RECENTLY PUBLISHED MASTER'S THESES AT AALTO UNIVERSITY, FINLAND

In following, we highlight the abstracts of the Master's Theses published in **2022** at the Aalto University in the fields of photogrammetry, laser scanning, geodesy and remote sensing.

Master's Theses:

Lasse Andersson: Object-based image analysis of high-resolution aerial data for mapping urban areas

Eetu Jutila: Land cover change detection using Sentinel-1 satellite images

Joonas Heikkilä: Integration of airborne LiDAR and image data

Henri Heilala: Puustotunnusten automatisoitu laskenta (Automation of tree characteristics calculation)

Bijay Karki: Open-source photogrammetric tools for 3D urban modelling – A case study using mobile phone images

Jani Mölläri: Updating building information using airborne laser scanning data

Golda Marthandavilakom Prakasam: Detecting ice jams on the rivers in northern Finland using Sentinel-1

Caj Snickars: Detection of road edges from multiple data sources

Pasi Talvitie: Keidassoiden pintarakenteen muutosten havainnointi kaukokartoituksen avulla (Detecting change in raised bogs using remote sensing)

Ilpo Tuomisto: Pistepilvipohjaiset sisä-ulkotila integraatiomenetelmät kaupunkiympäristöissä (Pointcloud-based indoor and outdoor integration in built environment)

Madeleine Östersund: Monitoring bark beetle infestation using remote sensing

ABSTRACT OF THE MASTER'S THESIS

Author: Lasse Andersson
Title of thesis: Object-based image analysis of high-resolution aerial data for mapping urban areas
Number of pages: 49
Thesis supervisor: Vaaja, Matti
Thesis advisor: Julin, Arttu
Keywords: object-based image analysis (OBIA), image classification, segmentation, machine learning
Language: English

Abstract

With the volume of high-resolution remote sensing data constantly increasing, also methods to efficiently utilize the data are needed. Automated processes for feature extraction, classification and mapping are expected to be a growing field in the geospatial industry. This thesis looks into one of the methods used to extract information from high-resolution remote sensing data.

Object-based image analysis (OBIA) is a method that combines image segmentation and subsequent analysis of the segments. In this thesis OBIA is coupled with a random forest (RF) machine learning algorithm to extract and classify different urban land cover features. The method is applied to three different input images: RGB ortho image, CIR ortho image, and intensity image derived from airborne laser scanning data. Different approaches and variables are compared and analyzed to find out which combination yields best results.

Object-based image analysis proved to be a method that can be applied to high-resolution aerial data and used to semi-automatically extract and map different features. Shadows were found to cause problems with the optical RGB and CIR images but using intensity image overcame this issue. However, the optical images had higher spatial resolution which perhaps captured more precise segments for features such as buildings. All in all, the intensity image approach achieved the most accurate results and was able to nicely capture different urban features.

ABSTRACT OF THE MASTER'S THESIS

Author: Eetu Jutila
Title of thesis: Land cover change detection using Sentinel-1 satellite images
Number of pages: 43
Thesis supervisor: Rautiainen, Miina
Thesis advisor: Törmä, Markus
Keywords: Sentinel-1, land cover change, remote sensing, machine learning, random forest
Language: English

Abstract

Finland aims to be carbon neutral by 2035. To achieve that goal, Finland needs to reduce carbon dioxide emissions significantly soon. The land-use sector has a critical role in these plans as it is both a major source of emissions and an important carbon sink. Thus, there is a great demand for accurate and up-to-date information about land use and its changes to support decision-making and international climate reporting. Today, one method to find these changes is to utilize time series of openly accessible satellite imagery.

This master’s thesis studied land cover changes that occurred in forests between the years 2020 and 2021 with Sentinel-1 Synthetic Aperture Radar (SAR) imagery in the Uusimaa region in Finland. The research question was whether the land cover changes detected from the Sentinel-1 time-series can be used as clue information during the update process of the Topographic Database maintained by the National Land Survey of Finland. The goals of the study were to develop a well-performing change detection method and to evaluate the feasibility of the applied SAR image mosaics for change detection analysis.

The selected method was spectral-temporal combined analysis where the Sentinel-1 time-series were stacked into a multi-band file that was then classified with several types of classifiers, such as random forest, gradient boost, and support vector machine classifiers. Additionally, two machine learning pipeline optimizers, TPOT and Autokeras, were piloted. Random forest and TPOT-based implementations achieved the best performance with potential but still mediocre results. Hyperparameter tuning of the classifiers and a larger training dataset are ideas that might help to increase the change detection performance in the future.

ABSTRACT OF THE MASTER'S THESIS

Author: Joonas Heikkilä
Title of thesis: Integration of airborne LiDAR and image data
Number of pages: 70
Thesis supervisor: Vaaja, Matti
Thesis advisors: Rönnholm, Petri; Piiroinen, Rami
Keywords: LiDAR, integration, airborne, remote sensing, camera, system calibration
Language: English

Abstract

Airborne mapping systems can capture remote sensing data from large areas efficiently. Usually, these systems consist of a LiDAR sensor, cameras, and positioning devices GNSS and IMU. Many times, LiDAR data and images are still used separately when mapping and modelling of the environment without first integrating different sources of data. For integration of LiDAR and camera data, system calibration of the whole sensor setup is required. This can be done by common reference frame, which is usually the coordinate frame of IMU, or with direct integration by solving the relationship between LiDAR sensor and camera.

This thesis presented a way of integrating LiDAR and image data by performing system calibration through IMU. All the sensors of airborne system, LiDAR, two cameras and GNSS antenna were calibrated against the IMU frame. Relationship between LiDAR point cloud and images were found with collinearity equations. Point clouds were coloured with the RGB values of the pixels from the images. The main purpose for the coloured point cloud, is to help in the future with the electrical distribution and transmission network inspections like solving the vegetation clearances, inspecting the components, and modelling the distribution infrastructure.

LiDAR intensity values were used for evaluating the integration errors. Corresponding points were searched from intensity derived raster images and raster images generated from the coloured point clouds. Average error measured, were 5.4 cm for nadir camera and 5.8 cm for oblique front camera. It was concluded that some systematic error remained after the system calibration, mainly with the lever-arm and boresight components between IMU and the cameras. However, the accuracy of the system calibration was sufficient for colouring most of the distribution network components correctly.

ABSTRACT OF THE MASTER'S THESIS

Author: Henri Heilala
Title of thesis: Puustotunnusten automatisoitu laskeminen (Automation of tree characteristics calculation)
Number of pages: 53+2
Thesis supervisor: Rönnholm, Petri
Thesis advisor: Kämäri, Hannu
Keywords: canopy height model, tree characteristics, remote sensing, laser scanning, forest plan
Language: Finnish

Abstract

The amount of open, publicly available forest data in Finland has been rapidly rising during the past decades. With the evolution of technology also the quality and coverage of said data has increased. This thesis tries to figure out if open data can be used to calculate sufficiently accurate tree characteristics for forestry purposes. Sufficient accuracy was defined by comparing the results of the method created during this thesis and other methods that are currently widely used for forest inventory purposes.

During the writing of this thesis a tool was developed which uses the Finnish Forest Centre's canopy height model and forest stand data provided by the customer company. Using the created PyCrown and python-based solution, the following tree characteristics were calculated for given input forest stands: number of trees per hectare and average height of trees. The results obtained from the created solution were then compared to data obtained from a forest harvester machine, which was used as reference data in the study. The study shows that there was systematic underestimation regarding the number of trees per hectare, which was also noted earlier in other relevant studies. The average height of trees was systematically overestimated, which is a direct outcome of shorter, smaller trees not being spotted from behind taller trees and their crowns. Since shorter trees are not detected, they aren't considered when calculating stand's average tree height. The proposed method created in this thesis is in line with previous relevant studies when it comes to the error of detected trees per hectare. As for average tree height, the error is more significant.

The accuracy of the method created in this thesis can certainly be improved by taking a closer look at the tree detection parameters given to the PyCrown-tool. The parameters need more research and data within the Finnish forest domain.

ABSTRACT OF THE MASTER'S THESIS

Author: Bijay Karki
Title of thesis: Open-source photogrammetric tools for 3D urban modelling – A case study using mobile phone images
Number of pages: 42 + 8
Thesis supervisor: Vaaja, Matti
Thesis advisor: Ingman, Matias; Virtanen, Juho-Pekka
Keywords: 3D urban modelling, façade reconstruction, open-source photogrammetric tool, mobile phone photogrammetry, DIY photogrammetry
Language: English

Abstract

Internet is flooded with images taken from mobile phone cameras. An estimate of more than 1.4 trillion photos was taken in the year 2021 and about 90% of which accounts for mobile phones. Technology has advanced a lot in the last decade when it comes to computer vision, image processing, and 3D reconstruction along with improvement in the camera hardware i.e. lens and sensor system in every new generation of phones. Several open-source software for 3D reconstruction are readily available which could offer cost-effective solutions as an alternative to commercial products. Moreover, the use of mobile phone images could even lower the cost of instruments.

In this thesis, a 3D model of a façade on the southern end of the old Helsinki market hall in Kauppatori is created from the images taken from a mobile phone (Huawei P10) using one of the open-source photogrammetric tools i.e. Meshroom. Two sets of images were taken, each in auto focus and manual focus mode. A commercial tool i.e. Agisoft Metashape was used as a benchmark to create the 3D models using the same sets of images. All models were created in a complete default setting. The resulting mesh models were then compared to an existing TLS point cloud of the same structure.

Cloud to mesh distance was computed for analyzing the accuracies of the models. Absolute RMSE values of both models generated from Meshroom were identical and less than 8 cm. However, visual observation clearly shows the models had differences in absolute and local accuracies. Several cross sections were analyzed to access the local accuracies within the models. The models tend to warp away from the point cloud towards the outer edges of the façade. Since the study was also intended to encourage beginners with a DIY approach, data acquisition and processing were made as simple as possible. So, there are several rooms for improvement. The results demonstrate a tremendous possibility of open-source photogrammetric tools and mobile phone images as a cost-effective solution for 3D modelling applications.

ABSTRACT OF THE MASTER'S THESIS

Author: Jani Mölläri
Title of thesis: Updating building information using airborne laser scanning data
Number of pages: 66 + 5
Thesis supervisor: Vaaja, Matti
Thesis advisors: Holma, Hannele; Rönnholm, Petri
Keywords: ALS, BDR, spatial analysis, point cloud
Language: English

Abstract

The population and information system should contain all the buildings in Finland. Digital and population data services agency is responsible for the building data along with the municipalities. Municipalities are liable for updating and maintaining the data in building and dwelling register (BDR), where the digital and population data services agency receive their building information. The quality and up-to-dateness varies between the municipalities.

The main goal of this thesis is to find out if it is possible to analyze the correctness of the registries with spatial methods by using airborne laser scanning data along with data from topographic database and aerial photos.

With the data and software used in this thesis, it is possible to analyze the correctness of the registries. The new analysis workflow gives results that are better than with the traditional way of doing the analysis and gives a more accurate state of the registers.

ABSTRACT OF THE MASTER'S THESIS

Author: Golda Marthandavilakom Prakasam
Title of thesis: Detecting ice jams on the rivers in northern Finland using Sentinel-1
Number of pages: 60
Thesis supervisor: Rautiainen, Miina
Thesis advisor: Luojus, Kari
Keywords: ice jam, Sentinel-1, synthetic aperture radar, ground range detected, SAR, remote sensing
Language: English

Abstract

Ice jams related flooding causes tremendous loss both physically and economically in society by destroying habitats, damaging the infrastructures, water supply, navigation. Hence, it’s of great importance to account this phenomenon. Ice jam study using Synthetic Aperture Radar (SAR) data has gained demand, however only a few studies came out using Sentinel-1 data, especially with vertical transmit & vertical receive (VV) and vertical transmit & horizontal transmit (VH) backscatter polarization for detecting ice jams.

This study aims to put forward an automatic algorithm to detect the ice jams using Sentinel-1 backscattering intensities VV and VH for the first time in Kemijoki River system in Finland. 10 days average mean mosaics of Sentinel-1 Ground Range Detected (GRD) products were used as input. The algorithm was successful in detecting ice and ice jams during the study period from December to March between 2018 to 2021. VH backscatter polarization gave the best results in delineating the ice jam. To quantify the results, River Lake Ice Extent product based on Sentinel-2 and for visual validation RGB (red, green, blue) composites of Sentinel-2 Mosaics have been used. Visual validation was the most trusted in this method. The recall and precision were above 70 percent. Cloud cover and lack of good in-situ reference data was also a draw back for the validation of result. The potential ice jam detected in Rovaniemi is opening the wider possibility for applying similar technique for finding ice jams for the entire Finland.

ABSTRACT OF THE MASTER'S THESIS

Author: Caj Snickars
Title of thesis: Detection of road edges from multiple data sources
Number of pages: 63
Thesis supervisor: Vaaja, Matti
Thesis advisors: Rönnholm, Petri; Laaksonen, Heli
Keywords: road edge detection, LiDAR, orthophoto, YUV, road vector
Language: English

Abstract

Besides presenting its own process for road edge detection, this thesis presents also various data sources and methods that could be used for road edge detection. The study is done on two different test areas that are different from each other. The Espoonlahti test area is a city suburb and the Ingels test area consists of forest roads. The process is done with an orthophoto in a YUV color space and as well with a LiDAR intensity image. The found road edges from both data sources are merged for a combined result. All the results are then compared to measured reference points.

The presented process uses object-based image analysis (OBIA) for segmenting the input image. The polygons are given color values as attributes, which then are filtered using the color value as well the distance to a road centerline vector. For each road centerline segment, a median road width is calculated using the detected road edge points. Using the median values, a polygon of the road surface is created.

In this research, LiDAR gave the best comparison result with a median accuracy of 0.92 m for the Espoonlahti test area and 1.12 m for the Ingels test area. Orthophoto gave the worst result with 1.35 for the Espoonlahti test area and 1.40 for the Ingels test area. The resolution of the LiDAR intensity image is 0.5 m and the orthophoto is 0.25 m. The combined result of orthophoto and LiDAR performed between the LiDAR and the orthophoto comparison results. The median result is 1.04 m for Espoonlahti and 1.15 m for Ingels for the combined result.

ABSTRACT OF THE MASTER'S THESIS

Author: Pasi Talvitie
Title of thesis: Keidassoiden pintarakenteen muutosten havainnointi kaukokartoituksen avulla (Detecting change in raised bogs using remote sensing)
Number of pages: 84 + 25
Thesis supervisor: Rautiainen, Miina
Thesis advisors: Räsänen, Aleksi; Silvan, Niko
Keywords: remote sensing, climate change, raised bogs, geomorphology, GEOBIA, supervised classification, maximum likelihood, aerial images, PlanetScope
Language: Finnish

Abstract

Raised bogs are the most typical wetland type in Southern Finland. They get all their water and nutrients from precipitation. The surface of the raised bogs is characterized by dry ridges, hummocks, and wet depressions, hollows. Climate warming reduces winter snowfall and increases evaporation, which is estimated to lower the groundwater level in raised bogs. This can lead to increased forestation and have warming effects locally.

In this work, the changes occurring in the water level of hollows are studied over a 70-year time series using aerial and satellite images as data. The research sites are two raised bogs located in Western Finland: Häädetkeidas and Kauhaneva.

Long-term change was monitored using character-based segmentation of aerial images and supervised maximum likelihood classification. The change during a single growing season was examined using satellite images and supervised maximum likelihood classification. The results were compared with weather data collected during the review period.

The results show a decrease in both the amount and the area of wet hollows on raised bogs in the period 1947–2017. In Häädetkeidas, a 13.8 % decrease in amount and 14.8 % decrease in area was detected, in Kauhaneva the amount decreased by 5.3 % and area by 6.8 %. The mean temperatures in the area have risen over 1° C during the same period. However, the change in water levels during single growth season can be significant. This is caused mainly by differences in the amount of meltwater in spring.

The observed drying trend in the raised bogs over the last 70 years is in line with the expected effects of climate change.

ABSTRACT OF THE MASTER'S THESIS

Author: Ilpo Tuomisto
Title of thesis: Pistepilvipohjaiset sisä-ulkotila integraatiomenetelmät kaupunkiympäristöissä (Pointcloud-based indoor and outdoor integration in built environment)
Number of pages: 34
Thesis supervisor: Vaaja, Matti
Thesis advisors: Virtanen, Juho-Pekka; Rantanen, Toni
Keywords: point cloud, indoor, outdoor, integration, registration
Language: Finnish

Abstract

Point cloud datasets gathered from indoor environments can bring additional value to city models. Accurate 3D point cloud data can be used to visualize, plan and model urban environments and buildings. Low overlap between the point clouds is a typical challenge in the integration of indoor and outdoor datasets.

The integration methods can be divided based on the overlap between the datasets into cases where there is no overlap between the datasets and cases where there is some overlap between the datasets. In cases where there is no overlap, the doors and windows of the building can be used for rough alignment of the datasets. When there is some overlap between the datasets, regular point cloud registration methods such as the iterative closest point algorithm can be applied to register the datasets.

The effect of the overlap between the indoor and outdoor datasets was tested by conducting a case study on point cloud datasets gathered from indoor and outdoor areas of a market hall building in Helsinki. Two different overlap conditions were compared to a ground truth situation. Cloud to cloud distance and cross sections taken from the point clouds were used to determine how successful the integration of the datasets was.

Larger overlap between the datasets resulted in better alignment of the indoor and outdoor datasets, but even the smaller overlap resulted in a relatively successful integration. In both cases the difference to the ground truth registration was in the order of magnitude of centimeters. Additional scans that increase the overlap between the datasets can be beneficial if the overlap between the original datasets is low.

ABSTRACT OF THE MASTER'S THESIS

Author: Madeleine Östersund
Title of thesis: Monitoring bark beetle infestation using remote sensing
Number of pages: 49 + 7
Thesis supervisor: Rautiainen, Miina
Thesis advisors: Honkavaara, Eija; Näsi, Roope
Keywords: bark beetle, Sentinel-2, UAV, multispectral imagery, Random Forest
Language: English

Abstract

The spruce bark beetle (Ips typographus L.) is a serious threat to the Finnish boreal forests due to the economic losses they cause. The spread of the bark beetles has been monitored by manual field work for many years. But due to increasing outbreaks, there is a need for more efficient methods to monitor the outbreaks at larger areas. Unmanned Aerial Vehicles (UAVs) mounted with multispectral and hyperspectral sensors have already given good results at individual tree level. As the technology of satellite systems is evolving and satellites with higher spatial resolution have come available, many studies have been done using these. However, in Finnish conditions, even a 10 m/pixel resolution is not enough to recognize the decrease of tree health caused by the bark beetle.

This study aims to develop a method for combining high-resolution UAV data with lower-resolution satellite data for bark beetle monitoring. A literature review was conducted on previous methodologies in bark beetle monitoring as well as UAV and satellite combinations in different fields, explaining tools and background for this thesis. A methodology was developed for combined analysis of satellite and drone data. The integration was implemented by utilizing the UAV data to extend the ground truth data. First, multispectral drone data was used to estimate health indices of individual trees.

The drone data was then resampled to fit Sentinel-2 10 m x 10 m pixels and used as training data in a Random Forest estimation of the satellite’s pixels’ health indices. In addition, a trend analysis of the Sentinel-2 imagery was done on summer months 2019-2021. The combined method presented in this thesis performed at an 89% overall accuracy. The results of this thesis will help managing forests on a wider level than is now possible in Finland. The results were promising particularly considering monitoring of wide areas, however, in for the Finnish situation with fragmented outbreaks the forthcoming higher spatial resolution satellite systems might provide more efficient tool for detecting new outbreak areas.