RECENTLY PUBLISHED MASTER'S THESES AT AALTO UNIVERSITY, FINLAND

In following, we highlight the abstracts of the Master's Theses published in **2021** at the Aalto University in the fields of photogrammetry, laser scanning, geodesy and remote sensing.

Master's Theses:

Dobosz, Natalia: Detecting Deviations of Building Elements with Laser Scanning

Haaranen, Daniel: Point cloud quality of SLAM based mobile laser scanners

Järvenpää, Antti: Metrological characterization of a consumer grade flash LiDAR device

Jääskeläinen, Ari: Quality evaluation of airborne laser scanning based 3D building models

Sund, Otto: Feasibility study of a camera-based system for overhead crane positioning

Vaaltola, Mikael: A process for creating cloudless multi-temporal satellite imagery mosaics

ABSTRACT OF THE MASTER'S THESIS

Author: Natalia Dobosz
Title of thesis: Detecting Deviations of Building Elements with Laser Scanning
Date: 31.12.2021
Number of pages: 67 + 10
Thesis supervisor: Petri Rönnholm
Thesis advisor: Heikki Kauhanen
Keywords: point cloud, BIM, laser scanning, deviation analysis
Language: English

Abstract

The increasing costs and construction delays are common issues during civil engineering projects. These problems are very often related to insufficient geometric quality control of buildings and other civil engineering structures during the construction phase. Traditionally, construction work validation was performed manually, by comparing selective on-site measurements with 2D drawings. In order to identify construction errors more efficiently, researchers proposed to compare as-built state of the construction site with its as-designed model. In construction industry, laser scanning is considered to be a fast and accurate way to continuously gather up-to-date information about situation on the site. The data about the planned state of the project are provided by Building Information Models.

In this thesis, Cloud-to-Cloud distance-based method was utilised to compare as-built and as-designed state of the building. From the given Building Information Model and laser scanning point cloud, the proposed approach identified building components deviated from their planned positions. Firstly, the input data were pre-processed and registered in the common coordinate system. Next, Cloud-to-cloud distances were calculated between each planned building element point cloud and laser scanning points. Then, the computed distances were divided into three classes: correct, deviated and missing. The element was assigned a state based on the most frequent class. The implemented method was verified with synthetic as-built point cloud data generated based on Building Information Model. The proposed workflow was tested against data with different deviation values, noise levels and with missing components. The conducted analysis indicated that the proposed method could be a valuable tool for geometric quality control able to identify which components were built incorrectly.

ABSTRACT OF THE MASTER'S THESIS

Author: Daniel Haaranen
Title of thesis: Point cloud quality of SLAM based mobile laser scanners
Date: 14.06.2021
Number of pages: 76
Thesis supervisor: Matti Vaaja
Thesis advisors: Aino Keitaanniemi, Tomi Rosnell
Keywords: mobiililaserkeilain, pistepilvi, tarkkuus, SLAM, maalaserkeilain
Language: Finnish

Abstract

Simultaneous localization and mapping or SLAM based mobile laser scanners (MLS) are challenging traditional terrestrial laser scanners (TLS) especially in indoor mapping. The popularity of mobile laser scanners is explained by their competitive price and efficient mapping time compared to terrestrial laser scanners. Less than one centimeter accuracy is often required for mapping done for surveying purposes. If one wants to use mobile laser scanners as a replacement for terrestrial laser scanners the accuracy and quality of the point cloud measured by mobile laser scanners has to be examined. In this work we evaluate the factors which affect the accuracy and quality of point clouds mesaured by SLAM based mobile laser scanners. In the theoretical part we present the operational principles of laser scanners, terrestrial laser scanner and mobile laser scanner systems. We also present the theory behind SLAM and how it is used in mobile laser scanning. These topics are considered taking the quality of the point cloud into account.

In the experimental part we investigate the point clouds of two industrial mobile laser scanners, Navvis M6 and Navvis VLX and a point cloud measured with the lidar sensor build into the Iphone 12 Pro Max. These point clouds are compared to a reference point cloud measured with a terrestrial laser scanner, Leica RTC360, using four different methods. The goal of the experimental part is to find out how and how much do these mobile laser scanner point clouds differ from a point cloud measured with a terrestrial laser scanner. In the point clouds measured with M6 and VLX no significant error caused by the SLAM was detected. The distance between points measured with M6 and the reference point cloud was on average 8,17 millimeters and between VLX and reference on average 12,55 millimeters. In the other hand, the point cloud measured with the Iphone was deformed most likely due to the SLAM method. The point clouds measured with Navvis mobile laser scanners differed from the reference point cloud especially in angular shapes where the angles were described as round. These point clouds had also much more noise than the reference point cloud, and from the two, the point cloud measured with VLX had more noise than the M6 point cloud. The thickness of an uneven and dark wall was about 11 millimeters in the reference point cloud, up to 20 millimeters in the M6 point cloud and up to 40 millimeters in the VLX point cloud. The details of the Iphone’s point cloud were deformed in almost everywhere except in the floor where it was described similar to the reference.

ABSTRACT OF THE MASTER'S THESIS

Author: Antti Järvenpää
Title of thesis: Metrological characterization of a consumer grade flash LiDAR device
Date: 13.12.2021
Number of pages: 51 + 34
Thesis supervisor: Matti Vaaja
Thesis advisors: Heikki Kauhanen
Keywords: Apple iPad Pro, LiDAR, time-of-flight, metrology, accuracy, precision
Language: English

Abstract

The work included theoretical review of the technology and error analysis. Though the work focuses on the accuracy of the flash LiDAR sensor, this part also included positioning methods of the system. Investigation of positioning methods was considered important, as it is directly linked to the total accuracy in practical applications.

In this work data was evaluated both visually, and statistically using measurement deviations. The experiments included inspection of illumination power distribution, accuracy dependency on both detection range and target material, significance of colour image feed in depth map creation and accuracy anomalies within a depth map.

During the work, the standard deviation of measurements was noted to be less than half a centimetre within the effective range, 0.2–5 m, of the device. However, the data quality was significantly affected by the enrichment of depth sensor observations with colour images. The system seemed to smoothen features and produce false depth values to sharp edges in a depth map. The system does not provide access to raw depth data, but only to this processed product more suitable for AR applications, where the system is intended to be used. As a result, the data processing solution is not optimal for measurement purposes.

Despite the shortages found in this work, the system has still potential for measurement purposes. Conventional methods providing the same data and information might be difficult, time consuming, or expensive compared to the tested technology, which makes it appealing. In addition, many of the found artifacts could also be filtered from the data with proper methods. In the future the applicability for data collection may improve also if the manufacturer decides to open access to unprocessed data.

ABSTRACT OF THE MASTER'S THESIS

Author: Ari Jääskeläinen
Title of thesis: Quality evaluation of airborne laser scanning based 3D building models
Date: 13.12.2021
Number of pages: 70
Thesis supervisor: Matti Vaaja
Thesis advisor: Joonas Jokela, Pauli Putkiranta
Keywords: 3D building modelling, airborne laser scanning, CityGML, LOD2
Language: English

Abstract

3D building modelling is an increasing trend with multiple current and future applications. The National Land Survey of Finland (NLS) has started to produce its own nationwide 3D building models based on airborne laser scanning (ALS) and 2D building footprint data. The models are produced with a data-driven modelling method and are compliant with the CityGML LOD2 and the Finnish Public Administration Recommendations 210 (JHS210) specifications.

In this research the production process of the NLS building models is briefly described and suitable methods for the quality evaluation of the models are studiedand applied. The geometric and topological quality is evaluated using a built-in validation tool of the production software TerraScan, and an open source CityGML validation tool called val3dity. The correctness of the models is evaluated by computing and analyzing the point-to-plane distances between the modelled roof planes and their respective points in the original point cloud. The completeness of the produced data set is evaluated by comparing the number of the original building footprints of the National Topographic Database to the number of produced building models. Building models from eight production areas, consisting of almost 300,000 models, are used in the evaluation processes.

The results of these evaluation processes show a good overall quality throughout the produced data set. The geometric validity level of 97.6 % is better than with many other datasets validated with val3dity in other studies. Visual deformations are however present even in some valid building models. The correctness analysis shows RMSE values less than 3 cm for buildings with correct source data and simple roof shapes. The completeness level of 87.6 % is in line with earlier studies done in the NLS with older data sets from different areas. The issues found in the data set are mainly related to the properties of the data-driven modelling method, quality issues in the source data, and minimization of manual editing.

ABSTRACT OF THE MASTER'S THESIS

Author: Sund, Otto
Title of thesis: Feasibility study of a camera-based system for overhead crane positioning
Date: 14.06.2021
Number of pages: 33 + 13
Thesis supervisor: Matti Vaaja
Thesis advisor: Petri Rönnholm, Matti Kurkela
Keywords: overhead crane, camera-based system, camera calibration, photogrammetry
Language: English

Abstract

The automation of industrial applications is a rapidly developing area. The demand of more efficient and automated applications is an everyday problem in industrial environments. The aim of this study was to investigate the feasibility of a camera-based system for overhead crane positioning. Furthermore, a camera-based system can provide solutions for developing different automated applications. Today, laser sensors are a commonly used method for accurate crane positioning and distance calculation.

This thesis presents a camera-based system for overhead crane positioning. Two industrial cameras were mounted to an overhead crane's trolley for image acquisition. In addition, a pre-mounted high-resolution monitoring camera was also included for research interest. The objective was to obtain accurate position information of the crane by photogrammetric image measurements. An imaging capturing method was developed and tested to accurately acquire images from all cameras simultaneously. In total, 100 images were acquired for each camera. Camera calibration was performed before image acquisition using photogrammetric software.

The accuracy of the camera-based system was assessed by calculating 3D camera positions from all 100 images. Laser measurements were used as reference positions. The best positioning accuracy, ± 3 mm, was achieved by the high-resolution camera. The positioning accuracy of the industrial cameras were ± 10 mm.

In conclusion, this study showed that camera-based systems can provide methods for overhead crane positioning. However, lower-end industrial cameras may not be suitable for accurate crane positioning. A camera with low resolution may not provide sufficient accuracy for image positioning measurements. This thesis did not consider real-time positioning and requirements for fast positioning calculations.

ABSTRACT OF THE MASTER'S THESIS

Author: Mikael Vaaltola
Title of thesis: A process for creating cloudless multi-temporal satellite imagery mosaics
Date: 13.12.2021
Number of pages: 78
Thesis supervisor: Miina Rautiainen
Thesis advisors: Joona Laine
Keywords: cloud detection, image mosaicing, remote sensing, Sentinel-2
Language: English

Abstract

Free and open earth observation data is being collected by new generations of satellites in increasingly significant volumes. Innovative applications utilising satellite imagery are constantly developed with potential to impact important environmental, economic, and social issues of varying scales. However, the increasing availability of remotely sensed data also highlights challenges in converting earth observations from data to information and insights. One such challenge is extracting timely ground information of cloudy areas using optical satellite images. Clouds and cloud shadows impact measurements by passive sensors and limit the usefulness of optical imagery in areas with persistent cloud cover.

This master's thesis addressed the issue of extracting value from cloudy Sentinel-2 images of the Abyei area during its yearly rainy season. The thesis explored the feasibility of creating cloudless mosaics from optical remotely sensed data by utilising existing cloud detection methods. The usefulness of cloud-free composite images as a method to gain timely insights into areas with continuous cloud cover was also evaluated. An automated processing pipeline for creating cloudless mosaic images by utilising cloud masking was developed and is presented in the thesis.

Cloudless mosaics of the Abyei area during the rainy season of 2020 were created from Sentinel-2 data using the developed processing pipeline. Based on visual evaluation, the generation of cloudless mosaics from optical satellite imagery was deemed to be a suitable method to gain timely insights into areas with persistent cloud cover. The source code of the developed software was made public and can be applied to generate cloudless mosaics of other areas of interest. Future development possibilities include deploying the processing pipeline to a public cloud computing platform and adding support for additional sources of remotely sensed data besides Sentinel-2.