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Chapter IV

Geographical applications in virtual reality

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Abstract

The aim of study was to create a brief literature review about virtual reality and its geographical applications. This article contains introductions to LiDAR 3D-data with a focus on airborne and terrestrial laser scanning, and a historical overview on virtual reality and its geographical applications. This chapter is a literature review about the use of virtual reality (VR) and its geographical applications. The concept of VR has become very topical to geography students and teachers at the University of Helsinki due to the newly introduced virtual reality cabins and uses of those in the department's research projects. This article provides an introduction on the use of virtual reality in education.

Keywords: 3D data, Virtual Reality, VR, Airborne laser scanning, ALS, Terrestrial laser scanning, TLS, LiDAR, Education, teaching

3D-data from airborne laser scanning and terrestrial laser scanning

In geographical applications, the most prominent method to collect 3D-data has been LiDAR. Two the most common applications for LiDAR technology are airborne and terrestrial laser scanning. In this section, we introduce two methods for collecting 3D-data in remote sensing: airborne (ALS) and terrestrial laser scanning (TLS). These approaches utilize LiDAR (Light Detection and Ranging) technology, which uses light in the form of a laser pulse to measure distance to objects. LiDAR methods have the potential to collect millions of measurable survey points in minutes. The final product for ALS and TLS is typically a georeferenced point cloud that have many applications is virtual reality, for instance.

With the LiDAR, the distance from the sensor to the target is measured based on the time between the emission of the pulse and the detection of the echo that is backscattered to the sensor (Hyyppä et al. 2008). The sensor emits multiple laser pulses, the returns of which are classified. Multiple returns provide useful information that can help assess forest structure, for example. The first returns can be assumed to echo from the top of the canopy, while the last returns most likely originate from the ground level.

TLS is a LiDAR approach where the scanner is attached to a mobile platform, which can be transported wherever the target is located. TLS has the potential to provide very dense point clouds and the applications are practically endless. One can, for example, apply the method to archaeology, urban modelling, and forestry. However, the approach is expensive and requires a lot of funding. Still, the TLS method is very interesting, especially, from the point of view of virtual reality applications. The following sections go deeper into the concept of virtual reality and its applications in scientific research and teaching.

Virtual reality (VR)

History

Virtual reality (VR) groups together several technical inventions, which try to allow a user to experience simulated environments. Yung and Khoo-Lattimore (2017) conclude that virtual reality uses navigable and interactable 3D environments to achieve real-time simulations for user's different senses. They also found out that there are three defining elements to VR. First being able to look around in the simulated environment, usually by using a head mounted display (HMD). Second one is immersion, though suspension of belief and by having objects physically represented as in sensible objects in the virtual world. The third one is interactivity, achieved by having some sort of control over the experience.

According to Cipresso et al. (2018), a virtual reality system can be categorized by the degree of immersion. There are non-immersive systems, which consist mainly of a desktop and are simple and the most affordable. Secondly, semi-immersive systems such as stereo images of a 3D scene. The immersive systems are what most people see virtual reality as nowadays. They usually consist of an HMD, along with audio and haptic devices.

The history of VR began in the 1960's (figure 2) with Sensorama, a multimodal experience of 3D scenes and smells that could be considered the first VR device (Omer et al. 2019). The first system to include an HMD and head tracking was the Sword of Damocles. Head tracking in the system was explored with both mechanical arms and ultrasonic waves (Sutherland 1968).

Cipresso et al. (2018) has mentioned that during the commercialization of VR that started in the 1980's, appeared the first instances of what we could now consider as hand tracking or haptic devices. Data Glove, a sensory device was launched in 1985 and could measure the flexion of fingers along with their orientation and position. Binocular-Omni-Orientational Monitor (Boom) launched in the late 1980's allowed moving and broad virtual environments, along with mechanical hand tracking.

Since 2000's, improvements in processing speeds and the general hardware sizes have allowed companies to produce more consumer orientated VR devices (Omer et al. 2019). Especially video game companies have advanced VR to have higher field of views along with lower latencies. The development has also allowed the introduction of new sensors, for example eye-tracking systems (Cipresso et al. 2018). Also, the inclusion of smartphones into VR systems has allowed a wider userbase for the devices. Modern HMD systems can be divided into three categories: the first and the second being smartphone using headsets with or without additional functionalities. The third category includes headsets with their own graphics, specifically designed to be used without a smartphone (McMillan et al. 2017). They are the ones that provide a total immersion in a virtual environment when used along with other sensory equipment.

LiDAR and virtual reality

When LiDAR and especially TLS produced data is used within a virtual environment, new approaches can be found. When using an HMD, the dataset can be projected to the user based on his/her head orientation and position in real time. VR allows the visualization, integration, manipulation and querying of geospatial data (Zhao et al. 2019). Kreylos et al. (2006) found supporting evidence to their hypothesis that visualizing data in VR allows for more accurate and confident observations in less time. The immersion provided by an HMD is essential for identifying quality problems in the LiDAR data and allows workflow to be more efficient and accurate (Kreylos et al.

2008). In another study, the participants thought that using VR to viewpoint clouds allowed them to have a better idea of depth and the data's real-life implications. They also thought it to be especially beneficial to be immersed and to be able to manipulate the data in real time (Burwell, Jarvis & Tansey 2012).

Using VR to viewpoint clouds isn't totally problem free. In the Burwell et al. (2012) study, some participants also seemed to experience an information overload. This problem was due to the data having a fixed level of detail in all scales. Also viewing data in VR requires high end hardware: to have an immersive and intuitive visualization the system needs to be able to support 48–60 stereoscopic frames per second (Kreyolos et al. 2008). Kreylos et al. (2006) also believe that having the ability to manipulate the data directly in the visualization is crucial for the usage, which increases the cost of a system due to the need for hand tracking or other censors.

Zhao et al. (2019) have theorized a workflow for exporting LiDAR data into a VR system. Currently a game engine is needed to run a simulation in VR. One of the most common ones is Unity (Unity 2020), which is a cross-platform game engine (Navarro et al. 2018), but others with similar functionalities are available as well. Unity has the advantage of a free license and an accompanying development environment. It has been used together with LiDAR data on multiple studies (e. g. Mures et al. 2016, Garry et al. 2018, Navarro et al. 2018).

The VR engine used in Unity does not allow point clouds to be imported straight away, but instead requires data in a mesh format, which is a combination of vertices, edges and faces (Navarro et al. 2018). Before the mesh creation, the points can have shading values or RGB values assigned to them (Zhao et al. 2019). To create a mesh from the point cloud, the data first needs to be generalized, to reduce the amount of points. After the reduction, it is triangulated and imported to unity as a mesh. Finally, it is used with a Unity based program or script (Navarro et al. 2018).

Virtual reality in education

Virtual reality has been used in teaching since 1960's (Kavanagh et al. 2017). In the beginning they we mostly used in different kinds of pilot simulators, but slowly they have spread to other areas of education and training too. But even though it has become more common especially in higher education, its role is still limited in specific questions and subjects rather than being for used basic teaching method. Naturally studies what are originally based on the platforms of virtual reality are done in it, but also when tasks and practices which are too expensive, dangerous or difficult to perform in traditional ways. So, the reasons to for VR to spread is the possibilities it serves, safe environment and its cost-effectiveness on some occasion.

However, there are also problems in VR. According to Kavanagh et al. (2017) software usability is the most common issue, covering 48.6% of reported problems in VR use according to their studies. New software requires its own studying before VR itself can be used for studying other subjects. So at least the basics mechanics of the software need to be managed.

We see that in geography VR has several different possibilities to be used. In urban and regional planning, 3D pictures are used to demonstrate and observe plans. For example, in complementary building it's fast way to examine heights and shadows of building in right scale, and with 3D observing the picture is much more realistic than in 2D. Different kind of 3D softwares are also fast and flexible way to compare different solutions in placing buildings and structures without need to make the whole plan from the beginning.

Again, in physical geography getting to know your study area beforehand is easier and cost-effective compared to travelling to location. That is especially in distant locations and difficult terrain or wide areas. The benefits of VR can also be exploited in examining geomorphological formations and studying them. The process of erosion and the formation of different kinds topography are also easy present via VR.

Conclusion

This review shows that virtual reality (VR) can have prolific applications in the science of geography. LiDAR data, especially, has various applications to be used in the Department of Geosciences and Geography. The applications for virtual reality are practically endless and this report shows that especially educational applications are viable.

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