Using VR to explore the 3D city model obtained from LiDAR data

Folosind VR pentru a explora modelul de oraș 3D obținut din datele LiDAR

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Abstract. *3D city models are tridimensional representations of cities, focused on buildings that can be used as a base for numerous analyses such as heat demand estimation, solar radiation estimation, visibility analyses, noise analyses, or for urban and emergency situations planning. Geospatial data used to develop such models can be acquired through different methods, one of them being using a LiDAR point cloud. Virtual Reality can be a useful tool in exploring these 3D city models and may offer a better understanding of the different situations that need to be analyzed. The aim of this paper is to investigate the possibilities of exploring the 3D model of Baia Mare city in a VR environment.*

Key words: *3D City Model, LiDAR, Virtual Reality*

1. Introduction

A 3D city model is a tridimensional representation of the built environment. A semantic 3D city model contains, additionally to the geometric information, other elements of urban knowledge, attributes of the represented objects and spatial relationships between the objects [1]. These city models are used in various applications such as underground land administration [2], life cycle assessment of building energy systems [3], city-scale ventilation analyses [4] and life cycle assessment of building stocks [5]. 3D city models can also be used to assess the energy demand of an urban area [6], [7], to calculate the amount of sun exposure of a building, in order to predict the efficacy of installing solar panels [8], to estimate the seismic damage [9], to plan the response in case of emergency situations [10] and in many other applications, synthesized in a study by Biljecki et al. [11]. 3D city models can be a tool to increase the energy efficiency and mitigate the effects of the climate changes [12]. Therefore, the

Smart City concept was introduced and it represents a solution to mitigate the impact that rapid urbanization and population growth have on the environment [13].

3D city models can be generated from different types of geospatial data, obtained through various techniques, such as TLS (terrestrial laser scanning) [14], [15], MLS (mobile terrestrial laser scanning) [16], [17], [18], ALS (airborne laser scanning) [19], [20], photogrammetry [21], [22], or a combination of ALS and photogrammetry [23].

While many papers focus on the data acquisition and 3D modelling of the buildings, they don't seem to address the visualization issue, which is essential for a better understanding of the various analyzed situations. In a study by Li et al., 2022 [24], a non-photorealistic visualization of 3D city models in a VR (Virtual Reality) environment was proposed. While this representation can be useful for experts in numerous fields, it may be difficult to comprehend for the general population. In this article, we aim to investigate the possibilities of exploring a 3D city model obtained from LiDAR (Light Detection and Ranging) data in a VR environment.

2. Materials and methods

Laser scanners use opto-mechanical assemblies that utilize an emitted laser beam and a received portion of the beam to determine the distance between the sensor and the object [25] by measuring the time of propagation [26].

ALS (Fig. 1) is one of the most used methods of geospatial data acquisition that allows collecting a large volume of data from platforms such as UAVs (Unmanned Aerial Vehicles), planes or helicopters. The main components of an airborne laser scanner are [26]:

- ✓ Scanner assembly, composed of laser, scanning mechanics and optics;
- ✓ Airborne GNSS (Global Navigation Satellite System) antenna;
- ✓ Inertial measurement unit (IMU), that records acceleration data and rotation rates;
- ✓ Control and data recording unit;
- ✓ Operator laptop;
- ✓ Flight management system.

Additionally, a GNSS ground station is required, to serve as a reference station.

The result of airborne laser scanning is a LiDAR point cloud, such as the one in Fig. 2 that represents a collection of object points with a known and accurate 3D position.

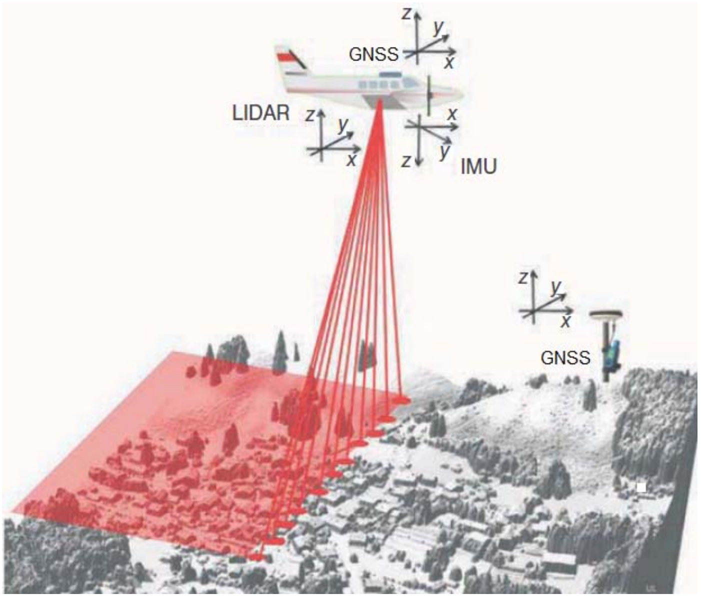

Fig. 1. Principle of airborne laser scanning [26]


Fig. 2. LiDAR Point Cloud

3D city modelling from a LiDAR point cloud involves point cloud classification, in order to determine the class that each point belongs to (ground, building, low vegetation, medium vegetation or high vegetation) and buildings footprint extraction. To generate the 3D city model of an area in Baia Mare City, we classified the point cloud in Fig. 2, each point being assigned one of the classes from Fig. 3 and we extracted the buildings footprints (Fig. 4) using a trained Deep Learning model. CGA (Computer Generated Architecture) rules were applied in CityEngine to generate the 3D models of the buildings. The rules included generating the streets, extruding the buildings footprints to a certain height derived from the LiDAR point cloud, modelling of the floors, windows and doors and adding textures to the surface. We obtained the 3D model of an area from Baia Mare city (Fig. 5) [27].

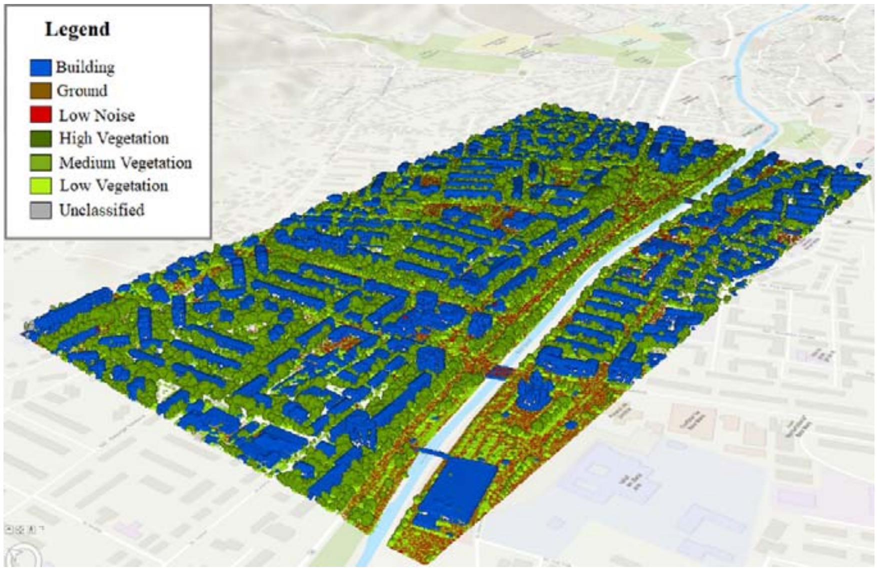

Fig. 3. Classified LiDAR point cloud

Fig. 4. Buildings footprints

Fig. 5. 3D model of an area in Baia Mare city

3. Creating a virtual reality application

In order to create the virtual reality application, we used ArcGIS 360 VR Experience.

We added the bookmarks in Fig. 6, which are used to navigate the virtual model on a desktop application (Fig. 7), on a mobile application (Fig. 8) or in a VR environment, using a VR headset. On the desktop application, the view can be changed by using the mouse cursor, while on mobile, the view can be changed by tilting and moving the device. When using a VR headset, the user can change the view by moving around.

Fig. 6. Bookmarks

Fig. 7. Virtual model of the city on a desktop app

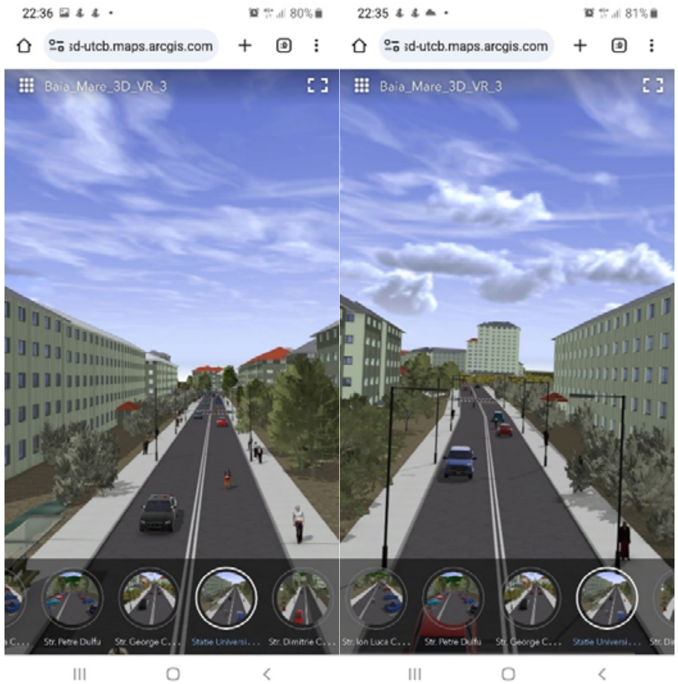

Fig. 8. Virtual model of the city on a mobile application

Unreal Engine is a 3D computer graphics engine, used to create visuals and immersive experiences [28]. While it is mostly used for videogames, it can also be used to enhance the visualization and exploration of 3D city models.

In this regards, we exported the model in a *.udatasmith format, a file standard used to import 3D scenes into Unreal Engine projects [29]. Then we imported the model in Unreal Engine (Fig. 9) for further editing. We added realistic textures of the sidewalks, soil, building walls and roofs, and other objects such as the total station in Fig. 10. We also edited the lighting, sun brightness and cloud opacity to achieve a more realistic view of the area.

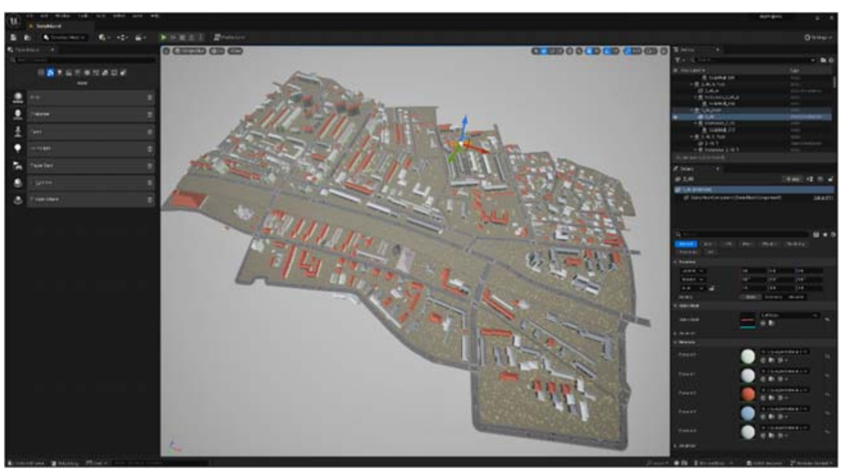
Fig. 9. 3D city model in Unreal Engine

4. Results and conclusions

3D city models can serve as a base for numerous analyses that support decision making and urban sustainability. The accuracy of these models depends on the data used to generate them and ALS is an efficient solution to acquire large amount of data in a short time.

Deep Learning models that use convolutional neural networks are the actual standard for LiDAR point cloud classification and building footprint extraction and can lead to accurate 3D city models.

By applying CGA rules to the buildings footprints, the buildings can be modelled in detail, with elements such as windows and doors.

VR visualization of the city model allows a better understanding of the analyzed situations and can lead to more efficient decisions. When comparing the models obtained in CityEngine and the models obtained in Unreal Engine, we noticed that by importing and editing the 3D model in Unreal Engine, we obtained a more photorealistic representation that can describe the reality more accurately than CityEngine alone (Fig. 10).

Fig. 10. Comparison between the CityEngine model and the Unreal Engine model

Therefore, we propose the following workflow for using VR to explore the 3D city model obtained from LiDAR data (Fig. 11):

a. LiDAR point cloud acquisition and classification and building footprint extraction;
b. Applying CGA rules to obtain the 3D models;
c. Data export in *.udatasmith format;
d. Editing the 3D city model in Unreal Engine;
e. Realistic model visualisation;
f. VR exploration of the model.

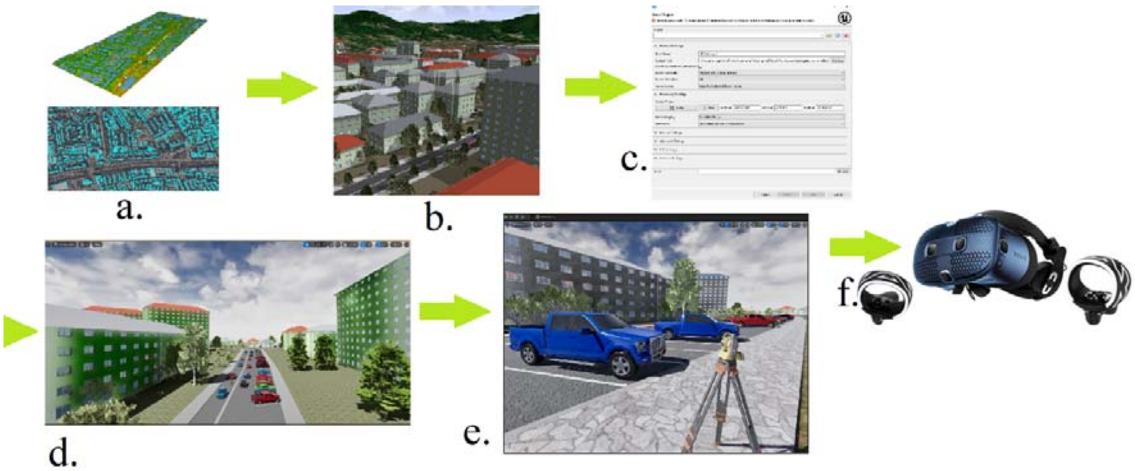

Fig. 11. Workflow for exploring the 3D city model obtained from LiDAR data

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