Annual Report 2024

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	Sensor Fusion
	M.Sc. Laura Balangé	Quality Modeling
	M.Sc. Rudolf Frolow	Sensor Fusion
	Dipl.-Ing. Lyudmila Gorokhova (until 30.06.2024)	Kinematic Positioning
	Dr.-Ing. Gabriel Kerekes	Terrestrial Laser Scanning
	M.Sc. Philipp Luz (until 31.10.2024)	Digital Map
	Dr.-Ing. Martin Metzner	Engineering Geodesy
	M.Sc. Ronja Miehling	Robotic Total Station
	M.Sc. Christoph Sebald (until 30.06.2024)	GIS for Climate Data
	Ph.D. Stanislav Shevchuk	Total Station, Image Processing
	Dr.-Ing. Li Zhang	Engineering Geodesy
Technical Staff:	Nasser Alhamad (since 01.09.2024)	
	Martin Knihs, Master Precision Mechanic	
	Dipl.-Geogr. Lars Plate	
External Teaching Staff:	Dipl.-Ing. Jürgen Eisenmann	Senior Surveying Director Department 4 - Land Consolidation, Real Estate Cadastre - at the State Office for Geoinformation and Rural Development (LGL)
	Dr.-Ing. Frank Friesecke	Authorized signatory of STEG Stadtentwicklung GmbH
	Dipl.-Ing. Jonas Stadler	Ludwigsburg District Office - Land Consolidation Department
	Dipl.-Math. Ulrich Völter	Managing Director of Intermetric
	Dr.-Ing. Thomas Wiltschko	Head of Team System Safety, Mercedes-Benz AG
PhD-Students:	M.Sc. Julia Aichinger	Terrestrial Laser Scanning
	M.Sc. Christian Bader	Kinematic 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

Guest (via Erasmus): Prof. Janina Zaczek-Peplinska (TU Warsaw)

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“ at 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 also co-opted into Faculty 2 “Civil and Environmental Engineering”. Furthermore, the IIGS is actively involved in the Center for Transportation Research at the University of Stuttgart (FOVUS). Thus, the IIGS actively continues its close collaboration with all institutes in the field of transportation, especially with those belonging to Faculty 2.

Since 2011, Prof. Schwieger has been a full member of the German Geodetic Commission (Deutsche Geodätische Kommission – DGK). Furthermore, since 2020, he has been the head of the „Engineering Geodesy“ section within the DGK since 2020.

The institute’s main educational tasks 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 geo-mobility. The IIGS is responsible for these fields within the curricula of “Geodesy and Geoinformatics” (Master and Bachelor, taught in German) and for “GeoEngine” (Master’s course “Geomatics Engineering”, taught in English). In addition, the IIGS offers several courses taught in German for the curricula of “Aerospace Engineering” (Bachelor and Master), “Civil Engineering” (Bachelor and Master), “Architecture and Urban Planning” (Master), “Transport Engineering” (Bachelor and Master) and “Technique and Economy of Real Estate” (Bachelor). Furthermore, lectures are offered in English to students in the Master’s course “Infrastructure Planning”.

The cluster “Integrative Computational Design and Construction for Architecture” (IntCDC) at the University of Stuttgart was awarded funding for the period 2019 to 2025. The cluster IntCDC aims to harness the full potential of digital technologies in order to rethink design and construction, and to enable groundbreaking innovations in the building sector through a systematic, holistic, and integrative computational approach. As a member of the IntCDC cluster, the institute’s research in new construction methods is intensified in cooperation with architects, civil engineers, computer scientists, production engineers, social scientists, and other researchers from various institutions within and outside the University of Stuttgart. A new funding application for 2026 and the following years has already been submitted.

The research and project work of the institute is reflected in the course contents, ensuring that students are always presented with the current state of the art. As a result, student research projects and theses are often implemented in close cooperation with industry and external research partners. The main research areas focuses on kinematic and static positioning, analysis of engineering surveying and construction processes, machine and robot guidance, monitoring, geo-mobility, as well as process and quality modeling. Daily work is characterized by intensive collaboration with other engineering disciplines, particularly traffic engineering, civil engineering, architecture, and aerospace engineering.

There has been a major change in the GeoEngine degree program. Starting in 2025, it will be renamed Geomatics for Environmental Monitoring (GEM). The GEM program builds on the previous geodetically and metrologically focused engineering Master’s program in geo-engineering but now expands to include topics related to sustainability, environmental studies, and climate research. Applications for the English-language Master's GEM program can be submitted until January 15 and July 15 each year.
The study program offers three specializations - Geodesy, Mapping, and Environment - of which students must select at least two. The state-of-the-art curriculum provides students with the latest advancements in geomatics, remote sensing, satellite geodesy and environmental cartography. This fundamental knowledge is supplemented by practical, real-life projects that integrate geodetic technologies into environmental sciences. By combining theoretical knowledge with practical skills, the program also introduces students to related fields, equipping them to address environmental challenges effectively on a global scale. As a result, future

graduates can expect excellent career opportunities in fields such as geomatics, geodesy, environmental consulting, urban planning, and related areas.

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

A real-time Error State Kalman Filter (ESKF) capable of fusing the measurements from the Inertial Measurement Unit (IMU), Robotic Total Station (RTS), and odometer was implemented on a sensing robot of IntCDC (Cluster of Excellence Integrative Computational Design and Construction for Architecture). The project is a collaboration between three institutes: in addition to the IIGS, these include the Institute for Photogrammetry and Geoinformatics (ifp) and the Institute for System Dynamics (ISYS). After conducting various test scenarios, the accuracy of the results and measurement characteristics - such as latency and non-equidistance - and their effects on the estimated pose were analyzed.
A further step focused on the as-built geometry of the Large-Scale Construction Robotics Laboratory (LCRL) hall. The available data for this purpose included Terrestrial Laser Scanning (TLS), Simultaneous Localization and Mapping (SLAM) point clouds, and architectural plans. Initially, both point clouds were segmented, and geometric parameters such as wall dimensions, the angles between adjacent walls, and the angles between the floor, ceiling and walls were estimated. The Building and Habitat Object Model (BHoM), which describes the as-planned geometry, was available for the building. The aim was to use the aforementioned geometry sources to complete the BHoM with the as-built geometry. These sources were captured with different accuracies. Accordingly, stochastic models describing the accuracies were needed.
For stochastic modeling of the TLS point cloud, the elementary error model developed by the IIGS was applied. The model considers different types of errors, such as instrumental, atmospheric, and object-related, and generates a variance-covariance matrix for the point cloud. Figure 1 shows the Helmert positional errors for the TLS point cloud. However, no error model was available for the SLAM point cloud.

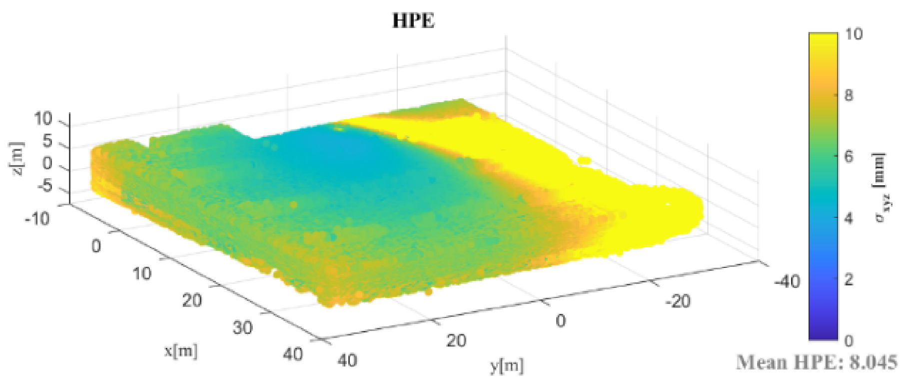

Figure 1: Helmert positional error of the TLS point cloud after the registration

Therefore, the Monte Carlo simulation was used to generate 5000 point clouds. The stochastic model was generated by performing point-to-point measurements between the point clouds and the reference point cloud. The results are depicted in Figure 2. For the architectural plans, an assumed accuracy was considered based on a literature review.

The geometric parameters of the building were fused considering the stochastic models. The fusion was performed in two different scenarios: in the first one, only the SLAM and the architectural plans were fused, with TLS used to validate the results. In the second scenario, all sources were fused. The next step would be to extend the BHoM model with as-built geometry.

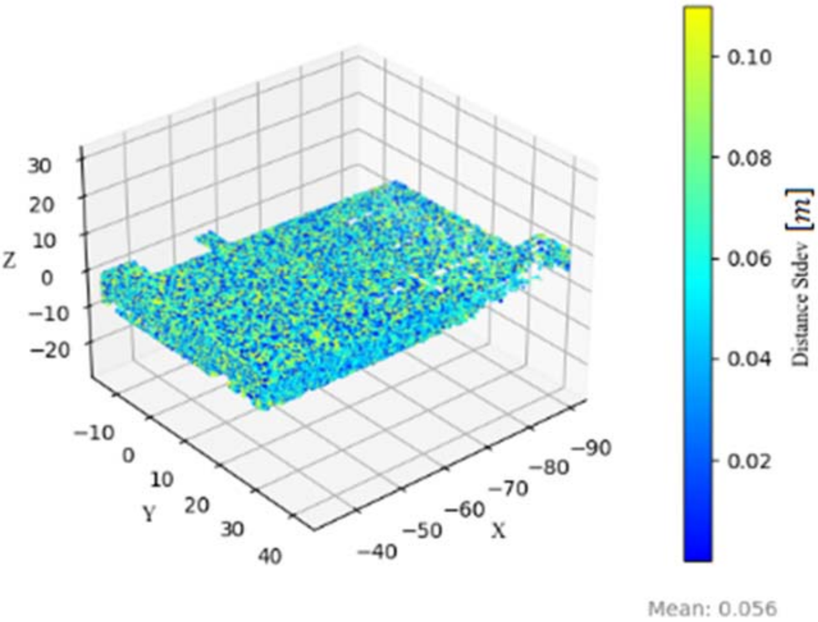

Figure 2: 3D distance standard deviations estimated by point-to-point measurement analysis

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

3.2. Holistic Quality Model for the Extension of Existing Buildings

Gefördert durch DFG Deutsche Forschungsgemeinschaft

IntCDC CLUSTER OF EXCELLENCE

Within IntCDC, the research project "Holistic Quality Model for Extension of Existing Buildings" focus on developing a holistic quality model for existing buildings. The project is a collaboration between four institutes: in addition to the IIGS, these include the Institute of Acoustics and Building Physics (IABP), the Institute of Construction Management (IBL), and the Institute for Social Sciences (SOWI). This collaboration enables a holistic approach to the realization of the quality model. The main research focus of the IIGS is the assessment of technical quality.

As part of the joint work, the crucial aspects of the existing building stock extension were identified and the relevant factors for the quality model were defined. In this context, the importance of interrelations was also considered further, as these must now be considered not only at a single point in time but also between different control and decision points throughout the process.

The focus of the disciplinary work was on validating TLS measurements for fiber composite system components in geometric quality assessment. For this purpose, test specimens were fabricated in cooperation with the Institute of Aircraft Design (IFB) using two different resin systems in order to investigate the influence of the resin on the measurement accuracy. The measurements were then conducted using a Trimble X7 laser scanner (cf. Figure 3 left). In order to be able to investigate the influence of the surface additionally, a scanning spray was also applied during the measurements. In order to generate an additional reference data set, measurements were conducted using the industrial ATOS (Advanced Topometric Sensor) measuring system (cf. Figure 3 right). The analysis of the measurements shows that the average deviation of the TLS measurements, without a scanning spray from the reference measurements is 0.02 mm, while an average deviation of 0.53 mm is observed in the TLS measurements with a scanning spray. This indicates that TLS measurements without the additional use of a scanning spray provide satisfactory results that can be used for the geometric quality assurance of composite fiber system components.

Figure 3: Measurement Set-up for TLS measurements without scanning spray (left). Measurement set-up with ATOS System (right).

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

3.3. Cyber-Physical On-Site Construction Processes Using a Spider Crane Robotic Platform

The RP16-2 project, part of the Cluster of Excellence IntCDC, focuses on the robotic assembly of form-fit timber building systems. The project aims to further develop the existing cyber-physical construction (CPC) instrumentation platform. The project is a collaboration between three institutes: In addition to the IIGS, these include the Haptic Intelligence Department (HI) of Max Planck Institute for Intelligent Systems and the Institute for System Dynamics (ISYS), University Stuttgart.

Gefördert durch DFG Deutsche Forschungsgemeinschaft

IntCDC CLUSTER OF EXCELLENCE

The current set of tasks in the ongoing phase of the project involve the implementation of automated positioning of construction components, held by the robotic cranes using image-assisted total stations (IATSs). The functionality can be realized by performing the steps of IATS camera calibration, object (construction component) recognition, position tracking, and position as well as pose analysis.

Camera calibration has been performed and tested for Trimble Ri (coaxial camera) and Trimble S7 (non-coaxial camera) IATSs. Manufacturer-supplied calibration parameters provided a pixel-to-angle conversion accuracy of 0.06 gon (equivalent to several pixels). However, these parameters were insufficient for photogrammetric post-processing in position tracking, necessitating additional calibration using a test object.

For object recognition, feature-based algorithms such as SIFT and ORB were implemented. SIFT stands for “Scale-Invariant Feature Transform” and ORB stands for “Oriented FAST (Features from Accelerated Segment Test) and rotated BRIEF (Binary Robust Independent Elementary Features)”. However, these methods exhibited low efficiency (in both precision and recall) and limited performance (5–6 FPS at 1280 x 720 resolution).

To improve recognition, ArUco markers (monochrome digital codes, developed by the "Application of Artificial Vision" (A.V.A.) research group at the University of Cordoba) were introduced, enhancing detection accuracy even at extreme angles (60–70° to the image plane). This approach also improved processing performance (12–14 FPS at 1920 x 1080).
Based on the recognition algorithm, a tracking cycle was developed. Using homography transformation, the center of the construction component is identified in order to steer the instrument as it follows the object.
ArUco marker coordinates are used to determine the object's position and orientation in the camera coordinate system. The IATS's horizontal and vertical angles, position, and orientation are then used to convert these coordinates into an external coordinate system (see Figure 4).

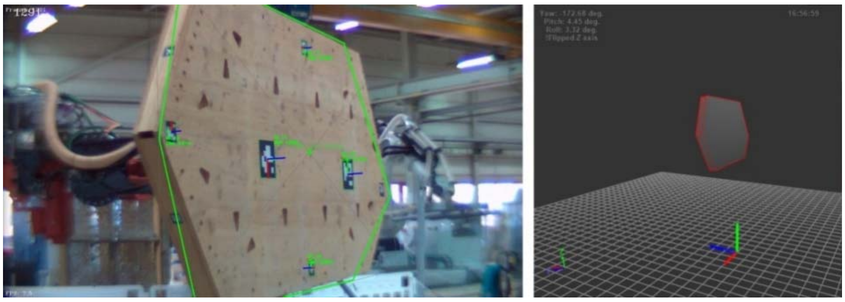

Figure 4: Object recognition and pose estimation using ArUco markers

For analysis and visualization, the object's CAD (Computer Aided Design) model is used. The positioning accuracy of the method is currently under evaluation. As an alternative, deep learning-based object recognition is being considered for future improvements.

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

3.4. Digitize, Visualize, Convince - the Geoinformation of Tomorrow

This Stuttgart Change Labs Project is an interdisciplinary collaboration organized as an innovative teaching class and was conducted during the winter semester 2024/2025. The aim of the project is to demonstrate how the digitalization of existing buildings and visualization in a virtual environment support decision-making processes.
This class is carried out by small groups of Master's students from the Geodesy and Geoinformation (GuG), supervised by the IIGS and the Institute of Photogrammetry (ifp), together with Bachelor's students in Informatics, supervised at the Visualization Institute (VISUS).
An example high-rise building was used in this project (cf. Figure 5). It is the experimental demonstrator SFB (Sonderforschungsbereich, English: Collaborative Research Centre) 1244, an adaptive 36 m tower located on the Vaihingen Campus of the University of Stuttgart.
Using several acquisition sensors such as TLS and image-based methods (SLAM), the geometry of the SFB tower was captured precisely and efficiently. The resulting point clouds were merged and visualized. Furthermore, a deformation analysis was performed after segments of the tower were intentionally actuated to simulate a structural deformation. Finally, a visualization of the point cloud in a virtual reality set-up was performed. With this information, the tower designers can make decisions based on the actual geometry of this globally unique demonstrator.

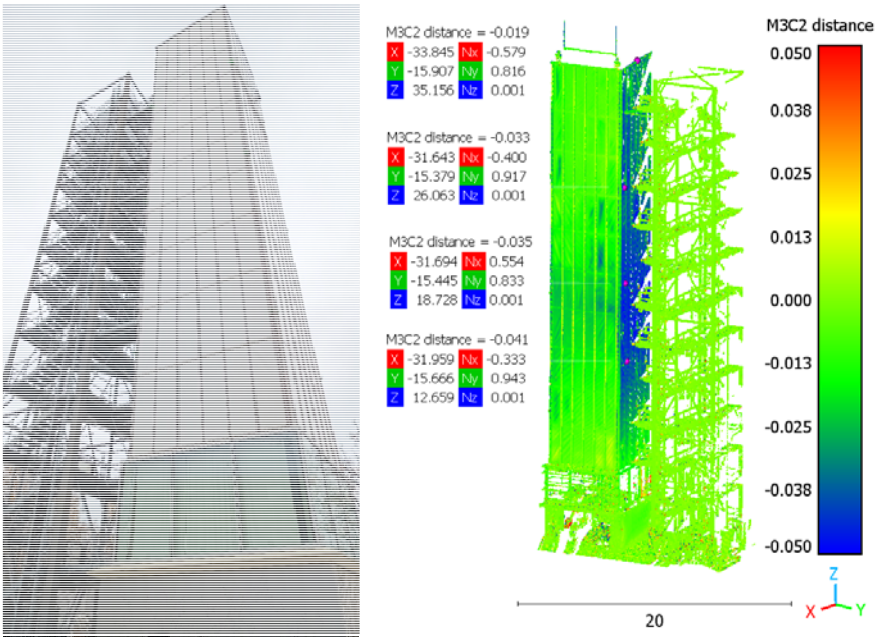

Figure 5: Left: Image of the SFB 1244 demonstrator; Right: results of deformation analysis of two states – passive and actuated.

3.5. ConMoRAIL

The ConMoRAIL project started in April 2023. Its aim is to develop a monitoring system that is cost-effective, on-board autonomous and permit-free, meaning it should not require special authorization from the German railway regulatory authorities to be installed and used during regular service. The main intent of this system is to precisely locate and detect specific track faults while operating in regular service and to store detected faults in a database that can be used to facilitate track maintenance.
This project is conducted in cooperation with the Institute of Railway and Transportation Engineering (IEV) at the University of Stuttgart and the Württembergische Eisenbahn Gesellschaft (WEG).

The first major milestone was the configuration and setup of the monitoring system mentioned above. This included the acquisition and installation of two IMUs and a low-cost GNSS receiver, with its antenna mounted under the train roof. These sensors were then integrated using a real-time computer to synchronize the incoming data streams. The synchronized data was then used for further processing.
Additionally, a sensor fusion algorithm was developed to combine the different data streams to obtain dense position information. This high density of positions plays a crucial role in detecting overlapping track faults. While the developed algorithm currently relies solely on sensor data only, it will be refined to incorporate additional data, such as map data from OpenStreetMaps (OSM). The results are intended to be used for validation and updating the track condition against a baseline.

The project is funded by the DFG (German Research Foundation) under the project number 515687155.

3.6. Ghosthunter III

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

The aim of the Ghosthunter III project was to further develop an application from previous projects for Android smartphones (cf. Figure 6), enabling the reliable detection of wrong-way drivers on freeways and their slip roads. This should allow both the wrong-way drivers themselves and other road users in the vicinity to be warned at an early stage. The following partners were involved in the project: NavCert GmbH, IIGS at the University of Stuttgart, and the Institute of Space Technology and Space Utilization (ISTA) at the University of the Federal Armed Forces in Munich.
In the project, a comprehensive analysis of smartphone positioning errors was first conducted. Initially, a measurement campaign was carried out to collect data on the accuracy of smartphone positions. Based on this data, simulation data was modeled to replicate positioning errors and test the integrity of the Ghosthunter app. Furthermore, the estimation of the protection level was investigated using neural networks in order to enhance the app's reliability in detecting wrong-way drivers. Additionally, server load was analyzed to determine how the solution can be scaled to support a large number of users.

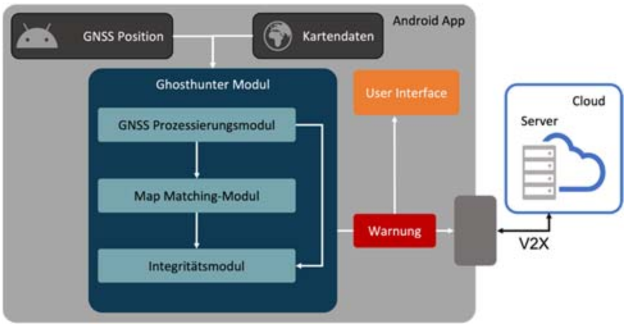

Figure 6: Overview of the Ghosthunter app

The results show that the developed data modeling effectively in simulates position errors and verifies the accuracy of the Ghosthunter app. The use of neural networks for protection level estimation has the potential to improve the app's performance. The analysis of server utilization provides important insights for scaling the solution.

Overall, the project provides valuable insights into the accuracy of smartphone locations, the performance of the Ghosthunter app and the scalability of the solution. The results can help further optimize the app and prepare it for a larger user base. In summary, the central components of the developed app were described. The implemented algorithms in the areas of map matching, wrong-way driver decision and significance check of the wrong-way driver decision were explained in more detail.

In addition, an overview was provided of the runtime tests conducted to ensure the real-time capability of the application. It was demonstrated how the OpenStreetMap (OSM) data is used as the basis for the map data and how this data is stored in a SQLite database. In addition, the various methods for verifying the integrity of the map data and the algorithms were presented. Finally, the results of the Monte Carlo simulation for wrong-way driver detection and the runtime results of the individual components of the app were presented. Overall, the findings showed that developed app was able to achieve good results in wrong-way driver detection and real-time capability was ensured.
The project was presented to the project sponsor in a final presentation in January 2024, after its scheduled completion in November 2023.

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

3.7. CoKLIMAx

The CoKLIMAx project, which ended in June 2024, aimed to make climate and satellite data from the Copernicus Climate Change Service (C3S) and its Copernicus Climate Data Store (CDS) accessible to municipalities. The project was a collaboration between four partners: in addition to the IIGS, these include the University of Applied Sciences Konstanz (HTWG), the city of Konstanz and the Climate Service Center (Helmholtz-Institute hereon, Hamburg). Climate change poses a major challenge for our planet and our existence, especially for municipalities. They are increasingly affected by extreme conditions such as heatwaves, droughts and floods, requiring adjustments in municipal planning to strengthen resilience (climate resilience). Access to comprehensive climate data is crucial for municipalities to identify risks, assess vulnerabilities, and plan targeted adaptation measures. The project focused on developing of user-friendly tools and efficient workflows for the data collection, processing, provision, and application of Copernicus climate data, involving all municipal stakeholders, especially the administration. The tools and applications developed were summarized in the project as the Advanced Municipal Climate Data Store Toolbox (AMCDS Toolbox). By combining a powerful platform (e.g. CODE-DE) and software (e.g. ArcGIS Enterprise), provided and used by a multi-stakeholder collaboration, together with Copernicus climate data and expert knowledge, municipalities can make informed decisions for municipal development based on climate data.

Applications were developed and tested in the project, which together form the AMCDS toolbox. The data from the CDS and its variables it contains were used to address the topics of heat, water, and vegetation for municipal administration in the context of creating climate resilience. On the one hand, users were provided with analysis and visualizations, while on the other hand, sample workflow scripts (in Python) were made available on the project homepage so that experienced users could adapt and use them for their own applications. All of this was implemented using commercial software such as ArcGIS Enterprise Notebook, ArcGIS Online, and ArcGIS Pro, as well as open source software such as QGIS. The resampling of some CDS data, which has a very coarse resolution, was often considered essential in order to be able to use it clearly in the municipal environment. In summary, it can be stated that climate data, particularly future projections, has significant potential for municipal planning processes and for strengthening climate resilience.

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.

3.8. Direct B-spline control point method

For modeling point clouds from terrestrial laser scan data, one approach is to represent the laser scan data using B-spline surfaces. B-spline surfaces contain several advantageous properties that allow real objects to be modeled. In this context, methods are often used that determine B-spline control points from laser scan data using least-squares estimation. A new approach, the direct B-spline control point method, does not rely on adjustment but instead uses the laser scan data directly as control points. To generate a tensor product B-spline surface from laser scan data using the direct B-spline control point method, several processing steps are required, which were developed using a test object in the form of a cucumber leaf. The simulated laser scan data of the cucumber leaf consists of approximately 15.000 points. Beyond modeling laser scan data with a B-spline surface, the developed method is designed to overlay laser scan data from two epochs using the so-called mapcut method with curvature parameters. This overlay enables a direct comparison of associated B-spline surface points.

As the direct B-spline control point method was developed based on simulated data, its functionality is to be tested on real data. Two test objects were created for this purpose. The first test object consists of an accumulation of sand with various elevations and depressions. The second test object is a replica of a part of a Greek sculpture that was created using clay. The clay test object features sharp edges in some areas, as well as elevations and depressions. Both test objects were scanned with the Leica HDS7000 laser scanner. Compared to the simulated data, the real-world test data, with up to 150.000 points, contains significantly larger number of points and a more irregular object surface. Figure 7 shows the measurement setup with the Leica HDS7000 and the two test objects in the measurement cellar at the University of Stuttgart.

Figure 7: Measurement of two test objects

3.9. Refining and Extending Real-time Lane Perception with a Navigation Map

In recent years, advanced driver assistance systems (ADAS) have become prevalent in high-end commercial vehicles. These systems utilize onboard cameras and/or LIDARs to gather information about the surrounding environment, particularly the position and movement of road objects, which are crucial for various autonomous driving tasks. However, the reliability of this perception is often limited to a short range of approximately 100 meters and can be compromised by factors such as occlusion, insufficient lighting, or unclear lane markings. To address these limitations, this project proposes enhancing and extending lane perception using navigation maps.

The approach begins with topological reasoning applied to each perception input frame, which consists of sequences of discrete geometric points outlining the lane boundaries. Connection points are identified within the lane group by detecting changes in distance between neighboring lanes and variations in curvature. Then, the lane group structure is represented graphically, modeling connection points and lane segments as two types of interconnected vertices. Using the navigation map, this graph is extended by matching connectivity and predicting the geometry beyond the perception range through curve fitting.

The effects of prediction range and different curve families on prediction accuracy were evaluated, achieving an average error of less than 3 meters over a 100-meter prediction range. Additionally, it was demonstrated that using a series of consecutive perception input frames stabilizes the predicted geometry over time. Ongoing experiments focus on more complex road structures and integrating other perceived road objects into the prediction algorithm.

3.10. Fast Ground Segmentation for 3D Point Cloud

For LiDAR based environment perception applications, a crucial task is to separate ground and non-ground points from a complete LiDAR scan. This is because typical automotive applications have different focuses. For example, in collision avoidance applications, the focus is usually on the above-ground objects such as pedestrians and vehicles. However, for automated vehicle navigation applications, ground level infrastructures such as lane markings and road borders is of high interest, especially when it comes to the precise trajectory planning and control. Typical LiDAR based ground segmentation methods model the ground surface as an ideal 3D plane. From the estimated ground plane, ground and non-ground points can then be intuitively separated using a simple point-to-plane distance threshold. However, such approaches struggle in sloped road scenarios, where assuming a flat ground may result in significant mis-segmentations of both ground and non-ground points. Besides, due to the lack of ground height priors, plane fitting is usually an iterative process. This poses another challenge when deploying such methods to on-board systems, as the computational demand will grow accordingly with the increasing maximum number of allowed iterations. To address these problems, deterministic ground segmentation approaches have been introduced over the past few decades. The main idea of deterministic ground segmentation methods is to treat ground segmentation as a binary labeling problem, which can be solved by examining a series of predefined heuristic rules with the help of a proper point cloud representation, such as the LiDAR range image or a 2D ground grid map. Inspired by this, we propose a fast ground segmentation method in this work. For the 3D point cloud representation, the projected polar grid map is chosen. As the labeling criterion, the change in slope between neighboring grid cells is selected. Through comprehensive evaluations conducted on the well-known SemanticKITTI and nuScenes datasets, the effectiveness and efficiency of the proposed method was demonstrated. An example of ground segmentation result from the proposed method is illustrated in Figure 8. It can be seen that the ground and non-ground points are clearly separated from each other.

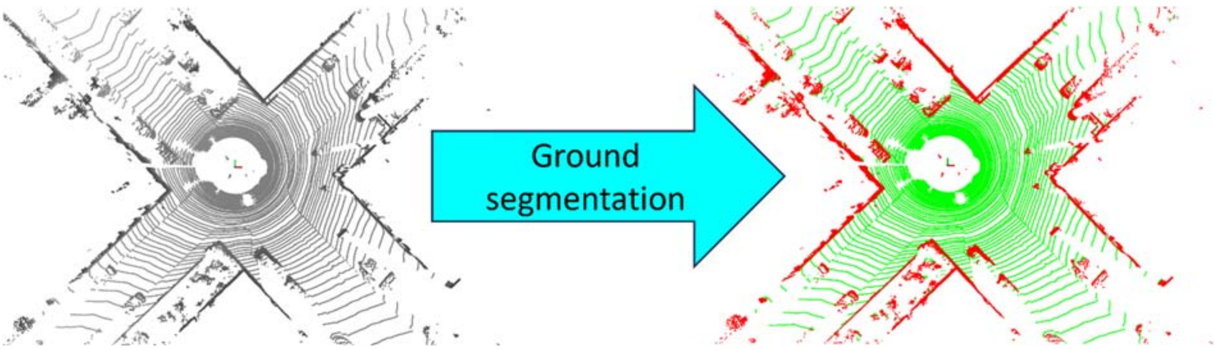

Figure 8: Example ground segmentation result from the proposed method on SemanticKITTI

3.11. Awards

- Bürkert University Prize 2022 (annual award)
  Awarded to MSc Ronja Miehling for her Master's thesis in the MSc Geodesy and Geoinformatics course: *Entwicklung und Evaluierung eines Algorithmus zur Liniensegmentierung aus Punktwolken für Faserverbundsysteme / Development and Evaluation of an Algorithm for Line Segmentation from Point Clouds for Fiber Composite Systems*
  (Awarded on 15.11.2024 at the annual celebration of the University of Stuttgart, awarded for best Master thesis of Faculty 6: Aerospace Engineering and Geodesy by the Christian Bückert Foundation)

- IntCDC Best Publication Award 2024 (annual award)
  Awarded to Kannenberg, F., Zechmeister, C., Gil Pérez, M., Guo, Y., Yang, X., Forster, D., Hügle, S., Mindermann, P., Abdelaal, M., Balangé, L., Schwieger, V., Weiskopf, D., Gresser, G. T., Middendorf, P., Bischoff, M., Knippers, J., & Menges, A. for the paper *Toward reciprocal feedback between computational design, engineering, and fabrication to co-design coreless filament-wound structures. Journal of Computational Design and Engineering, 11(3), Article 3. https://doi.org/10.1093/jcde/qwae048*
  (Awarded on 14.11.2024 as part of the IntCDC Status Seminar 2024, awarded for a maximum of two Master's theses by IntCDC)

- IntCDC Master's Thesis Award 2023 (annual award)
  Awarded to MSc Ronja Miehling for her Master's thesis in the MSc Geodesy and Geoinformatics course: *Entwicklung und Evaluierung eines Algorithmus zur Liniensegmentierung aus Punktwolken für Faserverbundsysteme / Development and Evaluation of an Algorithm for Line Segmentation from Point Clouds for Fiber Composite Systems*
  (Awarded on 01.03.2024 as part of the IntCDC Research Network Colloquium 2024, awarded for a maximum of two Master's theses by IntCDC)

3.12. PhD Seminar

The 15th Doctoral Seminar of the Engineering Geodesy Section of the DGK was organized by the Institute Engineering Geodesy and Measurement Systems at Graz University of Technology. A total of 9 presentations mirrored the work of PhD candidates. Fruitful discussions between more than 80 participants from Croatia, Austria, Switzerland, and Germany were possible during the coffee breaks and in the evening at the highly anticipated get-together including flat rate conditions.

4. Publications

Refereed Publications

Bader, C., & Schwieger, V. (2024). Advancing ADAS Perception: A Sensor-Parameterized Implementation of the GM-PHD Filter. Sensors, 24(8), Article 8. https://www.mdpi.com/1424-8220/24/8/2436

Haag, P., Balangé, L., Di Bari, R., Braun, K., Weißert, J., Zhang, L., Schwieger, V., Leistner, P., Kropp, C., & Jünger, H. C. (2024). Development of the Holistic Quality Model and Assessment – Integrating the Economic Quality Aspect and establishing an Extended Interrelation Analysis. Developments in the Built Environment, 100511. https://doi.org/10.1016/j.dibe.2024.100511

Kannenberg, F., Zechmeister, C., Gil Pérez, M., Guo, Y., Yang, X., Forster, D., Hügle, S., Mindermann, P., Abdelaal, M., Balangé, L., Schwieger, V., Weiskopf, D., Gresser, G. T., Middendorf, P., Bischoff, M., Knippers, J., & Menges, A. (2024). Toward reciprocal feedback between computational design, engineering, and fabrication to co-design coreless filament-wound structures. Journal of Computational Design and Engineering, 11(3), Article 3. https://doi.org/10.1093/jcde/qwae048

Kerekes, G., & Schwieger, V. (2024). An approach for considering the object surface properties in a TLS stochastic model. Journal of Applied Geodesy, 18, 115--131. https://doi.org/doi:10.1515/jag-2022-0032

Khikmah, F., Sebald, C., Metzner, M., & Schwieger, V. (2024). Modelling Vegetation Health and Its Relation to Climate Conditions Using Copernicus Data in the City of Constance. Remote Sensing, 16(4), Article 4. https://doi.org/10.3390/rs16040691

Sebald, C., Metzner, M., Tewes, T., & Schwieger, V. (2024). Nutzung von Copernicus-Klimadaten in Kommunen am Beispiel der Stadt Konstanz. zfv – Zeitschrift für Geodäsie, Geoinformation und Landmanagement, 4 / 2024, Article 4 / 2024. https://doi.org/10.12902/zfv-0478-2024

Non-Refereed Publications

Kerekes, G., & Schwieger, V. (2024). Possibilities and Limitations in the extrinsic Synchronization of Observations from Networks of Robotic Total Stations. FIG Working Week Accra 2024.

Luz, P., Metzner, M., Stapelfeld, M., Lichtenberger, C., Pany, T., & Schwieger, V. (2024). Falschfahrerdetektion per App kann für mehr Sicherheit sorgen. ZVS Zeitschrift für Verkehrssicherheit, 1/2024, 87–88.

Luz, P., Metzner, M., Stapelfeld, M., Lichtenberger, C., Pany, T., & Schwieger, V. (2024). Erkennung von Falschfahrern per App. DVR REPORT - Magazin für Verkehrssicherheit, Deutschen Verkehrssicherheitsrats (DVR), 1, Article 1. https://www.dvr.de/fileadmin/downloads/dvr-report/DVR_Report_2024_01_barrierefrei.pdf

Presentations

Balangé, L., Bornschlegl. S. Haag, P., Horn, R.: RP18-2: Holistic Quality Model (HQM) for extension of existing buildings: social, environmental, technical and economic integration Holistic Quality Model, Research Network Colloquium 2024, 01.03.2024, Stuttgart.

Balangé, L., Bornschlegl, S., Haag, P., Weißert, J.: RP18-2: Holistic Quality Model (HQM) for extension of existing buildings: social, environmental, technical and economic integration, Status Seminar 2024, 14.-15.11.2024, Bad Boll

Gorokhova, L., Lauer, R. P. A., Gong, Y.: RP16-2 Cyber-Physical On-Site Construction Processes using a Spider Crane Robotic Platform, Research Network Colloquium 2024, 01.03.2024, Stuttgart

Hierholz, A., Reß, V., Abolhasani, S.: RP26-1: AI-supported Collaborative Control and Trajectory Generation of Mobile Manipulators for Indoor Construction Tasks, Research Network Colloquium 2024, 01.03.2024, Stuttgart

Hierholz, A., Reß, V., Abolhasani, S.: RP26-1: AI-supported Collaborative Control and Trajectory Generation of Mobile Manipulators for Indoor Construction Tasks, Status Seminar 2024, 14.11.2024, Bad Boll

Wasserloos, P., Shevchuk, S., Tashiro, N.: RP 16-2 Spider Crane Robotic Platform for On-Site Construction, IntCDC Status Seminar 2024, 14-15.11.2024, Bad Boll

Schwieger, V.: Integrative Computational Design and Construction for Architecture – Ingenieurgeodätische Beiträge. TU Wien, Österreichische Gesellschaft für Vermessung und Geoinformation, 18.01.2024, Wien.

Schwieger, V.: Geometrie für alle – die Ingenieurgeodäsie und ihre aktuelle Bedeutung. Technik Forum Backnang, 14.02.2024, Backnang.

Schwieger, V.: Positioning and Control of Construction Machines and Robots, Quality Control in Construction, Research at IIGS. Lectures at Technical University Warsaw, Poland, 05.-08.03.2024, Warsaw.

Schwieger, V., Kerekes, G., Yang, Y.: New methodical aspects for TLS Monitoring. The importance of deformation and displacement monitoring for the safety of construction investments, Scientific and Technical Seminar, 13.03.2014, Warsaw (digital).

Schwieger, V.: Integrative Computational Design and Construction for Architecture – Ingenieurgeodätische Beiträge. LUH, Geodätisches Kolloquium, 14.05.2024, Hannover.

Schwieger, V., Pany, T.: Projekt Ghosthunter. Sitzung des Deutschen Verkehrssicherheitsrates (DVR), 27./28.06.2024, Aachen.

Schwieger, V.: Geometrie für alle – Aktuelle ingenieurgeodätische Herausforderungen. Volkshochschule Stuttgart, Wissenschaft aktuell, 09.07.2024, Stuttgart.

Schwieger, V.: Vorstellung der Abteilung Ingenieurgeodäsie, Jahressitzung des Ausschusses Geodäsie (DGK), 27.-29.11.2024, München.

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 Geodesy”
- 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 & GEM at the University of Stuttgart

Li Zhang

- 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 4 „Engineering Geodesy and Measurement Techniques“ of “Deutscher Verein für Vermessungswesen (DVW)”

6. Doctorates

Christian Bader
Multi-Sensor Multi-Object Detection and Tracking for ADAS, Applied to Trucks
Main reviewer: Prof. Dr.-Ing. habil. Dr. h.c. Volker Schwieger,
Co-reviewer: Prof. Dr.-Ing. Hans-Christian Reuss

Annette Schmitt
Untersuchungen zum geometrischen Verhalten von Holz mittels optischer Sensoren
https://doi.org/10.18419/opus-15605
Main reviewer: Prof. Dr.-Ing. habil. Dr. h.c. Volker Schwieger
Co-reviewer: Prof. Dr.-Ing. habil. Alexander Reiterer (Universität Freiburg)

Lukas Hart
3D-Digitalisierung von Industrieanlagen zur anschließenden Herstellung passgenauer Dämmlösungen
Main reviewer: Prof. Dr.-Ing. habil. Michael Möser
Co-reviewers: Prof. Dr.-Ing. habil. Dr. h.c. Volker Schwieger
Prof. Dr.-Ing. Stefan Knoblach

7. Master Theses

Qianrong, Yi
Development and evaluation of a real-time error state Kalman Filter for localization of an indoor robot (Abolhasani/Zhang)

Chammout; Hussein
Berechnung von Heatmaps auf Basis einzelner GNSS-basierenden Schiffpositionsdaten und Visualisierung in DTSweb (Metzner/Schwieger)

Khadem Haghighat, Seyed Pouria
Geometrical representation of an existing building using stochastically modeled plans, SLAM and TLS point clouds (Abolhasani/Zhang)

Ruck, Sabrina
Entwicklung einer Android-App zur Visualisierung von touristischen Informationen für Besucher des Stadtkerns von Vaihingen an der Enz (Luz/Schwieger)

Xu, Qiuyu
Self localization of roadside radar unit based on vehicle trajectory (Luz/Metzner/Zhang)

Yang, Zhiya
Development and evaluation of map matching algorithms for lane precise digital road maps (Luz/Metzner)

8. Bachelor Theses

Großkopf, Julia
Qualitätsbeurteilung der thermographischen Informationen von Punktwolken des Leica BLK360Laserscanners. (Kerekes/Schwieger)

Mayerle, Felix
Entwicklung und Implementierung eines Datenbankmodells zur effizienten Speicherung von Gleis- und Sensordaten zur Anwendung in Echtzeit Map-Matching Verfahren (Frolow/Schwieger)

Pappas, Stylianos
Untersuchung der Intensitätswerte von TLS Punktwolken mittels diffus reflektierender Oberflächen. (Kerekes/Schwieger)

Pfeiffer, Lars
Automatisierte Ableitung von natürlichen Böschungsflächen und Strukturlinien aus einem DGM-Raster (Metzner/Schwieger)

9. Education

SS24 and WS24/25 with offered Lectures/Exercises/Practical Work/Seminars

Bachelor Geodesy and Geoinformatics (German):

Basic Geodetic Field Work (Frolow)	0/0/5 days/0
Engineering Geodesy I (Schwieger, Abolhasani, Miehling)	4/2/0/0
Engineering Geodesy II (Schwieger, Gorokhova)	1/1/0/0
Geodetic Measurement Techniques I (Metzner, Frolow; Alhamad)	3/1/0/0
Geodetic Measurement Techniques II (Frolow)	0/1/0/0
Integrated Field Work (Miehling, Kerekes)	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):

Deformation Analysis (Zhang)	1/1/0/0
Industrial Metrology (Schwieger, Balangé)	1/1/0/0
Land Development (Eisenmann)	1/0/0/0
Monitoring Measurements (Schwieger, Kerekes)	2/2/0/0
Terrestrial Multisensor Systems (Zhang, Frolow)	1/1/0/0
Geomobility (Zhang, Balangé, Frolow)	2/2/0/0
Measurement Techniques in Closed Loops (Schwieger, Abolhasani)	1/1/0/0

Master GeoEngine (English):

Kinematic Measurement Systems (Schwieger, Shevchuk)	2/2/0/0
Monitoring (Schwieger, Shevchuk)	1/1/0/0
Thematic Cartography (Zhang, Miehling)	1/1/0/0
Transport Telematics (Metzner, Miehling)	2/1/0/0
Terrestrial Multisensor Systems (Zhang, Shevchuk)	2/1/0/0

Bachelor and Master Aerospace Engineering (German):

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

Master Aerospace Engineering (German):

Industrial Metrology (Schwieger, Balangé)	1/1/0/0
Transport Telematics (Zhang, Miehling)	2/2/0/0

Master Civil Engineering (German):

Geoinformation Systems (Metzner, Abolhasani)	2/1/0/0

Master Infrastructure Planning (English):

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

Master Architecture and Urban Planning

Point cloud and what now? Contemporary methods of inventory recording (Miehling)	0/0/0/4