RECENTLY PUBLISHED MASTER'S THESES AT AALTO UNIVERSITY, FINLAND

In following, we highlight the abstracts of the Master's Theses published in **2020** at the Aalto University in the fields of photogrammetry, laser scanning, geodesy and remote sensing.

Master's Theses:

Heikkilä, Juhani: The effects of solar activity on optical satellite remote sensing imagery

Huuskonen, Erja: Sea-level rise and land uplift in Kvarken and High Coast area in 2300

Järvinen Arttu: Airborne laser scanning data comparison based on roof features

Kauhanen, Heikki: Designing, implementing and deployment of a survey drone

Mehtälä, Ismo: Analysis of the stability, drift and aging behavior of the hydrogen masers and GPS clocks in use at the Metsähovi radio observatory

Putkiranta, Pauli: Geometric calibration of rotating multi-beam lidar systems

Ruotsala, Anni-Helena: Detecting clandestine graves

Tanis, Cemal: Operational monitoring of snow cover using digital imagery

Viitikko, Samuel: Utilization of remotely piloted aircraft systems on infrastructure construction projects

ABSTRACT OF THE MASTER'S THESIS

Author: Heikkilä, Juhani
Title of thesis: The effects of solar activity on optical satellite remote sensing imagery
Date: 14.12.2020
Number of pages: 46+4
Thesis supervisor: Miina Rautiainen
Thesis advisor: Miina Rautiainen
Keywords: solar cycle, satellite images, Landsat 8 OLI, optical remote sensing
Language: English

Abstract

Satellite remote sensing is a branch of science that has seen very fast growth in the past few decades. More and more freely accessible satellite imagery is beginning to be available for use and it is playing an increasingly large role in many facets of important decision making in modern society. With the fast increases in the number of lives affected by decisions influenced by optical remote sensing data, increased scrutiny of it becomes prudent.

In this thesis it is investigated if solar activity has any effect on optical satellite remote sensing. The Sun is the Earth's largest source of incoming energy and spaceborne optical instruments function by measuring sunlight reflected off targets on the Earth's surface, but the Sun is not a static radiation source and experiences cyclical variation. Solar activity also influences the Earth's climate and changes in atmospheric conditions could affect the light passing through it. The associated theory is presented by shortly reviewing related literature and based on it, it is hypothesized that values measured by optical satellite sensors should correlate with the changing of phases of solar cycles.

The method performed is a time series analysis using satellite images taken during solar cycle 24's decline from maximum to minimum (2013-2019). The images used are of carefully chosen reference target areas taken by the Landsat 8 OLI instrument and those of consecutive years are formed into image series. The same process is done for both images based on at sensor spectral radiance values and those based on TOA reflectance values.

Median pixel values of OLI spectral bands 1-8 are extracted from all images in 26 series in total (7x2x13 images) and their behaviour during the changing phase of the solar cycle is studied. The exact results vary by band but both TOA reflectance and at sensor spectral radiance values have clear declining trends for all bands except for aberrant B7, which behaves seemingly randomly

The results are insufficient to provide a definitive answer to the researched question because Landsat 8 OLI bands do not have any official estimations published for their sensor degradations, which should explain an unknown portion of the observed decline in pixel values. The results nonetheless are not contradictory with the hypothesis made and when comparing them to the reported sensor degradation estimates of Landsat 8 OLI's predecessor, Landsat 7 ETM+, it is concluded that it seems likely that at least a portion of the detected decline is due to solar activity.

ABSTRACT OF THE MASTER'S THESIS

Author: Erja Huuskonen
Title of thesis: Sea-level rise and land uplift in Kvarken and High Coast area in 2300
Date: 16.3.2020
Number of pages: 51+10
Thesis supervisor: Maaria Nordman
Thesis advisors: Mirjam Bilker-Koivula
Keywords: sea level rise, land uplift, Kvarken Archipelago, High Coast, Bothnian sea, Baltic sea
Language: English

Abstract

This thesis was pursued as a part of the LYSTRA project that promotes the UNESCO World Heritage Site of the High Coast and the Kvarken archipelago. The ice sheet and the subsequent post-glacial rebound shaped the study area during the last glacial period. Relative sea level fall has been characteristic of the area due to high land uplift rates. Global climate change and the resulting global mean sea level rise are slowing down the relative sea level fall in the area, and they might turn it into relative SLR. This thesis aims to project the relative sea level rise in the study area in 2300. Global mean sea level projections for 2300 are adjusted to the study area following the example of two studies that project sea level rise until 2100 in the Swedish and Finnish Coast. The projections follow three base emission scenarios, which present the low, middle, and high emission levels.

This thesis includes a literature review and empirical research. The literature review introduces first the mechanisms of sea level rise on a global level and the global sea level rise projections that extend to 2300. After that, the processes affecting the local sea level are presented. The empirical part includes the collection of suitable data from the literature and forming the regional projections from the global projections. Sea level rise visualizations are then generated based on the regional projections, and the changes in coastline and landscape are analyzed.

Projecting the sea level until 2300 is a matter of high uncertainty, mainly stemming from the related climate scenario and imperfect understanding of the mechanism of SLR. This thesis resulted in four visualization levels of sea level rise under medium and high emission scenarios: 1 m, 3 m, 5 m, and 10 m. The Kvarken archipelago is low elevated, and even SLR of a meter submerges large parts of the archipelago and majority of the glacial features in the area. Sea level rise of 10 m submerges the area practically wholly, while the High Coast is not remarkably affected due to its high-elevated, steep topography. The use of the low emission scenario results in the relative sea level fall in the whole study area. Reaching the low emission levels would require substantial mitigation of global temperature rise.

ABSTRACT OF THE MASTER'S THESIS

Author: Arttu Järvinen
Title of thesis: Airborne laser scanning data comparison based on roof features
Date: 20.1.2020
Number of pages: 65+8
Thesis supervisor: Matti Vaaja
Thesis advisor: Harri Kaartinen, Antero Kukko
Keywords: ALS, multispectral, single photon, LiDAR, point cloud, data comparison
Language: English

Abstract

Laser scanning is nowadays one of the most important technology in geospatial data collection. The technique has developed together with the other technologies and sciences, and the systems can be used with many different platforms on land, in the ocean and in the air. Airborne laser scanning (ALS) started right after the invention of the laser in 1960's and the usage grew in 1990's, when the first commercial system was released. The development has augmented the ways of surveying and the systems have new features and more options to collect as accurate data as possible. Several wavelengths and higher frequencies able thousands or even millions of measurements per second. The multispectral systems enable the characterization of the targets from the spectral information which helps for example in the data classification. Single photon technique provides higher imaging capability with lower costs and is used in the extensive topographic measurements. The processing of the point clouds are more important when the densities grow and the amount of noise points is higher. The processing usually includes preprocessing, data management, classification, segmentation and modeling to enable the analyzing of the data.

The goal of the thesis is to compare and analyze the datasets of five different airborne laser scanners. The conventional LiDAR datasets are collected from low altitude helicopter with the Riegl's VUX-1HA and miniVUX-1UAV systems. The state-of-the-art sensors, Titan multispectral LiDAR (Teledyne Optech) and SPL100 single photon LiDAR (Leica), are used in the data collection from the aircraft. The data is collected from the urban area of Espoonlahti, Finland, and the comparison is based on the roof features. Other land cover classes are left out from the investigation. From the roof features are investigated the differences, accuracies and qualities between the datasets. The urban environment was selected because the lack of ALS research done for the built environment, especially in Finland. The thesis introduces the background of the airborne laser scanning, theories and literature review, materials and methods used in the project.

The laser scanners used in the work produce dense point clouds, where the most dense is up to 80 pts/m2. Based on the results the accuracies vary mainly between 0 and 10 cm. The scanners with infrared wavelengths produce better than 10 cm accuracies for the outlines of the roofs, unlike the green wavelength scanners. The differences in the corner coordinates are between 1 and 8 cm with a few exceptions. SPL100 system has the best height accuracy of 4.2 cm and otherwise the accuracies vary between 5 and 10 cm. The largest deviation compared to the roof planes occurs in the miniVUX-1UAV data (over 5 cm). For the surface areas the infrared frequencies produce differences of 0 to 2 percent from the reference data, whereas the differences of the green wavelength are mainly 1 to 7 percent. For the inclinations no significant differences were observed.

ABSTRACT OF THE MASTER'S THESIS

Author: Heikki Kauhanen
Title of thesis: Designing, implementing and deployment of a survey drone
Date: 29.07.2020
Number of pages: 87 + 15
Thesis supervisor: Matti Vaaja
Thesis advisors: Petri Rönnholm
Keywords: UAV, unmanned aerial vehicle, surveying, prototyping, point cloud
Language: Finnish

Abstract

In this research, an unmanned aircraft system (UAS) capable of conducting a survey mission was designed, implemented, and deployed. The research was constrained to cover multirotor type rotary wing vehicles, but the literature review briefly examined other types of drone applications and operational principles as well. Applications identified in the literature review were later utilized to compare to the experimental results of the research.

The experimental part of the research defined the characteristics required from the surveying drone system. Results were applied to simulate a drone system capable of conducting surveying tasks as effectively as possible while being cost efficient. Simulation results include a list of parts required to assemble the drone and performance characteristics of the vehicle. In the implementation stage, the survey drone was built using the simulation results. This made it possible to order only the parts identified in the simulation, thus reducing the time and resources required for the implementation. The surveying task suitability of the drone was tested by conducting a surveying test flight at the Asuntomessut Tuusulassa 2020 -event location. The test flight was planned using Mission Planner suite and flight times derived from the simulation results so that the duration of the test flight closely matched the maximum flight time according to the simulation. The real flight time of the test flight matched the planned flight time as well as the simulated flight time within the tolerances stated in the simulation program.

Finally, the material gathered from the test flight was used to create a 3D point cloud which was compared to a terrestrial 3D point cloud captured the same day from the event area. Comparison revealed quality issues of the terrestrial scans so the material could not be used to validate the accuracy of either dataset but it was successfully used to test the workflow of orienting the two different point cloud datasets into a common coordinate system. Furthermore, the research verified that both datasets were suitable for centimetre level surveying missions.

ABSTRACT OF THE MASTER'S THESIS

Author: Ismo Mehtälä
Title of thesis: Analysis of the stability, drift and aging behavior of the hydrogen masers and GPS clocks in use at the Metsähovi radio observatory
Date: 18.5.2020
Number of pages: 73+22
Thesis supervisor: Martin Vermeer
Thesis advisors: Joni Tammi, Juha Kallunki
Keywords: maser, GPS, oscillator, drift, stability
Language: English

Abstract

The stability, drift and aging behavior of the hydrogen masers and GPS clocks in Metsähovi Radio Observatory was analyzed in this thesis. There are six GPS clocks and four hydrogen masers in use in Metsähovi Radio Observatory. The data available for this purpose consisted of time difference observations in microseconds compared to the local main maser beginning from March 16th, 2005. The data was derived from the 1PPS output of the masers and clocks. A locally designed clock comparing system is used for collecting the data.

The data was pre-processed to eliminate the distorting effect of gross error observations on the analysis. Analysis methods used were statistical analysis (standard deviation) and wavelet analysis as well as drift and aging parameter calculations. Existing studies were also consulted. No data in the frequency domain was available for this thesis, therefore all analysis was conducted in the time domain. R programming was used as a tool in the analysis.

Statistical analysis revealed a varying periodicity in standard deviations of hydrogen maser data which was attributed to the clock comparing system. Wavelet analysis did not reveal any short-term periodicity of maser and GPS clock data. The calculated drift rates of the hydrogen masers ranged from 0.17 nanoseconds per day to 6.44 nanoseconds per day. The calculated aging rates of the masers ranged from 0.005 nanoseconds per day per day to 0.2 nanoseconds per day per day. It was concluded that the manual maser adjustment practice in Metsähovi Radio Observatory works sufficiently well and that there is no need for algorithms as an aid in the adjustments.

ABSTRACT OF THE MASTER'S THESIS

Author: Pauli Putkiranta
Title of thesis: Geometric calibration of rotating multi-beam lidar systems
Date: 20.1.2020
Number of pages: 68+24
Thesis supervisor: Matti Vaaja
Thesis advisor: Heikki Hyyti
Keywords: laser scanning, calibration, optimisation, lidar, point cloud
Language: English

Abstract

The introduction of light-weight and low-cost multi-beam laser scanners provides ample opportunities in positioning and mapping as well as automation and robotics. The fields of view (FOV) of these sensors can be further expanded by actuation, for example by rotation. These rotating multi-beam lidar (RMBL) systems can provide fast and expansive coverage of the geometries of spaces, but the nature of the sensors and their actuation leave room for improvement in accuracy and precision. Geometric calibration methods addressing this space have been proposed, and this thesis reviews a selection of these methods and evaluates their performance when applied to a set of data samples collected using a custom RMBL platform and six Velodyne multi-beam sensors (one VLP-16 Lite, four VLP-16s and one VLP-32C). The calibration algorithms under inspection are unsupervised and data-based, and they are quantitatively compared to a target-based calibration performed using a high-accuracy point cloud obtained using a terrestrial laser scanner as a reference. The data-based calibration methods are automatic plane detection and fitting, a method based on local planarity and a method based on the information-theoretic concept of information entropy. It is found that of these, the plane-fitting and entropy-based measures for point cloud quality obtain the best calibration results.

ABSTRACT OF THE MASTER'S THESIS

Author: Ruotsala, Anni-Helena
Title of thesis: Detecting clandestine graves
Date: 19.10.2020
Number of pages: 94+19
Thesis supervisor: Petri Rönnholm
Thesis advisors: Matti Kurkela, Anna Williams
Keywords: multi-angular, BRF, hyperspectral, imaging spectroscopy, Specim IQ, remote sensing
Language: English

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.

ABSTRACT OF THE MASTER'S THESIS

Author: Cemal Tanis
Title of thesis: Operational monitoring of snow cover using digital imagery
Date: 20.1.2020
Number of pages: 70+22
Thesis supervisor: Miina Rautiainen
Thesis advisor: Ali Nadir Arslan
Keywords: remote sensing, digital imagery, image processing, snow cover, cloud processing, environmental monitoring
Language: English

Abstract

Fractional snow cover (FSC) and snow depth (SD) are two important parameters used to calculate snow water equivalent and surface albedo, which are important physical quantities for applications in climatology, hydrology and meteorology. FSC is traditionally monitored using satellite data, but it is challenging for optical sensors to retrieve signals from the ground when forest canopy is present. Similar challenge exists for retrieving microwave signals from terrain with high slope rates. In addition to retrieval challenges, validation of FSC products are done using proxy parameters since in-situ FSC observations are very limited. This is because there are no devices or systems usable for continuous measurement of FSC and manual observation takes a lot effort and depends on subjective judgement. SD is traditionally observed by manual readings of snow sticks. Manual observations requires effort and presence of manpower, especially in remote areas. Also, temporal resolution of such observations are generally one day. In the last decades, manual observations are replaced with automated observations by ultrasonic and optical sensors in some countries, but the manual observation is still the primary method in many countries.

Using webcam photography for environmental monitoring is an emerging method. During the latest years, numerous environmental camera networks are established in different parts of the globe. These networks offer high resolution digital imagery in high temporal resolution. More digital imagery is also available from cameras and camera networks established for other purposes, such as monitoring ski tracks, traffic, harbours, urban areas etc. It is previously studied that environmental parameters are observed from digital images using image processing methods. A novel system is previously introduced by Tanis et al. for automated monitoring of different parameters from multiple camera networks. This system allows acquisition of images from different sources by defining camera networks on a toolbox, so that it can process and visualise the images on a processing chain customised by input from the user via graphical user interface. The toolbox is called Finnish Meteorological Institute Image Processing Toolbox (FMIPROT). It can work also on cloud, to create automated and continuous processing of digital imagery.

In this thesis, FSC and SD are estimated for multiple locations in Finland by processing images from MONIMET camera network for 2018 - 2019 season. Images are classified as snow covered or snow free in pixel level using an adaptive thresholding algorithm which determines a threshold value for the digital numbers (DN) of pixels in blue channel using histograms of the images. FSC is estimated by using snow presence in the pixels from the classification and spatial resolution of the pixels calculated from georectification of the images. Images are georectified using perspective projection. SD is estimated using an algorithm to find the intersection of snow surface and snow sticks by thresholding and segmentation. Estimations are assessed using

observations from in-situ measurements and observations by visual inspection. FMIPROT processing system is deployed on cloud and the near real time (NRT) monitoring is set up for the same parameters in same locations. The processing is integrated into "FMIPROT & Camera Network Portal" website so that the visualised NRT results are available for public.

ABSTRACT OF THE MASTER'S THESIS

Author: Samuel Viitikko
Title of thesis: Utilization of remotely piloted aircraft systems on infrastructure construction projects
Date: 22.4.2020
Number of pages: 80+1
Thesis supervisor: Matti Vaaja
Thesis advisors: Petri Rönnholm, Santtu Mankki
Keywords: Remotely piloted aircraft systems, aerial imaging, photogrammetry, project management, infrastructure construction
Language: English

Abstract

Use of remotely piloted aircraft systems (RPAS) has become increasingly popular within construction industry in past years. Currently, there is no consistent way of utilizing them effectively, and in some cases, the utilization contradicts with national legislation and regulations. RPAS-based products are typically limited to aerial images and videos that are used to direct discussion with different parties of the project. Utilization of aerial photogrammetry and photogrammetric models has not reached its full potential as theory and processes are poorly understood, and benefits of the products are not fully recognized.

The aim of this study is to provide a comprehensive basis for consistent RPAS workflow, and to inspect ways of utilizing photogrammetric models to enhance infrastructure construction project management and effectiveness. In this study, legislative and regulatory conformities were inspected and evaluated how they affect the proposed workflow. Moreover, experiences and observations on utilizing photogrammetric models were collected from several study sites as an empirical study and by actively discussing with site personnel
.
Utilization of a consistent RPAS workflow and photogrammetric models were found to be beneficial for infrastructure construction projects. Orthophotos were used to acquire over-view of the site's status while digital surface models enabled fast and straightforward volumetric measurements and measuring of progress on earthworks. Models enhanced project management's situational awareness and enabled more precise decisions to be made quicker. Furthermore, these aspects promote principles of lean construction. Findings on the benefits from study sites support the implementation of the RPAS workflow on infrastructure construction projects. Lastly, means of initializing the workflow to an organization is recommended.