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Producing 3D city model with the combined photogrammetric and laser scanner data in the example of Taksim Cumhuriyet square

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A B S T R A C T

The purpose of this study is the analysis, comparison, optimization and complementation of spatial data, acquired by various methods, with various and different standards; in order to produce three dimensional urban models with adequate quality for city planners and urban planners. Pilot application area of the study was determined to be Taksim Cumhuriyet Square. In the end of accuracy comparison, data taken with terrestrial laser scanner method for the buildings covered with reflective materials and geometric data taken with terrestrial photogrammetry method on translucent buildings are used. The model, which was visualized in this way, became dynamic with animations. When the scale of application is considered, no need for DTM or DEM study has been seen necessary. In the conclusion of the study, the presumed hypothesis has been tested on a selected pilot implementation area and it was proved to be feasible. It is a method that can be used in other urban regions, too. The resulting model is a three dimensional square model, powered by terrestrial laser scanners which use real photogrammetric data. It is processed onto three dimensional maps in its real scale (1/1 scaled). It significantly contributes to the complimentary three dimensional model of Taksim Cumhuriyet Square and urban planners' micro-scale planning studies. The model presents all the technical information with integrated data sets which are necessary for permanent square arrangement.

1. Introduction

Fard [1]; defines the urban models as "the digital representation of Earth's surface and the objects associated with urban spaces". Three dimensional urban models are three dimensional simplified representations of urban spaces. These models include models that represent the ground, buildings, flora and other human-made structures [2].

One of the most realistic examples of three dimensional urban models can be found in Google-Earth. In this application, there is a special option which is called 3D Buildings; this option is intended to illustrate three dimensional presentations of cities. However, it works only for the cities of which three dimensional models are added to the application. For instance, while we cannot see three dimensional presentation of Athens, we can do this for New York. The quality of three dimensional models for different cities are not the same; for instance, when New York is considered, building façades have low-quality resolution; however, in Washington DC, some of the important buildings such as White House has higher resolution, but some blocks remain untextured [1].

In visualization tools developed with the contemporary computational technologies, three dimensional urban simulation models, information sharing and interaction are improved [3]. Urban design is one of the areas which most frequently benefits of three dimensional urban models that are also a basis for GIS. By the three dimensional designs created in virtual environment, designers are able to describe their designs more easily and other parties can perceive the design without so much effort, and can contribute to the design by interpreting it. By this way, it provides opportunities for some modifications to the intended plan and to eliminate the shortcomings, if available, [4]. Three dimensional city square models give the impression of being inside the modeled area. For the planner, this makes it easy to read the studied area. Every kind of information related to physical space can be obtained of the model, as if you really are in the area. It helps the researcher to look at the area with the perspectives which resembles the study area. By this way, items that limit the squares (building, monument, wall, etc.), dominant items of the square, scale of the square, dimensions of these items based on the scale (width, height) can be perceived accurately by the planners. The above said models help us to

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understand the relationship between the topography and the items that constitute the topography and the city square. Besides, it gives information about the permeability and transparency of the texture materials used in the facets of the buildings. This is crucial, because the materials used in the facets, give information about the historical perspectives of which the buildings were constructed [4].

Virtual three dimensional model creation is considered to be an easy process due to recent advancements in computer technologies. But, restoration of real objects or the entire world and photorealistic numeric model creation still necessitates an enormous effort [5]. In order to produce three dimensional urban modeling, at first, three dimensional spatial data has to be collected from various sources, concerning the space to be modeled. Conventional methods to produce three dimensional models are geodesic measurement and photogrammetric studies. Geodesic measurement is limited due to its automation capabilities. Photogrammetry techniques use two dimensional images for three dimensional modeling [4]. Today, terrestrial and aerial laser scanning methods are also used in three dimensional modeling studies. One of the most important and the widest utilization areas of laser scanners is recording and modeling of buildings for the sake of three dimensional urban models [6]. Numeric photogrammetry and laser scanning technique are two most commonly used techniques for three dimensional numeric model acquisitions [5].

Laser scanning systems collect a massive amount of raw data called a "pointcloud" [7]. When the scanning control points are georeferenced to a known coordinate system, the entire point cloud can be oriented to the same coordinate system [7]. All points within the point cloud have *X*, *Y*, and *Z* coordinates and laser return Intensity values (XYZI format) [7]. Photographic images record passive solar or artificial radiation backscattered by objects in the camera's field of view. Laser scanning achieves the spatial resolution by scanning the instantaneous field of view with the help of mechanical devices, e.g. a moving mirror, over the entire field of view [8]. In contrast to the "classical" manual data acquisition techniques, like terrestrial surveying and analytical photogrammetry, which require a manual interpretation in order to derive a representation of the sensed objects, these new automatic recording methods allow an automated dense sampling of the object surface within a short time [8]. The largest ranges can be probed using the pulse round trip time measurement principle, obtaining cm-accuracy. Shorter distances, e.g. up to 100 m, can be measured faster and more accurate with the phased based measurement technique. Shorter distances, e.g. up to 2 m, can be measured with even higher precision, e.g. accuracy better than ± 1 mm, with triangulation [8]. In recent years Light Detection and Ranging (LiDAR), also referred to as laser scanning has emerged as a standard technology for three dimensional data acquisition. There are two basic types of LiDAR sensors: (i) fixed, ground-based sensors (Terrestrial Laser Scanning, TLS) and (ii) moving sensors that are mounted on mobile platforms such as aircrafts (Airborne Laser Scanning, ALS) or ground vehicles (Mobile Laser Scanning, MLS) [9]. Airborne laser scanning (ALS) data is available for many urban areas [10]. Today Airborne LiDAR Scanning is one of the most effective and reliable means of terrain data collection. The quality of the point cloud data produced by ALS depends on several factors: GPS and IMU accuracy, LiDAR ranging and angular accuracy, system lever arm precision, extended GPS base lines and boresight calibration [11].

Terrestrial Laser Scanners are comprised of a synthesis of technologies. They are the composite of rapid pulse lasers, precisely calibrated receivers, precision timing, high-speed micro-controlled motors, and precise mirrors and advanced computing capabilities [11]. Terrestrial Laser Scanners (TLS) are capable of superior point positioning accuracies compared to ALS or MLS Systems [11]. The field of applications for terrestrial laser scanning is very diverse [8]. Laser scanning technology has been successfully demonstrated on numerous projects related to civil engineering as-built drawings, deformation monitoring such as dam, huge bridges, visual effects for movies, ground surveys [12]. Terrestrial laser scanning is meanwhile frequently used to capture high quality 3D models of cultural heritage sites and historical buildings. However, the collection of dense point clouds can become very labor expensive, especially if larger areas like complete historic sections of a town have to be captured from multiple viewpoints. Such scenarios opt for vehicle based mobile mapping systems which allow for so-called kinematic terrestrial laser scanning [13].

Recently mobile laser scanning (MLS) campaigns are conducted providing data on urban environments in much higher detail, which can be additionally used for map updating purposes [10]. In recent times mobile lasers canning (MLS) has been used to acquire massive 3D point clouds in urban areas and along road corridors for the collection of detailed data for 3D city modeling, building façadere construction and capture of vegetation and road features for inventories. In comparison to TLS the MLS point clouds have a similar point density but cover larger areas [14]. These systems are fast and more accurate; which allow a very high dens point clouds to be acquired. But their use is still limited due to their cost and the huge amount of data they capture [15]. Safety and efficiency of data collection are compelling reasons to use mobile laser scanning. The potential to acquire a great deal of data in a short time is enormous, especially in areas that are not conducive to traditional methods of data collection. Data collection on 20 mile of highway per day is achievable by most systems. Imaging sensor capabilities may include hi-definition video or digital photography [7]. The position and orientation of the scanner(s) are determined using a combination of data from GNSS, an inertial measurement unit (IMU), and possibly other sensors, such as precise odometers. Surface point density is a function of the data collection rate and the vehicle speed [7]. Haala et al. [13] investigate the accuracies of MLS measurements from StreetMapper for architectural heritage collection and 3D city modeling [10]. They compare estimated planes on a selected building façade with walls from a 3D city model. They found constant errors between 12.6 up to 25.7 cm. Post-processing could reduce the distances to 7.4–9.0 cm. [10].

Advantages of imaging methods are their level of details, economic aspects, portability, handling in spatial limited environment and a short data collection time. Disadvantages remain in the post-processing when the texture of the object is poor. Advantages by using an active sensor system like terrestrial laser scanners are 3D survey capacities and the 3D surface acquisition. Nevertheless, this technology is not optimal for capturing linear elements and produces a large amount of data which implies to be reduced for further processing [16]. One of the most important disadvantages of laser scanners is not to be able to get color image of the object or getting it worse than photogrammetry. Photographs of an object should be taken in order to precise recording of the real color of an object [17].

Consequently, in most cases a combination of the abovementioned methods regarding their benefits may be the best solution [16]. Hybrid sensor systems combine data from different image sources and active sensors in order to create accurate and automatic urban models [2]. Since it benefits from metric information acquired from point clouds and descriptive information obtained of numeric images, the process of combination can be thought as an important step to an optimal three dimensional measurement tool [5]. The main element of the study's hypothesis shown in Fig. 1, is organized as 1/1000 scale numeric maps as a baseline for the main coordinate system, terrestrial laser scanners are used in concrete buildings and to determine the height of the buildings, terrestrial photogrammetry technique is used in glass buildings; and raster data to be covered onto the model are obtained from aerial photogrammetry and terrestrial photogrammetric images [4].