Blending tools for a Smooth Introduction to 3D Geovisualization

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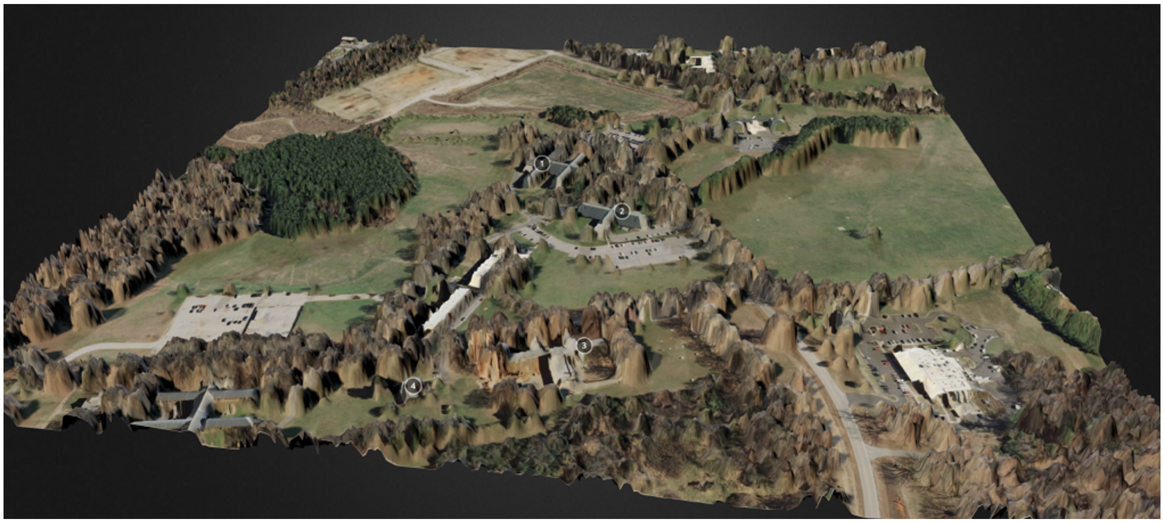

Figure 1: Student work: 3D Terrain of Dorothia Dix Park in Raleigh, North Carolina with draped orthophoto and four tagged landmarks. See the student's interactive visualization at https://sketchfab.com/models/3b20433015a84c93b7a22a1241361ae8

Abstract

Gathering data and practical examples for teaching 3D geovisualization can be time-consuming for instructors. We present a set of innovative, ready-to-adopt materials on 3D geovisualization for terrains. These material show how 3D visualization tools, Blender and SketchFab, can enable students to build 3D interactive visualizations of landscapes. With these tools, rapidly generating visualizations and experimenting with key graphics components, such as texture and lighting, does not require an extensive programming background. Written instructions and videos explain how to create and customize the visualization of a landscape with various surface properties. Additionally, step-by-step labs guide students through the process of creating their own 3D landscape visualization. These materials provide hands-on experience with a practical application of 3D visualization and expose students to several common types of geospatial data.

1 Introduction

The development of three-dimensional (3D) data visualizations, may prove a challenge for students without a rigorous programming background. An understanding of computer graphics concepts and programming is needed for developing custom 3D visualizations with libraries such as OpenGL or VTK. For this reason, instructors may be compelled to limit the topic of 3D visualization to literature surveys of perceptual studies on appropriate usage. In this paper, we contribute a set of pedagogical materials that can be used to familiarize students with certain computer graphics aspects of 3D visualization and allow them to gain some hands on experience by following step-by-step examples in a graphical user interface (GUI) environment. We focus on geospatial examples, since the geospatial domain is rich in 3D data and represents a case in which the nature of the data clearly justifies the use of 3D [7]. These materials can also serve to familiarize students with several common types of geospatial data and terrain analyses.

To make these materials accessible to students with limited knowledge of computer programming, we use tools that have graphical user interfaces for creating 3D scenes. Specifically, our lessons use Blender and Sketchfab, both of which enable users to import data, control texture and lighting, and navigate 3D scenes. Blender, a desktop software, has more functionality than Sketchfab, but Sketchfab, a browser-based tool, has a simpler interface and enables users to host and share their results online.

The "3D Visualization of Geospatial Data" materials found on GitHub [8] provide learning modules that introduce Blender and Sketchfab software and explain the process of transforming common geospatial data formats into 3D objects. They also explain how to visualize geospatial terrain analyses, hydrology and viewshed, and how to annotate and share geospatial analysis in form of an online interactive 3D model.

This papers describes the tools and data used in these lessons, explains the teaching module objectives in more detail, and provide usage recommendations.

2 Tools and Data

Before discussing the modules themselves, we first introduce the software tools, specify the geographic sites used in the lessons, and define the geospatial data and analysis terms used in the learning modules.

2.1 Blender and Sketchfab Software

Blender is a free and open-source software for 3D modelling, animation, and game design [1]. When coupled with a Geographic Information Systems (GIS) add-on [2]. Blender's 3D scene can be

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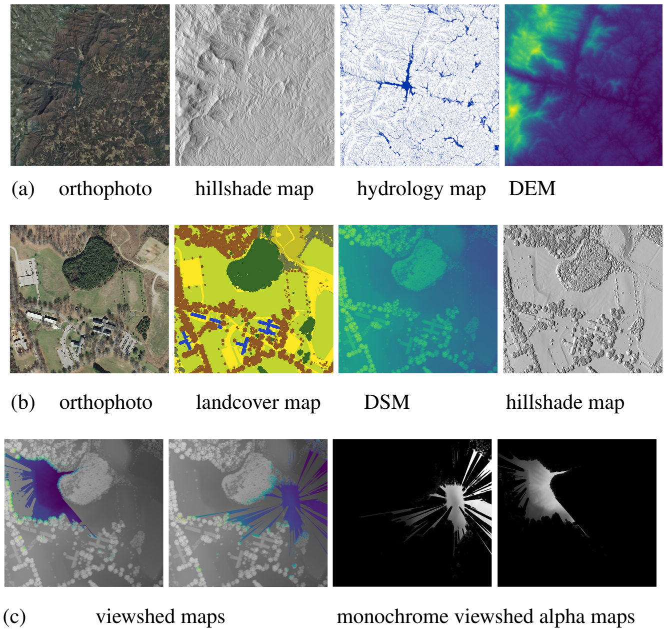

Figure 2: Sample datasets used in the lessons grouped by location: (a) the Great Smoky Mountains site in western North Carolina and (b) the Dorothea Dix Park site in Raleigh, North Carolina. (c) shpws viewshed data also from the Dorothea Dix Park site.

georeferenced to support various geospatial data types. Blender can also be programmed (through a Python-based API). This software has a complex user-interface that may be challenging for students with limited background in 3D modeling and rendering. Hence, we pair Blender with Sketchfab [6], a free cloud-based platform for sharing and interacting with 3D models. Sketchfab has a streamlined interface with preset lighting and simplified shading options. In this way, students can easily produce and share interactive visualizations while benefiting from the GIS capabilities and the 3D modeling power of Blender.

2.2 Geospatial Data and Analysis Terms

The materials feature two real-world datasets. The first site in the Great Smoky Mountains of western North Carolina is part of the Smoky National Park grounds. This large natural landscape consists of craggy, lake-dotted terrain. The second, smaller site, Dorothea Dix grounds in Raleigh, North Carolina, a former hospital campus was recently acquired by the city to be developed as a recreation destination. The more than 300 acre site includes a variety of buildings and vegetation types, making it an engaging tangible example. The terminology for the geospatial data formats in which these datasets are delivered are defined next.

The data includes vector and raster, two alternative geospatial data storage approaches. Vector data, most often stored in *shapefile* format, stores points, lines, and polygons along with data attributes. These geometric primitives represent geographic objects (such as cities or political boundaries). This data storage approach is referred to as vector data, as opposed to grid-based raster data. Geospatial *rasters* are geo-referenced images consisting of matrices of cells (or pixels), each of which contains a value representing a data attribute at that point, such as elevation or temperature. The vector and raster data included with the lessons are as follows:

- Vector Data
  - *Point cloud*. Point cloud datasets are composed of 3D point data that usually include elevation and color information about the Earth's surface. A common instrument to collect point clouds is LiDAR (Light Detection and Ranging) laser scanners. We retrieved a shapefile defining a point cloud for the Dorothea Dix site from the NC Spatial Data Download site [5].
- Raster Data
  - *Digital elevation model (DEM)* and and *digital surface model (DSM)*. Using interpolation in a GIS, we converted the Dorothea Dix point cloud to a DEM (Fig. 2(a)) and a DSM Fig. 2(b)). These are 3D representations of the Earth's surface. DEMs represent bare earth elevation information. A DEM for the Great Smoky Mountains site was downloaded from the USGS National Elevation Dataset [10]. DSMs, on the other hand, include the above ground surfaces such as tree canopies or buildings. These maps were provided to students in geotiff format.
  - *Hillshade map*. A hillshade map (Figs. 2(a) and 2(b)) is a grayscale 3D representation of the surface, shaded with respect to the sun's position. Hillshade can be used as a bump map to reinforce the 3D representation of the surface.
  - *Landcover map*. Land cover (Fig. 2(b)) is a commonly used raster map that represents land use patterns such as regions with vegetation, buildings, water, forests, and so forth.
  - *Orthoimagery*. An orthophoto (Figs. 2(a) and 2(b)) is a georeferenced images of the earth captured by satellite. An orthophoto for the Dorathea Dix campus was downloaded from the NC Orthoimagery Program [4].
  - *Hydrology map*. A hydrology map (Figs. 2(a)) represents surface hydrology including water streams and lakes.
  - *Viewshed map*. A viewshed is a raster map that represent the surface visibility from a given location. We provided two different viewshed representations. One draped on a grayscale color DEM (Fig. 2(c), left two images), and the other as monochrome alpha (transparency) maps (Fig. 2(c), right two images) that can be used as an emission texture in Blender and Sketchfab to generate a glow effect.

With these materials, students get to work with a variety of common geospatial data, while they can creatively design unique visualizations by combining different maps for texturing and lighting the surface model.

3 Structure of Lessons

The materials were designed to be delivered in two lessons, each comprised of two narrated and annotated video tutorials accompanied by written descriptions and assignments in a form of step-by-step instructions. The lesson configuration is summarized as follows:

- Lesson 1
  Introduction to Blender (Video 1 & Description 1)
  Introduction to Sketchfab (Video 2 & Description 2)
  Assignment 1: Working with Blender and Sketchfab
- Lesson 2
  Using GIS data Blender (Video 3 & Description 3)
  Applying GIS layers in Sketchfab & Blender (Video 4)
  Assignment 2: Blender to Sketchfab Workflow

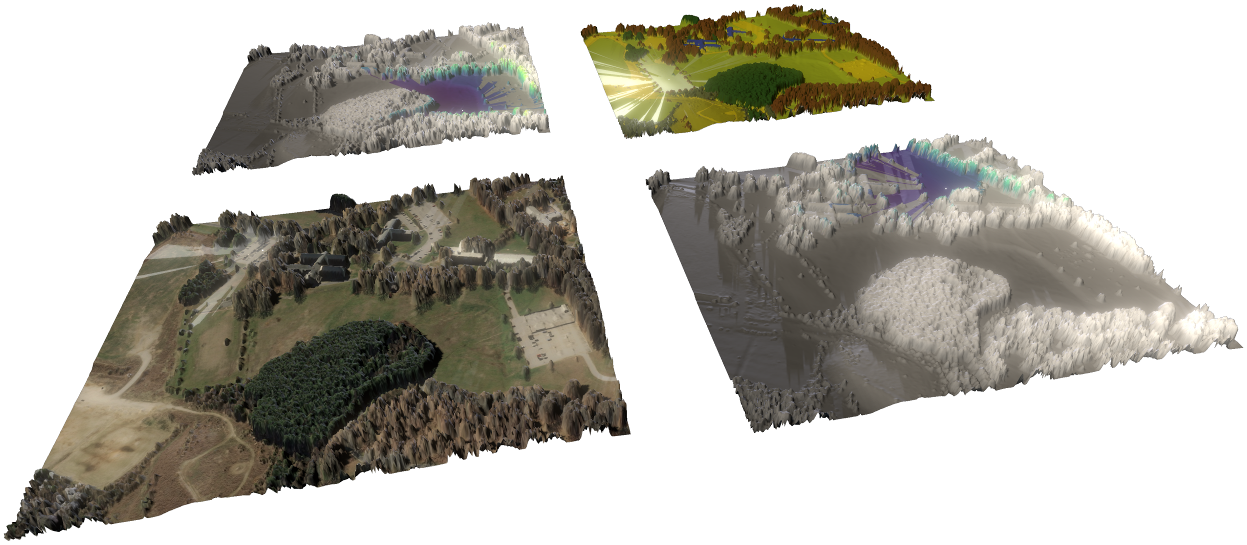

Figure 3: Student work for Assignment 2, Dorothea Dix landscape with four surface textures, clockwise from lower left: 1) orthoimagery 2) elevation, 3) landcover and 4) hillshade with the viewshed overlaid on each. See the interactive SketchFab post at https://sketchfab.com/models/6ccc4ac4a9cd4ae1adab86d1a0a4b718.

Lesson 1 provides a general introduction for Blender and Sketchfab, including their functionalities and interface. Video 1 familiarizes students with the basic components of the Blender interface with a focus on the features relevant to geospatial visualization, and explains basic interaction and operations on 3D objects as well as navigating the 3D scene. In the assignment, we ask students to prepare and render a simple 3D scene in Blender composed of at least five primitive objects (such as boxes and spheres). Video 2 focuses on the Sketchfab interface. We use a digital elevation model and watershed map to describe the work-flow for importing Blender models and preparing the environment, shading the 3D model and draping the watershed as a surface texture, and finally annotating and publishing the model (see Fig. 1). In the related assignment students repeat this procedure using a Blender file containing a terrain surface, an orthoiphoto and a visibility analysis map (a viewshed).

Lesson 2 focuses on processing geospatial data in Blender. The video shows how to set up the GIS add-on, georeference the 3D scene, import a terrain raster, refine the surface representation, import vector (point) features, transform 3D objects and use the Sketchfab add-on to export the models from the Blender interface. The second video demonstrates a more advanced shading work-flow using both Blender and Sketchfab. In the assignment, students are provided with a digital surface model (DSM), a shapefile containing four point features, four viewshed maps computed from the point features, and several surface textures (hillshade maps, orthoimagery, and landcover maps). They are required to deliver a 3D interactive model (online) that provides a visual comparison of the surfaces (see Fig. 3). Students can be encouraged to creatively explore various representation alternatives using the provided textures and preset lighting options.

4 Deployment

We used these lessons in a graduate-level distance education geovisualization course with nine students. The majority of the students are pursuing degrees in Geographic Information and Technology. All had prior experience with geospatial data and most possessed some basic programming skills, but none had studied computer graphics. The students were asked to watch the videos, complete the labs, and post lab results on the course forum. All students were able to complete the requirements of the lab. Two students had problems with positioning the models or camera. Specifically, in Assignment 2, one student did not align the models on the z-axis and another student positioned the camera beneath the models (they appear dark from below). These issues were easy to resolve because the results were posted online, so we could advise them how to correct the problems. One student asked a question about the size of the data causing a slow upload in Sketchfab. This may have been due to using a very large subdivision number (that would increase the number of faces and vertices of the file) or due to importing a great deal of data (multiple textures, point-clouds, etc.) into the scene. The latter could cause a large file size unless the "selection" is specified for export in Blender.

The interface for Blender is quite sophisticated, which comes with the drawback of complexity. If the students have some programming experience, the Python interaction could be emphasized when the lessons are delivered. After the materials were used in the geovisualization course, the lesson was extended to include Python code equivalents for the Blender GUI commands. For students with some programming experience, these scripts can serve as a summary of the steps involved in the visualization preparation process and provide a more repeatable way for students to experiment with parameter settings.

After the Python scripts were added, the lessons were again tested at a workshop presented at the International Cartographic Conference 2017 [9]. Instead of videos, live demonstrations were presented while attendees followed along. The speaker was accompanied by two teaching assistants. 26 people participated in the two hour workshop. Most of the attendees had a basic familiarity with Python programming. The remainder were either totally unfamiliar with Python or highly proficient programmers. The majority of participants successfully completed the interface introduction and the example assignment. In addition to the GUI procedure, more than half of the participants completed the supplementary scripting procedure in which they performed the same operations using the Blender Python scripting editor. Of those, the majority found the scripting method more efficient and engaging, but also acknowledged the role of working with the interface for a better understanding of the 3D modeling process. For future usage in short-form courses, we recommend sharing video material prior to the meetings so that attendees can obtain some initial familiarity with the concepts and interfaces during the interactive session. Additional suggestions for improving short-form sessions discussed by Zoss [11], such as printed hand-outs, could further benefit this format.

5 Usage Recommendations

Both of our testing audiences had a GIS background. Instructors using this for non-GIS students, such as a data visualization course, may chose to present a GIS primer to prepare students for these materials, including the terms defined in Section 2.2. Instructors using this for non-programming audiences, such as environmental science courses, could precede the lesson with a short introduction to Python or have students complete an on-line Python tutorial prior to delivering this lesson. Being able to visualize the results of executing lines of code may also reduce concerns about having less programming experience. Alternatively, instructors can focus on the graphical user interface and leave the Python programming capabilities as an optional extension for advanced students.

Lighting models and texture draping are used but not explained in these materials. Instructors could consider an active learning approach, allowing students to experiment with these properties during the lessons and then following up with lectures on these topics. Additionally, the drawbacks of 3D visualization, such as occlusion and perspective distortion [3], are not discussed in these lessons, but these materials could provide fodder for practical examples.

6 Conclusions

We presented a set of instructional materials for creating 3D geo-visualizations. The materials include videos, written descriptions, geospatial datasets, and lab assignments. The use of Blender with the GIS add-on provides geospatial functionality to create useful visualizations. Coupling this with Sketchfab enables students to easily share their results. With the online output instructors can provide timely feedback, students can populate professional portfolios, and researchers can collaborate remotely. Using relatable real-world application to create visually appealing representations, the lessons aim to incite further exploration.

Plans to extend the lessons include leveraging batch processing to demonstrate the workflow for automatically generating multiple datasets. A tool like this could be connected to streaming data sources. This will support exciting applications such as smart-city device or weather condition monitoring with 3D visualizations of the geospatial data.

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