Remote sensing data in the urban GIS

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Abstract — Urban development and management require the handling of complex spatial related objects as well. Nowadays there are data acquisition and data process technologies, which can satisfy such demands. The methods of data acquisition typically provide additional information for GIS beyond geometric data. During the data processing we can get further possibilities. Data from different source can be managed jointly and the information content of the data can be multiplied. Formal times, production of the corresponding high-quality data of the objects was a time consuming and expensive procedure. GIS data acquisition technologies such as Lidar, digital photogrammetry, remote sensing, terrestrial laser scanning and GNSS positioning enable to produce a complex spatial urban database with high resolution and high accuracy. Certainly, the data collection equipment may be still costly, but due to the efficiency of the acquisition method, the measurement time can dramatically be shortened. It is also an important aspect that a complex database enables multiple analysis so that the database can serve multiple disciplines.

In this study we present some of the data acquisition and data processing technologies, which are suitable to integrate into an urban database and can provide useful information for a wide range of applications through analysis and visualization. In urban development several factors need to be considered simultaneously, such as infrastructure, environment, heritage preservation, etc. Different spatial display capabilities can illustrate object of interests one-by-one, but also it is possible to model its surroundings as well. This way such tools can be used efficiently for urban planning by the municipal decision makers. In this study, we will present how to collect and how to utilize different resolution data (Lidar, close range and aerial photogrammetry, terrestrial laser scanning) in urban areas, how to create 3 dimensional models of objects or how to generate surface model of the city based on different data. There are examples presented indicating how to use different combinations of geometric, spectral and topographic data in practice.

I. GIS IN URBAN PLANNING

The Geographic Information System (GIS) is a system created to capture, store, analyze and manage spatial or geographic data. The GIS techniques are used in a wide area of global, regional and local planning. An essential issue for GIS is the quality and suitability for the analysis of the data used in the applied database. The concept of quality nowadays means not only geometric accuracy but also the quality of the further contents of the database. In addition to accuracy, the geometrical resolution is important. Further in the case of remote sensing data, it has significance the spectral (channel number) and radiometric (BPC- bit/channel) resolution. The traditional planning techniques of architecture and civil engineering are time consuming and static procedures. Today, there are many well-known data acquisition technologies that can deliver large amounts of data on their own, and when used combined, it can multiply the information content. [2]

II. DATA ACQUISITION TECHNOLOGIES

<u>Field data</u>

This is the oldest data acquisition procedure. It is used when we want to determine the location of a few discrete points, i.e. the determination of the field is abstracted to appropriately chosen discrete points (Figure 1). The task of surveyor to identify and to select the characteristic points of the field and register them. It is time consuming field work and it is using a limited number of keypoints. We can use GPS for lower accuracy, but if we need high accuracy, use of total station is suggested. These devices are indispensable for the construction of engineering structures, for monitoring of their movements. The field data acquisition procedure is time-consuming and not efficient enough, but the **most accurate data acquisition method**.

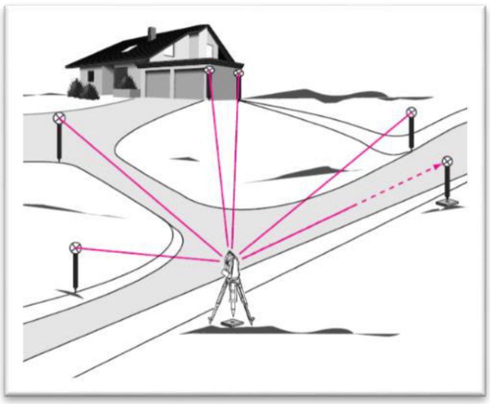

Figure 1. Measurement of discrete points [1]

Photogrammetry

Photogrammetry has advanced greatly in the last years. At the beginning of the XXI. century the digital photogrammetric cameras replaced the film-based equipments. The digital cameras with the high resolution, multi-ray imaging and high automation potential completely have renewed the photogrammetric technology. [2] In addition to traditional aerial photogrammetry, UAV (Unmanned Aerial Vehicle) platform for photogrammetry has been appeared. The use of UAV-s is having a big impact on photogrammetry. Due to the lower flying altitude, significantly higher resolution became available (1-2 cm, see Figure 2). Making aerial photos of larger areas still have to be carried out with traditional aircraft-mounted camera. For the urban GIS, close-range photogrammetry can also be efficiently used. Software have been developed that can process images taken with an amateur camera, as the use of non-metric cameras is widespread. Based on handhold images, one can create 3-dimensional models of buildings or other objects.

Sensors used in photogrammetry are very diverse in geometric, spectral and radiometric resolution. Their greatest advantage in urban environments is their geometric resolution (from mm to cm), which can be exploited in many areas. Detailed survey of small area, condition observe, open trench survey, rapid documentation of archaeological excavations, illegal construction supervision, engineering environmental management, waste management, intelligent transportation, and other aspects can be mentioned as relevant examples.

Figure *2.* High resolution UAV image

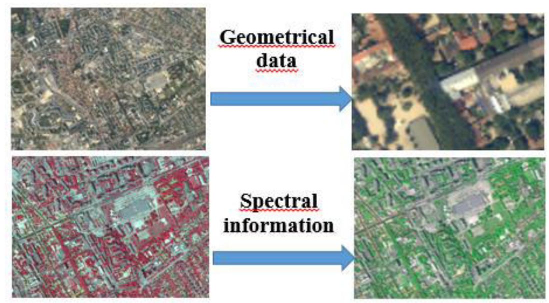

Figure 3. True colour and false colour othophoto of Székesfehérvár based on aerial images.

In aerial photogrammetry, there is a widespread method of shooting: in addition to the classical Nadir shooting at a given position (Figure 3), images can be taken forwards, backwards and sideways (Figure 4). These 'oblique' images make it possible to produce a spatial model of cities.

Figure 4. 3-dimensional model of Székesfehérvár by using oblique images

Photogrammetry is now being integrated into many activities involving geospatial data.

Remote sensing

Satellite remote sensing is capable of producing more data types, that expand the possibilities of urban information databases. The geometric, spectral and radiometric resolution of the satellite images have improved a lot in the recent years. Formal times, they had less applications in urban environments due to their poor geometric resolution. By now, this has changed. For example, the WorldView-2 is a commercial Earth observation satellite. WorldView-2 provides commercially available panchromatic imagery of 0.46 m (18 inch) resolution, and eight-band multispectral imagery with 1.84 m (72 in) resolution. [6]

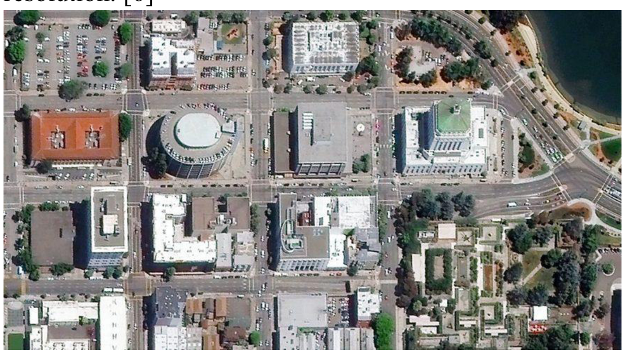

Figure 5. Figure Image of downtown Oakland captured by DigitalGlobe's WorldView-2 satellite. [6]

LIDAR

The invention of laser has started in the early 1960's. The main product of LIDAR (Light Detection and Ranging) survey is a 3D point cloud. The density of the point cloud depends on the sensor characteristics (scanning frequency and repetition rate), as well as the flight parameters (see an example on Figure 6). Assuming that the scanner is pulsing and oscillating at a fixed rate, the point cloud density depends purely on the flight altitude and speed of the aircraft. It is also important to understand that LiDAR sensor is only sampling positions without RGB (spectral information), creating a monochrome dataset which is challenging to be interpreted. To make it more meaningful, the data is often visualized using false-color based on reflectivity or elevation (Figure 7). [3].

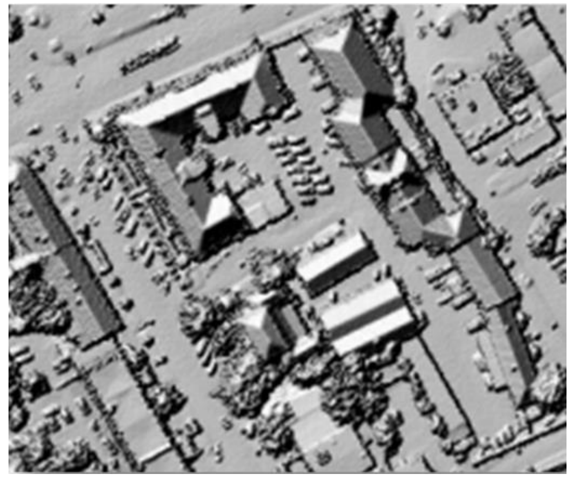

Figure 6. Surface based on LIDAR point cloud. (0,15m absolute and 0,05 m relative vertical accuracy)

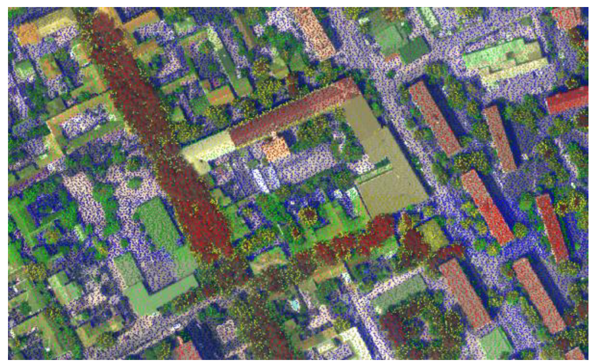

Figure 7.a Figure Orthophoto and point cloud [1]

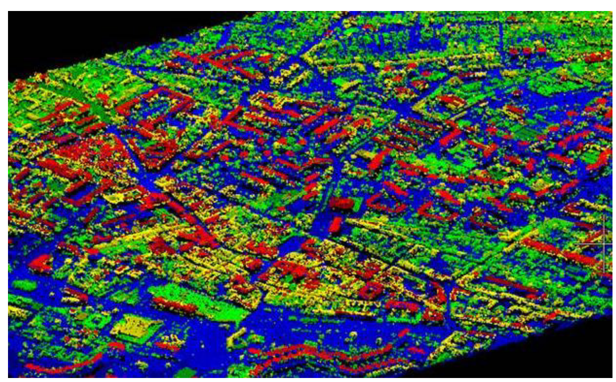

Figure 7.b 3D point cloud visualized using false-color based on elevation [1]

The LIDAR technology collects highly accurate geometrical data with high density, but the analysis and semantic interpretation require application-specific data processing methods. It is possible to overlay color on the LiDAR data in the post-processing phase based on supplementary information, such as images or other data sources. The color can also be added based on classification. [2,3] As the size of LIDAR equipments become smaller, they not only mounted on aircraft, but also on UAVs, increasing both the resolution and the accuracy.

Mobile laser scanner and terrestrial laser scanner

Mobile laser scanning technology combines the use of a laser scanner, the global navigation satellite systems, and an inertial measurement unit (IMU - adjusts input data for vehicle movements) on a mobile platform to produce accurate geospatial data. Terrestrial Laser Scanners has been developed for as-built modeling of architectural and engineering structures. They can be used for high-resolution modeling of terrain objects over limited distances in the range of 50–300 m. These equipments are a key player in the sector due to their low cost, durability and simplicity of usage. A point cloud can be quickly and easily produced, and the process is expected to become more affordable and automated. Mobile laser scanned measurements are characterized about by 30 mm absolute and 3-5 mm relative accuracy on distances less than 10 m. [7] Examples are shown on Figure 8a.;8b

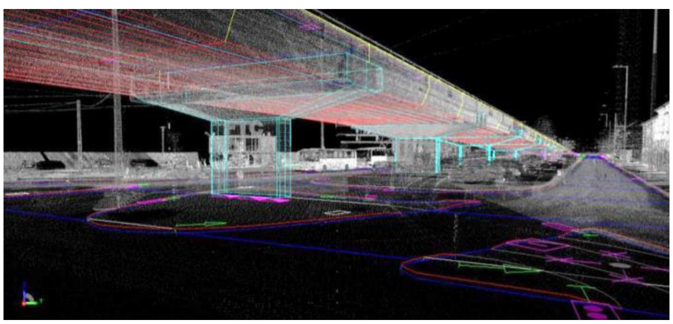

Figure 8a. Mobile laser scanned point cloud at a busy traffic junction in Budapest [8];

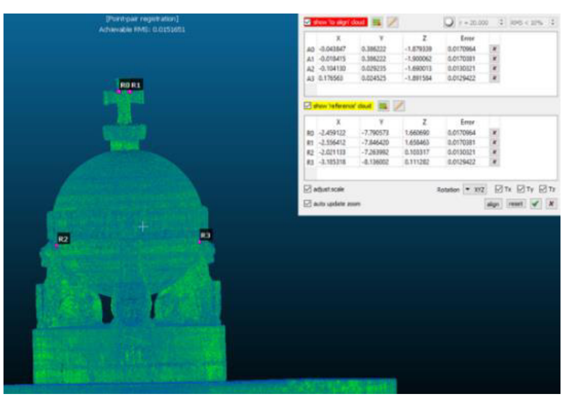

Figure 8b. Terrestrial laser scanned point cloud of the statue „Országalma” in Székesfehérvár [5]

Digital Terrain Model from analog maps

Low-resolution and accurate data, that can be derived from analog topographic maps can be used well for global city planning. They provide 3D information about the entire city (Figure 9).

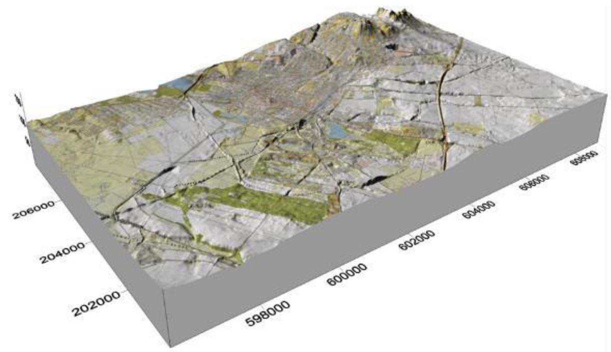

Figure 9. Visualisation of topographic maps on digital terrain model of Székesfehérvár (20 m grid size)

The approximate evaluation of the recorded data

	Field data collection	Photogrammetry	LIDAR	Mobile laser-	Terrestrial laserscanne	Multispectral remote
Horizontal accuracy	*****	*****	***	**	****	*
Vertical accuracy	*****	***	*****	**	*****	-
Spatial resolution	*	******	***	****	*****	*
Semantic resolution	*	***	*	*	*	*****
time required	*	**	*	*	*	*****
cost efficiency	*	*****	**	*	*	***

Table 1. summarizes the strength and weakness of the different data acquisition methods. It may help to find the optimal method for urban planning, which satisfies the needs of resolution and accuracy, and provides information on cost efficiency. Data from different source can be managed together and the advantages can be added.

Examples are shown on Figure 10 to Figure 15.

Figure 10. Green and artificial land cover, classified satellite image draped on DTM (20m grid size) [10]

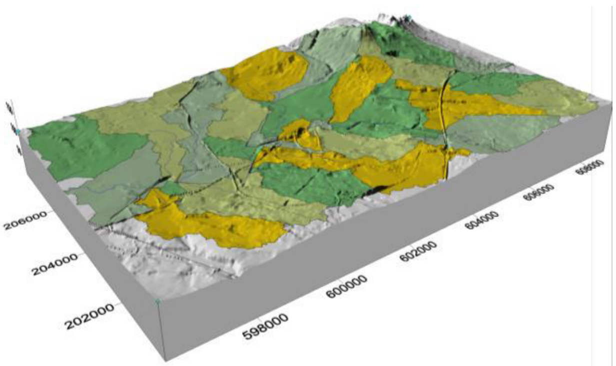

Figure 11. Watersheets of Székesfehérvár on DTM for global planning

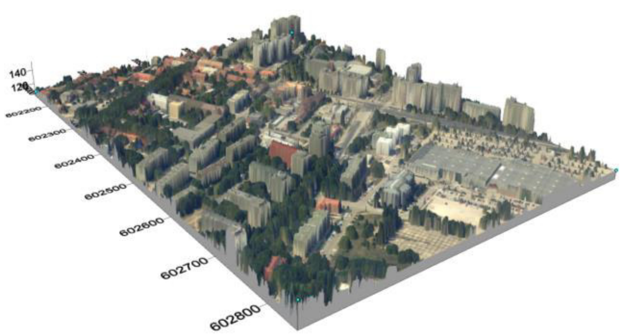

Figure 12. Figure 3-dimensional urban model, applied of LIDAR data (0,5 m) and high resolution true orthophoto (~0,2m), Székesfehérvár

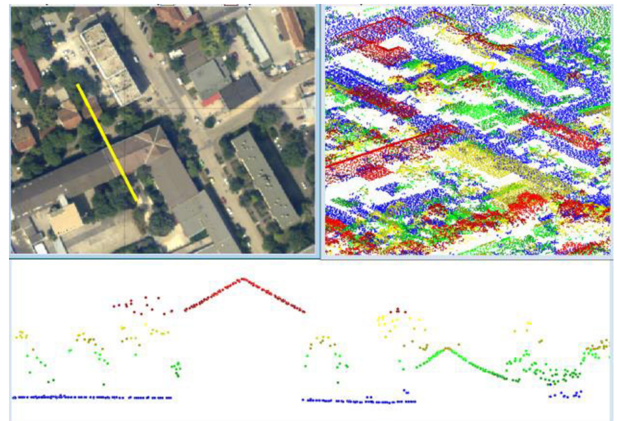

Figure 13. Orthophoto and LIDAR point cloud, Cross-section of a street.[1]

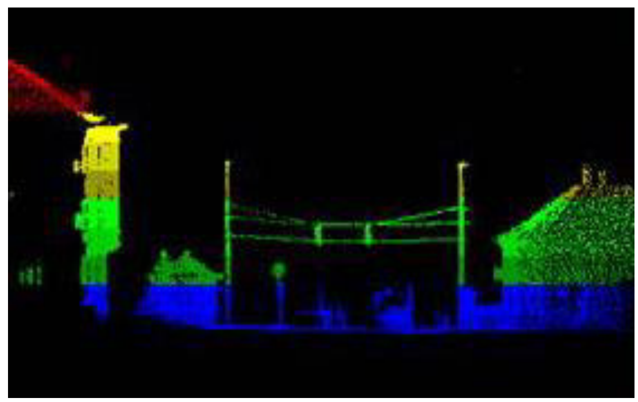

Figure 14. Cross-section of merged LIDAR and terrestrial laser scanned point clouds[2]

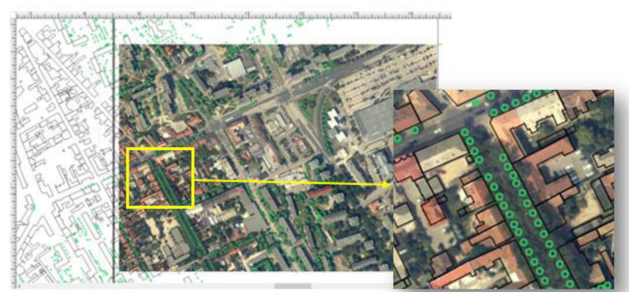

Figure 15. Cadastral map, high resolution true orthophoto and depicted individually measured trees in a common reference system

CONCLUSIONS

Data acqusition and processing techniques show different resolution and accuracy. It is important to understand that all of technologies have their strength as well as limitations, defined by the application they have been developed for. Usually, they can be used complementary, so joint use of these techniques is often recommended. None of these technologies is better than the other and none of them can be used optimally for all cases. The geometric resolution of LIDAR is better than the resolution of a satellite image, but the LIDAR itself has no continuous spectral information from the surface. We can prepare an industrial investment map using UAV technology, but the structure must be assigned field geodetic measurements. The technologies have changed, but the rule remains. The accuracy needs and efficiency demands are the primer factors to decide on the proper data acquisition method, and we choose the technique which best suits for our purpose.

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