accuracy of 0.33 m. Overall, these results indicate that the solution obtained by using the RIM model is better than the one from the CODE-GIM model. The solution is improved by 60%, 70%, and 67% in east, north, and height, respectively. This shows the benefit of using a regional rather than a global ionosphere model.

3.15. PhD Seminar

The 12th Doctoral Seminar of the Engineering Geodesy Section of DGK was organized by the Institute of Geo-Engineering at Technical University Clausthal. The DGK PhD Seminar of the Engineering Geodesy Section was organized as a live event. It took place from October 6 to 7, 2022 at the Aula Academia in Clausthal. A total of 11 presentations mirrored the work of PhD candidates from Austria, Poland, and Germany. From the IIGS Laura Balangė and Yihui Yang presented their results. Fruitful discussions among the approximately 60 participants were possible during the coffee breaks and at the evening at the well-organized get-together including locally brewed beverages.

4. Publications

Refereed Publications

Abdallah, A., Agag, T., & Schwieger, V. (2022). Validation of CODE-GIM and Regional Ionosphere Model (RIM) for Single Frequency GNSS PPP Solution using Bernese GNSS software - Case Study, Egyptian Nile Delta. XXVII FIG Congress 2022, Warsaw, Poland. https://www.fig.net/resources/proceedings/fig_proceedings/fig2022/papers/ts08c/TS08C_abdallah_tarek_et_al_11375_abs.pdf

Aichinger, J., & Schwieger, V. (2022). Studies on deformation analysis of TLS point clouds using B-splines – A control point based approach (Part I). Journal of Applied Geodesy, 16(3), 279--298. https://doi.org/doi:10.1515/jag-2021-0065

Balangé, L., Harmening, C., Duque Estrada, R., Menges, A., Neuner, H., & Schwieger, V. (2022). Monitoring the production process of lightweight fibrous structures using terrestrial laser scanning. 5th Joint International Symposium on Deformation Monitoring, Valencia, Spain. https://doi.org/10.4995/JISDM2022.2022.13830

Frost, D., Gericke, O., Di Bari, R., Balangé, L., Zhang, L., Blagojevic, B., Nigl, D., Haag, P., Blandini, L., Jünger, H. C., Kropp, C., Leistner, P., Sawodny, O., Schwieger, V., & Sobek, W. (2022). Holistic Quality Model and Assessment - Supporting Decision-Making towards Sustainable Construction Using the Design and Production of Graded Concrete Components as an Example. Sustainability, 14(18), Article 18. https://doi.org/10.3390/su141811269

Gil-Pérez, M., Zechmeister, C., Kannenberg, F., Mindermann, P., Balangé, L., Guo, Y., Hügle, S., Gienger, A., Forster, D., Bischoff, M., Tarín, C., Middendorf, P., Schwieger, V., Gresser, G. T., Menges, A., & Knippers, J. (2022). Computational co-design framework for coreless wound fibre–polymer composite structures. Journal of Computational Design and Engineering, 9(2), 310--329. https://doi.org/10.1093/jcde/qwab081

Hassan, A., Zhang, L., Kerekes, G., & Schwieger, V. (2022). Geodetic Data Fusion for Rock Cliff Monitoring: A Case Study of the Lianzi Cliff in Three Gorges National Geological Park in China. XXVII FIG Congress 2022, Warsaw, Poland. https://fig.net/resources/proceedings/fig_proceedings/fig2022/papers/ts04d/TS04D_hassan_zhang_et_al_11340.pdf

Kerekes, G., Petrš, J., Schwieger, V., & Dahy, H. (2022). Geometric quality control for bio-based building elements: Study case segmented experimental shell. Journal of Applied Geodesy. https://doi.org/doi:10.1515/jag-2020-0035

Kerekes, G., Jakob, R., Harmening, C., Neuner, H., & Schwieger, V. (2022). Two-epoch TLS deformation analysis of a double curved wooden structure using approximating B-spline surfaces and fully-populated synthetic covariance matrices. 5th Joint International Symposium on Deformation Monitoring (JISDM), 20-22 April 2022, Valencia, Spain. http://ocs.editorial.upv.es/index.php/JISDM/JISDM2022/paper/viewFile/13816/7605

Yang, Y. & Schwieger, V. (2022). Supervoxel-based targetless registration and identification of stable areas for deformed point clouds. Journal of Applied Geodesy. https://doi.org/10.1515/jag-2022-0031

Non-Refereed Publications

Balangé, L., Zhang, L. & Schwieger, V. (2022). Qualitätssicherung im Rahmen des Exzellenzclusters IntCDC. 208. DVW-Seminar: Qualitätssicherung geodätischer Mess- und Auswerteverfahren, Berlin 2022, 2.-3.Juni.

Luz, P., Metzner, M., Mendes, P., Stapelfeld, M., Lichtenberger, C., Pany, T., Grzebellus, M. & Schwieger, V. (2022). Ghosthunter III – Detection of wrong-way drivers. XXVII FIG Congress

2022, Warsaw, Poland. https://www.fig.net/resources/proceedings/fig_proceedings/fig2022/papers/ts07c/TS07C_luz_pany_et_al_11527.pdf

Schröder, T. & Schwieger, V. (2022). Qualitätssicherungssystem zur automatisierten Spalt- und Übergangsmessung am Ende einer Produktionslinie. 208. DVW-Seminar „Qualitätssicherung geodätischer Mess- und Auswerteverfahren 2022“ 2.-3. Juni, Berlin.

Schwieger, V., Zhang, L., Lerke, O. & Balangé, L. (2022). The Research Cluster Integrative Computational Design and Construction (IntCDC) – Current Engineering Geodetic Contribution. XXVII FIG Congress 2022, Warsaw, Poland.

Wieser, A., Balangé, L., Bauer, P., Gehrmann, T., Hartmann, J., Holst, C., Jost, B., Kuhlmann, H., Lienhart, W., Maboudi, M., Mawas, K., Medić, T., Paffenholz, J.-A., Florian, P., Rafeld, E., Schill, F. & Schwieger, V. (2022). Erfahrungen aus einem koordinierten Vergleich aktueller Scanner. Beiträge zum 214. DVW-Seminar: Terrestrisches Laserscanning 2022, Fulda, 8.- 9. Dez., TLS 2022. https://geodaesie.info/sr/terrestrisches-laserscanning-2022-tls-2022/8860/4870

Presentations

Balangé, L., Di Bari, R., & Hos, P. D.: RP18: Holistic Quality Model for IntCDC Building Systems, IntCDC Research Network Colloquium 2021, 24.02.2022

Balangé, L: Technical Quality Modeling within IntCDC, RP18 Workshop Hirsau, 06.09.2022

Balangé, L.: Quality Modeling and assurance concept for coreless filament winding, DGK PhD-Seminar Clausthal-Zellerfeld, 06.10.2022

Balangé, L., Di Bari, R. & Hos, P. D.: RP18: Holistic Quality Model, Status Seminar 2022 Bad Boll, 17.11.2022

Bühler, M., Sebald, C., Rechid, D., Baier, E., Michalski, A., Rothstein, B., Metzner, M., Schwieger, V., Harrs, J.A., Jacob, D., Panhuis, G., Rodríguez, R.C., Reinhart, V. & Scheffczyk, K.: Climate-resilient urban planning through the development of climate data integration strategies and tools based on information from the Copernicus Climate Data Store in the city of Konstanz, Germany, Poster Session at the European Space Agency (ESA) - Living Planet Symposium 2022, World Conference Center, Bonn, Germany, 23–27 May 2022.

Göbel, M., Schlopschnat, C., Treml, S., Yang, X., Gienger, A. Lauer, A., Abolhasani, S., Zhang, L., Balangé, L., Skoury, L. & Wood, D.: livMatS Biomimetic Shell Co-Design and Construction of an innovative segmented timber shell building, Status Seminar 2022 Bad Boll, 17.11.2022

Lauer, A., Lerke, O. & Gong, Y.: Robotic Platform for Cyber-Physical Assembly of Long-Span Fibre-Composite Structures, IntCDC Research Network Colloquium 2022, 24.02.2022

Lauer, A., Gorokhova, L. & Gong, Y.: Cyber-Physical On-Site Construction Processes Using a Spider Crane Robotic Platform, IntCDC Status Seminar 2023, 03.03.2023

Reinhart, V., Sebald, C., Vögt, V.: Das CoKLIMAx Projekt: Nutzung von Copernicus-Daten und Diensten für die klimaresiliente Stadtplanung mit kommunalen Anwendungspotentialen am Beispiel der Stadt Konstanz, Vortragsreihe "Fernerkundung / Copernicus für kommunale Anwendungen", 10. Deutsches GeoForum, Berlin, 23.-24.11.2022

Schwieger; V.: Quality in Engineering Geodesy - an introduction to the topic and to the workshop. Scientific Workshop on Uncertainty and Quality of Multi-Sensor Systems, FIG Congress 2022, Warsaw, 10.09.2022.

Schwieger, V.: Vorstellung der Abteilung Ingenieurgeodäsie, Jahressitzung des Ausschusses Geodäsie (DGK), Innsbruck, 21.09.2022.

Schwieger, V.: Vorarbeiten zur Entwicklung eines Gleisfehlerdetektionssystems mit Regelzügen und Low-Cost Sensorik, Hamburg, 213. DVW Seminar „MST 2022 – Multisensortechnologie: Von (A)nwendungen bis (Z)ukunftstechnologien Mulitsensorsysteme", 26.09.2022.

Schwieger, V.: Quality Control for Graded Concrete. IntCDC Conference 2022, Integrative Computational Design and Construction for Future Proof Architecture, Stuttgart, 12.10.2022.

Schwieger, V.: Map Matching Applications. Seminar SE 3.05 "GPS/INS-Integration und Multisensor-Navigation", Carl-Cranz-Gesellschaft e.V., Oberpfaffenhofen, 10.11.2022.

Sebald, C., Tewes, T.: CoKLIMAx - Nutzung von Copernicus-Daten und -Diensten für die klimaresiliente Stadtplanung mit kommunalen Anwendungspotentialen am Beispiel der Stadt Konstanz, Nationales Forum für Fernerkundung und Copernicus 2022, Berlin, 21.-23.06.2022.

Yang, Y.: Towards better targetless registration and deformation analysis of TLS point clouds using patch-based segmentation, DGK PhD-Seminar Clausthal-Zellerfeld, 07.10.2022.

Yang, Y. & Schwieger, V.: Supervoxel-based targetless registration and identification of stable areas for deformed point clouds. 5th Joint International Symposium on Deformation Monitoring (JISDM 2022), Valencia, Spain, 22.06.2022.

5. Activities at the University and in National and International Organizations

Volker Schwieger

- Full member of the German Geodetic Commission (Deutsche Geodätische Kommission – DGK)
- Head of the section „Engineering Geodesy" within the German Geodetic Commission (DGK)
- Chief Editor of Peer Review Processes for FIG Working Weeks and Congresses
- Member of the Editorial Board "Journal of Applied Geodesy"
- Member of the Editorial Board "Journal of Applied Engineering Science"
- Member of the 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
- Course Director of the MSc Program GeoEngine at the University of Stuttgart

Li Zhang

- Co-Chair of the Working Group 5.6 „Cost Effective Positioning" within the FIG Commission 5 (Positioning and Measurement),
- Chair of the Working Group „Quality Assurance" within the Commission 3 „Measurement Methods and Systems" of "Deutscher Verein für Vermessungswesen (DVW)"

6. Master Theses

Dalloul, Ahmed
3D model generation through autonomous scanning for infrastructure facilities. (Kerekes/Basalla, Schwieger)

Frolow, Rudolf
Entwicklung eines grid-basierten Map-Matching Algorithmus zur Anwendung auf spurgenauen Karten

Li, Zhan
Investigation of different approaches to tiling and memory management of map data for processing in map-matching. (Luz/Metzner)

Miehling, Ronja
Entwicklung und Evaluierung eines Algorithmus zur Liniensegmentierung aus Punktwolken für Faserverbundsysteme. (Balangé/Schwieger)

Yu, Huang
Investigation of the accuracy in the creation of 3D models using UAV. (Luz/Metzner)

7. Bachelor Theses

Airouta, Salam
Untersuchungen von Materialeigenschaften verschiedener Betonmischungen und Fertigungsmaterialien auf die Messgenauigkeit. (Balangé/Zhang)

Kassulat, Tim
Entwicklung und Evaluierung verschiedener Methoden zur Querschnittsflächenberechnung einzelner Fasern aus Faserverbundsystembauteilen. (Balangé/Schwieger)

Kunzi, Christian
Untersuchung der Registrierungsgenauigkeit bei Punktwolken am Beispiel des Turms an der Birke. (Gorokhova/Schwieger)

Speidel, Pauline
Evaluierung von unterschiedlichen Verfahren zur Bestimmung der Pose eines Bauroboters mittels eines RTS Netzwerks (Lerke/Schwieger)

8. Education

SS22 and WS22/23 with Lecture/Exercise/Practical Work/Seminar

Bachelor Geodesy and Geoinformatics (German):

Basic Geodetic Field Work (Kanzler)	0/0/5 days/0
Engineering Geodesy I (Schwieger, Abolhasani, Kerekes)	4/2/0/0
Engineering Geodesy II (Schwieger, Gorokhova)	1/1/0/0
Geodetic Measurement Techniques I (Metzner, Frolow)	3/1/0/0
Geodetic Measurement Techniques II (Haußmann/Kanzler/Frolow)	0/1/0/0
Integrated Field Work (Kerekes, Metzner)	0/0/10 days/0
Reorganisation of Rural Regions (Stadler)	1/0/0/0
Statistics and Error Theory (Schwieger, Balangé)	2/2/0/0

Master Geodesy and Geoinformatics (German):

Industrial Metrology (Schwieger, Gorokhova)	1/1/0/0
Land Development (Eisenmann)	1/0/0/0
Monitoring Measurements (Schwieger, Kerekes)	1/1/0/0
Terrestrial Multisensor Systems (Zhang, Frolow)	2/1/0/0
Geomobility (Zhang, Luz)	2/2/0/0
Projekt Geodäsie und Geoinformatik (Schwieger, Zhang, Abolhasani, Gorokhova)	0/0/0/6

Master GeoEngine (English):

Kinematic Measurement Systems (Schwieger, Basalla)	2/2/0/0
Monitoring (Schwieger, Balangé)	1/1/0/0
Thematic Cartography (Zhang, Frolow)	1/1/0/0
Transport Telematics (Metzner, Sebald)	2/1/0/0
Terrestrial Multisensor Systems (Zhang, Luz)	2/1/0/0

Bachelor and Master Aerospace Engineering (German):

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

Master Aerospace Engineering (German):

Industrial Metrology (Schwieger, Gorokhova)	1/1/0/0
Transport Telematics (Zhang, Luz)	2/2/0/0

Bachelor Civil Engineering (German):

Geodesy in Civil Engineering (Metzner, Luz, Kanzler)	2/2/0/0

Master Civil Engineering (German):

Geoinformation Systems (Metzner, Sebald)	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, Sebald, Kanzler)	2/2/0/0

Bachelor Transport Engineering (German):

Statistics (Metzner, Zhang, Kanzler)	0.5/0.5/0/0
Seminar Introduction in Transport Engineering (Gorokhova)	0/0/0/1

Master Infrastructure Planning (English):

GIS-based Data Acquisition (Zhang, Sebald, Kanzler)	1/1/0/0