

Exploring new ways of integration, visualization and interaction with Geotechnical and Geophysical Data

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Abstract

The work presented in this paper aims at exploring new ways of integrating, visualizing and interacting with geotechnical and geophysical data that may be more rich and interactive than those offered by most current Geographic Information Systems (GIS). Some visualization techniques enabling simultaneous visualization of the several data types available in our case study are proposed. Moreover, methods were developed to guide experts while defining layers and other relevant geological structures. The work is still in an early stage and its main goal has been assessing the validity and adequacy of the proposed techniques to the specific geotechnical and geophysical data under consideration.

Keywords: Visualization, geotechnical and geophysical data, VTK (Visualization Toolkit).

1. Introduction

Current systems for geological data visualization are robust, complete and comprehensive tools for the majority of spatial data, however they present some limitations regarding the representation of specific data (for example sparse data) or the fusion of data coming from different sensors. Usually geotechnical and geophysical information deals with sparse data with no spatial continuity resulting in large areas with no information available. Data coming from several modalities also poses problems to standard applications, which usually do not support simultaneous visualization of all available data types. In these cases, new methods and tools are needed to help interpreting the sparse data and to obtain more comprehensive visualizations [1].

This paper describes a set of experiments to test visualization and interaction techniques to improve and facilitate operations on geotechnical and geophysical data by experts. The software was developed in C++ using the graphical library VTK (Visualization Toolkit) [3].

The main advantages of the proposed techniques compared to those offered by the traditional systems are the possibility to integrate several representation of all available data in addition to the standard visualization (visualization of terrain data), the possibility to guide the insertion of additional information in sparse datasets, and further assistance in the construction of other representations (e.g. isosurfaces) based on the original data. Therefore, our aim is to extend the capacity of visualization systems for geographic data. Another objective is the possibility for experts to interact and add information to the original data to help the interpretation of geological formations.

Geotechnical data in general, and the data used in this work, have the particularity of being very sparse, not covering all geographical area under study, forcing experts to create mental models that allows them to interpret geological characteristics based on the available information. This implies the need to create new tools more suitable for the exploration of such sparse information allowing experts to reach conclusions more easily.

Another problem existing in many standard visualization systems when processing this type of data is the lack of tools well suited for experts to interactively add information for documentation (e.g. to include in reports). In many cases, the expert ends up having to export the images from the GIS in raster format and manually adding relevant information using any editing software. Our work also aims to facilitate the documentation and marking of data, and to enable sharing information among experts. The added information is included in layers, which can be grouped to produce better and more flexible visualizations. This interpreted vector information can also be exported to other platforms for computer aided design, reports or further processing (volume and area computation, for example).

This case study was based in information used to build a Tourism Resort located on the island of Porto Santo (Portugal). The site, located on seashore, suffers from water intrusion. The base formations are of

volcanic origin overlaid by more recent Quaternary sedimentary formations. These different geological formations have significant contrast in geoelectrical resistivity values, depending on porosity or moisture content, and in geomechanical deformation parameters depending on rock types. The integrated tridimensional representation gives useful information to designers while deciding, for instance, on building and other infrastructures implantation.

Section 2 presents the type of data for which we had to developed visualizations, as well as the methods of acquisition of those data. Section 3 presents the various types of visualizations proposed, and a guided method of isosurface construction. Section 4 addresses various issues that came up during the implementation. Finally, we present some conclusions and future work.

2. Geophysical and geotechnical data

Our experiments were mainly focused on the visualization of three types of data that have different acquisition methods and different purposes.

Geophysical data result from geophysical exploration using electrical resistivity and GPR (ground penetrating radar), which are in this case the basis of geotechnical and hydrogeological exploration. However, only visualization techniques for electrical resistivity data have been implemented yet.

Electrical resistivity pseudo-sections profiles are acquired over lines with several arrangements of four electrodes (two for current and two for potential lectures); after that, geophysical resistivity data inversion gives a structured grid corresponding to a perpendicular plane to the surface. Resistivity profiles can be obtained from the samples using linear interpolation. These profiles help experts to obtain a model for the geological area under study. Resistivity values are continuous scalars that vary with the materials of the subsurface, as soil and rocks, generally bad conductors (although they can have different conductivities), or water, which is a good conductor. Resistivity is measured in ohm.m (ohm-meters), ranging from close to zero for good conductors (particularly in the case of intruded sea water formations) to very high values for materials which are bad conductors [2].

The second and third data types result from the characterization and the geotechnical zoning interpretation areas. This information comes from Dynamic Probing Light (DPL) and Dynamic Probing Super Heavy (DPSH). These techniques involve the underground tapered tip probe penetration as result from the impact of a mass. The number of beats to penetrate a standard depth (0.10m) is related to the energy applied to the tip to reach a given depth range. The dynamic resistance is a scalar value measured in Kg/cm^2 , which ranges from zero for empty space to very high values for rocky areas.

2.1. Geophysical Data - Electrical resistivity profiles

An objective of geophysical exploration is to define a model of the geological area that helps the labeling of drilling wells for water, mining, bedrock detection, control and monitoring of environmental problems related to the intrusion of substances, as well as the degree of change in rock masses, among others. Profiles are obtained by measuring the electric potential (in various parts of the subsoil) generated by the introduction of electric current pulses treated by inversion methods to generate a spatial resistivity distribution providing a discreet profile that theoretically approximates the real value [4, 2].



Figure 1 Obtaining an electrical resistivity profile

2.2. Geotechnical Data – Dynamic probing (DLP and DPSH)



Figure 2 Obtaining dynamic probing super heavy (DPSH) data

DLP and DPSH are penetrometer tests involving the determination of the strokes number (N) needed to grant a certain depth of penetration. Each record registers the variation of dynamic resistance peak with depth (Rd) and the number of strokes (N) corresponding to the penetration of 10 and 20cm in the DLP and DPSH tests respectively [4]. Finally, a normalization formula is applied so that DLP and DPSH are expressed in the same physical unit.

3. Visualization and interaction techniques

The first objective of our work was the development of integrated visualizations for the various types of data. Several methods were also proposed in order to guide experts while defining layers and other relevant geological structures.

3.1. Visualization of electrical resistivity profiles

To represent resistivity profiles we used polygonal meshes for geometry and colour-mapping [3] for electrical resistivity along the profiles (Figure 3).

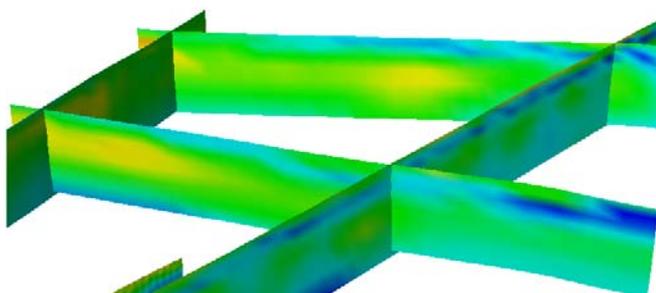


Figure 3 Visualization of electrical resistivity profiles

The visualization technique we adopted in this case is close to the one generally used in GIS since it is familiar to experts and represents the information collected by the sensors. We used a rainbow colour scale [5] to provide an intuitive interpretation, given that the blue tones correspond to areas where there is a greater possibility of having water, yellow/brown/red tones to rocky areas and greens correspond to intermediate zones.

3.2. Visualization of dynamic resistance data (DLP and DPSH)

Since dynamic probing light (DLP) and dynamic probing super heavy (DPSH) correspond to vertical drilling, they can be associated with a vertical line in a xyz plane, where x and y are fixed, and z varies. In addition to depth, the data also provides a scalar representing the ease or difficulty of drilling. Based on this information we proposed two different

visualizations: one used a graph (lines, bars or other) aligned vertically at the measurement point of the dynamic resistance this chart would represent the resistivity at the z coordinate. The second proposal consisted of a cylinder stack where the dynamic resistance value is represented by the grey value associated to each cylinder along z. After some tests, experts showed a preference for the second proposal, showed in Figure 4. A range of different gray shades was adopted taking into account the physical characteristics of dynamic resistance and its distribution in the underground. This scale was considered after various tests as the more representative visualization of the data.

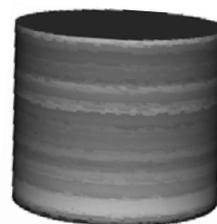


Figure 4 Visualization of dynamic resistance through a stack of cylinders with different gray levels

However, the dynamic probing visualization through a stack of cylinders was not entirely satisfactory, since the variations were not very significant and the high data range limited the use of color scales. To overcome this difficulty we improved the initial representation as shown in Figure 5: besides the different gray values for different dynamic resistance, we also used different diameters to code the same physical measure, allowing an easier data interpretation.



Figure 5 Visualization of dynamic resistance through a stack of cylinders with different gray levels and different diameters

3.3. Visualization of electrical resistivity isolines

Isolines enable a visualization delimiting areas with the same resistivity, making easier the definition of areas with higher or lower resistivity, as shown in Figure 6.

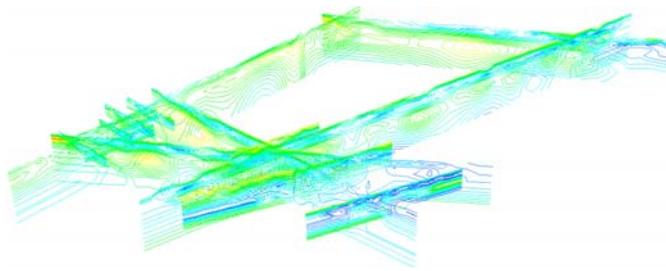
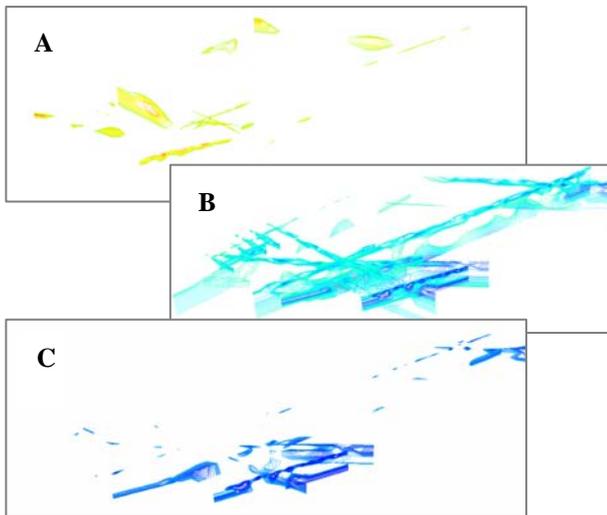


Figure 6 Visualization of electrical resistivity isolines

Isoline visualization with different resistivity ranges is provided. It is possible to visualize only certain values as isolines to explore different physical characteristics of the underground. Images A, B and C of Figure 7 illustrate the advantage of this representation: image A shows zones where the soil is predominantly rocky. Image B reveals a zone where there is water (low resistivity), but in image C isolines show a higher water potential, virtually confined to a more specific area of the underground. This visualization is intended to target underground properties helping experts to reach several conclusions. For example, from these visualizations it is easy to conclude that a certain underground area has an increased probability of having water, and therefore it will be most suitable for an attempt to capture water (e.g. for irrigation, swimming pools, etc.).



Legend:

- A – Higher resistivity areas
- B – Lower resistivity areas
- C – Very lower resistivity areas (subset of B)

Figure 7 Visualizations of electrical resistivity isolines, for different range values

3.4. Construction of electrical resistivity isosurfaces

The guided construction of surfaces by experts that delimit areas with similar physical characteristics is essential to make a visual interpretation more intelligible, defining the various layers of the underground. Experts can select interesting points on the isolines (dots in image C of Figure 8) that will be used to automatically create two types of representations: the open isosurface (or just surface) and the closed isosurface (volume). Open isosurfaces are useful to define borders between different layers; while closed isosurfaces may be useful to define a volume of the underground with the same physical characteristics. The isosurface representation is particularly interesting for users to define regions of interest corresponding to specific resistivity values (for example water layers as can be seen in images D and E of Figure 8).

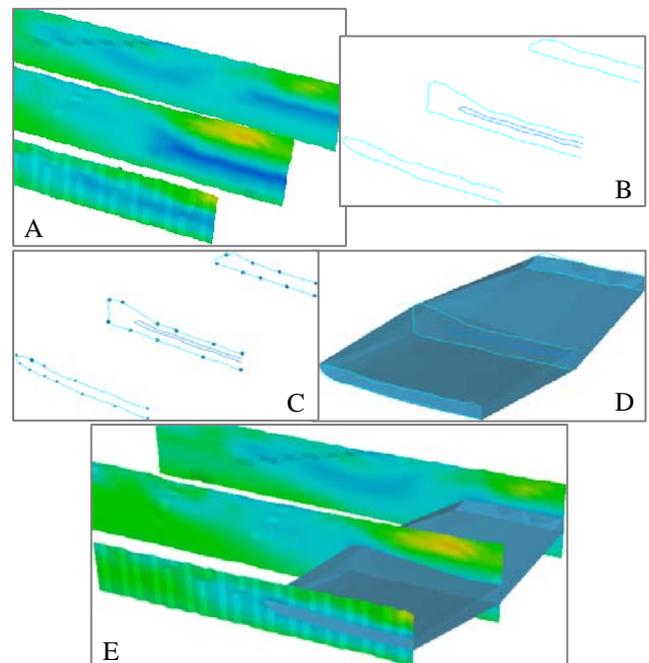


Figure 8 Isosurface construction process

Figure 8 shows a demarcation zone example: initially an area where there is a continuity of low resistivities is identified in view A, then, a view that shows isolines of low resistivity in each profile was adopted (B). The user marks the points of continuity (C) and generates a polygon mesh from these points (D). Finally, the volume corresponding to the low resistivity zones of profiles is shown (E).

3.5. Automatic selection of points on isolines

In the example of isosurface construction in Figure 8, the selection of points on each isoline was carried out

manually, point by point. Since this is a repetitive and time consuming process, we implemented a method to automate this selection (Figure 9). The user has only to select a single point on a certain isoline, and all points of the selected isoline are automatically selected. Using this method, the user selection process is much more efficient as shown in Figure 8, obtained by selecting a single point in each of the three profiles.

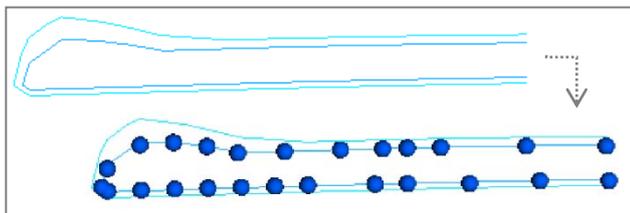


Figure 9 Automatic selection of points on isolines

4. Results and discussion

Although this project is still at an early stage, the proposed visualizations have been evaluated and validated by a small group of experts.

Image A of Figure 10 shows a typical integrated visualization provided by our methods. Resistivity profiles are represented using pseudo-colour, (where dark-blue corresponds to a low electrical resistivity and red to the maximum value in the data set), while dynamic mechanical resistance values (DLP and DPSH) are represented using a stack of cylinders with variable radius and grey levels (images B and C of Figure 10) that may help users with problems of color perception [6].

We also implemented visualizations of the data as isolines (Figure 7) making it possible to switch between visualizations. Finally, users can interactively select any viewpoint to gain insight and guide the definition of geological structures.

An attempt was made to establish a direct relation among geotechnical and geophysical data, in order to create new visualizations and methods to assist experts in building isosurfaces defining various geological structures. The ultimate goal is to provide in the same interface, access to more information using the same representation (resistivity profiles, DLP and DPSH); however, establishing a relation among these datasets is not easy. The explanation for this difficulty is that rocks may be porous and contain water that, unlike rocks, is a good conductor resulting in areas with low electrical resistivity, yet having a high dynamic resistance (rocks are difficult to drill) [2]. In other words, a direct relation was not possible to establish. However, combining resistivity profiles and dynamic penetrations (DLP or DPSH) for a specific location, can help determine the type of subsoil by comparing tables relating electric resistivity and dynamic resistance for different types of

materials. Therefore, the integration of various types of data increases the certainty about the underground constitution material.

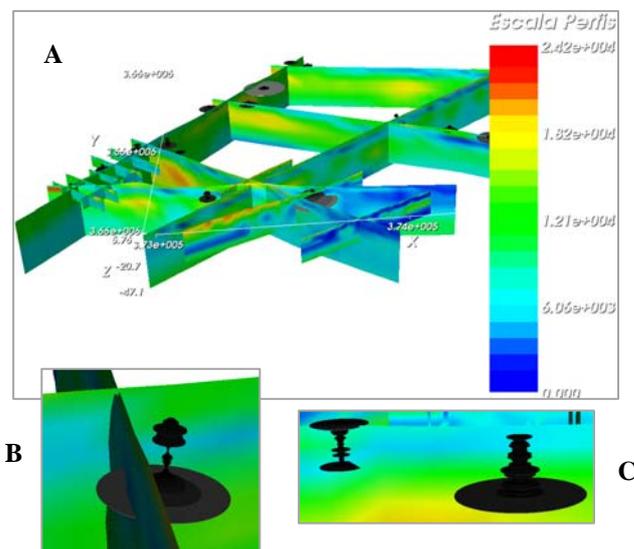


Figure 10 Simultaneous visualization of electrical resistivity profiles, DLP and DPSH (B and C show enlarged details of DPSH samples)

5. Conclusions and future work

This paper describes a set of experiments designed to explore new visualizing ways of exploring geotechnical and geophysical data, not offered by many standard spatial visualization software: for example, the simultaneous/integrated visualization of electrical resistivity profiles and dynamic probing (DLP and DPSH) in the same window.

The idea to establish a relation among geotechnical and geophysical data and visualize them using the same representation was not feasible due to the porosity of rocks. However, combining the information seems promising to help experts classifying geological structures.

A particularly interesting feature is the construction of isosurfaces guided by experts based on the integrated visualization of all available information. In isosurfaces construction, the available data, though sparse, is the starting point and can be presented by several means: polygonal meshes, isolines or sub-ranges of isolines, allowing the expert to select different underground sections.

The guided construction of these representations may evolve in future to be more automatic. As a long-term objective the idea is to obtain a semi-automatic representation that can be accepted or modified by the expert. Further improvements would be the use of a virtual reality environment, in which the user could walk through the data and guide the segmentation of different ground layers. This virtual reality visualization and

simulation could also help the data exploration by other professionals, including architects, engineers and designers.

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