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RECONSTRUCTION OF SCENES FROM GEO-REFERENCED WEB RESOURCES

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ABSTRACT

We present the results of a case study aiming to assess the reflection of the physical environment in the Web and its usability to enhance navigation services. The wealth of information contained in Web resources consists of its content, as well as of the semantics in its patterns. We analyze the potential to improve the navigation services beyond simple provision of landmarks. The suitability of the Web documents to provide supporting information for an automated urban navigation service is tested through the reconstruction of the semantics of georeferences in Web resources into scenes. This eases a wayfinder's cognitive load necessary to remember the set of route directions and to navigate in the environment. In a detailed analysis of the Web resources we identify usable patterns and ways to mine the information out of these patterns. This shows how the interpretation of georeferences in Web resources reflects perceivable properties of described features.

BIOGRAPHY

Martin Tomko is Postgraduate Student at The University of Melbourne, Australia, working on a thesis on granular route directions. He has a MSc in Geodesy from the University of Technology Bratislava, Slovakia (2003). His master thesis was done in cooperation with TU Delft, Netherlands, on spatial databases for mobile GIS. Martin Tomko was also representative for Slovakia in the CEN TC 287, Geographic Information.

INTRODUCTION

Current navigation services usually provide turn-by-turn route directions. These reflect the internal representation of the route in a database. However, they do not consider human spatial cognition and the way people experience space, which is then reflected in the ways they communicate route knowledge in route direction narratives [Weissensteiner and Winter 2004]. This mismatch makes navigation instructions susceptible to misinterpretation, which is a barrier to a successful location-based service (LBS).

Wayfinders – agents (in our case humans) navigating in an environment – use the knowledge of its features, extracted from route directions, to reconstruct the scene at decision points and form a mental model of the reality prior to the visit. Enhanced route directions provided to wayfinders by LBS should therefore include landmarks and other features of the environment, adapting the content to the knowledge and perception of the user. Building additional data sources with landmarks information is expensive and therefore few are available. The Web, as a "self-maintaining" information resource, can be used to reconstruct this information, as shown in [Ma et al. 2003; Tomko 2004]. The specifics of the matching between the semantics of the wayfinder as opposed to the semantics assigned by the content creator were addressed in [Winter and Tomko in press].

In this paper we look at the principles of scene reconstruction. We present a case study that starts from the supposition that the Web, as a collection of documents, reflects the physical reality in a manner usable to enhance current navigation services with information on the design and shape of our immediate spatial environment, the vista space [Presson and Montello 1988]. Our interest is focused on the possibility to reconstruct elementary scenes at decision points of a route. A scene, in this context, is the description of the physical setting of environmental features surrounding the place where the decision is taking place.

This research demonstrates that the wealth of information contained in Web resources, at least in urban environments, consists not only of the content. The semantics of the patterns of the content can be successfully evaluated and transformed into concepts from other spatial ontologies, namely those of wayfinders. In our case study we can reconstruct elements that are useful to enrich route directions. Having shown the path in principle, the open question is to formalize and implement the identified rules for interpreting natural language patterns.

FORMAL AND EXPERIENTIAL GEOREFERENCES

Georeferencing

The Web is an organic network of informally structured heterogeneous data sources, many of which provide some form of reference to geographic space. These georeferences link the descriptions of physical or social reality to particular locations or configurations in geographic space. This representation of locations and configurations is heterogeneous, as the process of its creation is as random and unstructured as its content.

Georeferencing, extending here a recent definition by Hill [2004], is: …relating information to geographic locations through place names (i.e., toponyms), place descriptions (e.g., "the green building"), place relations (e.g., "the building opposite to the church"), place codes (e.g., postal codes), or through geocode (e.g., geographic coordinates). These types of georeferences are found in Web resources, either in the content or in tags.

Georeferences in the content of the Web pages are usually made in natural language. They address the human reader, and require a proper understanding of some semantic and world knowledge, on the reader's side as well as from the creator. An example is the common location of georeferencing on websites under the category "contact us", pointing to a post address.

The annotation of Web resources through tags brings the current Web closer to the vision of the Semantic Web [Berners-Lee et al. 2001], or the spatially enabled Geospatial Semantic Web [Egenhofer 2002]. For an overview of formal georeferencing on the Geospatial Semantic Web, especially for extraction of landmarks can be found in [Tomko 2004] and other applications are demonstrated in [Toyama et al. 2003]. These approaches are beyond the focus of this paper. As we cannot expect that a sudden massive conversion of current Web resources to match Semantic Web requirements will happen soon, sophisticated algorithms parsing textual information on the Web are required.

Location semantics are closely coupled with spatial relation semantics. References to relations between several features can be perceived as a specific part of georeferencing. The ability to retrieve the relations between features of the environment using spatial relation references from natural language statements is necessary to reconstruct scenes of the urban environment. The human use of fuzzy terms designing spatial relations is causing problems for automated interpretation in a manner consistent with human understanding of these statements [Mark et al. 1995].

Georeferencing of wayfinders

People learn and communicate their environment by experiences, and interaction [Siegel and White 1975; Golledge et al. 1976; Golledge and Stimson 1997; Weissensteiner and Winter 2004]. Landmarks have a particular role in learning and communicating routes [Habel 1988; Cornell et al. 1989; Michon and Denis 2001]. As Denis *et al.* [1999] have shown, people prefer landmarks to determine points of re-orientation during wayfinding (decision points).

Lynch distinguishes landmarks among the structuring elements of a city [1960]: landmarks, places, paths, barriers and regions. However, his concept of a landmark is a narrow one; from a cognitive point of view the latter four structuring elements can equally form landmarks.

When wayfinding, people generate travel routes from their mental maps, communicating these routes by relating movement and orientation actions to landmarks at selected points along the route. Wayfinders can only perceive the environment through their senses, and remember mainly visually salient features of the environment. These features become part of their mental maps and are afterwards communicated in route directions, in order to form similar mental images among the direction receivers.

Current wayfinding services generate travel routes on metric travel networks, and due to a lack of landmark knowledge automated route directions rely on metrics. In human route directions, georeferences are used to evoke some wayfinding behavior at specific locations along the route. The direction "at the church turn right" uses a place description by referring to a feature by a categorical term. It could use the place name, the feature's name ("at the Trinity Church turn right"), if the route direction is given to a reader familiar with the place.

Imagine the following scenario -- Hillary, a tourist in Melbourne, Australia, found in her travel guide a recommendation for tea at the Hotel Windsor along with the address: 111 Spring Street. This information does not help her to find the place. She asks at her hotel reception for the route: "To the Hotel Windsor?"

Note that Hillary refers to the institution, Hotel Windsor, not to its address. Even locals may not know which building 111 Spring Street is, but they have an experience of the Hotel Windsor.

> "Ok, when you leave the Hyatt, turn right and walk down to the end of the street. At the intersection you can see to your left the Parliament, and opposite to the Parliament is the Hotel Windsor."

The direction giver refers to landmarks ("Hyatt", "Parliament") and to the structure of the street network [Klippel 2003], remembering experiences he believes will be shared by Hillary on location ("walk down", "you can see"). The direction giver seems to be convinced that she will recognise the Parliament, which means that it has a prototypical appearance, with characteristics shared by "usual" parliament buildings [Rosch 1978; Lakoff 1987]. The direction giver provided Hillary with a description of a scene and gave her an idea of the spatial layout of several salient features in the environment.

Web and Wayfinders' Georeferences

The location and configuration references inherent in the Web content form a rich pool of geospatial features, which can be used by wayfinding services for searching for landmarks [Tomko 2004]. Since the notion of landmark is subjective, bound to a shared or a shareable experience, services cannot automatically identify landmarks. Instead, they implement generic methods to identify *salient features* in spatial data sets, based on three qualities of landmarks: visual, semantic and structural ones [Sorrows and Hirtle 1999]. The features that have most distinct parameter values in the set are called salient features. These are considered for inclusion in route directions, as shown on examples of visually and semantically salient features in [Raubal and Winter 2002; Elias and Brenner 2004; Nothegger et al. 2004]. Landmark selection may depend on route properties – especially on the structure of the decision points [Klippel and Winter to appear] and on the context of the recipient [Winter et al. 2004].

The matching between locations and configurations inherent in the Web and the perceived reality of the wayfinder is necessary in order to enhance automatic route directions with real world features. The likelihood that a specific configuration of spatial features will occur multiple times is low in anthropomorphic as well as natural environments. Therefore, even if the selection algorithms do not succeed to select a feature at a decision point with enough saliency, the inclusion of multiple features can provide the wayfinder with a scene description that will be distinguishable and unique.

When navigating, the wayfinder has to recognise the place referred to by the direction giver. However, Web resources do not provide observations of visual, semantic or structural quality parameters of features of the environment in the first instance. Web resources intend to identify features (e.g., by a unique postal address), to find features (e.g., by route directions), or to establish trust in institutions (e.g., by naming an expensive location). Perceptual aspects of local features are usually irrelevant for their purpose.

This results in the necessity to process the information from the Web to extract the perceivable characteristics of the environment prior to including it in the route directions. The wayfinder uses concepts like church and intersection, as opposed to the Web content creator's concepts, such as house number, street name, or post code. In the following sections, we explore the possibilities and challenges to use the georeferences in Web resources to reconstruct the scene of the environment where the wayfinder navigates.

SCENE RECONSTRUCTION FROM GEOREFERENCES

The content georeferences on the Web are restricted to text (e.g., addresses, postcodes, or telephone numbers) and images (e.g., photographs, sketches, maps)—methods that are not designed for automated processing and interpretation. Textual descriptions or images are forms of narratives, and their semantics is inferred in active reading processes [Weissensteiner and Winter 2004], that needs to be emulated by automatic natural language understanding [Dale et al. 2000].

A higher degree of unification is possible for some forms of georeferences, typically for various national address standards [ICSM 2003]. The focus of these standards is however only mailing, and does not necessarily provide a correct georeferences for wayfinding. A postal address characterises a piece of land that can be represented geometrically by a polygon. However, address geocodes have semantics of their own: centroids of polygons, street front center points, building entrance points, or arbitrary points inside of the polygons are possible examples. Geocode data sets often use heterogeneous geocodes. The limitations are manifold: features might have no postal address at all (e.g., monuments), or be physically inaccessible from the road (malls, university buildings on campuses). Address patterns are often included in an imprecise, inconsistent, or incomplete manner, as, e.g., in the string "in Collins Street". Therefore, robust thesauri of geographical names need to be constructed to disambiguate the content of the text and of the references to features, such as "Melbourne, Victoria", and "Melbourne, Florida". For an example of a worldwide geographical thesaurus see Getty Thesaurus of Geographical Terms, http://www.getty.edu/research/conducting_research/vocabularies/tgn/).

On Web pages, address patterns are often integrated with parts of text containing natural language statements, often referring to relations between features of the environment (e.g., "close to"). The extraction of georeferences is affected by pattern matching, Web resource layout issues, and by problems of parsing natural language content affected by language and cultural differences. Also, the level of detail of the georeferences provided by the resources is important. A model for place name-based information retrieval was proposed in [Jones et al. 2001]. Similarly, a useful notion of localness was introduced by [Ma et al. 2003], describing the extent to which a Web site provides regional information, the level of detail of the resource (localness degree), and the ubiquity of the resource.

The successful extraction of location information from Web resources enables to construct a candidate set of potential features in the selected environment. Then, localness analysis can contribute to filter only the most relevant features in the specified location. Still, there is no certainty that the identified resources address an existent, permanent and visually salient feature that is useful for a wayfinder. The reliability of the results can be increased by analysing the scene - spatial relations of the identified feature to its neighbours. Their respective Web resources provide references to the original feature and in return certify the correctness of the georeferences. This is an alternative application of the spatial co-occurrence as introduced in [Ma et al. 2003].

Natural language statements in Web resources are as flexible and various in georeferencing as people are in speech acts. Particularly private Web resources show narrative forms of georeferencing, often in the context of wayfinding information. Such statements communicate locations, frequently perceived through subjective personal experience with the environment. They also communicate spatial configurations: different elements of the environment can be related through statements describing their spatial relationships.

For scene extraction we propose to exploit techniques of document data mining, with Web pages as documents, containing natural language and semi-structured parts, hyperlinks and other media such as images or movies. Symbolic, heuristic, or neural network natural language processing techniques [Dale et al. 2000] can be applied. Particularly helpful are techniques of data mining in texts [Merkl 2000], as applied for example in [Tezuka et al. 2004]. Another approach would be symbolic natural language processing which consists of tokenization, lexical analysis, syntactic analysis, semantic analysis, and pragmatic analysis to understand the speaker's intended meaning [Dale 2000]. The reason is that Web documents contain semi-structured natural language in a double sense:

- They contain text that is explicitly structured, in constrast to spoken or written utterances, the two classical applications of natural language understanding. This explicit structure itself implies tasks of natural language processing, such as tokenization. Furthermore, documents are enriched with other communication media, such as images. Data mining in images is a research area on its own; however, in our case text and images are related, and their processing should be linked to increase the level of understanding. Finally the considered documents are hyperlinked with external references. Parts of their meaning can be concluded from content in the linked documents. Again, this exceeds traditional approaches of natural language processing.

- The underlying tagging by the XML dialect HTML brings in syntactic structures that help at least with tokenization and syntactical analysis. As mentioned earlier, the Semantic Web [Berners-Lee et al. 2001] will support more of these tasks, such as semantic analysis.

Natural language descriptions often include terms providing a description of a spatial relation between described features. Vague or fuzzy expression as “close to”, “nearby” and “further down” are used as often as more exact terms as “next to”, “opposite”, “within a distance” and “after”. The context-dependent interpretation of fuzzy topological relations is beyond the focus of this paper; for an introduction see [Worboys 2001].

The basic actions of a wayfinder are to change direction (“turn”), and to change location (“move”). Investigating the verbs or actions in route directions results in action ontologies that define the degrees of freedom of a traveler in a particular mode of traveling [Kuhn 2001; Timpf 2002]. As the Web contains natural language descriptions, investigating action ontology patterns is a viable mean to locate georeferences [Winter and Tomko in press].

A CASE STUDY IN SCENE RECONSTRUCTION

Experiment

In a case study we present the possibilities of exploiting the content of georeferences in Web resources, especially in form of natural language and address. The case study concerns a segment of Hillary’s route from the Hyatt to the Hotel Windsor, namely the environment of the turn at the corner of Collins Street and Spring Street (1 to 5 Collins Street) in Melbourne, Australia (Figure 1).

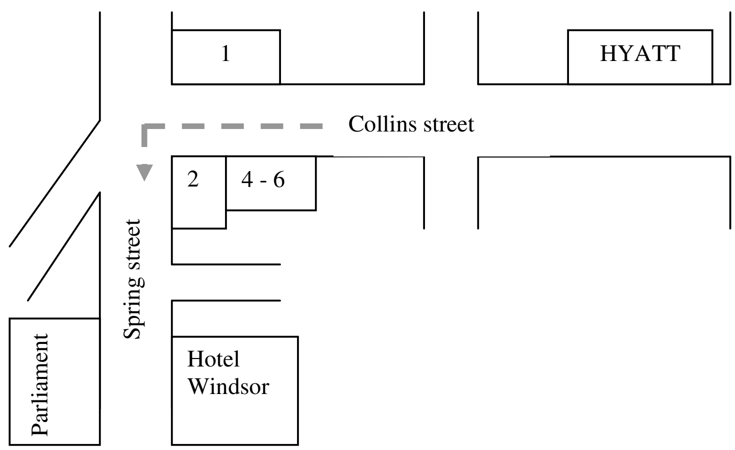

Figure 1: Reconstruction of the situation at 1 to 5 Collins Street.

Imagine the actions that Hillary’s next-generation WebGuide system would need to perform in order to provide her with user-friendly route directions. WebGuide should reconstruct the layout of the environment—the decision point, identify visual, semantic and structural qualities of local features to determine their salience, and finally present them in natural language description of the route.

We have manually collected a directory of Web resources referring to features, institutions, or events along the street segment 1 to 5 Collins Street, Melbourne. We queried Google on the 6th of October 2004 with strings such as “1 Collins Street” “Melbourne”, limited to search in Australian Web resources and filtered out the first 50 valid search results for each address. Web resources that were not directly accessible via Google (e.g., searchable databases like the Yellow Pages) were excluded. In other work we assess the relevance of these resources as landmarks for wayfinders [Tomko 2004].

Keyword-based search delivers large numbers of results, with many false hits. Our Google search with the query string “2 Collins Street” “Melbourne”, for example, returned 93,400 links, but many of them invalid or irrelevant to the intent of the searcher. However, many of the found Web resources refer to the correct address: 2 Collins Street is one of the high-rise office buildings in this central business district area, with multiple Web resources describing the many businesses located here. Still, the query misses Web resources that contain the valid short form “2 Collins St”, the street name in wrong spelling, or, although being relevant, contain no street name at all. An examination of postal address patterns in the Web resources for 1 to 5 Collins Street showed 29 different captions and header types when referencing to location. This does not include all the descriptive references in natural language. The search was performed manually, but HTML parsers are able to search for specific tag groups and patterns (`http://htmlparser.sourceforge.net/`). A drawback of these parsers is that one has to build the pattern library.

Identification of scene elements

The search performed on the segment 1 to 5 Collins Street returned a rich variety of Web resources. A look at a sample Web page from the set of returned resources will be used to demonstrate what properties of scene elements one can retrieve and how we can identify them in the Web page.

The first resource found by Google Web search on "1 Collins Street" "Melbourne" pointed to a specialized tourist guide of Melbourne's architecture: h`ttp://www.walkingmelbourne.com/building_pro-file.php?ID=322`. This is not a typical Web page, describing a single item, or describing a single feature of the material world. Such Web pages usually contain a single georeferences, and its resolution is therefore less ambiguous even in an automated manner. Because of its focus, *Walkingmelbourne.com* contains a wealth of various georeferences. It is therefore a good example of a resource where we can identify many perceivable scene properties.

The page is designed as a HTML table, with the main content in the middle column. The right column contains typical navigation buttons. It is important to note that the button *contact* may be, in our context, misleading. It points to the contact information of the Web page owner, not to the content itself. Automatic parsers need to be able to distinguish whether a specific keyword or georeference is related to the main topic of the Web page, or to its author.

The body of the page contains the *building profile* of *1 Collins Street*. This address pattern is repeated several times in the body of the page, which is a good indication that the information contained are related to a feature georeferenced by the address. The frequency of a specific address string in the body of a page should be therefore considered by automatic parser.

Further, the page contains an architectural description of the building. The keyword *built* points to the age of the building. It is repeated several times in the page content. As demonstrated in our work [Winter and Tomko in press], action ontologies are an important source of context for extraction of georeferences from natural language statements. The verb *built* describes the existence of a feature, and in relation with an address pattern is a good hint of the physical existence of the feature. This is enforced by the word *landmark* in the proximity of the address.

Finally, the appearance of an incomplete address pattern *Spring Street* should be noted. The occurrence of other georeferences should be entered in a candidate set and observed in the remaining search results, or in the search results of other features with neighboring georeferences. This allows to partially reconstruct the street network dependencies, as shown in the next section. For an interesting example of street network structure reconstruction from Web search results, see [Jones 2004]. The context of other search results for a specific address reveals further details about the feature described. For instance, the floor numbers from the address georeferences can be collected and we can deduct the minimum height of the building. In the case of 1 Collins Street, we are able to say that it has to have at least 16 floors. National specifics of address formats are, however, a problem for a global implementation of these rules.

Reconstruction of perceivable feature properties

To reconstruct a perceivable image of the reality for a wayfinder from Web resources the first step is to extract the features that are potentially relevant, by their georeferences. In the second step their (spatial) relations to each other have to be identified. For example, the large number of businesses registered at 2 Collins Street suggests an aggregated perceivable feature of a larger office building. Such spatial properties can translate into natural language descriptions. Afterwards, a selection of identified perceivable features can be made according to their relevance for a given context of a wayfinder.

We have pointed to georeferencing ontologies and the spatial relations and proximity statements that are found in natural language descriptions in Web resources. With all these tools at hand, one can derive from the examined Web resources perceivable facts about 1 to 5 Collins Street such as:

- 1 Collins Street has a name: Rialto Tower.
- 1 Collins Street is at least 16 floors high.
- 1 Collins Street is an office building.
- 1 Collins Street is a landmark of Collins Street and has won an architecture prize.
- Opposite of 1 Collins Street is 4-6 Collins Street.
- 4-6 Collins Street has a name: ANZAC house.
- 4-6 Collins Street is within 150 meters of the Parliament train station.

- 2 Collins Street is adjacent to 4-6 Collins Street.
- 2 Collins Street has a name: Alcaston House.
- 2 Collins Street has at least 6 floors.
- 2 Collins Street has also a Spring Street entrance.
    - It is either a corner building, or it reaches across the block.
    - Spring Street is *close* to Collins Street.

Such derived statements can be used by an intelligent service to enrich route directions with landmark references. By coupling HTML or XML parsers, datamining engines (especially those able to interpret natural language statements) and formalized ontologies of geocodes, postal addresses, or action ontologies in Web Ontology Language (OWL) {W3C, 2004 #55}, these references can be automatically extracted. Consecutively, an ad-hoc knowledge base can be built and exploited by a service. Agent systems can incrementally improve these knowledge bases to match less usual patterns in georeferencing, or to adapt the system to various natural languages.

DISCUSSION

The wealth of information provided through heterogeneous Web resources provides a rich resource of descriptive information that enables the reconstruction of perceivable characteristics of the environment. Resources were particularly rich in our case study since we selected an area in a business district. Other urban neighborhoods may address a lesser amount of information on the Web, however, the knowledge base for processing the resources will be the same.

One of the problems faced in our investigation is the low quality of Web resources. For instance, several Web georeferences refer to 3 Collins Street and 5 Collins Street, however, corresponding entrances of buildings cannot be found in the external world. An analysis of Web resource georeferencing relevance (quality and reliability), as well as the assessment of the resource "landmarkness" can be found in [Ma et al. 2003; Clough et al. 2004; Tomko 2004]. Further, intelligent geocoding is necessary for query processing – wayfinders perceive the physical features along a route from outside. Thus, the formal semantics of geocodes need to be taken into account. Finally, spatial relations between features ("next", "opposite", …) need to be interpreted, in the queries and in the query results alike.

CONCLUSIONS

We showed that an interpretation of georeferences in the content of Web resources enhanced with perceivable properties of features can be used as a mean to provide georeferences in route directions that will communicate to the wayfinder a richer image of the reality to be encountered. This case study shows that the Web contains the information necessary, but its extraction is made difficult by the heterogeneous and unstructured aspect of the majority of the Web content.

We have shown that the creation of geographic thesaurus is necessary in combination with parsers able to find address patterns. Further, action ontologies and spatial relation ontologies are necessary to identify whether the content of a specific Web page really describes the georeferenced feature, and what are its perceivable properties. Our approach may overcome some of the obstacles posed by the datamining for single landmarks on the Web. The interpretation of the information in context helps to verify the information in cases when the frequency of a georeference is low. This is a modification of the co-occurrence measure, when the occurrence of a related feature is verified through an independent search.

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