Module Description

Multi-sensor multi-dimensional GeoSensing

General information

Module Code
GEOSensing

Module Category
Specialization

Lessons
3 lessons per week

ECTS
3

Module Language
English

Module Description
In the GEOSensing module important topics and trends in modern kinematic and multidimensional geospatial sensing are addressed: mobile and autonomous platforms and sensors, methods for georeferencing and extracting geospatial information as well as technologies and methods for sensing underground information by means of Ground Penetrating Radar (GPR) – or GeoRadar in short.

Multi-Sensor Systems and Mobile Sensing

In the first part of the module, platforms, sensors, control components, and applications of mobile and autonomous mapping platforms are studied. Typical localization and mapping sensors, including modern LiDAR technologies, will be addressed. A special focus will be placed on sensor and system integration, synchronization and calibration. With the robot operating system (ROS), a software framework frequently used in mobile mapping will be introduced.

Georeferencing and Information Extraction

The focus of the second part is placed on georeferencing methods and on the extraction of information from mobile multi-sensor data. With inertial navigation and SLAM, two important localization and georeferencing concepts are introduced and discussed. This is followed by an overview of classical and AI-based methods for processing and extracting information from multidimensional geospatial data from mobile and autonomous sensor platforms. The second part is concluded with the presentation of the use case of road and rail infrastructure management based on multi-sensor mobile mapping data.

GeoRadar / Ground-penetrating Radar (GPR)

The third section is devoted to Ground-Penetrating Radar (GPR), an advanced, non-invasive geophysical technique for real-time subsurface imaging. Initially, the fundamental physical and electromagnetic principles underlying this technology are explained. Subsequently, the core methodologies for data acquisition, inclusive of appropriate platforms, are detailed. The discussion extends to typical applications such as underground utility detection and mapping, geophysical surveys, infrastructure asset inspection and archaeological investigations. Within this context, the processes involved in the analysis and interpretation of radargrams are demonstrated.

Learning Objectives, Contents, and Methods

Learning Objectives, Competencies to be Acquired

- Students will obtain a comprehensive overview of the state-of-the-art and technology of multi-sensor mobile mapping platforms, sensors and applications and will be able to discuss and judge their suitability for typical mapping tasks.
- They understand the main requirements for building and operating multi-sensor systems and based on the Robot Operating System ROS, they get an insight into the typical components and tasks of a mobile and autonomous sensing system and can explain their role and importance.
- Students will get an insight into recent developments in LiDAR technology – both in terms of sensors and registration methods – and will be able to discuss their impact on current and future projects.
- They will learn key concepts and methods for localization and georeferencing of multi-sensor data. They can discuss the concepts, strengths, and weaknesses of the two main techniques: inertial navigation and SLAM.
- Students will understand data pre-processing techniques and of established and emerging information extraction methods and are able to choose and discuss suitable methods for typical geospatial information needs.
- Students understand the fundamental physical and electromagnetic principles of Ground-Penetrating Radar (GPR) technology.
- They acquire knowledge about methodologies and platforms for effective GPR data acquisition.
- They develop basic skills for interpreting radargrams for some typical applications.

Module Contents

Module Introduction / GeoSensing Fundamentals

- Geospatial reference systems
- Sampling theorems
- Reference data / ground truth
- Evaluation

Multi-Sensor Mobile Mapping Systems

- Platforms (airborne, vehicle-based, portable, handheld, autonomous) and Localization and Mapping Sensors
- Kinematic Systems: synchronization, tracking and calibration
- Applications / Use Cases

Autonomous / Robotic Systems

- UAVs – new airborne platforms for indoor applications and infrastructure inspection
- Autonomous Operations and Tasks (Localization, Planning, Control, Perception)
- ROS (Robot Operating Systems) - open-source software development kit for robotics applications

LiDAR Technology and Trends

- LiDAR principles (recap) and recent developments: Solid State, Multi-frequency and Single Photon LiDAR
- LiDAR signal processing (Full Waveform etc.)
- (Automated) Point Cloud Registration Methods (ICP etc.)

Georeferencing Methods

- Direct vs. Indirect vs. Integrated Georeferencing
- Inertial Navigation (Fundamentals, Sensors and Systems, Mathematical Models, Error Sources and Compensation)
- SLAM (Simultaneous Localization and Mapping) – Visual and LiDAR SLAM

Data Processing and Information Extraction

- Data Preprocessing and Handling (Resampling, Filtering, Partitioning)
- Typical Information Methods applied to Mobile Sensing Data: 3D Reconstruction, Regression, Object Detection, (Image) Segmentation, Classification

Use Case Professional Streetview Services / Infrastructure Management based on Mobile Mapping Data

- Data Capturing, Cloud Platform, Services, Business Case

GeoRadar / Ground Penetrating Radar

- Physical principles of electromagnetic waves
- Signal propagation in different media
- Technology and components (antennas, platforms, etc.)
- Data acquisition (set up, strategies, planning)
- Data processing (pre-processing, filtering, enhancement, software and tools)
- Data interpretation (radargram analysis, identifying subsurface features)
- Case studies and examples

Module outline

- Multi-Sensor Systems and Mobile Sensing (approx. 5 weeks)
- Georeferencing & Information Extraction Methods (approx. 5 weeks)
- GeoRadar (approx. 4 weeks)

Teaching and learning methods

- Lectures (approx. 2 lessons per weeks) – face-to-face teaching or self-study
- Exercises (approx. 1 lesson per week)

Pre-requisites

Python Programming

Understanding of basic geospatial concepts and technologies (geodetic datums, coordinate systems, GNSS surveying, UAV photogrammetry)

Assessment

Final module exam

Exam type	Written exam
Exam duration	90 minutes
Permitted aids	Written summaries (max. 3 pages A4, single-sided, handwritten)