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Visualisation of Archaeological Data Using Voronoi Diagrams

Topic: Architecture

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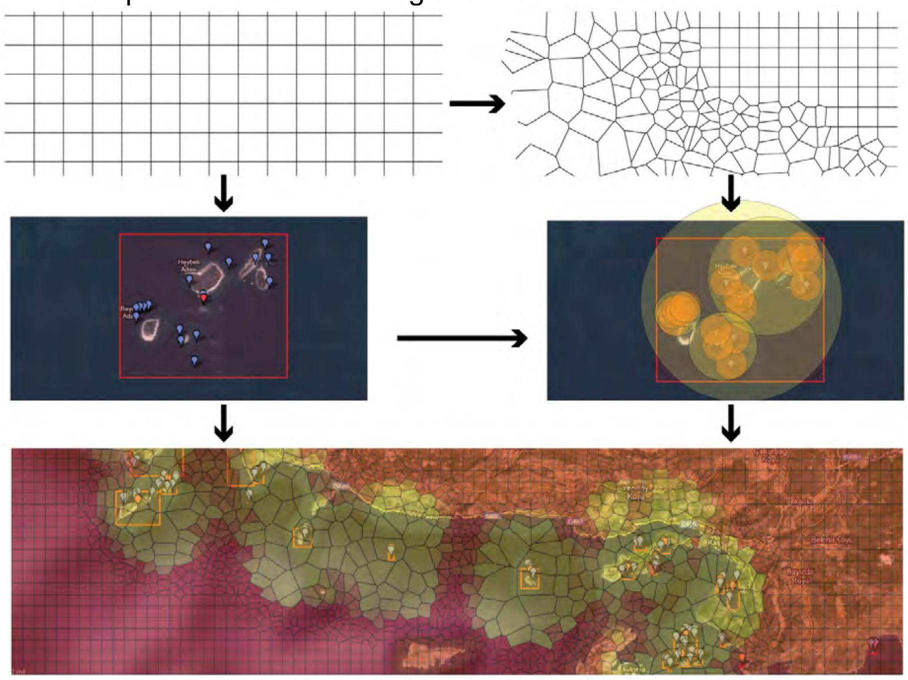
Abstract:
The widespread usage of computers brought new challenges into the design, production and external representation of data with generative approaches. Within the last few years, generative methods have gained attention especially in the context of cultural heritage. As generative model describes a rather ideal object than a real one, generative methods are a basis for visualisation of archaeological data. In order to make archaeological data accessible to cultural heritage experts and to the general public, we created generative geospatial maps which accounts for the dissemination of data through online systems. The result is a generative voronoi diagram based on Grasshopper plug-in and Rhinoceros software.

In this study, an alternative approach on the external representation of archaeological data has been put forward by using voronoi diagrams as an interface. These diagrams are spatial decomposition of a given space, determined by distances to a specified family of objects. Thus, they enable the division of such multi-dimensional spaces into subspaces. This presented external representation approach is based on deformation of the point cloud formed. Within the constraints of the data gathered, the point cloud is deformed according to the number of findings in the each region. On the next stage, the point cloud is turned into voronoi diagram to highlight the density of archaeological data based on the geographical distribution, and it helps to externalise the relationship between different regions around the coastal line.



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Abstract

The widespread usage of computers brought new challenges into the design, production and external representation of data with generative approaches. Within the last few years, generative methods have gained attention especially in the context of cultural heritage. As generative model describes a rather ideal object than a real one, generative methods are a basis for visualisation of archaeological data. In order to make archaeological data accessible to cultural heritage experts and to the general public, we created generative geospatial maps which accounts for the visualisation of data through online systems. In this study, the voronoi polygons are drawn onto Google Maps while the geospatial data is processed in Javascript using generative voronoi diagrams.

An alternative approach on the external representation of archaeological data has been put forward by using voronoi diagrams as an interface. These diagrams are spatial decomposition of a given space, determined by distances to a specified family of objects. Thus, they enable the division of such multi-dimensional spaces into subspaces. This external representation approach is based on deformation of the point cloud formed. Within the constraints of the data gathered, the point cloud is visualised according to the number of archaeological finds in each site. On the next stage, the point cloud is turned into voronoi diagram to highlight the density of archaeological data based on the geographical distribution, and it helps to externalise the relationship between different sites around the coastal line.

Introduction

Data visualisation is the study of visual representation of data, for communicating information clearly and effectively. The conventional ways to visualise data such as tables, histograms, pie charts and bar graphs are widely used in many fields [1]. In the field of archaeology, visualisation is used as a tool for analysis of data to convey the interpreted meanings. As a visualisation tool, allowing archaeologists to visualise the above ground appearance of sites out of the information gathered from the foundations, the earliest 3D models were aiming to replace the paper model equivalent of the illustrations made by a talented hand. However, the potentialities of the digital technologies are far exceeded just to copy the talented hand. Digital technologies became a tool for the analysis, visualisation and dissemination of data at various stages of the archaeological interpretations.

In this project, generative methods are applied to display the data collected and stored in a web-based information system developed for a model of online system using the data collected during underwater surveys conducted on the coastal region of Lycia, Turkey. The system currently contains information on c.700 finds in the form of sketches, measurements, drawings, photographs of finds. Combined with Google Maps, this database illustrates the initial technological steps towards the development of an online system for the display of large data sets in interactive maps. Related to this information system designed and developed using the Wamp software bundle, the geospatial data is processed in order to visualise the archaeological finds at a specific site. The data is extracted from the MySQL database using PHP language. Further processing, clustering and visualising of the data are completed using JavaScript language. The result is a visual tool that is displayed as voronoi diagrams and linked to interactive maps in a hierarchical format.

Literature Review

The visualisation of archaeological information is one of the most attractive ways in which computer technology can be employed in archaeology. The term visualisation includes almost any exploration and reproduction of data by graphical means. In his overview of computer applications in archaeology, Richards argues, that these exploration techniques allow “visual interpretation of data through representation, modelling, and display of solids, surfaces, properties, or animations” [2]. Thus, computer applications in archaeology refer mostly to the 3D modelling of the sites in order to display the interpretation of archaeologists. Moreover, 3D models can now serve as research tools to interpret various kinds of data [3]. However, it is often criticised that nowadays 3D models lack archaeological complexity. In other words, these models are blank, that is, they only serve as visualisation tools but do not provide any further information. The current techniques of surveying such as photogrammetry and laser scanning offer numerous methods for the insertion of the complexity lost during the creation of digital models. Acknowledging these methods, we offer a special approach to detach the link between archaeological data and representation of reality in 3D format.

Visualising is a tool to understand and represent reality. The idea here is not only the representation of archaeological data, but also to retrieve data out of the archaeological object. In a way, visualising is a tool for archaeologists to solidify the information. Alternatively, visualising is a tool for users to experience the environment virtually. Whether it is composed of the computer reconstructions of the objects and of the photographic realities of panoramic immersion, virtual environment empowers the visualising process. As Barceló states, future advancement of virtuality techniques should not be restricted to “presentation” techniques but to explanatory tools [4].

Voronoi diagram is a mathematical tool applied across many scientific disciplines. It shows boundaries between neighbours. Similarly, voronoi polygons are polygons whose boundaries define the area that is closest to each point relative to all other points. Voronoi diagrams and polygons are applied to various academic fields from music to architecture. However, voronoi diagrams have little application examples in the digital heritage domain. A specific example that is closely associated with the subject of this paper is the example by Delort. He presents an approach for visualising large data sets in an interactive map [5]. His technique retains hierarchical relationships between data items at different scales.

Leaving aside the complex systems of 3D dimensional environment, we propose the geospatial display of the archaeological data as explanatory tool. The generative methods of data display are linked to the information system for creating interactive geospatial maps. The information system accommodates the complex nature and extensive amount of archaeological data collected for the dissertation project of Varinlioglu [6]. For this purpose, a prototype has been implemented and tested showing the effectiveness of the method for visualising large data sets using voronoi diagrams.

Web-based Information System for the Virtual Museum

This online information system for systemic data collection, description, and interpretation, currently contains information on 22 geographically distributed archaeological sites. Combined with the GPS locations of sites and findspots, the result of integration of the database with Google Maps illustrates the distribution of sites along the Lycian shoreline of Turkey. Essentially an online database for systemic data collection, description, and interpretation, the system currently contains information on c. 700 finds through sketches, measurements, drawings, and photographic entries of individual archaeological finds, in addition to regional descriptions and observations made by divers.

The information system has been developed with a web-based, client-server architecture. All data storage is done on the server side, while data input and display are done on the client side. The server application works on a web server and is supported by a relational database management system (RDBMS) and the native file system for data storage and retrieval. The client application works on web browsers and communicates with the server application synchronously and asynchronously through the Internet. Using the AMP software bundle, the information system is a platform free, web-based information system, which works on the Apache server, stores its data on MySQL database system and is programmed using PHP scripting language.

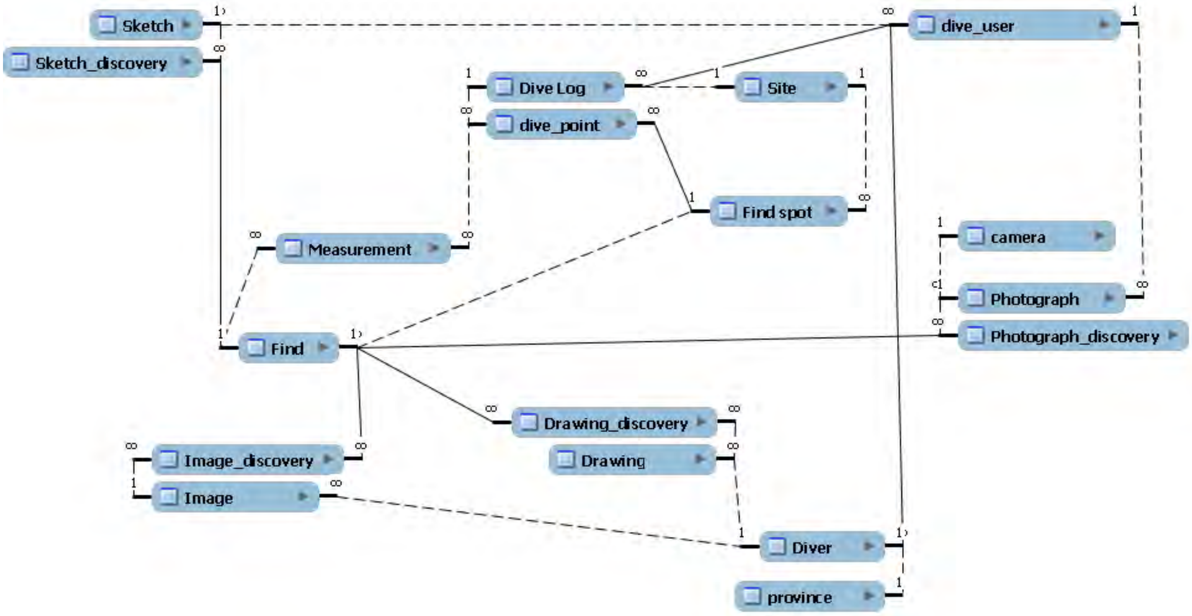

Figure 1 Diagram of the database structure

The information system was composed of major components that are self-competent information systems on specific topics, which are closely linked to each other. Each component covers several record types and includes all data entry interfaces and database queries. These components were categorized as dive-logs including researchers/divers, sites, findspots, find logs including measurements, photographs, sketches, and analysis/visual media such as drawings, images, notes (Fig.1). Dive logs together with findlogs recorded during field surveys are listed with location information of the geographically distributed regions, named as sites. The Situated within the geographical boundaries of the sites, the findspots are defined by geographical coordinates and bearings. At these spots, the finds are logged into the database with measurements, photographs and sketches. For displaying the mapping data, an external Internet Map Server is used.

The mapping component was primarily used for findspot, site and dive log components for the designation of geographical locations of finds, the extents of dives and sites. The locations of findspots were marked as single points, the sites as rectangular areas, and the dives as two points defining a straight line. Mapping tools were available for expanding, contracting, zooming and removing rectangular areas. As maps are updated automatically by Google, the coordinates of the entered locations were displayed on the updated map automatically (Fig. 2). To facilitate the entry of coordinate information, the mapping component allowed coordinates to be entered as various formats. The format of the coordinates was automatically determined by the system and converted into decimal degrees during data storage. Latitude and longitude of the marked location were indicated on the corresponding data form elements.

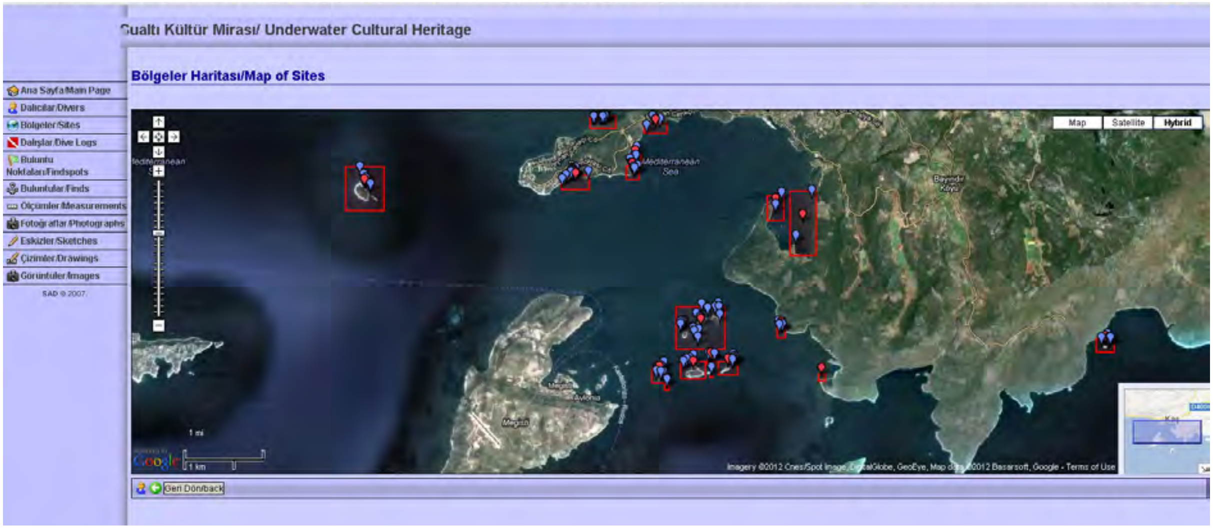

Figure 2 Interface of the information system designed for the virtual museum.

The component was linked to findspots for displaying the distribution maps of finds and to dive logs to keep track of the area covered during the surveys. The information system has built-in lists of sites with data on their geographic boundaries. Once a site is selected, boundary information is retrieved from the server and the extents of the map are updated to display the selected site. In order to increase ease of use, a custom windowing interface was developed, which allowed map display having a fixed dimension and position on the page to be undocked from its location and resized freely. Ability to enlarge map display size without affecting other data entry elements greatly enhanced the friendliness of the mapping component and facilitated marking on the map.

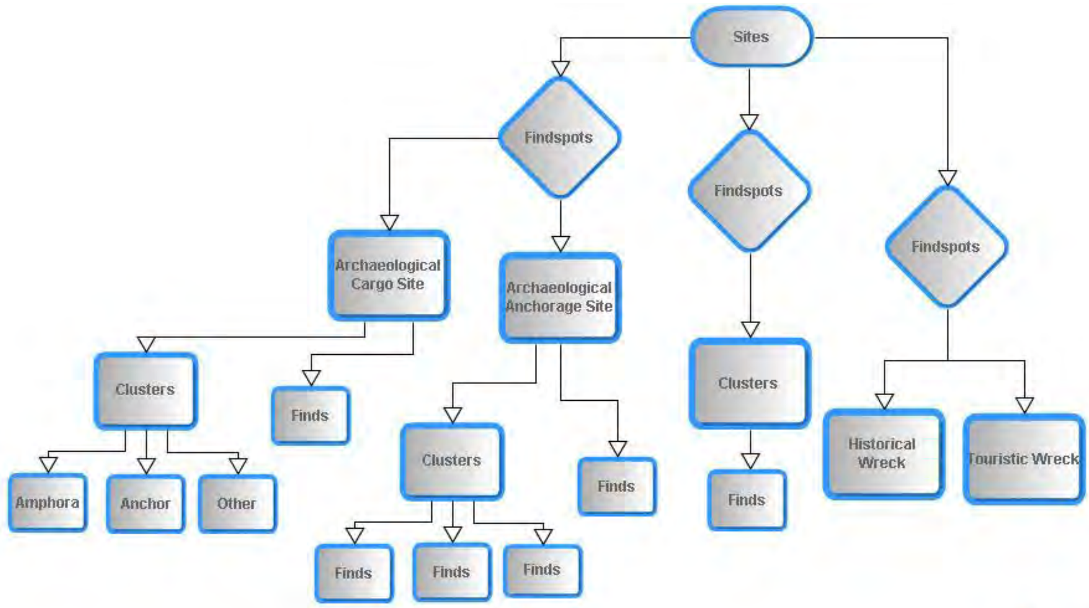

Figure 3 Hierarchical tree-map of the archaeological finds

The interface of the information system displays the sites and the related findspots on the same Google maps image. Unless an interaction occurs such as zooming of clicking on the findspots, the overlapping tags create clutters for the user. To eliminate clutters, the findspots are only displayed as blank spots. In other word, the properties of the findspots, such as the number and type of the find linked to that findspots are not displayed in this model. As displayed in Fig. 3 the clustering archaeological finds of a site forms a tree-map hierarchy. An archaeological site contains numerous spots related to finds. Each find type, whether a single amphora or a whole wreck site, has location information.

Problem Definition

The geospatial data is displayed through tags of findspots on the Google Maps. However, this display is rather confusing as the tags give no clue about the classification of the finds related to these findspots. Moreover, the quantity of the finds related to the findspots is not displayed in these tags. In other words, the visualisation through standard Google Maps tags is insufficient for both the users to understand and interact within this virtual environment and for archaeologists to make relevant analysis out of this data. In order to avoid any clutter/noise in the display of these geospatial maps, we proposed a generative method for the display of geospatial data.

Proposed Approach

Our method for visualising the archaeological data is threefold. First, the geographically distributed archaeological spots are clustered with respect to their distance on the map. Named as sites, these clusters gather all the finds in one geographical spot. Then, the spots closely placed to each other at a given scale cause clutter in the display. These clutters, overlapping and confusing display of data, prevent the users differentiating the findspots and the related information. To avoid this distraction, clusters of findspots are hierarchically organized and displayed. Finally, these clusters are represented on a map by voronoi polygons. According to the density of finds at a chosen spot, the voronoi diagrams are generated with color densities representing the find numbers (Fig. 4).

The first step is to retrieve the information from the database. As the information system is designed and coded in the WAMP software bundle, the queries from the MySQL database are coded in PHP language. In these queries, the main reason was to retrieve the geospatial coordinates, latitudes and longitudes of findspots and the number and type of archaeological finds at each findspot. This data is collected into a comma separated value (csv) data format and passed into to the JavaScript program which handles the clustering and the visualiation. Csv format is preferred as it was easy to parse the information in the program.

The second step is to prepare clusters of finds so that no clutter appears on the screen of users. Delort [5] mentions the difficulty of measuring clutter because it is task and device dependent and also subjective. For example, a desktop machine with huge screen can display the points on map with a lot of distance between them, but the same map may appear on a mobile phone with points on top of each other. To control the clutter finds that are located in the same spot are joined into clusters. But this is not enough as the clusters may be located in a distance that is too small to separate the two points in the map screen for the selected zoom level. Therefore the distances between each cluster or find is calculated and stored in a distance matrix. From this matrix, starting from the lowest distances the finds are added to the clusters. The newly constructed clusters appear in between the original points proportional to the amount of finds in the spot which makes the process weighted. This process continues until the distances between clusters or points become larger than a selected minimum threshold value.

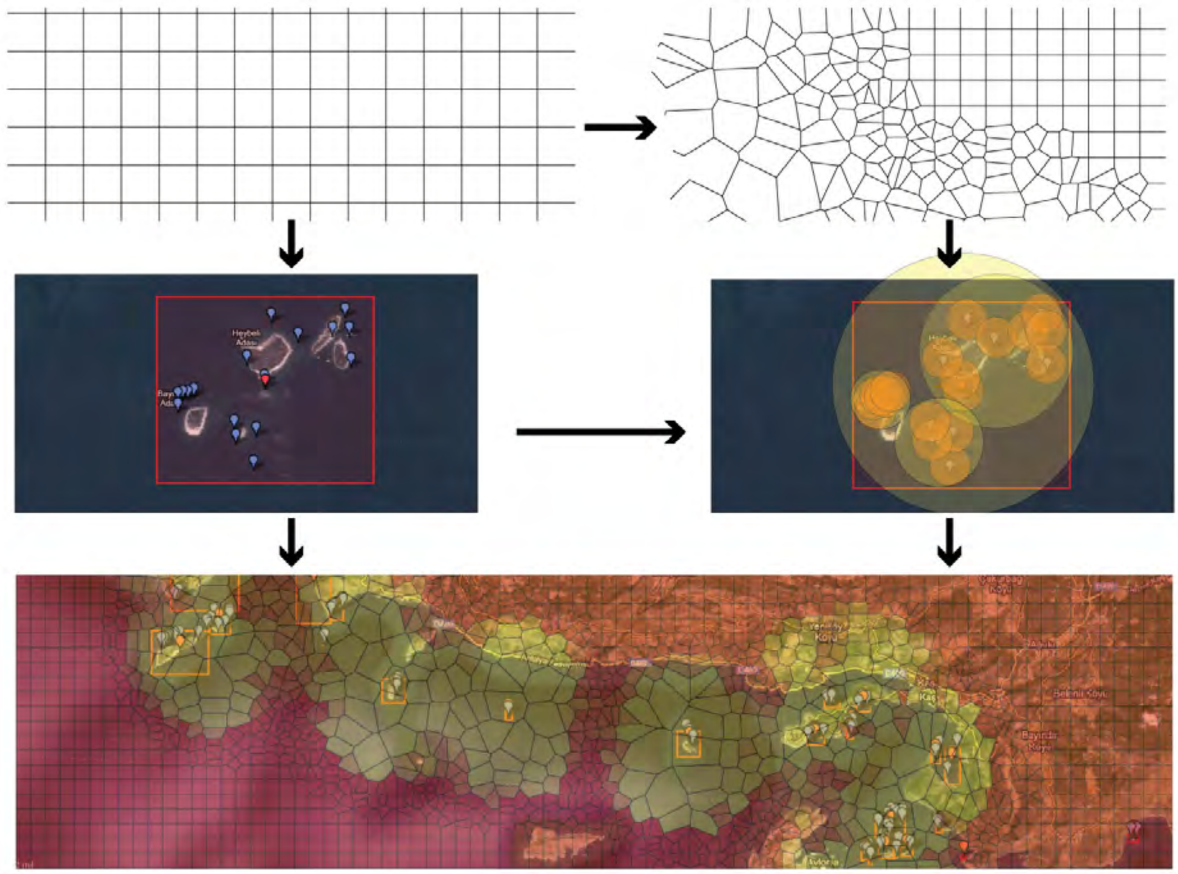

Figure 4 Voronoi diagrams for the visualisation of geospatial maps

After clusters are joined, voronoi diagram of the area is drawn so that the centroids of the voronoi are located on the points of the clusters. Voronoi diagram is chosen for the representation of the density of the finds as it allows a generative way to visualise find density in one place. Moreover, the voronoi polygons are highlighted with different colours representing the amount of finds in the area. When the user clicks the polygon, a popup box outputs the number and type of the finds founded in the area. The finds are represented with the icons of the finds.

If the user changes the zoom level, that is if the user zooms in or out from the current view the clusters are recalculated. The minimum accepted values for distance between finds are decided for each zoom level and in every zoom level change. The clusters are shown in a way that they are within those minimum values.

Conclusion

The information system has been developed with the objectives of preservation of the data gathered during field surveys, accessibility by the interested parties, the integration of multi-aspects of archaeological research under a single roof, and user-friendliness for the users. As the system was not limited to any site, the user can do different kinds of spatiotemporal searches on the data, especially on Google Maps.

Related and linked to this database system, we presented a technique for visualising clusters of spatial data in interactive maps. The technique retains hierarchical relationships between data items at different scales. Using the voronoi polygons, the geospatial information is conducted to the users of the system. This visualisation method offers new ways to display the archaeological data.

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