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Use of Geographical Information for Non-Visual Perceptualisation

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ABSTRACT: Non-visual perceptualisation of geographical information can be a valuable addition to, or even replacement for, a traditional cartographic display. This is especially true for navigation applications on mobile devices with a small screen size, where it can benefit more than just those with sight impairments. The HaptiMap project aims to encourage the incorporation of such enhanced accessibility into the user interfaces of mobile location-based applications. This paper discusses some of the issues faced by HaptiMap regarding the usability of geographical information for non-visual perceptualisation, and the solutions that have been proposed.

KEYWORDS: non-visual perceptualisation, usability of geographical information, human computer interfaces, application programming interfaces, data structures

1. Introduction

Assistance with pedestrian navigation whilst on the move is an obvious application for mobile communications devices. Efficient communication of the relevant geographical information through a small screen has been well researched (e.g. Brown & Laurier (2005), Cheverst et al (2000)) but has also been shown to disengage the user from the environment (Leshed et al, 2008) as well as impede the geographical understanding of the environment (Aslan et al, 2006). In addition a user may have difficulty interacting via a display screen because of disability, e.g. blindness. Non-visual perceptualisation is thus worthy of research as an alternative method of communicating geographical information to the user of a mobile device.

HaptiMap is a large-scale integrating project financed under the European Commission Seventh Framework Programme between September 2008 and August 2012. The full project title is "Haptic, Audio and Visual Interfaces for Maps and Location-based Services" and a key aim is to encourage the incorporation of enhanced accessibility into the user interfaces of mobile mapping and location-based applications. Developing methods of non-visual perceptualisation of geographical data and addressing the usability of geographical data for this purpose is central to this. The target application area is pedestrian navigation, with a particular (although certainly non-exclusive) emphasis on blind and visually-impaired users. This paper will discuss some of the needs that have been identified and solutions that have been proposed within HaptiMap for manipulating geographical data in order to perceptualise it non-visually.

2. Non-Visual Perceptualisation

Some examples of such non-visual methods developed by HaptiMap partners are:

- A *Haptic Belt* containing multiple vibrator motors, which when worn round a user's waist and combined with heading information, can indicate the direction of a point of interest or a route to follow (Pielot et al, 2010).
- The *Viflex* – a hand-held device containing a small platform that can exert a force in different directions on the user's fingers/thumb, or be manipulated by the user to indicate a direction or deflection, with variable levels of force feedback and/or vibration (Roselier & Hafez, 2006).

- *Sonification*, whereby pre-existing audio (e.g. music) or artificial audio may be manipulated to give the impression of coming from a particular direction when listened to through headphones (Strachan et al, 2005).

What these output methods have in common is that their requirements for the format in which geographical data is retrieved are substantially different from those for conventional rendering of a cartographic map. At this level, maps are typically “visualised” by making logical queries regarding the position of various geographical features relative to each other and to the user’s current location. The results of these queries are then presented using some non-visual methods such as those listed above. Types of queries could include:

- What is the first geographical feature of a certain type (e.g. boundary fence/wall, building) that a straight line from my current location in a particular direction would intersect, and how far away is it?
- I am lost while out hiking in difficult terrain – in which direction do I need to walk in order to get back onto a marked path via the shortest distance?
- How far am I from the edge of a polygon (Geofence) defining an area of town regarded as dangerous?

It is clear that in order to be able to make these kinds of queries, access is needed to the raw vector data underpinning the map. For example, a Web Map Service would not be suitable as it only shows geometric features already rendered for visual interpretation, whereas with non-visual perceptualisation some of this interpretation must be done by the application – the data presented to the user has to be filtered to reduce its information content, because the “bandwidth” of the non-visual communication channels is not as high as that of the visual channel.

3. Availability and Usability of Vector Data

The main problem with using vector data in these types of applications is that the amount of information contained can be overwhelming for a typical human-computer interface (HCI) developer who only wishes to extract e.g. centre lines of paths in a forest, or details of open spaces to use in an urban navigation application. To get details of just one feature would involve implementing a parser for the whole file format or database and there is a very steep learning curve to even get started.

Personal observations within the HaptiMap project have shown in addition that HCI developers tend to be unfamiliar with the typical file and electronic transfer formats commonly used for transmission of geographical information and with the way such information is typically structured, i.e. in terms of points, linestrings and polygons. Experimental systems such as those mentioned above by Pielot et al (2010) and Strachan et al (2005) tend to make use of geographical information only in the form of discrete points, unless in the context of augmenting a visual rendering of an existing map through non-visual means (HaptiMap, 2010).

This is clearly an issue in terms of encouraging reuse of existing geographical information in these emerging multi-modal applications—and thus very relevant to the goals of the HaptiMap project. One of several methods by which HaptiMap aims to achieve its goals is through the development of a toolkit for building accessible mapping and location-based applications. In effect this toolkit is a standard software library with an application programming interface (API) written in the widely used C programming language. The toolkit provides, among other features, a standardised cross-platform API supporting Windows Mobile, iPhone, Android, Symbian and Linux/MeeGo mobile platforms. This provides simple cross-platform support for both specialised hardware for haptic/tactile output and for access to device internal sensors, such as accelerometers or a GPS receiver. The feature most relevant to this discussion however, is a system to make accessing and using geographical information relatively simple for developers who do not have GIS programming experience, but are nonetheless competent programmers.

It is perhaps important to note that the target users of the toolkit are also software developers, i.e. not “end users” in the conventional sense of the term. This means that we are more concerned with technical details of how the geographical information is logically structured, and the electronic formats in which it is stored and transmitted, than in how it is presented through a front-end user interface—the hope being that we can empower these developers to make geographical information easier to interpret for end users, by in turn making it easier for them to acquire, interpret and manipulate the information. Ideally this will enable developers without prior GIS programming knowledge to create useful mapping and location-based applications.

The API functions provided by the toolkit for querying geographical data form a subset of the overall toolkit API. API usability (wherein the developers writing software that uses the API are considered to be the “users”) is being increasingly recognised as important (Daughtry et al, 2009), and evaluation of the toolkit from a developer point of view is an important part of the HaptiMap project. This will address such issues as having a clear feature list, and consistent function naming and argument order, as well as clarity of documentation, amongst others. The usability of the geographical data structure exposed through the API is a more subjective issue, and formal evaluation may necessitate assessing developers’ experiences using this and other sources in more depth; the exact mechanism by which this will be done has not yet been decided.

4. Simplified Data Model

A HaptiMap application may require geographical information to be retrieved from multiple sources with various different logical structures, file/transfer formats, co-ordinate systems, attribute models etc. A key aim of the toolkit is to hide this complexity from the end user. As most of the technical requirements related to this simplification and abstraction are specific to the individual sources of data, it makes sense to perform it as close to the data source as possible. To this end an architecture has been defined that uses multiple “geographical data plugins”, one for each data source. The toolkit may use data from more than one source concurrently. It is the role of these plugins to transform data into the simplified data model used by the HaptiMap toolkit, which is defined below.

The data model has been defined as a result of discussions between HaptiMap partners, and represents a compromise between representing the data structure from typical existing sources as closely as possible whilst providing a simpler “user-facing” structure. It can be seen that there are certain similarities with the data model used by OpenStreetMap (2011), specifically in terms of the small number of highly simplified geometric primitives allowed, however in general the HaptiMap model is more specifically tuned to the needs of accessible navigation on mobile devices (e.g. integer co-ordinates for efficient calculations, structured attribute system for ease of representation of standardised accessibility-related environmental features).

Co-ordinates. The key concept here is that all co-ordinates accessible to the user through the toolkit API, whether obtained from a location sensor device (e.g. a GPS receiver) or a source of map data (e.g. a NAVTEQ MapTP server or an OpenStreetMap XAPI server), are integer values in a regular grid with cartesian co-ordinates. Where available, height values should form a coherent part of a 3-D co-ordinate system when combined with 2-D position co-ordinates.

The toolkit does not impose any requirement on how this 3-D cartesian system is implemented “behind the scenes”; that is the job of the geographical data plugins. Typically however, a projected co-ordinate system, perhaps with values in centimetres, is used for the 2-D system and geoidal heights used for the third dimension. Obviously this is not a true 3-D system, however the xy -plane of the 2-D projected co-ordinate system coincides approximately with the geoid surface.

Geometries. The toolkit supports geometric objects based on a greatly simplified subset of the international standard Simple Features model (ISO, 2004), comprising only the elements Point, LineString and Polygon, as illustrated in Figure 1.

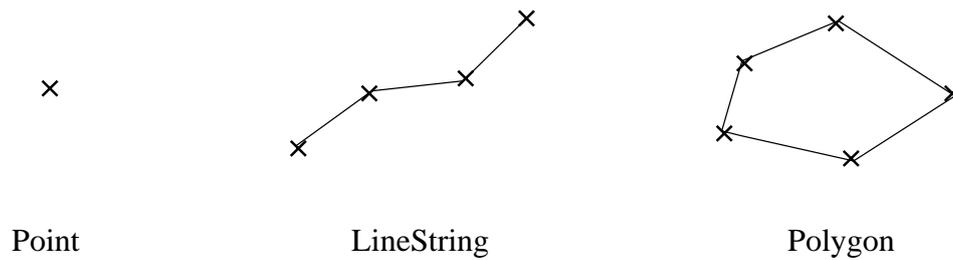


Figure 1. Geometric Primitives in the HaptiMap Toolkit

Note that the toolkit polygon is a simplified version of that defined in the ISO model. It consists solely of one outer closed LineString (also known as a LinearRing) defining the boundary, and no interior LinearRings.

Feature Types. Another output from HaptiMap in addition to the toolkit will be a set of content guidelines for accessible maps and location-based services. These will define a common model into which features relevant for accessible navigation, such as path, road and building locations, may be categorised irrespective of the original source of such data. The “intelligence” for transforming the features into the HaptiMap model will be contained within the geographical data plugins. This means that the user can access geographical data using a common feature model, no matter what the source.

Attributes. Each feature may have an unlimited number of attributes associated with it; an attribute consists of an integer attribute code indicating what property the attribute describes, together with an attribute value: either a single integer, an array of multiple integers, or a string.

The data model is also well suited to visual rendering; despite its simplicity it is possible to represent all the information that appears in conventional online maps (e.g. Google maps). In addition, because the data is stored as vector data rather than pre-rendered tiles the fast graphical processors in modern smart-phones can render the visual appearance of the map to accentuate features or only display features of interest. Over slower wireless networks the transfer of vector data is also considerably faster and local caches can hold more information making the user experience much more responsive.

5. Summary

The HaptiMap project aims to encourage the incorporation of enhanced accessibility into the user interfaces of mobile mapping and location-based applications. The phrase *enhanced accessibility* covers various features that make such applications easier (or indeed possible) to use for people with various disabilities, e.g. blindness. It is anticipated that the enhanced accessibility will also be useful to people without such disabilities, e.g. by removing the need to look at a display screen in order to perform certain tasks. Non-visual perceptualisation of geographical information is an essential part of enhancing accessibility in such a manner.

Observations within the HaptiMap project have revealed that accessibility of conventional sources of geographical information themselves (by HCI developers) is also an issue, due to lack of familiarity and the learning curve faced by non-specialist GIS developers when working with detailed geographical information in vector format. A solution has been proposed to this problem which involves including a simplified API for accessing geographical information from multiple sources as part of the “HaptiMap Toolkit”. This has now been implemented and is currently undergoing testing, with formal evaluation from the point of view of software developers also to take place as part of the project.

6. Acknowledgements

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8. Biographies

Dr Paul D Kelly received the degree of PhD in Electrical & Electronic Engineering from Queen's University Belfast in 2005. Since then he has developed research interests in geographical data processing and digital audio and video processing, with a particular emphasis on C programming. He is currently employed by Queen's University Belfast as a research fellow.

Dr Stuart Ferguson has over 25 years experience in computer graphics and software engineering. He is the author of the book *Practical Algorithms for 3D computer Graphics* (2001). He is currently a lecturer at Queen's University Belfast where he is researching real-time application program implementations for mobile devices.

Dr Karen Rafferty has over 10 years experience working within the fields of image processing, computer vision, virtual reality applications and intelligent devices that can perceive and respond to their environment. She has authored over 30 journal and conference papers in these areas. Her first book on *Virtual Reality* was published in 2007.

Dr Jian-Xun Peng has over 15 years experience in avionics, nonlinear system modelling and control, artificial neural networks and computer graphics. He has authored over 40 journal and conference papers. He is currently with Queen's University Belfast where he is researching application context sensing and developing software for the European Commission-funded HaptiMap project.