VISUALIZATION OF CONTENT AND SEMANTICAL RELATIONS OF GEONOTES

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ABSTRACT

The total population of GPS-enabled location-based services (LBS) subscribers is constantly increasing. These GPS-enabled devices produce a wide range of media content (e.g., text/audio notes, pictures, or videos) enhanced by geo-tagged information. This fact poses a challenge regarding how to store and retrieve it and opens new research opportunities for visualizing this type of data. The overall aim of our research efforts is to develop novel approaches and methods for visualizing the content of these documents that will be placed in maps using GPS coordinates as well as to visualize the semantical, temporal, and spatial relations between the documents themselves. In this work, we concentrate on text documents and other data formats that could be transformed into text. We combined different visualization and interaction techniques, such as glyph-based techniques and visual clustering, to achieve our research aims. Our visualization tool, called GNV System (GeoNotes Visualization System), demonstrates the interplay of different interaction techniques and components as well as their functionality. It will be presented in this paper.

KEY WORDS

Information Visualization, Visualization Software, Geosciences, Visual Information Systems, HCI, GPS

1 Introduction

According to a study conducted by ABI Research [1], the total population of GPS-enabled location-based services (LBS) subscribers will reach 315 million in year 2011, in significant contrast to 12 million in 2006. This estimation indicates a heavy increase of the use of GPS-enabled devices, e.g., smartphones or PDAs. In the future, we will have to deal with a huge amount of GPS-encoded data produced by these mobile devices. Therefore, we should search for novel possibilities for visualizing such geospatial data. The format of data produced by these devices is different. It can be text, voice, picture or video. In the scope of our current efforts, we only focus on those formats of the data which can be transformed into text and use the term *geonote* to refer to this content type.

Geonotes are GPS-encoded which make them suitable for visualization in a map. Moreover, we should think about visualizing the content and possible semantic rela-

tions they have. We have concentrated our work on analyzing and finding novel visualization and interaction techniques to facilitate the problem of the ever increasing number of geonotes. We developed a system that visualizes geonotes in maps and provides visualization of the content and semantic relation between these geonotes. It is important to notice that our work mainly covers the visualization part of the problem. Design and implementation of data mining approaches and geonote format transformation to text are beyond the scope of our work.

In the next section of this paper, we present an overview of related work in the field of geospatial visualization. We continue with a sample scenario in Section 3. This scenario depicts possible uses of our application. In Section 4, we present the design of our system and illustrate the most interesting features. Section 5 covers implementation approaches and technologies. Finally, we give a conclusion in Section 6.

2 Related Works

In this section, we mainly present related work in the field of geospatial visualization focusing on two points: the content visualization of text and the visualization of semantic relations of text documents.

There are different approaches of text visualizations. One of them is the use of colors to represent the grammatical structure of a text. The aim of this approach is to get some insight into the writing style and sentence structure as well as to provide some perspectives about whether the text is fictional or scientific [3]. A more sophisticated approach is described in the work of Keim and Oelke regarding literature fingerprinting. Here, a sequence of feature values per text is calculated on different hierarchical levels and presented to the user as a characteristic fingerprint [4]. The focus of these approaches is to get an insight about a specific style or genre of a document. In our context, we are interested to learn more about the content itself. The well-known Tag Cloud approach is one of the ways to visualize the content of the text. It is a "list of most popular tags, usually displayed in alphabetical order and visually weighted by the font size" [5]. There are some research efforts that present improvements of this approach (see, for example, [5] or [6]).

A further task in our case is to visualize geonotes in a map and to show possible semantic relationships. An interesting approach has been used in the development of the FEMARepViz toolkit [7], which offers an architecture for visualizing text documents in a map. FEMARepViz is used to extract and visualize temporal, geospatial, and summarized disaster and emergency information from the FEMA National Update Reports [7]. The application visualizes documents using Google Maps or Google Earth. It classifies the documents into a predefined set of categories. The authors claim a high classification accuracy. They use clustering based topic detection and segmentation algorithms for uncategorized documents. This application provides a very good solution of the problem to visualize notes in a map and categorizing the text into specific topics, which could be considered as a kind of content relation visualization. However, the visual representation of the classification is done through an icon metaphor, which is not the most suitable way when dealing with clustering. The reason is that the user might loose the overview of all cluster members, and it is hard to perceive the cluster as a whole. Furthermore, FEMARepViz does not visualize the content of documents.

As far as our literature research shows, there has been no solution provided to the problem we presented. There are some partial solutions, but they all lack some of the components needed to solve the whole problem. Substantial work has been done on text visualization, cluster visualization, etc. However, there have been no attempts on combining these techniques to provide an answer to the issues we described earlier.

3 Sample Application: Forensic Investigation Scenario

In this section, we present a scenario that describes how our visualization concepts could be used. This will help us in a better understanding and giving us ideas of other fields where our conceptual ideas could be applied. Additionally, we will get an insight into requirements that defined our design which will be shown in the next section.

Let us assume that a murder has occurred, and the forensic agents are in the crime scene. There can be more than one forensic agent taking notes about the crime scene. These notes can be uploaded to a repository and hold the GPS locations where the audio notes are taken. Later on, all agents can compare the notes by visualizing them on the map using our system. Let us imagine that agent John Doe logs in from his office; he sees other notes from his colleagues visualized on a map. When he clicks on some of the notes from that location, he can see the note's visualization on a predefined area of the display. This way he can get an insight of the content of each selected note. John can change the visualization view and switch to another view to see the semantic relations between the notes. Here, he can find all the notes semantically related to the selected note (it is also possible to add clustering criteria, such as space

and time). When John sees these *clusters*, he can find out that there are notes from different locations that match the selected note. This might help to identify common patterns between two or more crimes. Thus, forensic agents can possibly discover some correlations between their findings. Imagine that within few days another murder has occurred, but in some other part of the city or county. This other murder falls into some other police district, and both of them do not seem to be correlated. However, when agents upload their notes to the system, it can support them by showing possible patterns that connect these two cases. John can watch the content of other cases that are in the same cluster with his case. He can find that one case has some interesting similarities and that a certain pattern exists between them. So, he might get the idea that the murders are committed by the same person. In this way, our system may help agents to gain more knowledge of the case which will hopefully lead to better crime solving results.

4 The GNV System

In this section, we present the GNV System (GeoNotes Visualization System). First, we describe the overall architecture, continue with a description of used metaphors and present our visualization and interaction techniques that we designed to solve our particular problem.

4.1 Architecture

At first, we introduce the high-level architecture in order to describe the different components of our system. Then, we proceed with a more in depth explanation of the architecture considering the different processes involved in generating the visualization.

As we can see in Figure 1, our system design incorporates at least two other sub-architectures into one (three if we consider the JavaScript call to the Google Map API server). Of course, the mobile phone/PDA should be GPS-enabled in order to store the coordinates of the recorded note. The communication between the PDA and the Web Service server follows a service oriented architecture. This web service stores the geonote. If the geonote consists of an audio file then it will be converted to text. Afterwards, the web service extracts the most frequent tags (which will later be used to query and visualize the message). Text and related tags are stored in the database. As next step, the correlated web server generates the actual code for visualizing these geonotes which will be rendered by the client browser. This part of the system can be treated as a standard Client-Server Architecture, but at the client (browser) side, there are two additional requests needed to display the visualization: we use the Google Map API to display the geonotes (this implies that the browser should support JavaScript). An application that combines the Google Map API and other data sources is called *Web Application Hybrid* [8]. The browser initiates a simple HTTP request on a web server (Apache Server, IIS, . . .) which returns a HTML page with JavaScript. This script calls the Google
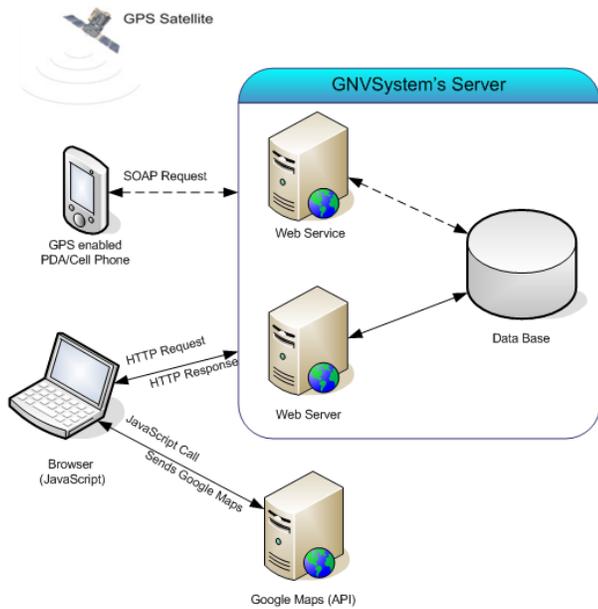
Figure 1. Overview of the general architecture
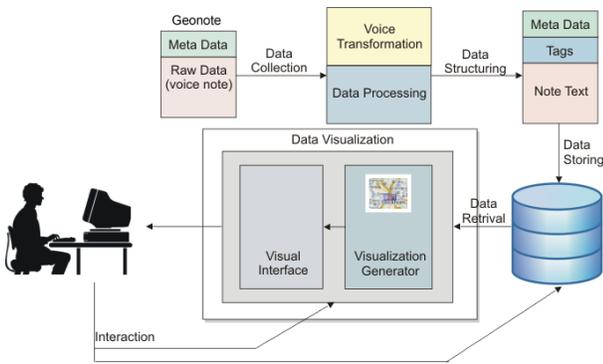
Figure 2. Architecture in more detail (process view)

Map server, and then the page is rendered. So, the browser actually does two 'calls' and displays the page using two data sources (our application data and Google Maps).

In Figure 2, we see that a geonote has some meta data attached (which is later stored in a separate table in the database). This meta data holds generic information, such as name of the file, time created, GPS coordinates, etc. We mentioned that geonotes can also be audio files. If that is the case, the geonote is firstly transformed into text which is later data mined. Once this process is complete, we have a note transformed into text which additionally includes the most frequent tags and the meta data, see the box in the right-upper corner of Figure 2. This information is finally stored in the database.

A user can interact with our visualizations in two ways: he/she can use various dynamic queries to filter out the data in the database (he/she will interact with database), or he/she can use various visualization techniques to interact with the visualization itself through the GUI (examples of such techniques are zooming, panning, etc.).

4.2 Visual Metaphors

In the following subsection, we discusses metaphors chosen to visualize geonotes in the map, their content, and their semantic relationships between each other.

Geonote Metaphor Our aim was to present more information about each geonote instead of presenting them as simple markers in the map. In order to facilitate this, we developed a note metaphor realized by a specific icon as described in Figure 3. This *geonote icon* shows three important attributes of a geonote: the relative age of the geonote, the number of words, and the duration if the content of the note is playable (e.g., in case of audio notes). Each attribute value is normalized, i.e., we compute the overall range of all values for each attribute which results in the horizontal background stripe of the icon. Then, the attribute value for each geonote is represented by a more color-saturated stripe that overlaps the background stripe from the left (progress bar metaphor).
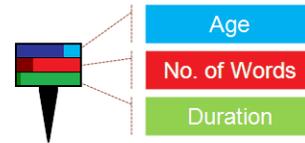
Figure 3. A geonote icon

Considering the fact that the age of the note would be an interesting detail for knowledge discovering processes, we decided to visualize this attribute of the geonote by the upper (blue) stripe. The bigger the dark-blue colored part is, the older the note.

The second stripe of the geonote icon depicts the number of words the textual geonote has. This helps users to identify the size of the documents at a first look. The color coding is similar to previous example: the bigger the dark-red colored part is, the larger the geonote. As we can see in Figure 3, our geonote is not very large.

The third stripe visualizes the duration of the note. This only have a meaning when dealing with time-dependent formats, such as voice notes. Again, our visual representation follows the same method as the above mentioned examples.

Figure 4. Tag Cloud metaphor

Geonote Content Visualization Metaphor We have used a well-known metaphor to visualize the content of the geonotes: the Tag Cloud technique, see Figure 4. We think that this metaphor suits our needs well, since it offers a good insight into the content of geonotes. Tag Clouds

show the most frequently used words in the text in form of tags of different sizes dependent on the weight of the tags. The weight is the percentage of the word occurrences in the text. So, a high weight value leads to a big font size.

Cluster Metaphor   As can be seen in Figure 5, our cluster metaphor is pretty intuitive. It allows users to perceive clusters very fast by showing notes as colored dots in rounded rectangles. We added several interaction techniques to enrich the overall experience and utility of this metaphor as described in the next subsection.
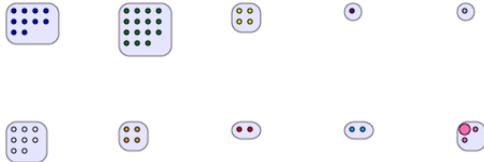
Figure 5. Cluster metaphor showing 10 clusters of different size. The actual selected note is displayed as a bigger dot.

4.3   Visualization and Interaction Techniques

We divided our GUI into three distinct panels as displayed in Figure 6. These panels hold different visualizations or tools. Changes made to one of the panels should reflect to the others, thus making the application interactive and user friendly. For instance, if the user selects a geonote icon in the map, then the same note should be highlighted in other panels as well by using coordinated views techniques.

The Map Panel displays each geonote icon in a map using the Google Map API. Users can see the geographical position of geonotes and interact with them. The Google Map API offers different ready to use control tools, such as zooming, panning and overview techniques through a small map in right-down corner. We also built our own control for selecting geonotes in the map through mouse interaction. This control was added to the standard controls.

The Notes Visualization Panel, which is located below the Map Panel and denoted by an orange rectangle (Figure 6), holds three tabs. The first tab "TagCloud" displays the content visualization of a selected geonote. The "Cluster Tab" visualizes the semantic relations of geonotes. The third tab "Search Results" displays the search results in form of a simple adjustable list. Because of the limited space, we give no further explanations on this tab.

The Tool Panel denoted by a blue rectangle in Figure 6, holds different tools that are necessary for interaction and general adjustments. It contains tools for searching, advanced (spatial and temporal) filtering, clustering options, and Tag Cloud options. Also, it offers an information box at the bottom for displaying the meta information of the selected geonote.

Now, as we have defined the main parts of our prototype implementation, we continue with more details about certain visualization and interaction aspects. As we already mentioned, changes in one part of the GUI or the visualization should affect changes in other related parts (e.g., in
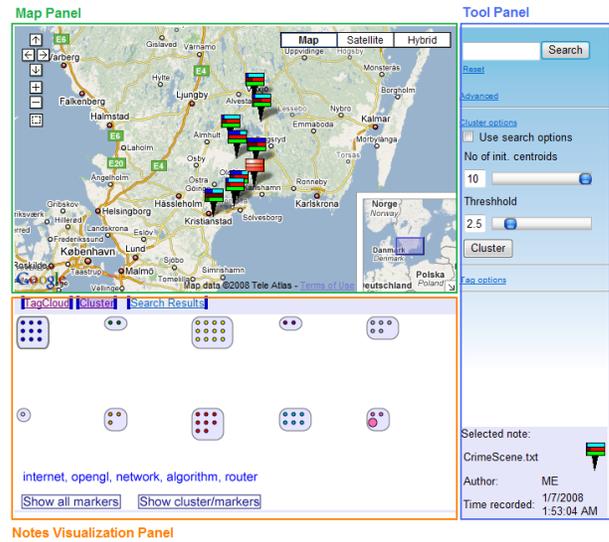
Figure 6. The three panels of the GUI
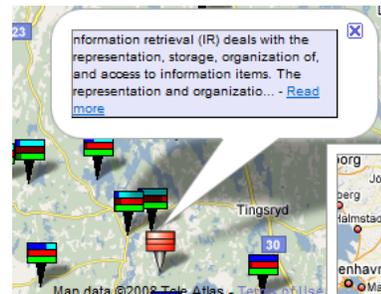
Figure 7. Information window for a geonote icon

case of clicking/selecting a note in some part of the GUI or visualization, the same note will be highlighted in every other visualization). This helps the user to realize the state of the system and to know what he/she is doing all the time.

If users double click on a geonote in the Map Panel (Figure 7), the prefix of the document text will be displayed nearby. In this way, one gets some more details about the document beside the tag cloud representation. Here, the user can also select the "Read more" link to get the whole content of the geonote. In order to select a certain region, we need to use a selection tool. Users can pick the aforementioned selection tool attached to the standard tool area of Google Maps and do two diagonal clicks on the map to specify the desired area (Figure 8). Then, we could use this area as a spatial filter for searching or clustering.
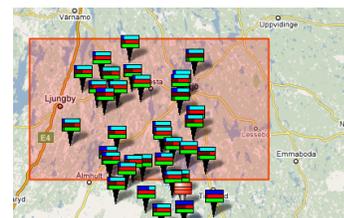
Figure 8. Selecting an area in the map
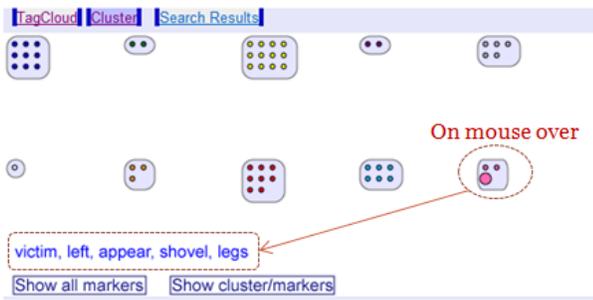
Figure 9. Cluster content view
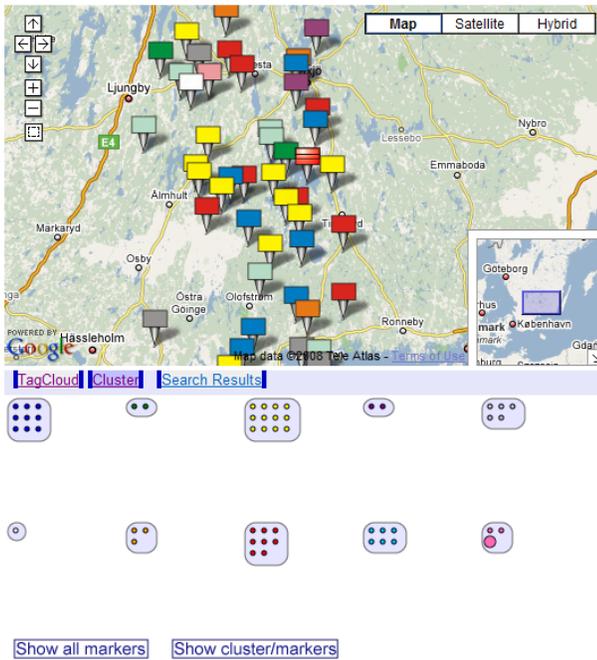
Figure 10. Spatial representation of clusters in the map

We presented our cluster metaphor in Figure 5. One possible problem with this metaphor is that it does not give any insight of the cluster content. We do not know what kind of documents are in the individual clusters. So, we added a feature to overcome this problem: when a user places the cursor over the cluster, our tool displays the five most used tags by the documents contained in that cluster as shown in Figure 9. With the help of this interaction technique it is possible to get an insight into the content of documents contained in a specific cluster.

Another interesting feature of our tool is that it shows the spatial representation of the cluster members (geonotes) in the map. This is useful if we want to see how members of different clusters are related in a spatial context. For instance, we might notice that geonotes of two clusters are more concentrated in some region. This could show some spatial relation of these clusters although their content may vary. To see the spatial representation of cluster members, we just need to click the "Show cluster/markers"
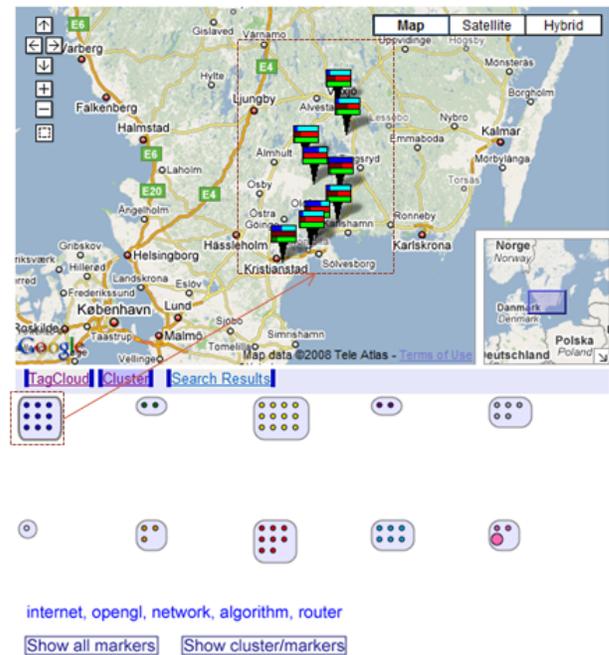
Figure 11. Spatial representation of a single cluster in the map

button. Then, the geonotes icons will be replaced with markers colored with the color of the cluster they belong to as shown in the upper part of Figure 10. Additionally, we might want to see the spatial representation of a single cluster. In this case, we should hide all the cluster members of the other clusters. This is done by clicking on the cluster we are interested in, see Figure 11. We implemented standard zooming and panning functionalities if the clustered geonote icons do not fit on the screen.

In summary, our visualization tool offers tailor-made options and interactions to show geonotes. Such options include advanced filtering options, cluster options, Tag Cloud options, as well as interaction and search options. Considering the space limitation of this paper, we focused on showing only those features that are relevant to solve the problems we stated in Section 3.

5 Implementation

This section is dedicated to the implementation of the GNV System. We firstly present the used technologies and give then a brief description of the most important implementation approaches.

5.1 Technologies and Tools

We used different kind of technologies and technical solutions to implement our system. GNV System is a web-based application that uses several scripting and programing languages (ASP.NET with C♯, Google Map API, JavaScript, AJAX and ECMA script used in SVG), MS SQL2005 database, and SVG to represent the clusters.

The system can be described as three-tier client-server mashup [8] (cp. the general architecture in Figure 1). We use an IIS web server which runs ASP.NET, AJAX, and the MS SQL2005 database server on one side, Google Map API which is outside of our system, and a client with a browser running JavaScript on the other side. All these components communicate with each other using different calls and request methods. A lot of processing power is spent on the server side (e.g., the clustering process), but considerable amount of processing also happens in the client (browser using JavaScript/ECMA script, especially for animating cluster changes and interaction with the visualization).

5.2 Implementation Approaches

We used different approaches and technologies. Note that our implementation only covers the part of the visualization software and not the data processing or data storing part. Here, we will show some of the issues which are related to the focus of our work.

The Google Map API offers a very simple way to visualize markers through the use of an external XML file. The parsing of this file is done through JavaScript and fed to the Google Map API. So, we used this feature and additionally implemented the server side generation of a XML file containing the list of geonotes.

In order to implement the Tag Cloud visualization, we created a HTML server side generated file which uses CSS to set the font size. It is implemented using AJAX technology for faster loading [9] and uses Java Scripting to implement tag interaction.

Our cluster visualization is displayed through a SVG file generated on the server too. We used the K-Mean clustering algorithm [10]. The simplicity of this algorithm is the key reason why we chose it. However, the main drawback of this algorithm is that it does not return the same results each time of its run. We plan to embed a better cluster algorithm as part of our future work.

6 Conclusion

In this paper, we presented our prototype application GNV System. Our visualization approach introduces a novel combination of visualization and interaction techniques which facilitates the issue of the increasing amount of geonotes. Our prototype allows users to get valuable insights regarding the content of geonote without the need to read or play an entire geonote. The GNV System visualizes the semantic relationships between the geonotes, thus providing spatial and temporal context through the use of various interaction techniques. It also offers a seamless interaction of the various components of the system.

So far, no formal evaluation has been made to the system. However, it will be done in the future, and we hope to prove the functionality and efficiency of our prototype. Moreover, the results of the evaluation could give valuable feedback to possible improvements of the system.

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