EduServ 17th
Distance e-Learning Courses
Spring 2019

3D Sensing, Scene Reconstruction and Semantic Interpretation

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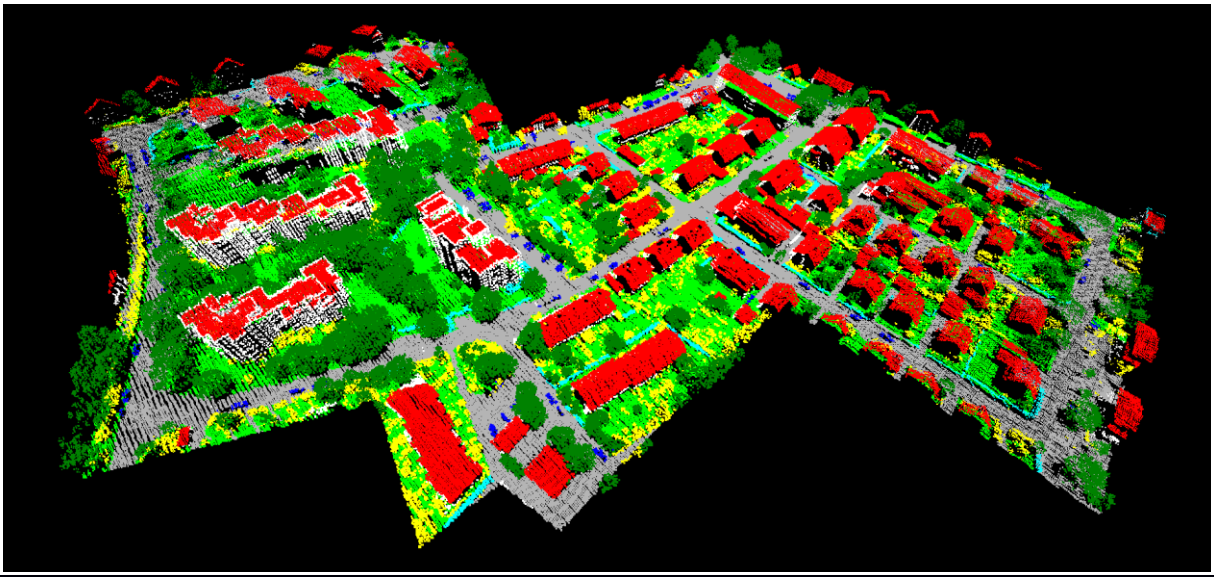
Target audience: University and PhD students in fields related to photogrammetry, remote sensing, computer vision and robotics; staff from survey and mapping agencies, public authorities and interested third parties involved in the acquisition, automatic characterization and semantic interpretation of 3D scenes.

Introduction: The adequate acquisition and analysis of a scene are of great interest for photogrammetry, remote sensing, computer vision, computer graphics and robotics. In this regard, 3D data have become a standard data source for numerous applications. The capability to interpret such 3D data, in turn, allows dealing with a variety of high-level tasks such as scene modelling, autonomous exploration of unknown scenes or autonomous navigation without collisions. To obtain such a capability, many applications rely on a semantic interpretation of the acquired data. In this course, we will first provide an overview of different concepts to obtain 3D data either directly by measurements or indirectly from acquired imagery. Subsequently, we focus on the semantic interpretation of 3D data. In this context, we will present the classic approach relying on the use of handcrafted features and the state-of-the-art end-to-end learning approach relying on deep learning techniques.



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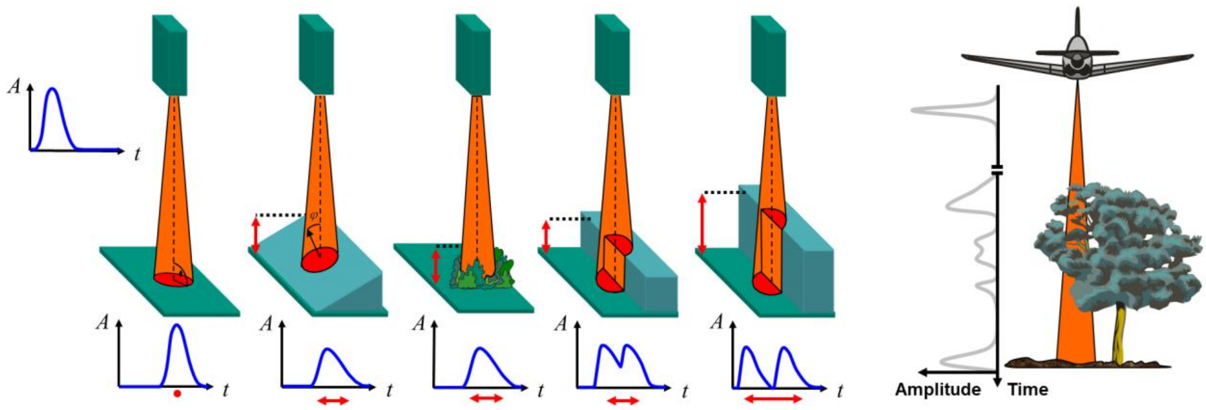
Course objective: After completing this course, participants are familiar with the fundamentals of geometry acquisition via (passive and active) optical 3D sensing techniques. They are also aware of different approaches for the semantic interpretation of 3D data in the form of irregular 3D point clouds. In this regard, they know the classic approach focusing on the use of handcrafted features and the state-of-the-art approach relying on deep learning. Participants are able to use the gained knowledge and transfer it to other applications.

Course outline: The pre-course seminar will provide an overview regarding the acquisition, automatic characterization and semantic interpretation of 3D scenes. It will cover basic principles, best practices and recent trends related to the addressed topics. The e-learning part of the course is divided into four modules (see below). The first module will give a general introduction on geometry acquisition via (passive and active) optical 3D sensing techniques and an in-depth discussion of approaches tailored to acquisition based on consumer hardware or crowdsourced input data. The second module will focus on active optical 3D sensing as commonly used for the acquisition of large geospatial data and provide a survey on the extraction of descriptive features from such data. The third module will focus on the semantic interpretation of point cloud data and address all components of a typical processing workflow from given point cloud data to a semantic labeling with respect to user-defined classes. The fourth module is dedicated to deep learning techniques for the semantic labeling of point clouds as well as to the context-based classification of these data using graphical models such as Conditional Random Fields (CRFs). Questions of the participants regarding the course material will be answered through e-communication. For each module, an assignment will be given and answers of the students will be commented by the instructors of this course. Participants are invited to discuss with the instructors about their own work, the used data and the potential of the presented content in their context.

Module 1: Scene Reconstruction – From Captured Data to (Realistic) 3D Models
This module provides an overview on basic concepts of geometry acquisition via (passive and active) optical 3D sensing techniques. A particular focus will be put on the generation of 3D scene representations from acquired imagery using low-cost consumer hardware which is for instance commonly applied for large-scale 3D reconstruction from aerial imagery or for indoor 3D mapping. In this regard, the organization of large unstructured (e.g. crowdsourced) image collections and well-established 3D reconstruction techniques (from either imagery or RGB-D data) will be considered in detail. In this context, representations of acquired data in the form of 3D point clouds, voxel occupancy grids and 3D meshes will be discussed as well as different approaches for closed surface reconstruction from 3D point clouds. Finally, a reminder about the complexity of material appearance will be provided.

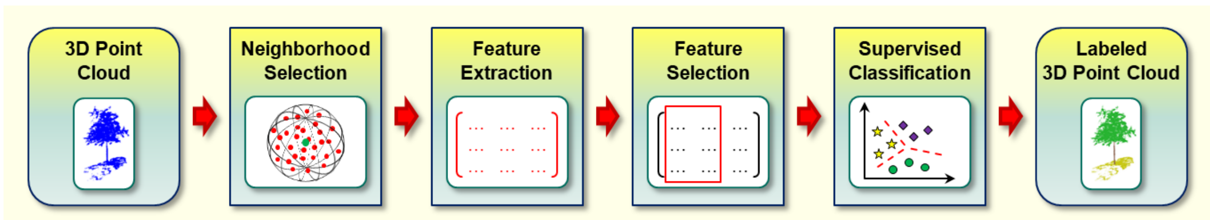
Module 2: Active 3D Sensing – From Measurements to Descriptive Features

This module addresses active optical 3D sensing as commonly used for the acquisition of large geospatial data via airborne, terrestrial and mobile laser scanning systems. In the first part of this module, a taxonomy for categorizing active systems for optical 3D sensing is introduced. This taxonomy includes a variety of aspects such as illumination, range, modulation, measurement, construction, detection and field-of-view. In the second part of this module, the interaction of incoming illumination at object surfaces is considered in detail as well as related basics on signal processing. Finally, a glance view on the extraction of descriptive features from data acquired via active optical 3D sensing will be provided.



Module 3: Semantic Interpretation I – From 3D Points via Features to Objects

This module focuses the semantic interpretation of 3D data in the form of 3D point clouds and covers a general end-to-end processing workflow from raw 3D point cloud data to semantic objects in the scene. After the pre-processing of acquired data to address signal noise and varying point density, the focus is put on the extraction of appropriate geometric and radiometric features. In this context, different options for defining local neighborhoods as the basis for extracting geometric features are discussed. Based on the defined set of features, the benefits of involving feature selection techniques are explained. Such techniques allow reasoning about the relevance of single features and feature (sub)sets with respect to the considered classification task. The selected features serve as input for classification, where classifiers relying on a diversity of learning principles may be exploited. This includes standard classifiers for point-based classification as well as more complex classifiers for context-based classification. In this module, the focus is set on standard classifiers, while context-based classification is considered in detail in the next module. Finally, an outlook on approaches relying on modern deep learning techniques is given which provide an effective alternative to the presented end-to-end processing workflow for semantic point cloud interpretation.



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Module 4: Semantic Interpretation II – From Fundamentals to Deep Learning and Context-Based Classification

This module covers fundamentals on deep learning regarding classical Artificial Neural Networks (ANNs) and modern Convolutional Neural Networks (CNNs). On this basis, the transfer of deep learning from image classification to the classification of 3D point clouds and digital surface models is discussed in detail. Besides such deep learning techniques, fundamentals on context-based classification will be presented which allows for deriving a spatially smooth semantic labeling. In this regard, we focus on graphical models such as Markov Random Fields (MRFs) or Conditional Random Fields (CRFs) and their application for the semantic interpretation of 3D point clouds.