The Use of Laser Scanning Data in Real Estate Analyses

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ABSTRACT

Laser scanning, including both the airborne and terrestrial laser scanning, is one of the most interesting and potential 3D data acquisition and monitoring techniques, which can support future studies of real estate and environmental economic. Vast data sets, even covering whole countries, challenge existing manners of proceeding. Existing laser data can be used for multidisciplinary tasks, such as in real estate studies. In Real Estate Studies, the study object consists of physical and legal entities of land and belongings on the land, the activities in the market, and actors managing and dealing with spatial rights. The article discusses possibilities to utilize large laser scanner data sets in studies of real estate economics and environmental economics with the help of case studies. The application areas to be discussed include monitoring land use, property valuation, and environmental impact assessment.

1. INTRODUCTION

Airborne laser scanning (ALS) is a method based on laser (lidar) range measurements from an aircraft and the precise orientation of these measurements between a sensor (the position of which is known by the use of a differential-GPS technique) and a reflecting object, the position of which (x, y, z) is to be defined (Fig. 1). Terrestrial laser scanning (TLS) is a similar method utilizing a laser on a mounted platform and recording the object from the horizontal perspective. Modern ALS enables up to 100 000 range measurements per second from an altitude of about 1 km. With a scan angle of 10^o, a pulse density of 4 pulses per square meter can be obtained at typical flight speeds. On an average day, about 200 km^2 of land can be surveyed. Because of shorter measuring distances than with ALS and stabile platform TLS systems provide dense and accurate 3D point clouds.

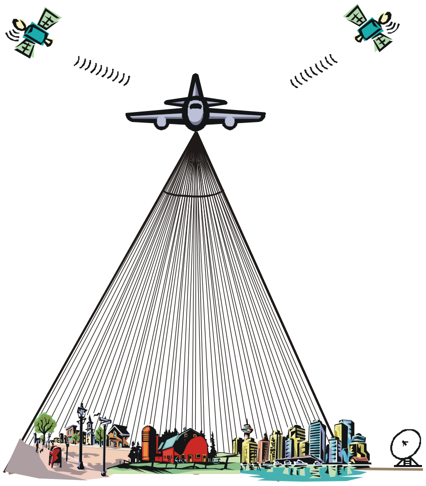

Figure 1. The principle of airborne laser scanning when applied to urban areas. The laser transmits pulses and determines the distance to the target based on the time spent. With the knowledge of the position and orientation of the laser beam when transmitted, the location of the reflected point on the target can be calculated.

Today terrestrial laser scanning is used for digital factory, virtual reality, architecture, civil engineering, archeology and cultural heritage, surgery, plant design and automation systems (robotics). Airborne laser scanning is used for DTM, 3D city modeling, powerline monitoring, change detection of coastal zone, forest inventory, to name a few examples.

Countrywide collection of airborne laser scanning, mainly due to DTM (Digital Terrain Model) derivation, is becoming increasingly common. In the Netherlands, the national laser scanning was initiated to meet the demand for detailed and up to date height information from water boards, provinces and Ministry of Transport (Rijkswaterstaat). The Netherlands was collected with a relatively sparse point cloud. Today, preferred point cloud density is about 0.5-1 point per m^2 (e.g. Artuso et al. 2003). The development of new systems however, allows higher flight altitudes, and thus lower costs per m^2. Today the costs of covering the whole Finland between Helsinki and Oulu (200 000 km^2) would cost less than 20 M€.

This paper aims at first studies for utilizing large laser scanner data sets in real estate and environmental economics. The application areas to be studied include the monitoring of land use, real estate valuation, environmental impact assessment, municipal engineering, and development of real estate 4D registers and fostering of activities in real estate economics.

The basic hypotheses for our research are

- Around 2010-2012, large areas in Scandinavia are covered with existing laser scanner data sets. Research in this project is aiming at developing basic relations between these infrastructural core data sets and real estate science to be then utilized after the collection of these national data sets.
- If the information contents and usability of such data sets is studied well in advance, it is possible to contribute to the planning of such acquisitions in a way that requirement of real estate engineering are taken into account.
- Contrary to other countries (Netherlands, Switzerland), in Finland the national laser scanner data acquisitions can be planned to be multidisciplinary in use (DTM, forests, cities etc).

2. PROCESSING OF LASER SCANNER DATA FOR REAL ESTATE ANALYSIS

The laser scanning survey results in point clouds (file of x, y and z coordinates of reflecting object), which can be used to calculate digital surface models (DSM), digital terrain models (DTM) and different object models. In addition, some laser scanners record an intensity of returning echo that can be used for understanding and classification of point clouds. Recently, the manufacturers have been able to offer systems, which can attach color values from digital photographs to each 3D point. Colored point clouds give feeling of photo-realism when examined from the viewing distance corresponding to laser point density.

DTM - Photogrammetricians have developed various methods to obtain DTM from laser scanning point clouds. Kraus and Pfeifer (1998) developed a DTM algorithm based on distinguishing laser points into terrain points and non-terrain points using an iterative prediction of the DTM and weights attached to each laser point depending on the vertical distance between the expected DTM level and the corresponding laser point. Pyysalo (2000) developed a modified recursive classification method for DTM extraction, where all points within 60 cm vertical distance from the lowest expected ground level were included equally in the next DTM model calculation. Axelsson (1999, 2000, 2001) developed a progressive TIN densification method where surface was allowed to fluctuate within certain values, controlled by minimum description length, constrained spline functions, and active countour models for elevation differences. Ground points were connected in a TIN. A sparse TIN was derived from neighbourhood minima, and then progressively densified to the laser point cloud. In every iteration, points are added to the TIN, if they are within defined thresholds. The method has been implemented to Terrascan software (see www.terrasolid.fi). Elmqvist et al. (2001) estimated the ground surface by employing active shape models by means of energy minimization. The active shape model behaves like a membrane floating up from underneath the data points. The energy function is a weighted combination of internal and external forces. The start state is a plane below the lowest point in the data set. Sithole (2001) and Vosselman and Maas (2001) developed a slope-based filtering technique, which works by pushing up vertically a structuring element. In the method by Wack and Wimmer (2002) non-terrain raster elements are detected in a hierarchical approach that is loosely based on a block-minimum algorithm. Extraction of the DTM can be considered as well-established. The precision of DTM extraction varies between 5 and 30 cm depending on surface type, pulse density, scanning angle, and vegetation cover.

DSM - Most usable technique to obtain DSM relevant to top of objects is to calculate the TIN of the highest reflections (i.e. by taking the highest point within a defined neighbourhood) and interpolate missing points e.g. by Delaunay triangulation. The object model is then obtained by subtracting the DTM of the corresponding DSM. The DSM is typically calculated by means of the first pulse echo and DTM with the last pulse echo. In order to guarantee, that there are no systematic errors between first and last pulse data, calibration using flat, non-vegetated areas, such as roads, roofs, and sports grounds should be performed.

Object delineation - The rapid development of computer-related techniques has enabled the introduction of automatic delineation of objects from the object model. For example, finding tree locations can be obtained by detecting image local maxima (e.g. Geogeon and Moore 1989). After finding the local maxima, the edge of the crown can be found.

Change detection – In the 4D data collection, the fourth dimension is the time. It refers to the multi-temporal 3D data collection giving also information about the changes. However, even the collection of 3D information with conventional mapping means is time consuming, costly and slow. Traditional surveying methods include tachymetric mapping and stereoscopic photogrammetry. The change between laser scanning surveys can be detected between the DSMs or the object models. By a simple subtraction, the change in the target is detected. In more sophisticated change detection, object-to-object matching can be used. Then the change can be directed to a specific target. A simple example of a naive matching algorithm is the following: first the objects are delineated with clustering algorithms, then the centers of the clusters are compared and if they fit within a specific distance, the objects are considered as match. The problem in the matching is that the clustering has to be accurate. Matching rate increases, when threshold distance of such a matching technique increases. While the matching rate increases, also the number of erroneous matches increases.

Visualization - The obtained geoinformation can be used to support real estate decision-making and manage the changes in the cultural landscape of countryside using visualization.

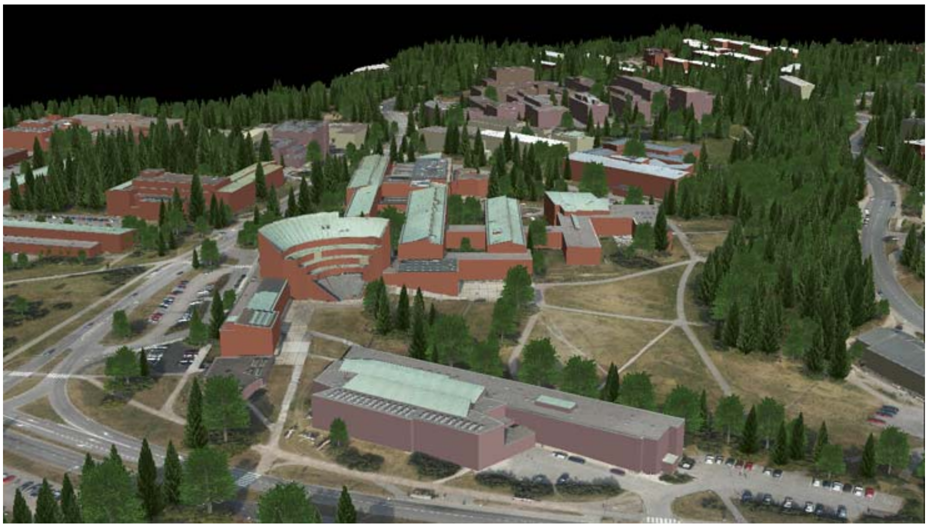

Figure 2. Accurate 3D modelling of Helsinki University campus area created from laser scanning data and digital aerial photos.

The approach for visualization of laser data developed applies following steps:

1. Pre-processing laser data
2. Removing low points and aerial points
3. Classifying laser points into point classes (terrain, low vegetation, middle vegetation, high vegetation, building, and error points)
4. Creating TIN-model of ground
5. Processing simultaneously taken aerial images or time series of old aerial images
6. Vectorizing buildings
7. Separating trees from high vegetation points and displaying them as RPC-cells.
8. Rendering views

The laser point cloud is first classified into terrain, low vegetation, trees and building classes. The terrain is classified into so-called model keypoint class, in which point clouds are sparsified in areas, where high density is not needed to describe the terrain changes. The terrain is also smoothened. Finally, triangulated surface model with siginificantly lower point cloud (but preserving the main terrain elevation changes) is created.

The basic approach of the vectorization method is to find planar surfaces from laser points, detect symmetry and adjust plane equations, find boundaries of planes, align boundary lines using images or intersection lines or with each other. Vectorization of buildings is manual approach with the help of simultaneously aerial images taken during laser scanning flight. Images can be used as perspective views for getting more accurate edge positions. Wall textures could have been extracted from terrestrial digital images. Software TerraPhoto is used to render city model scenes. Textures for building roofs and terrain surface are taken from aerial images.

3. PRACTICAL CASES OF LASER SCANNING IN REAL ESTATE ANALYSIS

The practical cases of using laser scanning in real estate analysis can be divided into

- Static reporting on the situation: 3D model of the target, possibility to fuse with maps and geospatial information systems, visualization of the property, the owner can use the 3D information to manage the property, assessing of the property for the taxing, reporting of the property for the buyer and insurance company, assessing the value of forest land, reporting about the size and volume of the objects, and guiding the land use, for example.
- Change analysis: analysis of the change of the target area, change of the forest ecosystem/environment, surveillance of the building construction, changes in the environment and cadastre system, land use analysis, spoiling of the environment and landscape, surveillance of the keeping of the agreements, sensitivity analysis of the terrain to floods, traffic noise assessment, visualization of the landscape changes, impact assessment.
- To determine factors in real estate transactions: static analysis gives the necessary background situation, with laser scanning several price factors can be reliable estimation from the existing data sets, which are basically impossible to retrieve by other means.

In the following, practical cases are given on the use of laser scanning in real estate analysis.

In Finland, typical transaction deals with the summer cottage. Some of the factors than can be obtained from laser scanning include

- Land quality of the shoreline
- Sensitivity to floods
- Shadowness analysis
- Roads
- Noise analysis
- Distribution of building and trees
- Topography
- Quality and amount of trees
- Closeness to neighbors
- Landscape depth
- Sunshine analysis

Figure 3 visualizes information provided by laser scanning. This kind of information can be showed to evaluators or potential buyers of the real estate without actually going into remote locations.

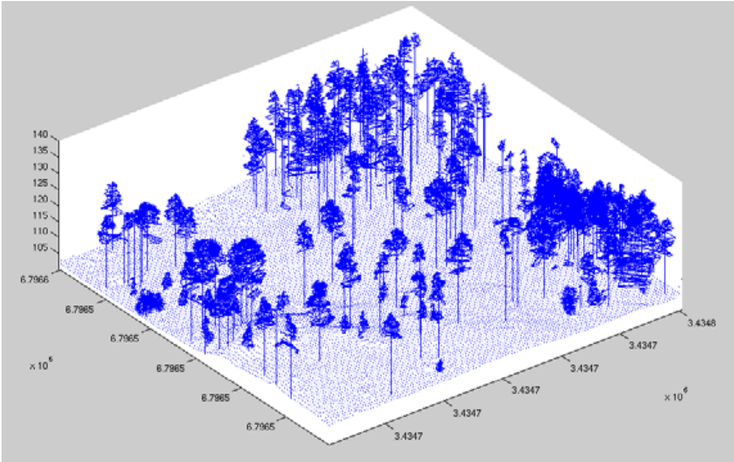

Figure 3. An example of 3D visualization of a forested real estate. (Pyysalo, 2000).

Sustainable use of the environment is one of the most important visions when economic actions are planned within our society. This requirement focuses especially to unimproved land, natural environment. According to the Finnish forest law, environmentally most valuable forest habitats and environments has been protected in our commercial forests. Based on inventories, our private forests includes about 96 000 protected environments. The preservation commitment is directed to forest owners, who are obliged to be able to identify most valuable environments, and to buyers of timber, who according to Finnish practices, are mainly responsible for harvesting actions. In private forests, forest management plans include areas to be preserved. They have, however, mainly been recorded at paper maps, from which they can be scanned to harvesting machinery. The present procedure is quite inaccurate, and most harvesters do not have any locating facilities. By using a laser scanning, it is possible to locate and record the scene object to object. For example, the individual tree assessment has been reported in Hyyppä and Inkinen (1999) and Persson et al. (2002). Since the value of the forests is mainly based on the tree stock, high quality knowledge of forest resources will bring high quality estimates of the price of the forest land. The method (Hyyppä and Inkinen, 1999) was tested together with two other segmentation algorithms in Finnish, Austrian and German coniferous forests and 40 to 50 % of the trees could be correctly segmented (Hyyppä et al. 2001). Persson et al. (2002) improved the crown delineation and could link 71% of the tree heights with the reference trees

Each Forest Property is unique in situation, size, site quality, terrain, tree species and their age classes and cutting possibilities. Therefore, direct comparison of responsible property transactions is often difficult to find. However, sales analysis is an important valuation tool. Sales adjustments or ratio analysis can frequently be applied for indirect sales comparison purposes. Sales analysis and other market analysis can often yield market factors such as a market discount rate, a risk factor or uncertainty factor that may be used in the Income Approach.

The Market Value of a Forest Property as natural resource properties and businesses is usually more or less than the value of the sum of their parts or component values. The components of a forest property are bare land, young seedling, growing stock and mature and realizable stands to be felled. For example, the Market Value of a forest real estate is rarely the sum of these independent component values (e.g. Airaksinen, 1989).

There are, however, other values connected to the forests besides timber production (e.g. Viitanen et al., 1989). The multiple use of forest produces many kinds of benefits, which can be divided into the following groups:

- Material benefits, such as wood, game and gathering products like berries and mushrooms
- The sheltering effects of forests
- Recreation use
- Cultural values like landscape/scenery
- Nature, conservation of biodiversity, carbon sink

Another example of the use of laser scanning for forests is the calculation of the growth, Figure 4. With the analysis of multitemporal data sets, it is possible to detect the growth of individual trees with accuracy of better than 0.5 m. That could be then used for calculation, how much CO_2 our forest intakes. Finland is expected to pay additional 200M€ annually due to the costs of CO_2 rights of the Kyoto protocol, because the growth of trees is not accounted in the Kyoto. It is estimated that the growth of trees could be calculated with annual costs of 4M€.

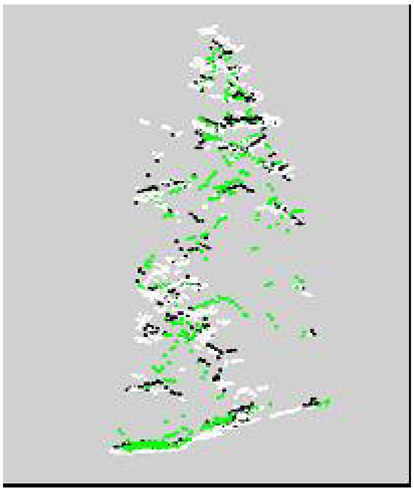

Figure 4. Growth of an individual tree measured using laser scanner and data acquisition performed in 1998 (green dots), 2000 (black dots), 2003 (white dots).

Property development involving large land use changes requires presently assessment of environmental impacts. Similar environmental impacts are assessed also as part of land use planning. Estimation of landscape changes and impacts of the development process are in a crucial role. Use of laser scanning data can be of great aid in such a process and could bring significant savings to the analysis, but could also provide non-professionals objective means to check the changes.

Real estate registers and databases form one of the most important basic structures of the society. Transactions related to real estates (e.g. exchange, leasing, mortgage, expropriation) should be effectively and reliably implemented and is one of the key factors of national competitiveness. Finnish registers are wide and of high quality, but still include some serious defects. Building registers miss many existing buildings. The updating of registers with the use of laser scanner data is a possible scenario.

Based on the technology developed in visualisation and change detection, the environmental impact assessment in landscape can be mainly build on top of these methods. The impact assessment model consists of digital terrain model of the ground, and geometrical model of the vegetation and buildings. Then the change of environment is planned according the planned construction process, and final results are depicted with visualisations tools. When studying impacts that are not planned, change detection methodology are integrated to visualisation tools.

The geometrical models also allow development of noise calculations and analysis of noise levels (and other type of immissions) after the changes, i.e. the noise impact analysis as well as determination of erosion risk using, soil types, slope maps, hydrological networks, and DEMs.

The information obtained from official registers is in many ways inefficient and does not cover all price factors, which leads to field checkings and analyses, when high quality results are required. With large data sets, these kinds of resources are not available, resulting in lower quality price models. Here the laser scanning data can help to reveal some important spatial factors in transactions. The main interest is vested in transactions of residential, onshore and forest properties – how the scanning data can reveal important price factors. The conventional modelling approach to estimate land prices (and values) is built on parametric statistical models, which are easy to use, interpret and, in some cases, they provide acceptable predictions (e.g. Hiltunen, 2005). However, in many instances the inflexibility of these orthodox methods imposes serious threats to their empirical validity; insufficient descriptive power or poor forecasting ability may result. Semi-parametric and nonparametric approaches to hedonic modelling of land prices have recently been under an extensive research. (e.g. Hannonen, 2005). The core implication is that these methods provide the necessary flexibility to uncover the genuine structure underlying the data and, as a consequence, should lead to more insightful inferences in land valuation applications. However, the consensus view in this body of research is that many techniques are highly sensitive to any errors that may occur in observations. Erroneous data causes adaptive models to overfit to false technical details of observations, which, in turn, invalidates much of their proper use in land markets, especially in valuations of single objects. With better data quality, we can break out of the current “parametric straightjacket” that oversimplifies analysis ignoring many important features that arise in practice.

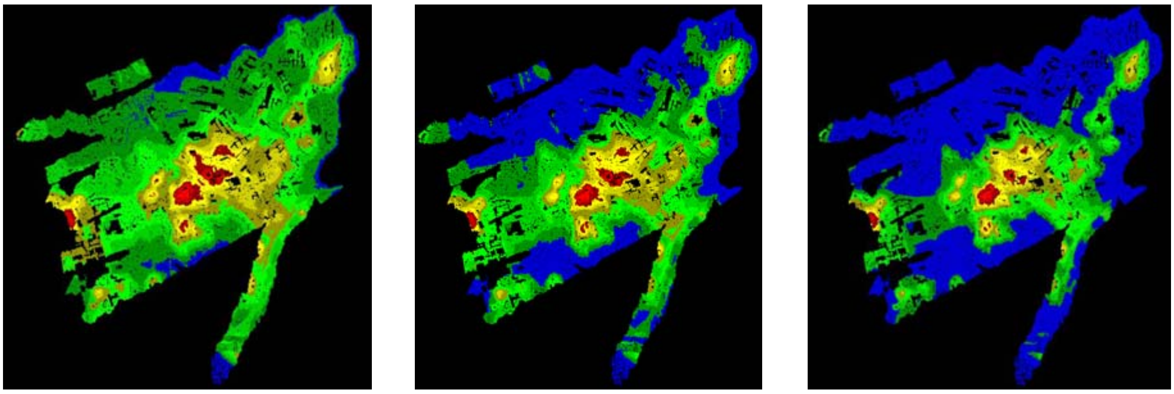

Figure 5. Flooding simulation from Otaniemi. This kind of simulation is valuable for planners, owners, buyers and insurance companies, at least.

4. CONCLUSIONS

In this paper possibilities to use existing laser scanner data for real estate analysis are highlighted. Countrywise laser scanning is becoming increasing common allowing most of the application presented in the paper. It is necessary the future laser scanning acquisitions at country level are planned to be used in a multidisciplinary way.

The weight of 3D information of our environment in real estate analyses and in other applications will increase rapidly as soon as usable data is available. Therefore, it is essential to start national laser scanning as soon as possible. The potential of new applications and innovations is significant. Currently, however, the use of 3D information is still very limited to narrow sub-areas. The authors except that in the future 3D information can be connective factor within many kinds of real estate analyses.

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