A Situated Cognition Aware Approach to the Design of Information Retrieval Systems for Geospatial Data

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ABSTRACT

Motivation – To improve the process of information retrieval (IR), specifically for geospatial data, by accounting for the natural processes of situated cognition where knowledge is a product of both action and context. **Research approach** – To focus on a specific topic (Mexican history), evaluate the limitations of existing approaches and design/implement a new system that overcomes these limitations. **Findings/Design** – As the theory situated cognition stipulates- all knowledge is situated in activity bound to social, cultural and physical contexts. It was found that the knowledge produced by information retrieval can be situated in the activity of exploring search results and bound to the context of geographic location (specifically, place names). In the design of our new application this made it important to allow the user to be able to have place-names for towns and cities visible throughout the search process. **Research limitations/Implications** – Tests were only undertaken with Mexicans living in the Mixteca region of Oaxaca with data about Mexican events, hence results may be culturally specific or specific to users from countries with a particular geography. **Originality/Value** – The results of this research should be of interest to designers of interactive maps and those who attempting to apply the theory of situated cognition to application design. **Take away message** – Taking account for the context in which users want to view the results of searches can improve the usability of IR applications. Specifically, this is demonstrated for geographic data where maintaining the visibility of place-names makes results generally more valuable.

Keywords

Situated Cognition, Information Visualization, Geo-visualisation, Information Retrieval

INTRODUCTION

The theory of situated cognition poses that knowing is inseparable from doing (Brown, Collins et al. 1989; Greeno 1989) and that all knowledge is situated in activity bound to social, cultural and physical contexts (Vanderbilt. 1993). Here we have a model of knowledge and learning that relies on thinking on the fly rather than simply the storage and retrieval of conceptual knowledge. In essence, cognition cannot be separated from the context and learning is seen in terms of an individual's increasingly effective performance across situations rather than simply in terms of an accumulation of knowledge.

Information retrieval (Manning, Raghavan et al. 2008; Hearst 2009) is the area of study concerned with searching for documents and information within documents. Traditionally this searching is done using static text based interfaces that operate using a model of the user's information need and numeric qualifications of relevance for each document. This offers the user little opportunity to interact with or explore results and fails to account for the fact that the user's information need, or needs, can change within the context of the results returned (Marchionini 2006). Moreover, the presentation of results in a static list format fails to exploit additional contextual information that could, according to the theory of situated cognition, effect the users cognition and in turn their evaluation of the results.

The objective of the work presented in this paper is to improve the process of information retrieval, specifically for geospatial data, by accounting for the natural processes of situated cognition. This is done by presenting results together with contextual information, in the form of an information visualisation (McCormick, Defanti et al. 1987), that can act to form cognition and allowing the user to explore search results as their cognition evolves.

As a case study we decided to focus on a specific topic: Mexican history. This subject was felt to be appropriate because of its large, yet manageable, scale and the fact that a large number of potential test subjects in the immediate vicinity of the university would be familiar, or at least interested, in the topic. An additional benefit was that a lot of relevant materials are available online or in printed form. There is also a temporal aspect to the data that can be used to provide additional context for searches.

RELATED WORK

To date there have also been a variety of information visualization techniques developed to support search activities. These include a variety of techniques for query specification (Michard 1982; Anick, Brennan et al. 1990; Young and Shneiderman 1993; Hertzum, Fr\ et al. 1996; Jones 1998), suggesting query terms, visualizing query terms within search results (Hearst 1995; Hoeber and Yang 2006), overviews of query terms in search results (Olsen, Korfhage et al. 1993; Spoerri 1993) and faceted navigation (Zhang and Marchionini 2005). However, these applications of visualization to general search have not been widely accepted to date. While usability results identify the potential of visualization in this area, overall results are not positive (Chen and Yu 2000; Hearst 2009). Feedback of search results ultimately requires the presentation of text and this can be problematic for visualization. It is not possible to read and visually perceive patterns at the same time and the nature of text makes it difficult to convert to a visual analogue for visualization (Hearst 2009).

Typically when a map is used to view additional information that is not exclusively geographic (Dykes, MacEachren et al. 2005) (e.g. events (Christophe 2009), news stories (MacEachren, Stryker et al. 2010; Tomaszewski 2011), economic statistics (Dykes and Brunsdon 2007; Bettina 2010), social statistics (Bettina 2010) or user annotation (Slingsby, Dykes et al. 2007)), place-labels are either completely omitted (Dykes and Brunsdon 2007; Christophe 2009; Bettina 2010), overlapped (Slingsby, Dykes et al. 2007; Bettina 2010; MacEachren, Stryker et al. 2010; Tomaszewski 2011) or selectively removed (Zhang and Harrie 2006). This destroys the context that would otherwise be available through those labels and ultimately makes the additional information harder to comprehend.

With some maps this is less of a problem since features such as familiar coastlines, borders or state boundaries can be included to provide the context that would otherwise be lacking (Bettina 2010; MacEachren, Stryker et al. 2010). This would not always be the case with the interactive map we planned to develop to help users search and explore the history of Mexico. If the map where to be completely zoomed out, the Mexican coastline is likely to provide some degree of context but this would not be the case if the user where to zoom into a small area of coastline or an area void of coastline. State boundaries could be included to provide context but this would rely on the user being familiar with the shape of the boundary and the zoomed-in area containing enough of the boundary to be recognisable. Current state boundaries might also be inappropriate when viewing historic data since these have tended to change significantly over the region's history (as have the national frontiers). Other boundaries (cultural divisions and geophysical features) tend to be only roughly defined so are unable to provide any substantial degree of context.

METHODOLOGY

The first stage of our investigation was to undertake requirements analysis to evaluate existing approaches to the task of information retrieval in our test area of Mexican history. This involved enlisting the help of a group of nineteen undergraduate students who were asked to perform a series of ethnographic studies and interviews to investigate both the objectives of persons wanting to explore Mexican history and how they might realise those objectives using available materials. The idea was that this would allow us to reveal any limitations of existing approaches and generate some ideas as to how these might be improved. The second stage of the investigation was to analyse any limitations in order to determine if and how the users' cognition is retarded and how the situation might be rectified with a new situated cognition aware design. The final stage of the investigation was to code a software prototype of the new design and evaluate its use. This allowed us to confirm and validate the conclusions of the first two stages by seeing if our new situated cognition aware design constituted an improvement over existing techniques.

RESULTS

The profile of people searching for information about Mexican history and their individual objectives tended to vary. Scenarios included things like students preparing for class projects, tourists preparing for a visit to a particular area of the country and locals researching the history of their home town. Despite this, the methods used to achieve individual objectives and the problems encountered were fairly consistent.

Where users employed a computerised approach to search for data they tended to use an online resource they considered to be reliable and comprehensive. Almost invariably this would be the online encyclopaedia Wikipedia (Halavais and Lackaff 2008; Lim 2009). When users where able to use Wikipedia to construct a query to return the results they wanted, they normally found the results to be of a high quality. The problem was not with the quality of the results but with the difficulty users had in finding results relevant to their queries.

The major limitation of Wikipedia, and text based information retrieval approaches in general, was found to be a lack of flexibility. An example of this lack of flexibility is the way in which text based approaches deal with searches that include a geographic context. If a user searches for historic events in a particular town or city (e.g. their hometown or a place they plan to visit) they will normally be able to find the events in that town or city, this is not a problem. The problem lies in the fact that a user is not made aware of significant events that occurred neighbouring or nearby towns and cities. In most cases these results are likely to be just as important as, if not more important than, the initial results returned. For example, a visitor to the state capital of Oaxaca de Juarez is very likely to be interested in visiting the birthplace of republican hero Benito Juarez in nearby San Pablo Guelatao. A search for events restricted to Oaxaca de Juarez would not return the birth of Benito Juarez.

If a user tries to resolve this type of issue by changing their initial search to include a larger region, augmented results would tend to be too large or too general. Moreover, the geographic divisions recognised by the users involved in our requirements analysis tended to overlap or be ill defined. These related to; political divisions (e.g. the state of Oaxaca), roughly defined cultural divisions (e.g. the region of the Mixteca) or geophysical features (e.g. the Sierra Juarez) – and were not well represented in the information retrieval systems surveyed.

In order to resolve this problem, the users felt they needed to see their results of their queries superimposed onto a map together with the names of particular towns and/or cities. While a map was felt to be the most natural representation for geographic data, it was felt that the names of towns and cities would provide proper geographic context for the data being presented. They also felt they needed to be able to move around the map to be able to view results in different geographic areas at different levels of detail.

These requirements related to the type of action that the users needed to be able to perform with the data and the sort of context they needed in order to interpret the data. As stated in the theory of situated cognition, the users' cognition was tied to the action (in this case browsing the map) and actions were tied to context (the names of towns and cities). These factors would be taken into account in our new design which would be a geo-visualisation (interactive map) that allowed users to explore the map while allowing them to view place-name labels alongside search results.

THE MEXICAN HISTORY BROWSER

The Mexican history browser application (see Figure 1) allows users to search for events in Mexican history with results highlighted on an interactive map of the country. The map accounts for the importance of context to cognition by ensuring that result labels never overlap place-name labels. The user can also zoom in and out of the map by rotating the mouse wheel. After zooming, labels are repositioned to continue to avoid overlap (see figure 2) with animation used to smooth the transition between views (Craig and Kennedy 2008). Here we use a standard "greedy" algorithm (Christensen, Marks et al. 1995) placing consecutive labels in one of 10 alternative positions around the locations of their point-features omitting labels when they cannot be placed without overlap. While place-labels are often omitted when the map is zoomed-out to show a larger area, these tend to be the labels of smaller towns or cities that would provide less context (see Figure 3). When the map is zoomed in, the labels of smaller towns and cities become visible. This type of behaviour is standard in most popular interactive map interfaces such as Google maps (2012). The user can also move the mouse cursor over event labels and geographic point features to 'brush' (Becker and Cleveland 1987) events and explore the data according to its location on the map.

We compared the usability of our map results display with that of text based approaches by observing a set of four users interacting with each type of system while employing a think aloud protocol. This was followed up by a series of interviews designed to elicit a better understanding of the relative merits of each system. This revealed that when using our map based system it was found that the additional geographic context allowed users to discover unsuspected patterns of events and discover geographically related events.

Comparing the performance with and without avoiding overlapping place-names also showed significant benefits for the new design. Due to the size of Mexico and its lack of coastline around a number of significant populated areas (of Mexico´s 10 most populous cities only Tijuana is coastal) even those with significant knowledge of the geography of the country where unable to relate the position of labels to anything other than the most basic of geographic context. Here the inclusion of state borders did little to help. When place-name labels where reintroduced, the improvement in the users comprehension was significant. This was often reflected in the language of the users who would remark that a particular group of events were 'close to' or 'on the way to' a particular town or city. In turn this lead the user to link the information to further knowledge related to a particular place. The users would say things like "this is in the Mixteca/Siera Juarez/Oaxaca state etc" or "I have a friend/relative/colleague that lives near/is from there". This rarely happened when place-names where overlapped and never happened with the text based approach.

FUTURE WORK

There are two principle areas of future work planned to evolve from the research described in this paper. Firstly, we plan to further develop the Mexican History Explorer application to better represent the temporal context of events by including a timeline (Plaisant, Rose et al. 1996) view of the data. We also plan to utilise the methodology utilised in this paper for the development of geovisualisation applications with other types of data in other domains. The first of these is to be an interface for a database of multimedia data relating to the Mixteca culture and indigenous people. This will serve the dual purpose of being a portal for researchers and a general electronic recourse for those interested in the rich and varied native culture of the larger Mixteca region and its people. The second application will display economic data together with the results of scheduling algorithms developed to optimise delivery routes for small businesses operating in the Oaxacan part of the Mixteca region.

CONCLUSION

In this paper we describe a situated cognition aware approach to the design of information retrieval systems for geospatial data using the example of a system for events in Mexican history. This began with a requirements analysis exercise focused on identifying the actions that users want to realize with their data and context that is important for those actions. In the case of our search system for events in Mexican history, we discovered that users wanted to search for events and explore results within the context of town and city place-names. The next step was to develop a system that supported the process of situated cognition by allowing the user to realize these actions with the relevant context. In our case this application took the form of the Mexican history browser which ensures that place-names remain visible at all times (without being overlapped or removed) and allows the user to move around the map repositioning result labels when required using animation to smooth the transition between views. A user evaluation of the new design showed significant improvements in usability over existing techniques. Allowing users to explore the map helped them to discover unsuspected patterns of events and discover geographically related events. Maintaining the visibility of town/city place-names provided essential geographic context for results helping users to relate results to known places and existing knowledge.

A general conclusion of the work presented is that software developers can benefit for accounting for the processes of situated cognition during the design process. The process of situated cognition is supposed to be universal so this should hold for designers of different types of application. With regard to the findings of our particular case study, we suppose that the need to explore research results should be universal so this should apply for designers of other types of information retrieval system. We also suppose that a similar type of interface could be used to view other types of event data such as news or meteorological events. The need to view results in the context of town/city place-names may, however, be specific to a particular culture or people who live in countries with a particular type of geography. It could be argued that, for example, users from the United States might be able to use familiar state boundaries for geographical context since the citizens of that country tend to be more familiar with its state boundaries. Similarly, persons from countries with more distinctive coastlines such as the Norwegians of Japanese may be able to use these geographic features for context. The personal opinion of the paper authors is that this would not be the case since the unit of the town or city is a more ingrained (and older) cultural entity than the national or physical border and therefore users would almost always prefer to use town/city place-names for context. However, testing with an international user group would be required to prove or dis-prove this hypothesis.

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REFERENCES

. "Quintura." Retrieved March 2011, 2011, from http://www.quintura.com/.

(2012). "Google Maps." Retrieved 28/3/2012, 2012, from http://maps.google.com.

Anick, P. G., J. D. Brennan, et al. (1990). A direct manipulation interface for boolean information retrieval via natural language query. Proceedings of the 13th annual international ACM SIGIR conference on Research and development in information retrieval. Brussels, Belgium, ACM**:** 135-150.

Becker, R. A. and W. S. Cleveland (1987). "Brushing Scatterplots." Technometrics **29**(2): 127-142.

Bettina, S. (2010). "Necklace Maps." IEEE Transactions on Visualization and Computer Graphics **16**: 881-889.

Brown, J. S., A. Collins, et al. (1989). "Situated cognition and the culture of learning." Educational Researcher **1**(18): 32-42.

Craig, P. and J. Kennedy (2008). Concept Relationship Editor: A visual interface to support the assertion of synonymy relationships between taxonomic classifications. Visualization and Data Analysis 2008. K. Börner, M. Gröhn, J. Park and J. Roberts. San Jose, CA, Society of Photo-Optical Instrumentation Engineers, Bellingham, WA**:** 680906-680912.

Chen, C. and Y. Yu (2000). "Empirical studies of information visualization: a meta-analysis." International Journal of Human-Computer Studies **53**(5): 851-866.

Christensen, J., J. Marks, et al. (1995). "An empirical study of algorithms for point-feature label placement." ACM Trans. Graph. **14**(3): 203-232.

Christophe, H. (2009). "FromDaDy: Spreading Aircraft Trajectories Across Views to Support Iterative Queries." IEEE Transactions on Visualization and Computer Graphics **15**: 1017-1024.

Dykes, J. and C. Brunsdon (2007). "Geographically Weighted Visualization: Interactive Graphics for Scale-Varying Exploratory Analysis." IEEE Transactions on Visualization and Computer Graphics **13**(6): 1161-1168.

Dykes, J., A. M. MacEachren, et al. (2005). Exploring geovisualization, Elsevier.

Greeno, J. G. (1989). "A perspective on thinking." American Psychologist **44**: 134–141.

Halavais, A. and D. Lackaff (2008). "An Analysis of Topical Coverage of Wikipedia." Journal of Computer-Mediated Communication **13**(2): 429-440.

Hearst, M. (1995). TileBars: Visualization of Term Distribution Information in Full Text Information Access. Proceedings of the Conference on Human Factors in Computing Systems, CHI'95.

Hearst, M. (2009). Search User Interfaces, Cambridge University Press.

Hertzum, M., E. Fr\, et al. (1996). "Browsing and querying in online documentation: a study of user interfaces and the interaction process." ACM Trans. Comput.-Hum. Interact. **3**(2): 136-161.

Hoeber, O. and X. D. Yang (2006). A Comparative User Study of Web Search Interfaces: HotMap, Concept Highlighter, and Google. Proceedings of the 2006 IEEE/WIC/ACM International Conference on Web Intelligence, IEEE Computer Society**:** 866-874.

Jones, S. (1998). Graphical Query Specification and Dynamic Result Previews for a Digital Library. ACM UIST, San Francisco, California, USA, ACM Press.

Lim, S. (2009). "How and why do college students use Wikipedia?" J. Am. Soc. Inf. Sci. **60**(11): 2189-2202.

MacEachren, A., M. Stryker, et al. (2010). "HEALTH GeoJunction: place-time-concept browsing of health publications." International journal of health geographics **9**(1): 23.

Manning, C. D., P. Raghavan, et al. (2008). Introduction to Information Retrieval, Cambridge University Press.

Marchionini, G. (2006). "Toward human-computer information retrieval." Bulletin of the American Society for Information Science and Technology **32**(5): 20-22.

McCormick, B. H., T. A. Defanti, et al. (1987). "Visualization in scientific computing." IEEE Computer Graphics & Applications **21**(6): 61-70.

Michard, A. (1982). "Graphical presentation of boolean expressions in a database query language: design notes and an ergonomic evaluation." Behaviour & Information Technology **1**(3): 279-288.

Olsen, K. A., R. R. Korfhage, et al. (1993). "Visualization of a document collection with implicit and explicit links." Scand. J. Inf. Syst. **5**: 79-95.

Plaisant, C., A. Rose, et al. (1996). LifeLines: Visualizing Personal Histories. ACM CHI'96 Conference.

Slingsby, A., J. Dykes, et al. (2007). Interactive Tag Maps and Tag Clouds for the Multiscale Exploration of Large Spatio-temporal Datasets. Proceedings of the 11th International Conference Information Visualization, IEEE Computer Society**:** 497-504.

Spoerri, A. (1993). InfoCrystal: a visual tool for information retrieval \& management. Proceedings of the second international conference on Information and knowledge management. Washington, D.C., United States, ACM**:** 11-20.

Tomaszewski, B. (2011). "Situation awareness and virtual globes: Applications for disaster management." Computers & Geosciences **37**(1): 86-92.

Vanderbilt., C. a. T. G. a. (1993). "Anchored instruction and situated cognition revisited." Educational Technology: 52-70.

Young, D. and B. Shneiderman (1993). "A graphical filter/flow model for boolean queries: An implementation and experiment." Journal of the American Society for Information Science **44**(6): 327-339.

Zhang, J. and G. Marchionini (2005). Evaluation and evolution of a browse and search interface: Relation Browser++. Proceedings of the 2005 national conference on Digital government research. Atlanta, Georgia, Digital Government Society of North America**:** 179-188.

Zhang, Q. and L. Harrie (2006). "Placing Text and Icon Labels Simultaneously: A Real-Time Method." Cartography and Geographic Information Science **33**(1): 53-64.

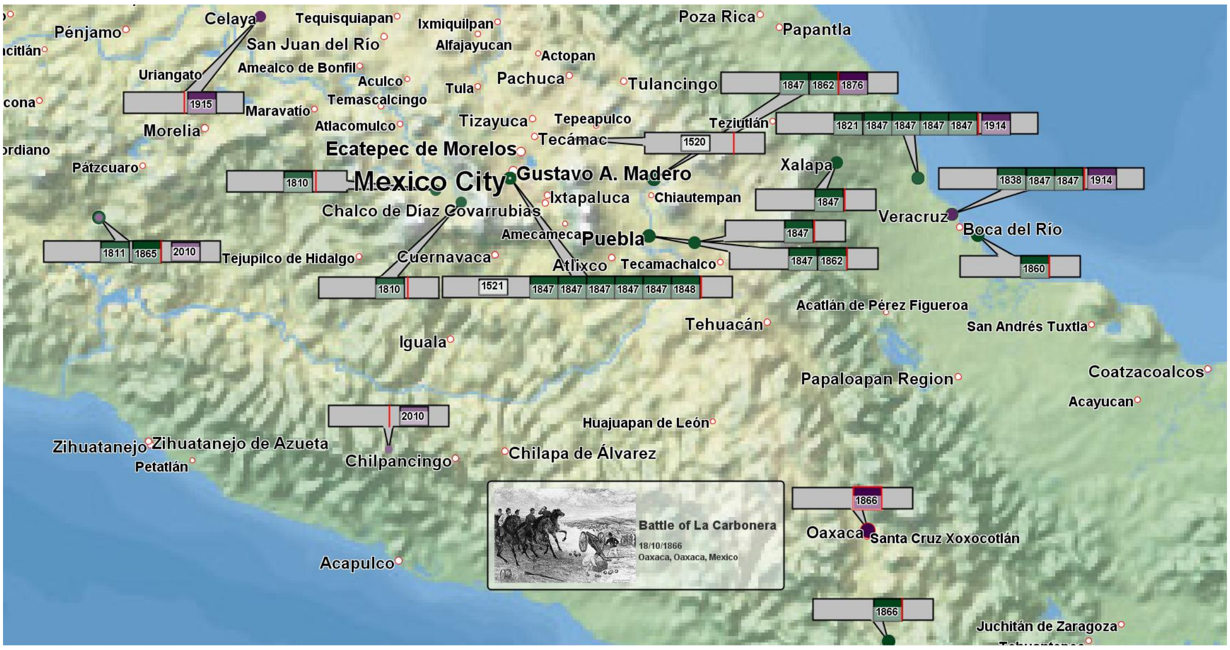

Fig. 1. Map view of the Mexican History Browser. Zoomed-in on southern central Mexico and highlighting the Mexican victory over the French Napoleonic armies at the battle of La Carbonera on 18th October 1866 in Oaxaca de Juarez.

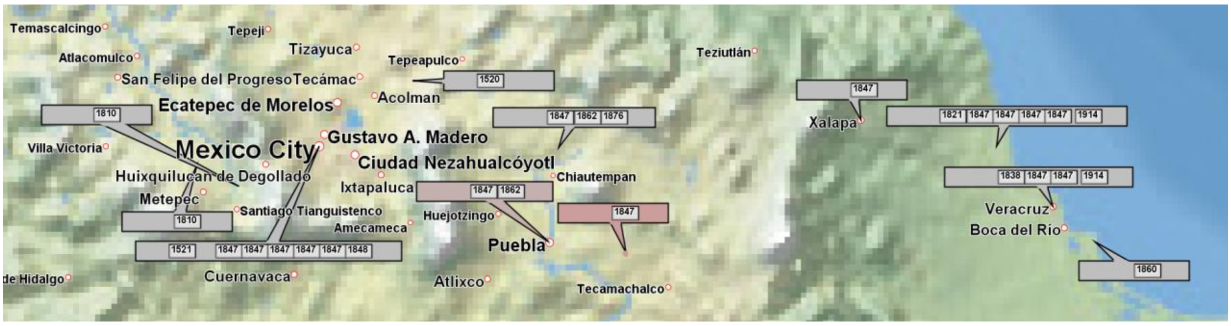

Fig. 2. After zooming, labels are repositioned to continue to avoid overlap with animation used to smooth the transition between views.

Fig. 3. Point feature label placement; LHS, place-labels are often omitted when the map is zoomed-out to show a larger area. RHS, when the map is zoomed in, the labels of smaller towns and cities become visible.