Web-based 3D processing and dissemination of multibeam sonar data

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The continuous detailed surveys of the various water bodies, over time, produce a large and ever-increasing volume and density of underwater sounding data. Three-dimensional data, such as that obtained by multibeam sonar systems, are quite complex to manage; and thus, their growing numbers increase the pressure on the development of new solutions dedicated to processing them. This paper presents a concept system for a web-based dissemination of multibeam data in a geographic context. In order to maintain an easily accessible user interface, processing and distribution of such datasets in the web environment requires the data to be converted into a file format which is fit for processing via a web browser. Because of this, the presented system uses the emerging 3D Tiles open standard for serving multibeam point clouds alongside reconstructed three-dimensional models of shipwrecks, to remote users in a web environment, by means of Cesium, an open source Web-GIS library for 3D visualization of geospatial data.

Keywords: GIS, web, multibeam sonars, 3D, point clouds, processing

1. Introduction

Multibeam sonar systems are a major source of underwater data, as they usually produce files describing the surface of the seafloor, or the approximate shape of various underwater objects, in the form of three-dimensional point clouds [1]. Each file contains several types of geospatial information stored in separate datagrams, which describe data such as the depth of measured points, as well as orientation and geographic coordinates of the sonar obtained during measurements [2]. In order to obtain a point set, which would be convenient for viewing (as presented in Fig. 1), the output 3D coordinates of each point must first be calculated from proper values stored in the input file.

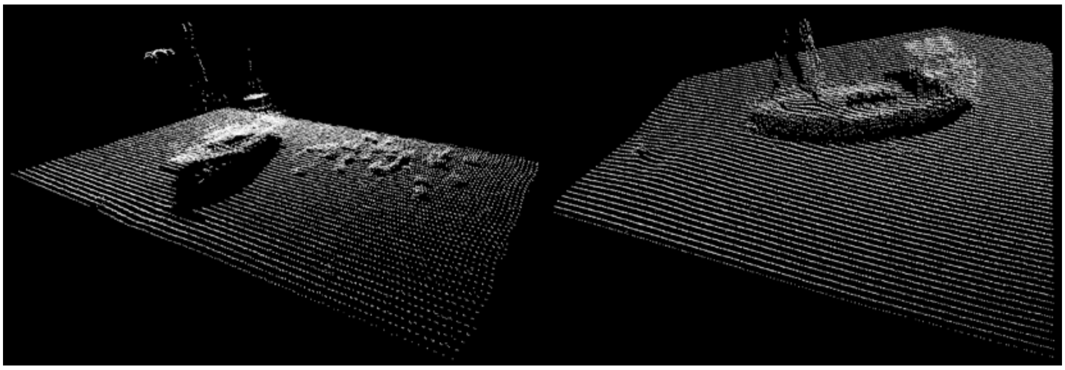

Fig. 1. Sample point clouds, representing underwater regions with shipwrecks.

Existing methods for storing multibeam sonar data are primarily focused on preserving disk space by the means of compression [3], and binary coding [4]. Since the data acquired by multibeam systems is usually split into many files, it can be difficult to view an area as a whole, and compare features such as spatial relationships between objects stored in separate datasets. On the other hand, storing the data as a large single file can lead to other problems, such as the increased amount of time required to read a desired fragment of the dataset, or to send the entire file through the network. Another problem is displaying the contents of such data in a 3D environment - existing methods for achieving this goal include partitioning the data, and displaying it with the use of specialized OpenGL software [5], as well as using HTML5 technologies (such as WebGL) for viewing streamed data inside a standard web browser in the form of point clouds [6], and Digital Terrain Models [7].

This paper presents a method for storing the underwater data acquired by multibeam sonar systems in a way that allows for its processing and dissemination in a geographic context, using open web standards.

2. Proposed solution

Convenient processing and dissemination of multibeam data requires the original files to be converted into a format which would be suitable for accessing smaller fragments of the data, and combining them into larger datasets describing the contents of the desired area in real time. After the conversion, the output files should preserve the accurate geographic coordinates of each point, which can be difficult in the case of data describing small objects located in world space [8]. In the case of distributing the data through the web, this raises an additional problem with the lack of standardisation; which means that the exchange of the data between different applications requires them to be adapted to each other's method of communication. Fortunately, these problems have been addressed in the emerging 3D Tiles standard of storage, integration and web-based dissemination of three-dimensional data, based on an open specification [9] proposed by the authors of Cesium, an open source JavaScript library for creating 3D Web-GIS applications [10]. The specification organizes geospatial data in a hierarchical structure consisting of sectors called “tiles”, where each tile represents a fragment of a larger dataset containing three-dimensional information. A single tile has a bounding volume which completely encloses its contents and may also contain 3D data in the form of point clouds or solid meshes (based on the GL Transmission Format). Each tile may also be divided into smaller sectors in several different ways using either uniform or non-uniform subdivision methods (Fig. 2). This enables the user to pick the appropriate method depending on the situation. For instance, a non-uniform k-d tree subdivision can offer a balanced tree for sparse datasets, while an octree will be more suitable for uniformly distributed data. The bounding volumes of the child tiles may overlap, which may be useful if a single object, such as a 3D model, is located inside more than one tile.

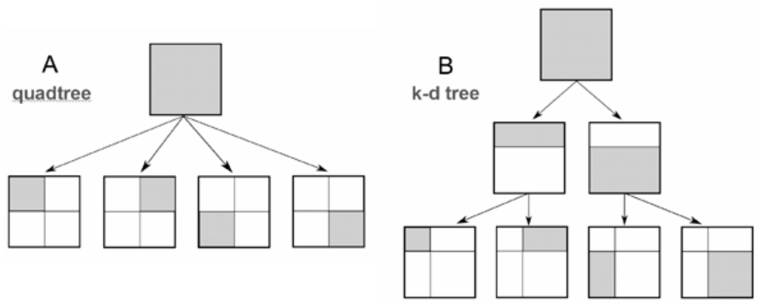

Fig. 2. Difference between a uniform quadtree (A) and a non-uniform k-d tree (B) tile subdivision.

The converted data must be stored on a server which will make them available to remote clients compliant with the 3D Tiles standard by issuing proper web requests, which can be generated with the use of the Cesium library. At the time of writing this article, the Cesium implementation of the 3D Tiles standard is available only in the experimental *3d-tiles* branch [11]. Unfortunately, since this implementation is still in early development, no conversion tools have yet been provided. This means that until this branch becomes stable, users are required to create their own data conversion software. A sample system utlilizing the 3D Tiles standard is presented in the following section.

3. Results

A concept system for web-based dissemination and 3D visualization of multibeam data in a geographic context has been implemented with the use of the emerging 3D Tiles open standard, and an experimental version of the Cesium library. The architecture of the system is presented in Figure 3. The pre-processed 3D Tiles containing original point data, as well as, reconstructed models of several shipwrecks (in the glTF format) are stored on the Tile server. From there, the data is made available through web requests generated by the Cesium Client launched on the devices used by remote users. The application provides the users with a three-dimensional visualization of the Earth, and basic tools for controlling the camera. It also allows for integration of data from many different sources, including WMS, WMTS, KML, Bing, OSM and GeoJSON.

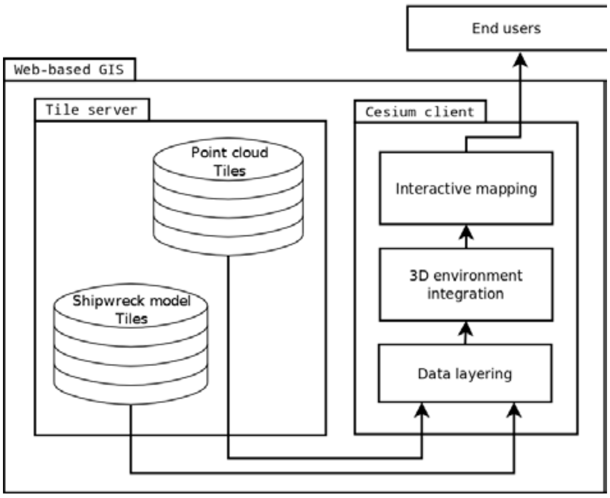

Fig. 3. Architecture of the proposed Web-GIS for 3D imaging and distribution of multibeam data.

The multibeam sonar data used in this article covers a large area of the Gulf of Gdańsk, as depicted in Figure 4. Several fragments of this data were converted into the 3D Tiles format by recalculating the coordinates of the original points, and dividing them into sectors small enough to be easily transferred via the web. Specialized software had to be created in order to perform the conversion process. The area of research was split into a regular tile grid where each tile covers 100 m^2 and the average tile size is around 150KB. In order to be presented with the data, the user needs to zoom in over an appropriately small area so the proper tiles can be downloaded without the need of transferring unnecessarily large datasets. In the case of point tiles, the data contains geographical coordinates of each point, as well as a colour value assigned to each point, calculated from its depth. Figure 5 shows a view of coloured point clouds, representing the seafloor along with several shipwrecks

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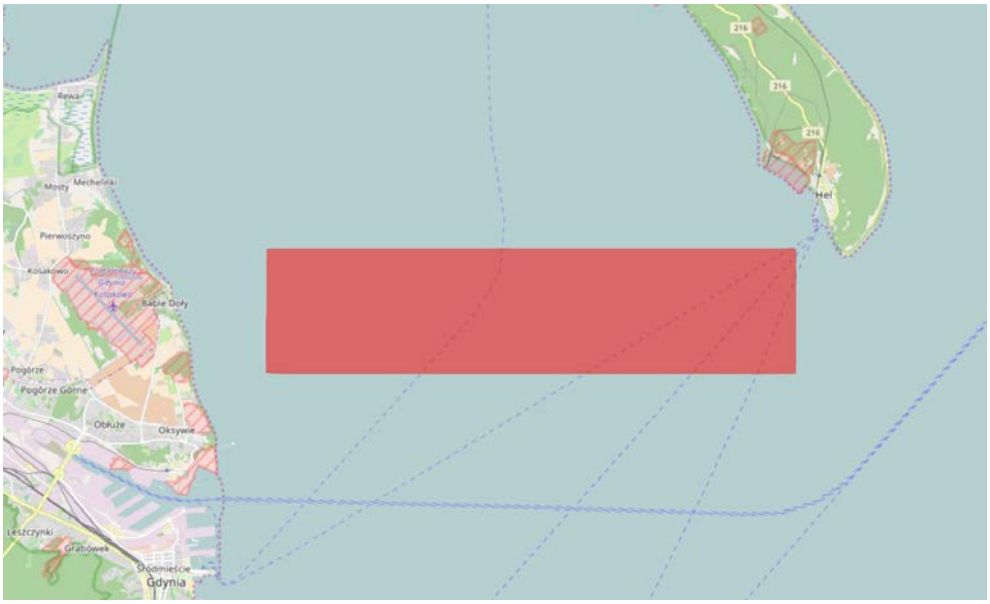

Fig. 4. A map of the investigated area.

Fig. 5. Sample point clouds representing a fragment of the Gulf of Gdańsk featuring shipwrecks.

Figure 6 shows the results of dividing the point data into tiles, where the bounding volumes of visible tiles are depicted in red.

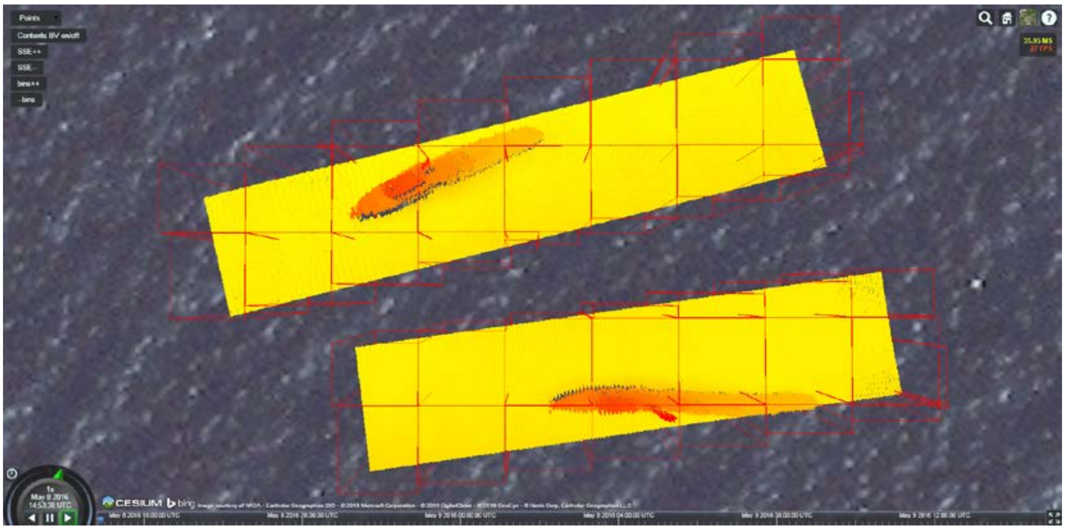

Fig. 6. The results of dividing multibeam point clouds into tiles.

The system is also capable of displaying 3D models representing the approximate shape of various shipwrecks found in the area, which have been reconstructed from the original multibeam data, and are served as Batched 3D Model (b3dm) tiles. A sample mesh is shown in Figure 7.

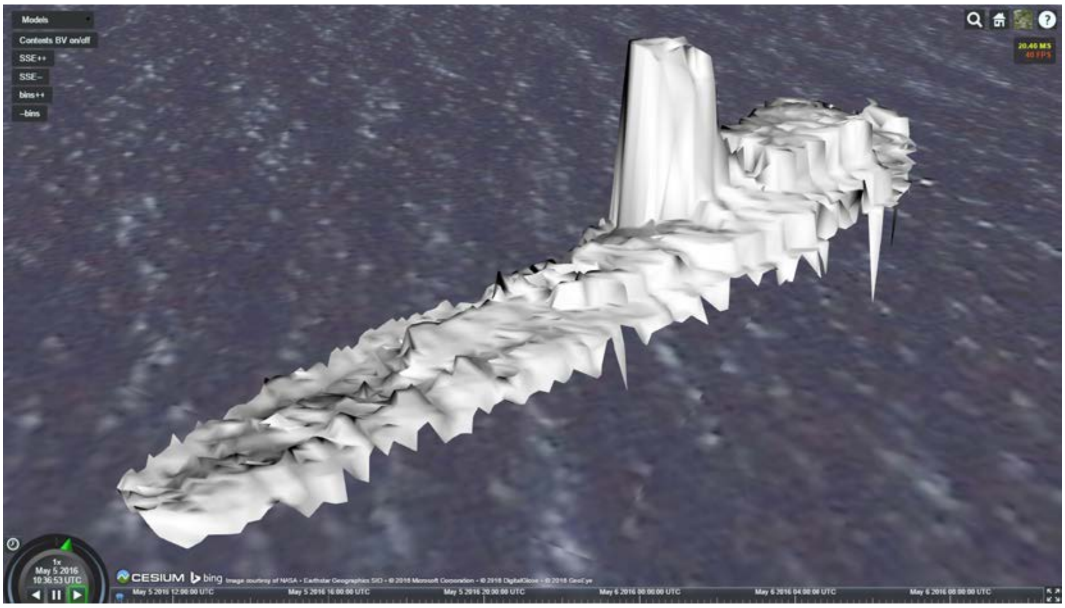

Fig. 7. Sample 3D model of a shipwreck reconstructed from multibeam sonar data.

4. Conclusions

The proposed solution allows for fast, convenient, and simultaneous, viewing of data stored in separate files in a geographic context, which can be useful when analyzing the spatial relationship between multiple objects. The data can be viewed in a WebGL-compliant browser without using specialized software, and distributed to remote clients with the use of technologies based on open standards. In its current state, the proposed solution does not allow the client to modify the three-dimensional data which resides in the server; but the upcoming versions of the 3D Tiles specification promise client-side data modification and upload in the near future.

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