RECENTLY PUBLISHED MASTER'S THESES AT AALTO UNIVERSITY, FINLAND

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

Master's Theses:

Jokela, Joonas (2016): CityGML building model production from airborne laser scanning

Kuusisto, Iiro (2016): Evaluation of the performance of two aerial lidar bathymetry systems in Finnish coastal and inland waters

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ABSTRACT OF THE MASTER'S THESIS

Author: Joonas Jokela
Title of thesis: CityGML building model production from airborne laser scanning
Date: 07.01.2016
Number of pages: 64
Thesis supervisor: Prof. Henrik Haggrén
Thesis advisor: Petri Rönnholm and Arttu Julin

Abstract

3D city models have become an important tool in many applications across different fields. Usually these 3D city models only represent the geometrical attributes of the city, which enables easy visualization of cities. Yet, different thematic queries, analysis tasks, and spatial data mining are out of the reach of models that only offer us information about their geometry. CityGML 3D city models bring an addition of semantic information to the models.

In this thesis, the process and different techniques of building reconstruction from airborne laser scanning are explained. CityGML standard will also be explained and what has to be done in order to go from 3D building models to CityGML. The main focus of this thesis was to study how well it is possible to automatically create CityGML 2.0 3D city models from data collected only by airborne laser scanning.

CityGML has five different levels-of-detail indicating the level of precision of the building. LOD1 and LOD2 were the most important levels for this thesis, and so it was tested how well different software were able to export reconstructed building models in the CityGML format with these precision levels. These exports were checked against the official specification of CityGML to see how well they met the requirements. It was also explained what more would be needed for the process and data, in order to produce higher quality models in LOD3. Two different test areas were chosen with different building and roof types. One area included detached houses, some partly covered with vegetation, and another area included mainly apartment houses.

The thesis shows that as of now, it is still quite challenging to automatically produce city models that are in line with the CityGML 2.0 standard. The model driven methods had problems when it came to building installations, such as chimneys. These could not be modelled with software that used model driven methods. Data driven methods on the other hand had problems when it came to the conversion from the building models to the CityGML format. Terrain and terrain intersection curve also turned out to be more difficult to model than anticipated. Most of the software used in this thesis were not able to automatically handle the addition of these elements. The elements were possible to add later on to the CityGML file but only with use of additional software tools.

Keywords: ALS, laser scanning, city models, CityGML, building reconstruction, modelling

Language: English

ABSTRACT OF THE MASTER'S THESIS

Author: Iiro Kuusisto
Title of thesis: Evaluation of the performance of two aerial lidar bathymetry systems in Finnish coastal and inland waters
Date: 08.08.2016
Number of pages: 110 +17
Thesis supervisor: Prof. Henrik Haggrén
Thesis advisor: Petri Rönnholm

Abstract

Aerial Lidar Bathymetry (ALB) is considered as an optimal surveying method in shallow waters, because traditional shipborne surveying can be very time-consuming or even dangerous. On the other hand, it cannot be taken for granted that ALB system can detect all the bottom hazards and performance of the ALB systems is highly affected by the water clarity. This paper aims to find out, whether ALB systems could be used for surveying of the shallow zones in Finnish coastal and inland waters.

Firstly, principles and functioning of an ALB system were explained. Its capabilities and limitations were also discussed. After that, same information of sonar was provided, because sonar is used as a reference in this study. The performance evaluation was divided into three parts: Point density and depth penetration, Feature detection, and Horizontal and vertical accuracy. Obtained results were compared against IHO Order 1a requirements, when it was possible. In the first part, point densities were calculated with CloudCompare and Matlab, and coverage was tested by utilizing grids. Feature detection capabilities were assessed by searching objects and calculating hit counts and measuring dimensions within three different depth intervals. Last part aimed to find out the horizontal and vertical accuracies of the ALB systems. This was done by comparing small areas with sonar reference data. Vertical checks were done by comparing lidar points to a sonar reference surface. Horizontal checks were performed by using Iterative Closest Point (ICP) algorithm between lidar and sonar test areas.

It was found out that Riegl had the best point density but the lowest depth penetration capability and LADS HD had the best depth penetration but the lowest point density. Chiroptera II was somewhere between these two, providing rather uniform data until its extinction depth of approximately 5-6 meters. It seemed that the power of the lidar affected the depth penetration the most. It was thought that if power could be raised without lowering the pulse repetition rate, it would be the most optimal set-up in Finnish waters.

Both systems were capable to find objects much smaller than the IHO Order 1a requirements, but sometimes, they failed to detect much bigger objects. Horizontal accuracy was centimetric in comparison with sonar reference data, thus passing the Order 1a requirements. Chiroptera II passed at least locally the vertical requirements of Order 1a. LADS HD passed the requirements narrowly in the same depth interval as Chiroptera II but exceeded the requirements in a deeper interval.

Keywords: ALB, sonar, point density, feature detection, accuracy, IHO Orders, Chiroptera II, LADS HD, Riegl VQ-820-G

Language: English

ABSTRACT OF THE MASTER'S THESIS

Author: Patrik Niskanen
Title of thesis: Seabed classification by multibeam echo sounder
Date: 04.05.2016
Number of pages: 63
Thesis supervisor: Prof. Henrik Haggrén
Thesis advisor: Petri Rönnholm and Jani Pötrönen

Abstract

A multibeam echo sounder is an acoustic instrument, which produces high-resolution and high-density point data from seabed. Every single observation is horizontally and vertically referenced. All observations are containing additional backscatter information. Received backscattering strength correlates to seabed reflectance properties. Backscatter mosaics are produced to visualize the backscattering properties of the seabed. The classification is based on backscatter strength of returning signal.

A large amount of corrections for the observations must be applied to achieve a comparable classification from multibeam dataset. Model-based automatic classification method fits the measured backscatter curves to theoretical curves, predicted by a physics-based model. The reliability of automatic classification is weak if no ground truth is available. Sediment sampling can be used for calibration of automatic classifier.

Due to a high acoustic frequency, only the first impact to the seafloor is affecting to the multibeam backscatter. The signal does not penetrate deeper from the surface top layer. Additional research methods are required for investigation of deeper sediment layers.

Generally, best classification results are achieved by combining multiple methods together. Seabed classification by multibeam echosounder is an efficient method to produce large-scale base information for more detailed field studies.

Keywords: Seabed classification, seabed mapping, multibeam echo sounder, sonar

Language: Finnish

ABSTRACT OF THE MASTER'S THESIS

Author: Topi Penttinen
Title of thesis: Open data and thermal satellite images in city monitoring system
Date: 19.05.2016
Number of pages: 64+8
Thesis supervisor: Prof. Henrik Haggrén
Thesis advisor: Isabel Pinto-Seppä and Hannu Hyyppä

Abstract

This thesis is focused on smart city monitoring systems covering both open data and visualizations. City monitoring systems are systems that combine and process information that is to be presented to the end user either in original format or as processed. Processed information could include Key Performance Indicators (KPr).

This thesis has studied the availability of beneficial open data, both of more traditional data sets and thermal satellite images, whose usability for detecting urban heat island effect has been discussed. KPIs, which are primarily meant for tracking different city operations during a longer period, often produce only a single value presenting the whole city. Values of this kind fit well for tracking the development, but to find out improvement potential behind the actual values needs more specific research. In this thesis, a possible visualization to highlight areas that perform less good on the KPIs measuring accessibility is presented.

Results of this thesis are a review of situation of open data recoverable in city monitoring systems, a processing chain to calculate land surface temperature rasters from thermal satellite images and a visualization which is based on adaptive clustering.

Keywords: city monitoring, KPI, visualization, clustering, satellite images

Language: English

ABSTRACT OF THE MASTER'S THESIS

Author: Monica Sandberg
Title of thesis: Land cover mapping with multi-temporal SAR and optical satellite data
Date: 4.2.2016
Number of pages: 74
Thesis supervisor: Prof. Miina Rautiainen
Thesis advisors: Oleg Antropov

Abstract

Satellite data are widely used within remote sensing to respond to the growing need for a deeper understanding of the Earth's bio- and geophysical parameters. Applications, such as land cover classification has for long been an important task within the field. Optical satellite data have proven to be efficient tools, however, they are unavailable in some conditions, such as cloudy weather. This deficit can be addressed with synthetic aperture radars (SAR), and recently, improvements have been made in their spatial and temporal coverage. Furthermore, a fusion of these data takes advantage of their different characteristics and can lead to even improved outcomes. The aim of this study was to develop and implement an effective land cover classification approach for the boreal forest zone by using multi-temporal SAR and optical data.

Optical and SAR satellite data were collected from the area around Hyytiälä, Finland. One Landsat 8 scene and a time series of Sentinel-1 data spanning over a year were used. Co- and cross-polarized data were available. A very high resolution (VHR) reference image was manually interpreted to form training and test data. Features were extracted from both data sets and those from the SAR data were reduced using feature selection. A land cover classification was then performed separately on each data set and with a fused data set. Different features were tested to find an optimal combination. The classifications were performed with the nearest neighbor rule and the maximum likelihood classifier. This resulted in several classification maps which were validated with the test plots.

The results showed that the single-sensor classifications were noisy. Classifications with only optical imagery performed better. Additionally, removing some of the original data from the calculations, which can speed up the process, led to worse results. The multisensory classifications with the fused data improved the results significantly. Much of the noise was no longer present. The best classification was reached with a fused data set of four SAR features from VH polarized data and four optical features, which gained a final accuracy of 89.8 %. This classification was done with the maximum likelihood classifier. Accuracies up to 97.3 % were also reached but this result had clear flaws in the visual interpretation. It was concluded that fusing optical and SAR data for land cover classification in the boreal zone is a very promising strategy and should be investigated further to reach even better results.

Keywords: data fusion, satellite data, land cover classification, boreal zone, multitemporal, Landsat 8, Sentinel-1, remote sensing

Language: English

ABSTRACT OF THE MASTER'S THESIS

Author: Niko Viljanen
Title of thesis: Environmental 3D photogrammetric hyperspectral and RGB measurements on lightweight Remotely Piloted Aircraft Systems
Date: 6.2.2017
Number of pages: 82+23
Thesis supervisor: Prof. Henrik Haggrén
Thesis advisor: Eija Honkavaara

Abstract

The use of Remotely Piloted Aircraft System's (RPAS) in Remote Sensing has increased rapidly in recent years. Their advantage compared to airplanes and helicopters is their small size and cheap price. A number of new hyperspectral instruments, suitable for light aircraft platforms due to their small size and light weight, have been developed for RPAS. One of these is a hyperspectral camera developed in Finland that utilises the Fabry-Pérot inferometer to measure a number of different wavelength ranges and collect whole image arrays. Unlike the old hyperspectral scanners that recorded only individual lines, these image arrays enable the creation 3D point clouds, orthorectified images and surface models using photogram-metric techniques.

This work developed a geometric processing chain for FPI and RBG camera images and examined how different environments and parameters affect the geometric processing of these images. In the work the measurement of coordinate errors of 3D point clouds, orthorectified images and surface models, created from FPI and RGB camera images with photogrammetric Structure-from-Motion (SfM) technique, was carried out. In addition, the work investigated if canopy height models (CHM) created from FPI and RGB images could be utilized to estimate biomass of vegetation instead of manual field measurement. This study utilized FPI and RGB images collected by the RPAS of Paikkatietokeskus in fields located in Vihti and forest located in Mustila Arboretum National Forest. The collected data was processed with the SfM technique to create 3D point clouds, which were used to calculate a digital elevation model (DSM) and a digital terrain model (DTM) as well as orthorectified images. CHM was calculated by subtracting DTM from DSM, and from this the average heights corresponding with the sampling frames of reference were extracted and compared. The measurement of absolute error of the field surface models and orthorectified images was carried out using reference control points, and these errors were compared with the results obtained in other studies. The assessment of the forest FPI-surface models was carried out using FPI-surface model which had highest overlaps.

This work shows that FPI and RGB imaging and the geometric processing of images of different environments pose their own challenges. The absolute accuracies of the field surface models and the orthomosaic coordinates were good (FPIs RMSEx = 11.9 cm, RMSEy = 11.9 cm and RMSEz = 13.0 cm; RGBs RMSEx = 4.0 cm, RMSEy = 4.0 cm and RMSEz = 5.4 cm) when compared to the other studies. In the best case the crops CHM correlated with the references well ($R2 = 0.75 – 0.87$), and thus its utilization in biomass estimation is possible. The accuracies of the forest FPI-surface models were worse (RMSEz = 31.0 – 309.5 cm).

Keywords: FPI-camera, RGB-camera, Structure-from-Motion, aerial imaging, RPAS, UAV, photogrammetry, remote sensing

Language: Finnish

ABSTRACT OF THE MASTER'S THESIS

Author: Enni Airaksinen
Title of thesis: Three-dimensional city modelling methods
Date: 16.5.2017
Number of pages: 97+2
Thesis supervisor: Prof. Henrik Haggrén
Thesis advisor: Jarmo Suomisto and Kari Kaisla

Abstract

Urbanization is a strong trend in the modern world. The continuous growth of cities leads to different urban development needs and challenges which have to be met by improved city planning, maintenance, management and development. Use of two-dimensional geographic information in city planning and development will not be enough in the future as cities become diverse and city complexity increases. Being able to look at cities and information about them in three dimensions aim to enable innovative city planning and development. In the future, new working methods will play a key role in urban development because information has been enriched with semantics.

The thesis describes methods to model cities in three dimensions and looks where these models are needed. The thesis documents two 3D city modelling projects based on the writer's experiences. The thesis goes through the processes of 3D city modelling.

Through the literature review, it was found that cities can be modelled in three dimensions by manual, semi-automatic and automatic methods. Photogrammetric methods and laser scanning technology are highly automated methods that can be used to model a 3D city model almost automatically. Desirable 3D city models concern reality mesh models, coloured point clouds and semantic city information models. 3D city models have a wide variety of use cases. Three-dimensional city information models belong to a broader context of urban development and digitalisation, a case in point is digital twins and smart cities.

The two 3D city model production projects revealed that it is much simpler and straightforward to realize a photorealistic mesh model than a semantic city information model. Creating a city information model requires extensive know-how about the technique and the requirements of the production process. Photogrammetric city modelling can be used to create photorealistic 3D city models rapidly and effortlessly.

Keywords: 3D city model, 3D city information model, CityGML, mesh model

Language: Finnish

ABSTRACT OF THE MASTER'S THESIS

Author: Aimad El Issaoui
Title of thesis: Difference between time-of-flight and phase-shift laser scanners in tree measurements
Date: 27.03.2017
Number of pages: 60
Thesis supervisor: Prof. Henrik Haggrén
Thesis advisor: Petri Rönnholm and Xinlian Liang

Abstract

Terrestrial laser scanning (TLS) has been proved to be a promising technique in tree measurements. In many studies TLS has been proved to provide some promising results in evaluating tree attributes such as number of stems, stem density, diameter at breast height (DBH), tree height, stem curves, stem volume, biomass, stem quality and change of stems. However, TLS measurements face the problem with the bad penetration through branches and leaves. Many previously mentioned studies have been done by using phase-shift (PS) laser scanners (LS). No studies about the difference be-tween PS-scanners and time-of-flight (ToF) scanners in forest inventory could be found. In order to use TLS widely in forest measurements, the differences between TLS techniques have to be known.

In this study, the differences between PS-technique and ToF-technique have been compared by scanning and analysing 6 test plots. Tree attributes were measured from each laser scanner in Single-Scan (SS) and Multi-Scan (MS) mode. The LS data was analysed manually and automatically. In the manual measurements the number of complete trees, number of stems and the height of the highest measurable point of the stem were measured. In automatic measurements the algorithm locates each stem, creates a stem curve and estimates a height for a tree.

The results indicate a better penetration for the ToF-scanner when it is compared to the PS-scanner when it comes to tree measurements. In both measuring modes (SS and MS), each result indicated a better penetration for the ToF-scanner. The biggest difference between ToF and PS was in the SS-mode. The following percentages show how much the ToF results differed from the PS results in the SS-mode: 52 % in finding complete trees, 10 % in finding stems and 13 % in measuring the highest point of the measurable diameter. The corresponding results in the MS-mode were 37 %, 4 % and 10 %. In the automatic measurements, the highest point of the measurable diameter was 6 % better in ToF-data in the SS-mode. In the same mode algorithm found from ToF-data 16 % more stems compared to PS-data. Corresponding results for MS-mode were 3 and 7 %.

Keywords: Laser scanning, laser scanner, phase shift, time of flight, photogrammetry, forest measurements

Language: Finnish

ABSTRACT OF THE MASTER'S THESIS

Author: Aino Keitaanniemi
Title of thesis: The Suitability of handheld simultaneous localization and mapping laser scanners for modelling the geometry of a building
Date: 31.10.2017
Number of pages: 79
Thesis supervisor: Prof. Henrik Haggrén
Thesis advisor: Matti Vaaja and Hannu Hyyppä

Abstract

This research determines the suitability of handheld simultaneous localization and mapping(SLAM) laser scanners for modelling the geometry of a building faster than with traditional methods. The research focuses on handheld SLAM laser scanners and the biggest focus is on the ZEB-REVO laser scanner. For the suitability of this laser scanner, the research was divided into a literature review and a practical research. The literature review explains how to make geometry models of buildings, the backgrounds of the SLAM laser scanners and the operational principle of ZEB-REVO. In the practical research, the suitability of ZEB-REVO for BIM modelling was tested by analysing results from different measurement subjects. However, the research do not include the modelling section of the preparation of the BIM.

Based on the results of the practical research it can be concluded that the suitability of ZEB-REVO for modelling the geometry of the building is good when the subject is optimal. ZEB-REVO provides good accuracy for BIM modelling when we take to account the time usage of the modelling process. In addition to accuracy, it can be compared with a directive modelling the boundary values of GSA (General Services Administration). On the grounds of these comparisons, the subject impacts the accuracy of the final model. In these cases, the optimal subject gives a good BIM model for the whole building. However, the accuracy of the interior is bigger than the boundary values. Though, even in the non-optimal case producing the BIM model is possible, only with weaker accuracy. These non-optimal subjects are environments where SLAM algorithm does not work correctly. In addition these factors, some characteristics of ZEB-REVO affect the final model. ZEB-REVO features a relatively small noise, a SLAM algorithm which can locate subjects from different environments well together and is capable of recognizing details more extruded than 2 cm. Additionally this study confirms the manufacturer’s recommendation of measurement distance and movement speed..

Keywords: ZEB-REVO, simultaneous localization and mapping, SLAM, handheld, building information model, BIM, modelling of geometry

Language: Finnish

ABSTRACT OF THE MASTER'S THESIS

Author: Pekka Raitio
Title of thesis: Comparison of tree species spectra and their utilization in remote sensing
Date: 26.05.2017
Number of pages: 53
Thesis supervisor: Prof. Miina Rautiainen
Thesis advisors: Aarne Hovi

Abstract

Boreal forests cover a significant part of the world's forests and play an important role in Earth ecosystem. However, there are two obvious deficiencies in the existing spectral databases of boreal tree species. Firstly, many species lack spectral data. Secondly, the methods used in the measurements are outdated and poorly documented.

In this thesis, reflectance and transmittance spectra of over six hundred leafs and needles from twenty five boreal forests tree species were measured under laboratory conditions. The measurements were carried out using carefully designed standardized procedures and data post-processing. An exceptionally comprehensive spectral library was collected during the measurement campaign over growing season in 2016. The dataset will be published in an open spectral database SPECCHIO. The study examined the effects of tree species, canopy light conditions, leaf or needle side, seasonal variation and needle age on the measured spectra. The aim was to determine the most significant wavelengths for tree species discrimination at the leaf and needle level and to examine which other factors influence the spectra. In addition, the implications of the results for remote sensing ware discussed.

The results showed that the importance of short wave infrared (SWIR) region in leaf and needle-level measurements is higher than previously noted. In SWIR region, tree species were found to explain up to 78 percent of variance in leaf albedo (reflectance + transmittance) for coniferous species and 62 percent for broadleaved species. Furthermore, with coniferous species, the influence of species on position of red edge inflection point was found considerable. The effect of leaf or needle side was most noticeable in the visible (VIS) region for broadleaved trees, where the abaxial side albedo was higher than the adaxial side albedo. Further, the results showed high transmittance of first-year needles in the near-infrared (NIR) and SWIR regions. In addition, the needle age clearly differed in green wavelength region where the measurements showed higher absorption for second-year needles. The effect of canopy light conditions on spectra was found to be minor. Seasonal variation had an influence on leaf absorption in VIS, the reflectance and transmittance in NIR, and the position of red edge inflection point.

The band intercorrelation analysis showed that leaf and needle spectra can be characterized into three broad wavelength groups that corresponded well to VIS, NIR and SWIR regions. However, the narrow red edge region showed spectral features that differed from these groups. The spectral database collected during the measurement campaign can be used in interpretation of remote sensing data. Found significant wavelengths and correlations can help in designing of wavelength band locations and widths of new remote sensing instruments.

Keywords: Terrestrial laser scanning, forest valuation, influence of wind, volume of tree stems

Language: Finnish

ABSTRACT OF THE MASTER'S THESIS

Author: Tero Taivassalo
Title of thesis: Applying terrestrial laser scanning on forest valuation
Date: 14.8.2017
Number of pages: 48
Thesis supervisor: Prof. Henrik Haggrén
Thesis advisors: Matti Vaaja and Arttu Julin

Abstract

The main goal of this study is to examine the performance of terrestrial laser scanning in forest valuations. Principles of the terrestrial laser scanning and alternative methods commonly applied in forest property valuations are introduced. Selected data from terrestrial laser scanning measurements are used in demonstrating the process of forest property valuation.

This study utilizes results of terrestrial laser scanning measurements of two trees, a pine and birch. The measurements had been carried out in windy and windless weather conditions. The total volume of the studied trees was calculated from the stem diameter determined for chosen height levels. The influence of wind on the volume of trees is examined by comparing results for different weather conditions.

Terrestrial laser scanning based determination of the volume of a tree stem is found to include significant inaccuracies. The accuracy of the tree volume determination is satisfactory up the height of 8 m for a 15 m high tree. Higher up point clouds disintegrate and the determination of the stem diameter is difficult. The total volume of the birch tree was obtained higher for windy than windless weather conditions but opposite for the pine tree. The uncertainties in the determined stem diameters introduce uncertainties in the calculated total tree stem volumes, which are at least as large as the differences in the total stem volume obtained for windy and windless weather conditions. Accordingly, the influence of wind on the determination of the total volume of the tree stems cannot be evaluated on the basis of the laser scanning data used in this study.

The valuation of an imaginary forest property is performed with two valuation methods, the summation and income methods, by using information from the determined volumes of the two tree and forest market. The influence of wind is weaker than expected. The difference in the value of the trees in windless and wind weather conditions is only 1.7 percent. However, the value of birch trees is 5.0 percent higher in windy than windless weather conditions, but the influence of wind is opposite for pine trees. When applying the income method, the total value of the forest property is 4 to 8 percent higher than for the summation method.

Keywords: Terrestrial laser scanning, forest valuation, influence of wind, volume of tree stems

Language: Finnish

ABSTRACT OF THE MASTER'S THESIS

Author: Hannu Teittinen
Title of thesis: Creation of a georeferenced point cloud from pictures acquired with an unmanned aerial vehicle
Date: 24.03.2017
Number of pages: 105+58
Thesis supervisor: Prof. Henrik Haggrén
Thesis advisors: Petri Rönnholm and Juho-Pekka Virtanen

Abstract

The use of unmanned aerial vehicles (UAVs) have become a common task for many fields of operation and industries in the 21st century. For photogrammetric and remote sensing purposes, the possibilities of a UAV have been studied and developed increasingly for about 10 years. The most common products of UAV-photogrammetry are digital elevation models (DEM), digital terrain models (DTM), orthoimages and other 3D-models. UAVs have the means to produce these end products, but there is still work to do in the accuracy of the mentioned models. Especially when we want to reduce the size of the UAV and increase the efficiency of the operation.

With large professional UAVs, it is possible to achieve a centimeter level accuracy of a photogrammetric process. Consumer priced products and smaller UAVs create different challenges with the amount and weight of quality sensors compared to the carrying capacity. This thesis studies the possibilities of acquiring a precise, georeferenced 3D-model from a video that has been collected with a small UAV. In the case study, a consumer grade, compiled UAV has been used with the worlds known action camera GoPro. GoPro adds its own challenges with the characteristics of its camera type. It is not possible to acquire as precise models with a mobile UAV compared to stationary images collected with a good quality perspective camera, but it is presumable that by 2020 the technology has developed so much, that anybody can buy a consumer priced camera equipped UAV to conduct centimeter level mapping- and modelling operations.

For support of the case study, a state of the art literary research has been conducted about the basics of photogrammetry, UAVs and the use of UAVs in photogrammetry. The actual point cloud created in the case study, was compared to a TLS-acquired point cloud from the same object, but also to other accuracy results from same kinds of studies.

Keywords: UAV, Unmanned Aerial Vehicle, Point cloud, 3D-model

Language: Finnish