RECENTLY PUBLISHED MASTER'S THESES AT AALTO UNIVERSITY, FINLAND

In following, we highlight the abstracts of the Master's Theses published in **2019** at Aalto University in the fields of photogrammetry, laser scanning, geodesy and remote sensing.

Master's Theses:

Hallikainen, Juuso: Tree identification from terrestrial laser scanning data

Ingman, Matias: Feasibility of low-cost 3D sensors for indoor modelling

Juola, Jussi: Multi-angular measurement of woody tree structures with mobile hyperspectral camera

Karvonen, Sami-Petteri: Optimizing photogrammetric results

Kauppinen, Miska: Assessment of small satellite SAR imaging capability for earth observation applications

Khan, Umer: Using remote sensing to detect forest degradation caused by small-scale farming in tropical Africa

Kokkonen, Tia: Visualization of terrestrial laser scanning data in virtual reality

Peltola, Aleksi: The land uplift rate at the world heritage site High Coast and Kvarken Archipelago observed with different methods

Rantanen, Toni: 3D Measuring and modelling processes in gamifying culture with extended reality

Yektay, Ziya: Sentinel-2 images for detection of wind damage in forestry

ABSTRACT OF THE MASTER'S THESIS

Author: Juuso Hallikainen
Title of thesis: Tree identification from terrestrial laser scanning data
Date: 16.12.2019
Number of pages: 57 + 5
Thesis supervisor: Matti Vaaja
Thesis advisor: Petri Rönnholm

Abstract

The requirements for more accurate and up-to-date spatial data increases constantly due to changes occurring in the environment. In addition, there is a technical and economical need to map trees, tree ages and sizes, as well in wide forest areas as park areas in cities by modern scanning techniques. The aim of this thesis was to investigate different positioning methods for terrestrial laser scanned trees. The second aim was to examine different techniques to identify the species of the positioned trees.

Laser scans from two separate relatively small woodlands were acquired for the thesis. These scans were utilised for tree locating and species identification. Tree positioning was based on the cylinder fitting method performed for tree stems provided by the scans. The results achieved by the positioning were analyzed based on the comparison to the manually measured reference values. To identify the tree species, the tree intensities and structure parameters extracted from the point clouds were used.

According to the study results, the classification of some tree species was relatively well succeeded. However, the identification of some other species did not succeed as expected. The best classification correctness of 80 percent was achieved using the combination of tree intensities and the structure parameters, as well as by the structure parameters only. Classification using the intensities only provided considerably more unreliable results. Instead of that, one tree species (spruce) identification succeeded perfectly in each case. However, tree positioning succeeded obviously well, so the tree locations deviated slightly from the reference values.

This examination indicated that a reliable evaluation of the tree classification results did not fully succeed with the relatively small tree sample size used in this thesis. To obtain more reliable estimate of success rate for the results provided by terrestrial laser scanning data, a larger sample size may be required. Furthermore, the laser scans for this work were performed in autumn when there were no leaves in the trees. This, of course, affected the intensity-based tree classification. However, modern tree positioning and classification methods appear quite promising. The future use of these techniques require further development and examination work.

Keywords: terrestrial laser scanning, tree positioning, tree species identification, forest mapping

Language: English

ABSTRACT OF THE MASTER'S THESIS

Author: Matias Ingman
Title of thesis: Radiometric calibration of the Finnish Geospatial Research Institute hyperspectral LiDAR
Date: 21.10.2019
Number of pages: 87 + 15
Thesis supervisor: Matti Vaaja
Thesis advisors: Hannu Hyyppä, Juho-Pekka Virtanen

Abstract

Low-cost 3D sensors used for indoor modelling are increasingly abundant on the market, and with more consumer-grade and low-cost professional-grade sensors being compatible with automatic processing, the number of potential users is growing rapidly. With increasing support for automated processing, the potential uses for sensors compatible with an automated processing system are a current topic of research. This research demonstrates the technical differences between three sensors (the Matterport Pro2 3D RGB-D camera, the Ricoh Theta V 360-degree camera, and the Leica BLK360 laser scanner) compatible with Matterport's automated processing system, compares their performance to each other through a reference point cloud, and for the Leica BLK360, shows how the results of automatic processing differ from the ones of Leica's proprietary manual processing system. A literature review on methods used for 3D indoor mapping and modelling is also conducted. This research applies both quantitative and qualitative methods. The primary quantitative method is examining the cloud-to-cloud and cloud-to-mesh distances of the resulting point clouds and meshes in comparison to a reference point cloud obtained by the professional-grade Leica RTC360 laser scanner. The analyses are conducted on the geometry of two scanned spaces, each with differing characteristics, as well as detailed segments of each. Additionally, a point density analysis is conducted to examine the presence of artefacts from the processing, and how the selected sensor affects these. The qualitative analysis is conducted on the full models and point clouds through assessing their visual quality, in terms of the space geometry and details, colour, and texture quality.

From the results of the research, it can be concluded that while none of the three selected sensors is universally the best choice for modelling an indoor space, all are feasible alter-natives depending on the needs of the user. Among the Matterport-processed point clouds, the BLK360 generally provided the most accurate results among the point clouds, having the highest share of points within 1 cm of the reference point cloud in all cases but one, while the Matterport showed the same result among the generated meshes. The worst-performing Theta V, with a maximum 99th percentile deviation of 0.077 m in the point clouds of the room geometries, also provided a full view of the room geometries, but failed to reproduce details at the centimetre level. The Leica-processed BLK360 point clouds were the most accurate point clouds in all cases but one, with a minimum of 82 percent of the points falling within 1 cm of the reference point cloud. While the lack of user input in the automated processing also eliminates the possibility of improving the results by altering the parameters, the accuracy of the resulting point clouds and models is well within the limits stated by the manufacturer, enabling the user to select the appropriate sensor to fit their specific needs.

Keywords: indoor modelling, Matterport, RGB-D camera, laser scanning, terrestrial laser scanning, panoramic camera

Language: English

ABSTRACT OF THE MASTER'S THESIS

Author: Jussi Juola
Title of thesis: Multi-angular measurement of woody tree structures with mobile hyperspectral camera
Date: 19.08.2019
Number of pages: 67
Thesis supervisor: Miina Rautiainen
Thesis advisor: Aarne Hovi

Abstract

Laboratory measurement settings that can acquire spectral and multi-angular information on canopy elements (e.g. leaves and woody tree structures) provide invaluable data for the interpretation and development of forest reflectance models and other optical remote sensing techniques. Previous studies have pointed out that the spectral properties of woody tree structures of boreal tree species have been studied little in comparison to leaves, and that there is a need to fill this gap in knowledge. This thesis presents a custom-built multi-angular measurement system with imaging capabilities that was used to acquire a hyperspectral dataset of boreal woody tree structures of the three most common tree species found in Finland. A total of six trees, two trees per species of Norway spruce (Picea abies (L.) Karst), Scots pine (Pinus sylvestris L.) and silver birch (Betula pendula Roth) stems were sampled at different heights (at every meter of height between 1–10 m) and sides (northward and southward facing sides of the stem), and the stem surface (bark) was measured with a novel mobile hyperspectral camera called Specim IQ. The camera operates in the wavelength range of 400–1000 nm. The acquired dataset contains hyperspectral images of 120 stem samples, each imaged from six different view angles. A designed pixel-by-pixel data processing chain is described. It can calculate and extract accurate pixel specific reflectance information that is invariant to uneven spatial distribution of incident irradiance from the lamp. Finally, the processed data was analyzed to reveal within- and between-species, angular, and spatial variations in stem bark reflectance for the three species.

In concordance to previous studies, this thesis found that the species varied highly in their mean spectra and were distinguishable from one another. In addition, the within-species variation and standard deviation between mean spectra of samples was surprisingly low with very similar spectral signatures between samples of the same species. Investigating angular variation revealed that both pine and birch present strong specular reflections in the forward-scattering angles, in comparison to spruce, which presented a hot spot effect in the backward-scattering angles when measured near the lamp. Birch and spruce showed weak trends when looking at the spatial variations occurring in reflectance due to sampling height or side of the stem. However, pine displayed a clear increase in reflectance from 1 m to 4 m height at 663.81 nm (red band) and from 1 m to 5 m height at 865.5 nm (near-infrared band).

The data obtained in this study show potential for future tasks such as tree species classification and the further development of forest reflectance models. The methods and materials presented in this study can give ideas for developing imaging goniometer systems that can acquire even more information on various vegetation canopy elements than what were presented in this thesis.

Keywords: multi-angular, BRF, hyperspectral, imaging spectroscopy, Specim IQ, remote sensing

Language: English

ABSTRACT OF THE MASTER'S THESIS

Author: Sami-Petteri Karvonen
Title of thesis: Optimizing photogrammetric results
Date: 17.06.2019
Number of pages: 53
Thesis supervisor: Petri Rönnholm
Thesis advisor: Petri Rönnholm

Abstract

The goal for this thesis was to study and examine various methods for optimizing photogrammetric products. The point clouds produced by most photogrammetry software are bigger than what most software are able to utilize. By optimizing these point clouds and the models created from them in order to represent the object with smaller number of points or faces while preserving geometrics details the use of these models could be furthered for example in visualization purposes.

As study material a point cloud of Lahti city hall was used. The data was collected by UAV and terrestrial images. The material was processed and examined using Cloud-Compare and Meshlab software. Numerical examinations were carried out by comparing the resulting face numbers and the standard deviation for point-to-mesh distances when compared to the non-processed point cloud. In addition, a visual estimation of these methods was carried out observing both details and larger areas in selected parts of the building.

The processes on point clouds reduced the model down to 40 – 68 % with standard deviations of 8.8 – 57.8 mm. Mesh operations reduced the model down to 0.1 – 15.1 % with 0.7 – 7.6 mm standard deviations. Based on visual interpretation, mesh operations pre-served different features of the models better than point cloud processes in most cases. The difference was especially notable in larger, flat surfaces without distinctive features in which the point cloud processes produced holes that the meshing-algorithm could not fill in at later stages.

Keywords: Photogrammetry, point clouds, optimizing

Language: Finnish

ABSTRACT OF THE MASTER'S THESIS

Author: Miska Kauppinen
Title of thesis: Assessment of small satellite SAR imaging capability for earth observation applications
Date: 06.05.2019
Number of pages: 67
Thesis supervisor: Jaan Praks
Thesis advisor: Jaan Praks

Abstract

Space assets have become more affordable due to miniaturization of sensor and satellite platform technology, which allows significant reduction in launch, operation and development costs. The first wave of new, radically smaller Earth Observation (EO) satellites was produced to enable real-time imaging with optical instruments and microwave remote sensing has been following the same trends. Imaging radar, such as SAR data, can be acquired in nearly all weather, day and seasonal conditions. Microwave instruments are more effective particularly over northern and polar regions, which are frequently covered by clouds. The SAR has also ability to penetrate canopy to certain extend and can provide information of the built environment. Recently appeared affordable small SAR satellites can increase temporal resolution of space-borne imaging, enabling new application areas, however the imaging capabilities or constellation performance of such new SAR instruments remain relatively unknown.

The aim of this study is to provide background and overview to the new small satellite SAR constellation missions, their imaging capabilities, performance, data quality and application examples by comparing selected three missions in this category, from which one, data was acquired for further image analysis. Also, the relationship of small satellite SAR missions towards their larger counterparts is examined. A particular focus is to assess the potential of the imagery of a new SAR data provider, Iceye, in relation to European Space Agency (ESA) instrument, Sentinel-1. Small satellites equipped with SAR sensors clearly create new opportunities for applications, enabled by the increased temporal resolution. These applications are largely, in the field of monitoring man-made objects and structures, especially in the surveillance sector, due to the properties of frequency bands used in the SAR sensors.

Keywords: earth observation, remote sensing, SAR, Sentinel-1, SmallSat, Iceye

Language: English

ABSTRACT OF THE MASTER'S THESIS

Author: Umer Khan
Title of thesis: Using remote sensing to detect forest degradation caused by small-scale farming in tropical Africa
Date: 17.06.2019
Number of pages: 63
Thesis supervisor: Miina Rautiainen
Thesis advisor: Virginia Garcia

Abstract

Deforestation and forest degradation mainly caused by human activities around the world present a serious threat to all the life forms that are dependent on forests, and Nigeria is not an exception in this regard. Illegal farming activities are destroying forest reserves from inside and it is necessary to get an estimate of how much forest area has been converted to farmlands for better forest management and for examining its potential impact on climate change. The aim of the study is to detect crop clearings inside forested areas using Random Forest (RF) and Landsat 8 imagery alongside GIS ancillary data including vegetation indices NDVI, GRVI and topographic variables such as DEM, Slope, and Aspect for better classification results. In order to examine the effect of GIS ancillary data on classification accuracy, two scenarios were designed. In scenario 1 only spectral bands were used for classification, while in scenario 2, GIS ancillary data was also incorporated into the Random Forest (RF) model. A pixel-based supervised Random Forest classifier with appropriate training data was deployed on both scenarios.

The results from scenario 2 proved to be more accurate with an overall accuracy of 95.5% and kappa statistics of 0.94, compared to scenario 1, which resulted in an overall accuracy of 92.5% and kappa value of 0.91. The study indicates the importance of GIS ancillary data for accurate classification of different crop type classes. The study also highlights the importance of near-infrared (NIR), shortwave infrared (SWIR) and digital elevation model (DEM) for vegetation analysis in the present study. The blue band also showed importance, especially in the case of classifying oil palm. The results show that the most dominant crops in the forested area are banana, cocoa, and cassava indicating the encroachment of illegal farming activities in the forest reserves. As only medium resolution imagery was available for the present study, in the future similar study with high-resolution imagery could further improve the results. Overall, the study shows that Random Forest along with GIS ancillary can be successfully used for detection of crop clearing in forested areas.

Keywords: random forest, deforestation detection, forest reserve, illegal farming, classification

Language: English

ABSTRACT OF THE MASTER'S THESIS

Author: Tia Kokkonen
Title of thesis: Visualization of terrestrial laser scanning data in virtual reality
Date: 21.10.2019
Number of pages: 62
Thesis supervisor: Matti Vaaja
Thesis advisor: Arttu Julin

Abstract

The aim of virtual reality applications is to offer immersive computer graphic-based environments. Creating these virtual environments requires accurate and photorealistic 3D models. Laser scanning is a fast and efficient method for producing large amounts of accurate point cloud data that can be used for VR applications.

This research determines whether point cloud data produced by terrestrial laser scanning is suitable to be visualized in virtual reality. The research was divided into literature review and empirical study. The literature review explains the fundamentals of terrestrial laser scanning and virtual reality and the typical attributes of point clouds and the requirements for their visualization. In the case study the point cloud data was tested in three programs that differ from each other by their operational structure and working principle: Faro SCENE LT software is designed for viewing point clouds, browser-based Sketchfab for publishing 3D models in internet and Point Cloud Free Viewer plugin for Unity that enables the viewing of point cloud data in a game engine.

In the case study was discovered that it was not possible to take advantage of all the attributes of point cloud data. The programs had very different level of tools to be used for point cloud data. In general, all the programs were suitable for usage of visualizing point cloud data in virtual reality. During the research was noticed the continuous development of the VR devices and applications and the lack of scientific research on this specific subject. VR has great potential in multiple application areas so the methods for producing and programs for processing 3D data are likely to develop even faster in the foreseeable future.

Keywords: terrestrial laser scanning, TLS, point cloud, virtual reality, VR, visualization

Language: Finnish

ABSTRACT OF THE MASTER'S THESIS

Author: Aleksi Peltola
Title of thesis: The land uplift rate at the world heritage site High Coast and Kvarken Archipelago observed with different methods
Date: 06.05.2019
Number of pages: 59+4
Thesis supervisor: Martin Vermeer
Thesis advisors: Maaria Nordman, Mirjam Bilker-Koivula

Abstract

The unique natural environment of the World Heritage Site High Coast and Kvarken Archipelago has been caused by a rapid land uplift. To determine the rate of land uplift, observations made by various methods are used: Time series of GNSS, absolute gravimetry and mareographs, and also the NKG2016LU land uplift model. GNSS measures the land uplift relative to the reference ellipsoid, absolute gravimetry measures the change of gravity and mareographs measure the relative height difference between sea level and the Earth's crust.

The measurement results of 16 different stations located as close as possible to the World Heritage Site, are used in this work. Depending on the location, the land uplift rate related to the geoid is between 8,6 and 9,5 millimeters per year in this area. Additionally, this work investigated how much the ground has risen related to the sea level during the last 100 years in the area and a future scenario is constructed until the end of the 21st century.

Keywords: Land Uplift, GPS, Absolute Gravimetry, Mareograph

Language: Finnish

ABSTRACT OF THE MASTER'S THESIS

Author: Toni Rantanen
Title of thesis: 3D Measuring and modelling processes in gamifying culture with extended reality
Date: 21.10.2019
Number of pages: 79
Thesis supervisor: Matti Vaaja
Thesis advisors: Hannu Hyyppä, Juho-Pekka Virtanen

Abstract

This study investigates the 3D measurement and modeling processes needed to automatically or semi-automatically create 3D models from a variety of cultural attractions for use in game engines. The criteria for the model were suitability for game engine visualization and gamification through augmented reality. Suitable processes were derived from three different case studies by taking part in them. The case studies used, were Dipoli, objects from National museum and the jail cells of Suomenlinna. Laser scanning, photogrammetry and depth camera technology were used as the measurement methods. The literature review gives an overview of the current state of 3D measurement and modeling as well as gamification and game technology utilization. In addition, various cultural 3D applications and the phases of modern measurement and modeling processes will be introduced.

The work resulted in method specific process descriptions to produce a game engine suitable 3D model. Based on the process descriptions, the applicability, functionality and limitations of the methods were discussed, and the results compared to the research literature. In addition, a review was made of future opportunities and their implications for case studies.

Keywords: 3D-measuring, 3D-modelling, laser scanning, photogrammetry, depth-camera, culture, game-engine, gamification, extended reality

Language: Finnish

ABSTRACT OF THE MASTER'S THESIS

Author: Ziya Yektay
Title of thesis: Sentinel-2 images for detection of wind damage in forestry
Date: 21.10.2019
Number of pages: 75
Thesis supervisor: Miina Rautiainen
Thesis advisors: Susanne Suvanto, Mikko Peltoniemi

Abstract

Using of Remote sensing for the sake of Earth Observation is getting more and more popular as the number of satellites that are able to measure electromagnetic radiation with a higher spatial, temporal and radiometric resolution is considerably rising. Of all usage of Earth Observation, detection of disturbances caused by natural catastrophe such as wind, earthquake and fire is highly important. On 12th of August 2017, a storm hit South and South East of Finland, bringing harsh disturbances to the forest area in which Pine and Spruce were the main types of land cover. The study area in this region contained the extent of a sentinel-2 image that covered an area of 100 km by 100 km. Two sentinel-2 images from 11th of August 2017 and 5th of September 2017 were used to measure spectra behavior of existing features before and after storm in the region. Forest use notifications data, by which damaged stands were identified, and forest-stand dataset, with which stands that were not touched by the storm (undamaged stands) were characterized, were used as ground truth data. For change extraction, univariate image differencing was used using six different indices, namely EVI, NDVI, NDMI, SATVI, TCB, and TCG. Two main approaches were taken in this thesis, namely pixelwise and average based, where in the former individual pixels were extracted (from stands) and used for training the models while in the later average of pixels inside each stand was calculated and used for training. Results achieved by average-based showed a better performance in terms of user accuracy and stability of the results than pixelwise approach did.

Keywords: spatial resolution, temporal resolution, radiometric resolution, EVI, NDVI, NDMI, TCB, STVI, TCG, univariate image differencing, forest use notification

Language: English