Open-source web-based viewer application for TLS surveys in caves

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Abstract. This paper introduces an open-source web viewer developed for terrestrial laser scanning (TLS) surveys carried out in caves. The survey data is visualized as a set of rotatable and measurable spherical panoramas supplemented with an overview map. The viewer includes a tool for measurements in the point cloud and a simple cross-section tool as well. The application was implemented using Pannellum, an open-source WebGL based panorama viewer and the OpenLayers web mapping framework.

Keywords. cave, TLS survey, web viewer

1. Introduction

In the recent years, laser scanning became more and more popular in cave surveying (e.g. Buchroithner, Milius, Petters 2011 or Silvestre, Rodrigues, Figueiredo, Veiga-Pires 2015). The authors also had previous works in the Pál-völgy Cave (Gede et. al. 2013) and the Szemlő-hegy Cave, Budapest. Due to the size of the equipment, TLS is usually used in spacious chambers of caves; however, these data can indirectly help in the research of narrower passages as well by verifying the results of various cave shape and size estimating models (e.g. Albert, Virág, Erőss 2015).

These surveys result in enormous amount of data in the form of dense point clouds. While this data can be very useful source material of further speleological research, its processing requires high-performance computers and

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special - usually expensive - software, which excludes several possible researchers from this possibility. Our aim was to develop an open source framework for viewing these point clouds on the web, as well as providing simple measuring tools for researchers and annotation possibilities for disseminating information connected to caves.

This tool is not a real 3D viewer, but a series of spherical panoramas emulating the point clouds of the separate scanning stations. The advantage of this solution is that it does not require any special hardware or software for viewing - the only thing needed is a decent web-browser with WebGL support.

There are, of course, similar solutions for this task, e.g. Leica's TruView or Faro WebShare. These software have, however, serious drawbacks: TruView depends on a client-side plug-in working only in Internet Explorer on Windows systems (Leica Geosystems 2015); WebShare requires a high performance server (FARO 2015).

2. The survey

The viewer application introduced in this paper was created for visualizing the data of a recent TLS survey. This survey was carried out in February, 2015, in the Béke Cave of the Aggtelek Karst Plateau in northeastern Hungary. This cave was discovered in 1952 and is part of the UNESCO World Heritage since 1995. Its total length is 7 kilometers, of which the main cavern is about 4300 meters. It has been formed by a constantly active cave stream, so numerous spectacular erosional forms (e.g. meanders, siphons, terraces) can be found in the cave. The cave is also abounding in stalactites and stalagmites, additionally, there is a large calc-tufa dam, subject of several recent geological studies.The cave is also used for medical purposes: its air is rich in carbon dioxide which is utilized in the treatment of respiratory diseases.

The first map of the cave was drawn by László Jakucs and his group in the years after the discovery. It served as a basis of the next, more accurate survey in 1964-65 by Gábor Kőhalmi. Based on the data of this latter survey, a new adit was built, connecting the cave to the nearby village of Jósvafő. These surveys represented the cave as a thin, solid line, but it was not enough for scientific research, and nature protection objectives. In 1990-95, Gábor Szunyogh and Judit Kisbán carried out an 1:100 scale survey with analogue methods and created a topographic atlas of the cave in 74 A1 pages (Szunyogh, Kisbán 2004; Aggtelek National Park, 2015).

During the present survey, the surveyor group worked 18 hours underground in 2 days. 32 scenes were scanned by a Leica ScanStation C10 terrestrial laser scanner (courtesy of the Institute of Geoinformatics, Alba Regia Technical

Faculty, Óbuda University), creating a continuous point cloud of an approximately 350 m long part of the cave. This scanner has 360° x 270° field-of-view which means that only a small circle under the scanner is not scanned. The scanner resolution was set to 1000 points per radian, which means one centimeter between the points on a perpendicular wall in 10m distance from the scanner. As the average width of the cave is about 4-5 meters, the actual point density is much more.

Although the field work was timed to the driest part of the winter, the melting of the snow caused by mild February weather resulted unexpected water level of the underground stream in the cave: its depth reached half a meter at some places, making sometimes troublesome to place the scanner and even to move in the caverns. Additional difficulties included the lack of electricity and lighting in the cave (the helmet lamps were the only light sources), and the hard terrain (the cave entrance can only reached by AWD vehicles on a rocky and muddy dirt road).

The point cloud was georeferenced using the control points of a previous geodetic survey. These control points (small metal rivets in the wall) were scanned in high resolution wherever it was possible.

3. The base viewer

The point cloud viewer is based on the open-source Pannellum panorama viewer developed by Michael Petroff (Petroff 2015). The original Pannellum viewer can be embedded to web pages using an <iframe> element, and supports equirectangular and cubemap panoramas - this latter in multi-resolution as well. The panoramas can be supplemented with annotations, hyperlinks and organized into “panorama tours” (multiple panoramas linked to each other) via JSON configuration files. Pannellum requires no plug-in or any additional software as it is JavaScript and WebGL based. The software supports traditional desktop use as well as touchscreens and – if the browser supports it – fullscreen mode.

The only drawback of Pannellum is that running in an <iframe> element means it is hard to interact with the embedding web page, which is essential in our case.

4. The modified viewer

As the MIT License (under which Pannellum is distributed) grants the right of modification, the viewer was restructured and supplemented with additional features.

The most important change is that the viewer is no longer embedded into an <iframe> but into a <div> element instead; embedding is realized with a JavaScript function call. It means that the panorama becomes an integrated part of the embedding HTML document's Document Object Model, therefore the page and the embedded panorama can interact with each other. To facilitate this, a set of event handler functions can be defined when embedding the viewer to events like "viewchange" (the panorama was rotated or zoomed into), "scenechange" (user changed to a new panorama) and other events in relation with the new functions dealing with the point cloud data.

Another significant modification is the use of point cloud data in panoramas. Any of the panoramas can be accompanied by such data, simply by defining its source and properties in the appropriate section of the JSON configuration file. Once the viewer loads the data, a panel appears in the corner of the panorama viewer with the Cartesian coordinates of the point under the mouse pointer, as well as buttons of two additional tools. The first one is a "tape measure" to measure distances in the point cloud. The user can place measure lines within the panorama that remain there while the measure tool is active. The second one is a dynamic section drawing tool. When active, the cross-section of the point cloud appears on a small panel. The section plane is a vertical plane crossing the current scanner station position, rotated always to the viewing direction – which means that the cross-section image changes if the panorama is rotated (Figure 1).

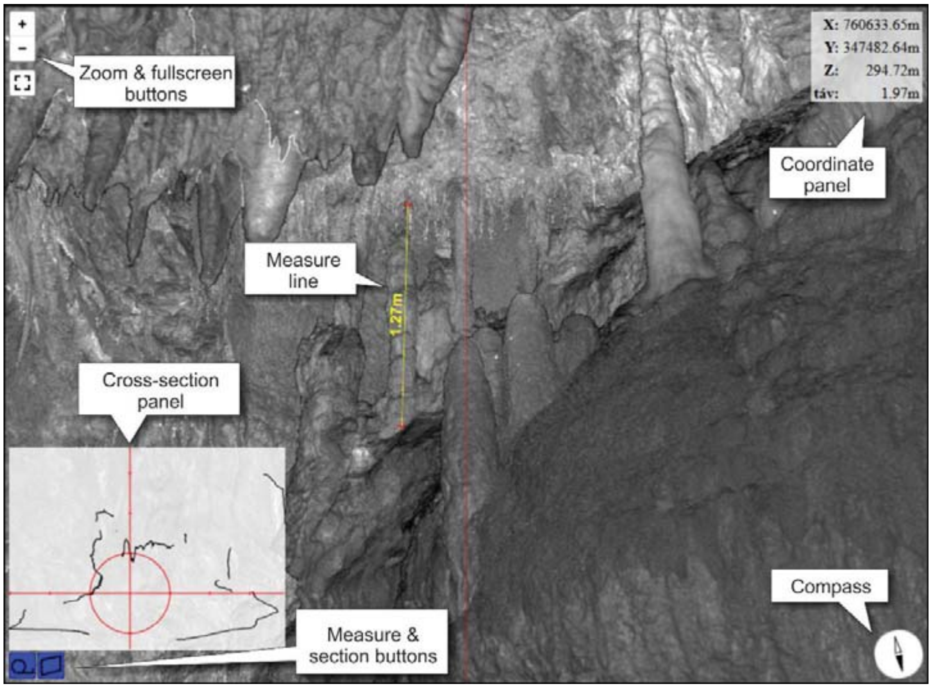

Figure 1. Features of the point cloud viewer.

5. Storing point cloud data

Due to the working mechanism of the scanner, the point cloud of a single scanning station consists of non-overlapping points forming a grid when using 3D polar coordinates (yaw, pitch and range) instead of 3D Cartesian ones. Therefore, the simplest way of storing the point positions is a raster format: a matrix of distance and intensity values, where the row number of the matrix is proportional to the pitch of the point while the column number to the yaw.

The intensity matrix forms an image (Figure 2) which can be used as an equirectangular panorama image in panorama viewers. Using a raster image format can also be an option for the distance matrix as well, encoding distances into 24-bit fixed point numbers treated as RGB codes. The only restriction is that the image must use a lossless compression. Our application stores the distance matrix as a PNG image (Figure 3). This way the data is compressed, which results in shorter downloading times and less space needed on the server, while there is no need of additional software components for decompressing as the JavaScript interface of HTML Canvas element (which is supported in all recent browsers) provides functions for reading image data.

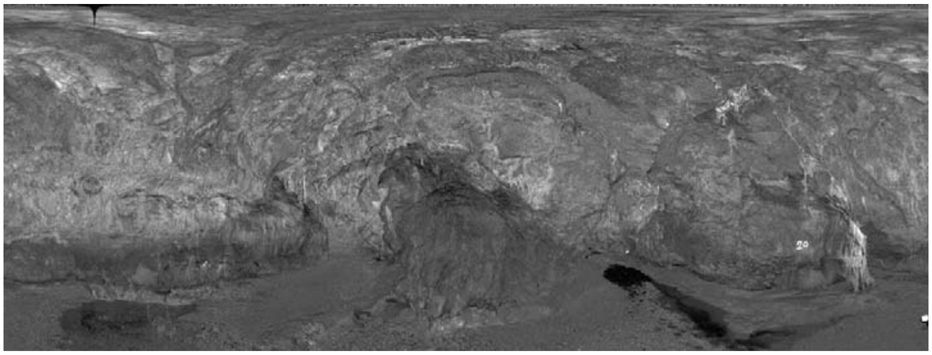

Figure 2. Intensity matrix as equirectangular panorama image

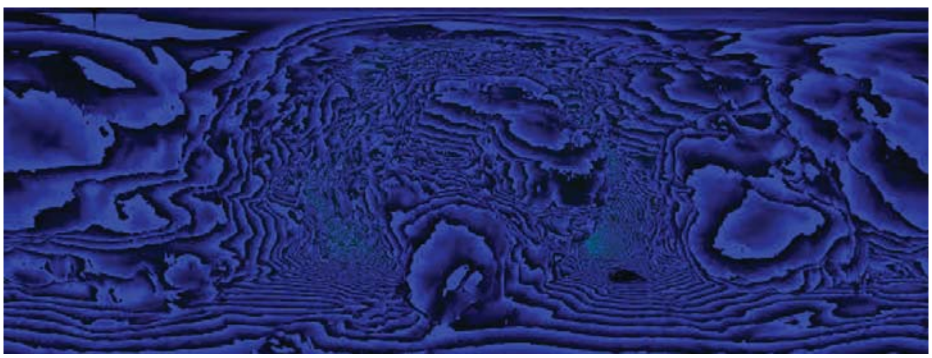

Figure 3. Distance matrix encoded as 24-bit RGB image

6. Integrating the panorama viewer and the cave map

Cave surveys usually consist of several scans therefore it is advisable to show information about the relative and/or absolute position of the scanner positions. The website of the current survey shows a possible solution for this. The website (http://lazarus.elte.hu/cavescan/beke/pano) consists of two panels: an overview map on the left side and the panorama viewer on the right (Figure 4). Initially the panels are equal in size, but it can be changed by dragging the separator line between them.

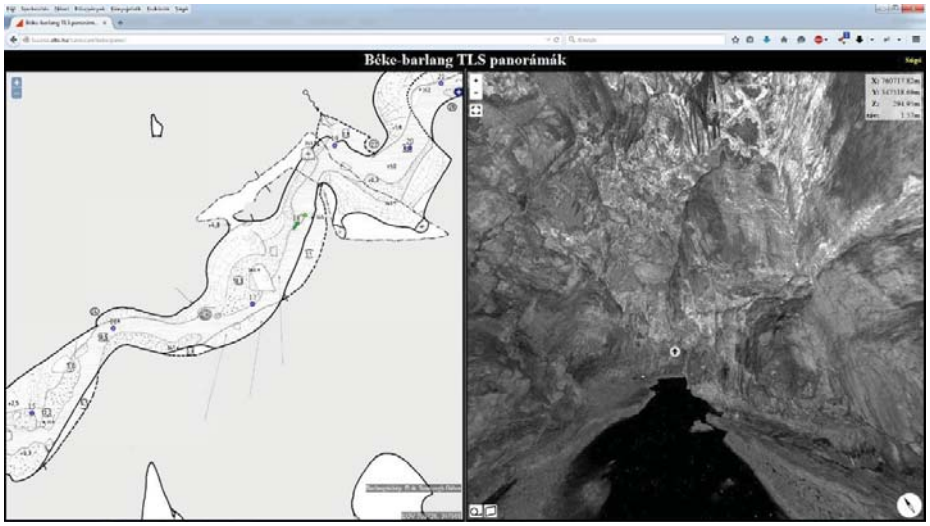

Figure 4. Screenshot of the sample website

The overview map was implemented using OpenLayers. Users can switch between two base layers: a georeferenced mosaic of a hand-drawn cave map and the vertical orthographic view of the point cloud. The places of the scanning stations appear as numbered dots; clicking the symbol switches the panorama viewer to the given station. The symbol of the active station is an arrow, always pointing to the viewing direction. A moving green dot on the map represents the current position of the mouse pointer if it is in the panorama viewer. If the cross-section tool is active, a red line indicates the horizontal footprint of the current cross-section.

The website is supplemented with brief help which appears in a popup window when the user clicks the “Help” link in the top right corner.

7. Feedbacks, Conclusions, Further plans

The first feedbacks show that this viewer is a useful tool for earth science researchers working on topics related to the cave, as they can examine the underground scenes and make measurements on it from the office without the need of special software or hardware.

Although the viewer supports touchscreen operations, a mouse is needed to get full functionality, as there is no touch gesture equivalent of moving the mouse without dragging something. Further examinations should find an efficient substitution of this event (that currently drives point cloud coordinate displaying) on touchscreens in a way that does not interfere with other touch gestures.

A simple 3D line tracking tool is under construction; this tool will allow users to draw polylines and polygons in the panoramas that can be saved as 3D vector graphics (in X3D or VRML format).

The viewer is free and open source and can be adapted to other uses even in its present form. To facilitate such use, we plan to add more flexibility to the application programming interface as well as a detailed documentation for developers and tools to produce the required JSON files, the distance and intensity matrices from various point cloud formats.

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