Mobile mapping on-demand –

Active representation and automated generalisation of spatial databases for the wireless handheld information appliance

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ABSTRACT

The Internet is going mobile, and tomorrow's user will expect to easily retrieve everyday information via his/her hand-held wireless appliance (integrated phone plus browser). Much of this information will have a strong spatial component (where is the nearest?), and will need to be presented as some form of map. The constraints of the display size, and the on-demand nature of the information retrieval will require the use of active representation and automatic generalisation, to present the vital information to the user without unnecessary clutter.

This paper analyses the impact of this new requirement on the cartographic business, and highlights the importance of active object technology in achieving the necessary presentation.

1. INTRODUCTION

1.1 The Internet as Information Source

Although the Internet has existed for over 25 years, it has undergone dramatic growth in the last five years, fuelled by cheap hardware and by the 'World Wide Web' as an application. The web itself is made possible by simple information access protocols such as http and html, which have led to the Internet becoming the major information repository for mankind. Aiding the take up of the Internet as an information source has been the availability of free or very cheap web browser software (e.g. Internet Explorer or Netscape Navigator).

As the majority of human-related information has a location component, it is natural that map display should become a preferred way of finding and presenting information. This has led to the rise of 'web mapping', as exemplified in the CamMap site (http://www.CamMap.com/) shown in Figure 8 and described later in this paper.

1.2 The mobile phone

If the growth of the Internet has been dramatic, that of the cellular telephone has been explosive. Dataquest reported by news channel CNNfn [CNNfn2000] calculated that 283 million cellular handsets were sold in 1999, with the estimate for 2000 being 410 million. From almost unknown five years ago, it has now become a commodity item, carried everywhere by people from all walks of life. As well as its initial role as a person-to-person communication tool, it is rapidly gaining ground as a means of enquiring for information. There has been recent hype over WAP (Wireless Access Protocol), and a WAP phone is shown at Figure 1.

The expansion of this information retrieval role is currently restricted by various physical limits, most of which will be eased by future technology already in the pipeline. The main such are:

- Display size and resolution – at the time of writing this is around 100x50 monochrome pixels, but new display technology will increase this dramatically, giving high resolutions, colour and foldaway displays. Voice synthesis is also an important alternative or complement to display for presentation of information.
- Keyboard size – small and getting smaller for ease of carrying. Voice recognition is the vital technology, which will help avoid the need for keying.
- Data download rate – for GSM, currently 9600 bits per second (bps), but GPRS being deployed now gives 100Kbps, and the G3 UMTS third generation licences recently auctioned will provide 2Mbps.
- CPU speed – currently far less than in desktop or laptop systems, but Moore's Law says that such power doubles every 18 months.
- Battery life – improved a lot in last year, but is in a fight against increased power consumption from better screens and faster CPUs. New battery technologies on the way will help.

1.3 PDAs, Palmtops, and GPS

The third strand of technology contributing to the information revolution is specialised hand-held devices. The most common is a 'Personal Digital Assistant' or PDA. These handheld devices started out as electronic address books, but they have evolved into electronic equivalents of the Filofax. Examples include the Psion 5mx, Palm V, and Compaq Aero (see Figure 2). Related but less portable devices include the palmtop computers, exemplified by the HP Jornada. These are more general computing devices, being scaled-down versions of laptops.

Other related devices are the GPS (Global Positioning System) receivers. These were bulky, but modern design is reducing them to very portable (see Figure 3).

Figure 1 - WAP phone

Figure 2 – PDA

Figure 3 - GPS - Casio

1.4 The Wireless Handheld Information Appliance (WHIA)

The future will bring a new generation of devices, which meld features from mobile phones, PDAs, palmtops and GPS to give a single optimal tool for communication and information retrieval. Such devices will become as common as the wristwatch is now. The capabilities of such devices can already be simulated by combinations of existing tools, such as using a PDA to access the Internet through an infra-red link to a mobile phone to access on-demand mapping (see figure 4).

The acronym WHIA may initially seem inelegant, but when pronounced "weir", it does have appropriate location connotations, as in the famous Yorkshire song 'Ilkley Moor' (Whia has tha bin sin I saw thee?)!

Although much more capable than any one existing handheld device, the WHIA will still have limitations enforced by the conflicting requirements of less weight, longer battery life against better screen, faster access. This means that intelligent presentation of information will become a vital lever for usability.

1.5 Where am I?

WHIAs of the future will always know where they are. Already any current mobile phone has to determine its geographic position relative to the cell phone network transmitters in order to hand over from cell to cell while travelling. Refinements to this location technology like Cursor from Cambridge Positioning Systems will give positions accurate to 25metres in the open, and to a metre or so in dense areas like shopping malls.

Satellite positioning (GPS) is an alternative technology, which gives better results in open area (it recently became 10 times more accurate because a military scrambling called SA was turned off). GPS is not so good in cluttered areas like city centres where the signal from the sky is shielded or confused by echoes. Future WHIAs will probably use a combination of techniques to always track their position to a few metres.

Having such location information available is a necessary starting point to the set of questions:

- Where am I?
- Where is the nearest…?
- How do I get to…?

The answers to such questions can be given by various techniques

- Synthesised voice (“at next junction, turn left”)
- Human operator voice (“turn left after the Pig and Whistle”)
- Text messaging (“in 250m turn left, then …”
- Graphical map displayed on screen
- Graphical map plus instructions sent to paper by fax

However, in all such cases, the primary source of answers will be a geographic information server. This paper contends that an active object database is key to finding and presenting the requisite geographic information in a clear and concise manner.

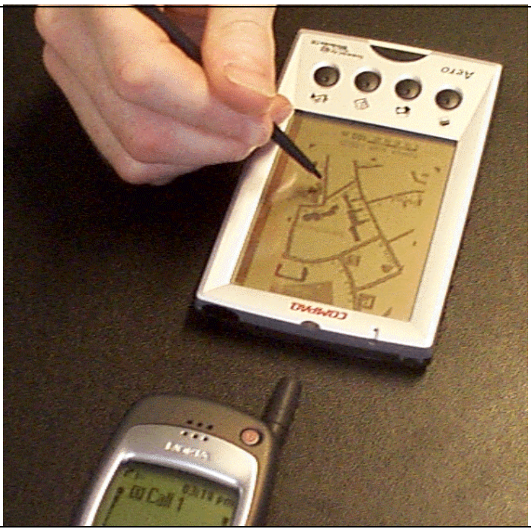

Figure 4 – Combine to simulate WHIA

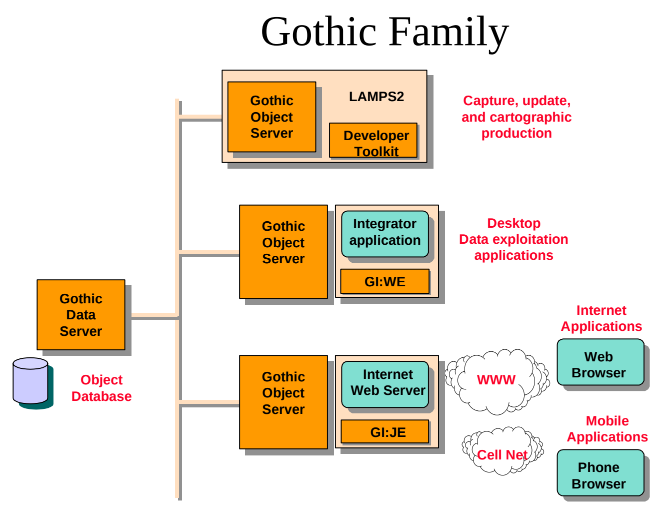

Figure 5 – Laser-Scan Gothic Family

2. ACTIVE OBJECTS

2.1 What are Active Objects?

The object-oriented (O-O) paradigm has been sweeping through the software industry for many years. O-O is a logical way of modelling the real world within a computer software system. All modern software-engineering languages (C++, Java) are built around the four key O-O concepts, of encapsulation, referencing, inheritance, and polymorphism.

- Encapsulation means that data and behaviour are not separated, but encapsulated together within objects that respond to messages sent to them.
- Referencing means that objects can have direct knowledge of related objects (a river ‘flows from’ a spring).
- Inheritance means that the object classes can gain capabilities from multiple superclasses, such as canals inheriting from ‘transportation’, and from ‘water’. This allows modelling the family structure of the real world (a church is a kind of a public building, which is a kind of a building, which is a kind of a man-made structure).
- Polymorphism means that different classes can respond to the same message with an appropriate behaviour (click on a factory and click on a road, and get different description types and different highlighting).

A new generation of spatial database, GIS and mapping systems is adopting O-O concepts and applying them to storage, retrieval, analysis and display of location-related information. This paper concentrates on the Laser-Scan Gothic family (see Figure 5) of spatial software, built around the Gothic O-O spatial database. More detail on this family is available in the paper on “Active Object Techniques for Production of Multiple Map and Geodata Products from a Spatial Database” [Hardy 1999b].

2.2 Characteristics of active object spatial database mapping system

A Gothic database mapping system has the following characteristics:

- Object database - provides efficient storage and retrieval of spatial objects
- Object Data Model (Schema) - allows modelling of the real world entities and their relationships.
- Continuous mapping (no sheet boundaries) - provides the area wanted at the scale requested.
- Object database views allow intelligent selection of subsets of objects for current purpose
- Active representation provides good cartography (see below)
- Active object Generalisation methods derive appropriate map features for current scale and need (see below).
- Validation methods ensure data integrity
- Open architecture allows access from workstation, desktop, web browser, or WHIA.

3. ACTIVE DISPLAY

3.1 Display Methods

A key aspect of O-O mapping is the use of display methods for all visualisation. Instead of the application having fixed rules about representation, or using a static table of styles, all drawing is done by sending a message to each relevant object saying ‘draw yourself’. The response to the message is to execute the object’s ‘display method’, which can use the power of the object database and spatial toolkit to decide what to do. It can:

- Decide to draw or not to draw itself, dependent on scale, specification, and surroundings
- Use a rich set of representation styles (line patterns, area fills, symbols)
- Change type according to scale – an area object may draw itself as point symbol if it is too small at this scale.
- Use a different ‘geometry’ (shape) according to scale, showing less detail at smaller scale.
- Draw itself more than once in different styles, e.g. to achieve road casings, or text labels
- Move itself into clear space to avoid edge of map or other collisions.
- Modify its representation according to scale and surroundings; e.g. shorten text label to match length of road.

All of these techniques are applicable to Web mapping and WAP mapping, as in the examples below.

4. GENERALISATION

4.1 Active Object Generalisation

Generalisation is the science (and art) of exaggerating those aspects that are important for this particular map purpose and scale, and removing irrelevant detail that would clutter the map and confuse the user. Generalisation has traditionally been a hard task to automate, being dependent on the skills of the human cartographer. People have tried for years to build centralised 'knowledge bases' of generalisation rules, with very limited success. In such systems, the map features themselves have just been passive items containing coordinates and attributes, acted upon by the centralised rules [McMaster, 1991].

In the object-oriented world, this is turned upside down. The map features themselves become objects that have generalisation behaviours defined in the database schema. The application itself becomes much thinner, and contains no knowledge about what, how, or when. It merely provides a framework for invoking and sequencing the generalisation processes by sending messages to selected objects [Ormsby and Mackaness 1999]

Gothic LAMPS2 includes an object-oriented generalisation facility, which allows the user to define the strategy for generalisation in terms of methods on the object classes [Hardy 2000]. Generalisation base object classes are provided which supply generalisation process methods for multi-object combinatorial operations (aggregation, typification, and displacement) and others for single object generalisation (collapsing, refinement, exaggeration and simplification). Note that these are implemented as behaviours of the objects in the database, not as commands within a program.

Kort & Matrikelstyrelson (the Danish state mapping agency) is using LAMPS2 in this way to derive 1:50K mapping from a 1:10K sourced database. The generalisation flowline makes considerable use of active object views using spatial query, to identify objects for generalisation. An example is to delete all minor roads less than 2km long, which have a dead end and do not have buildings within 100m of the dead end (see Figure 6).

In the future, increased computational power and improvements in software techniques will allow such active object generalisation to be done in real time, on-demand to satisfy a user request for appropriate mapping on his WHIA. Until then, the techniques are still very useful, but need to be applied in advance to produce a set of ‘usages’, and the results stored. The object database allows storage of multiple alternative geometries, so you can have one object (e.g. Trinity College), with one set of attributes, but with several alternative sets of coordinates, each suitable for a particular scale band.

4.2 Agent Generalisation

The power of object generalisation is being greatly enhanced by the AGENT project on multi-agent generalisation. This project [Lamy et al, 1999] is a collaboration under the ESPRIT programme (LTR/24939) involving Laser-Scan as providers of object technology together with a national mapping agency (IGN) as prime contractor, and academic partners (Edinburgh & Zurich, INPG). Some partners provide in-depth knowledge of generalisation algorithms, while others provide insight into multi-agent modelling. The contract involves 48 person years of effort over a 3-year period. The fruits of the project are being implemented in the Laser-Scan Gothic LAMPS2 mapping software.

In this context, agents are self-aware active software objects that co-operate, subject to a set of constraints, to achieve a goal. For map generalisation, it is the geographic objects such as houses and roads, which become active agents and co-operate through simplification, typification and displacement of themselves to achieve a cartographically acceptable generalised result. Figure 7 shows co-operating meso-agents handling urban blocks, communicating with the micro-agents that are the buildings and roads.

Agent-based generalisation achieves two major steps forward:

- An individual Micro agent (e.g. a building) tries different algorithms, keeping the results if the situation is better, discarding and trying different ones if the situation is worse, so avoiding using the same tool globally.
- Meso agents coordinate generalisation across sets of objects, so avoid consequential conflicts and retain gestalt (the overall coherence).

Like the active object generalisation techniques described in the previous section, these agent techniques at present are to be used in preparing generalised versions of objects to be used for different scale enquiries. In the future, they will be applied in real-time to satisfy mapping requests from WHIAs.

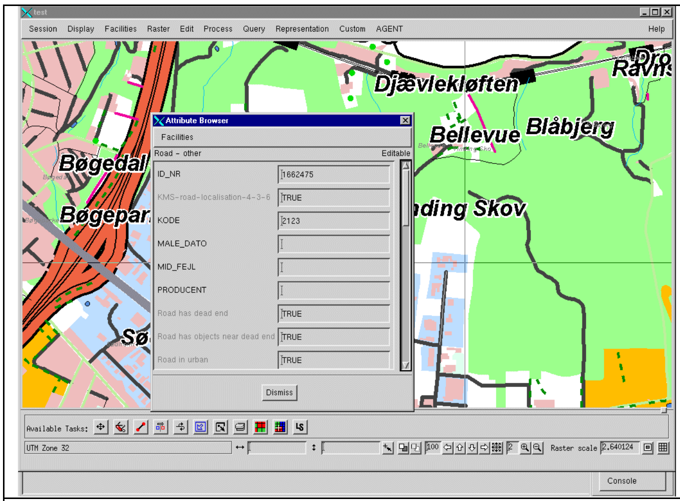

Figure 6 – KMS Active Object Generalisation

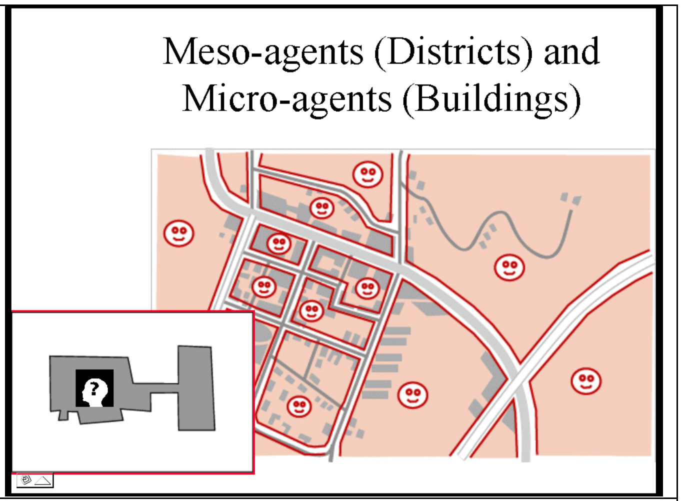

Figure 7 – AGENT Generalisation

5. WEB MAPPING EXAMPLES

5.1 CamMap

CamMap is a highly interactive web map of the area around Cambridge UK. In it, all the objects can be asked to describe themselves, and many (including all pubs, colleges and many public buildings) do so by providing web links to images and related web sites (e.g. for Kings College as shown in Figure 8). The site is free, so try it out yourself (http://www.CamMap.com). It uses a variety of active object generalisation techniques to present data from a continuous object database at different scales while retaining clarity.

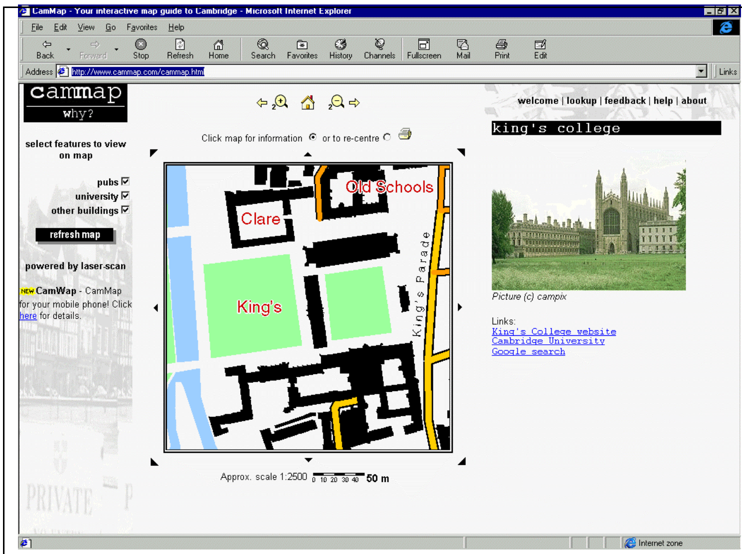

Figure 8 – Web Mapping – www.CamMap.com

Figure 9 – Text labelling

Figure 9 shows intelligent generalisation and positioning of text labels. Road numbers have been dropped where there is insufficient room. Road and pub names have been positioned so that they don't fall over the edge of the window or over important detail. Figure 10 shows automatic selection of appropriately pre-generalised geometry for a college according to viewing scale. The combination of these techniques produces a legible map presenting the maximum information, for any requested location at any requested scale, within seconds.

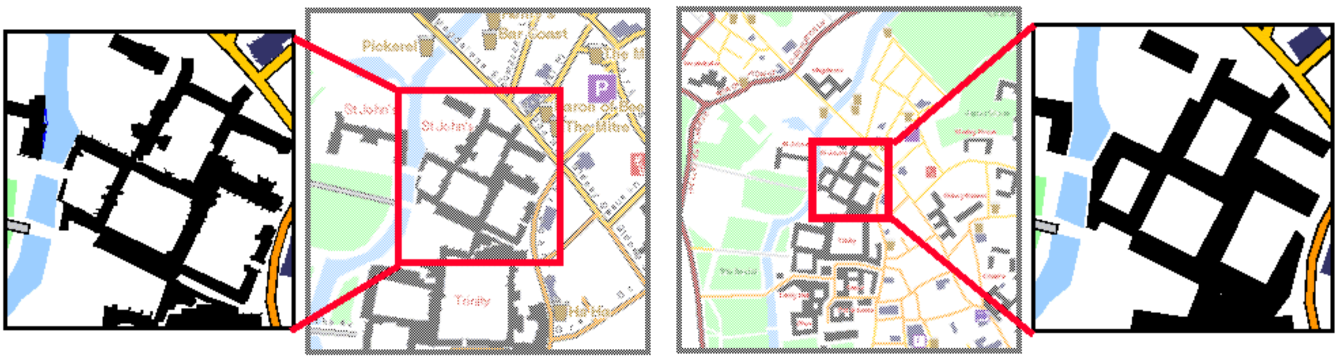

Figure 10 – Use of generalised geometry for college building outline according to viewing scale

5.2 Location Mapping

A commercial web site to provide location mapping is in the prototype stage of implementation. It has national coverage sourced and derived from Ordnance Survey digital map data. It allows lookup of an address by text or by postcode, and can provide a sequence of three location maps at increasing scales, leading the user to the desired location. As well as the on-screen version (Figure 11), the user can request a print-quality map which is delivered in Adobe Acrobat PDF format, for printing at A4 (Figure 12). Both map types are produced using active object representation and generalisation from a continuous object database.

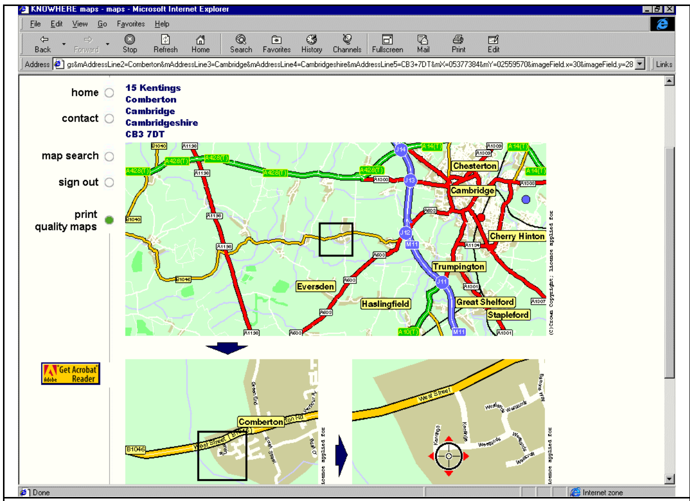

Figure 11 – Location mapping web map

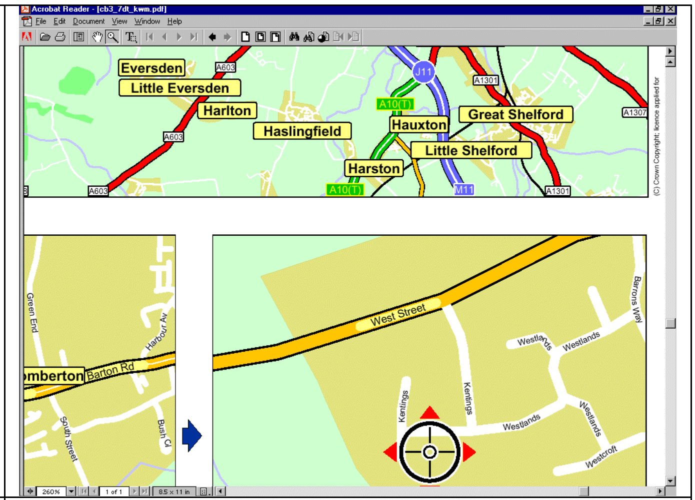

Figure 12 – Location mapping PDF map

5.3 LINZ

Land Information New Zealand already hold the master data for their 1:50K national topographic database in a single continuous Gothic dataset administered with LAMPS2, supporting on-demand hardcopy mapping. More recently, they have asked Laser-Scan to serve a copy of the data from Cambridge England to the Internet for use by NZ government departments. The web application uses a Java applet for better interaction than can be achieved with just HTML. Hardcopy output is still available via download of a generated PostScript file covering the area of interest. Display methods on the objects in the database choose if and how to draw themselves, to provide a clear map at a variety of scales (See Figure 13). NZ has recently chosen to make its topographic data freely available (as in the USA) rather than charging copyright fees. Topographic mapping of this type will become a valuable framework and backdrop for handheld spatial information retrieval on WHIAs in the future, for those countries that have the foresight to release their mapping in this way.

5.4 EDINA Digimap

EDINA Digimap, which is hosted at Edinburgh University Data Library (EUDL), provides on-line access to OS digital mapping for the UK Higher Education Community (Universities and Colleges). The current system is a limited prototype and EDINA are currently re-engineering Digimap to use Laser-Scan Gothic software, for deployment early in 2001. The active object dataset (Figure 14) underlying the new Digimap will be one of the largest continuous map databases in the world and will be an excellent testbed for future access to such information from WHIAs. The continuous object dataset and active object representation are key to providing good cartographic quality for demands for arbitrary sized areas of mapping at different scales.

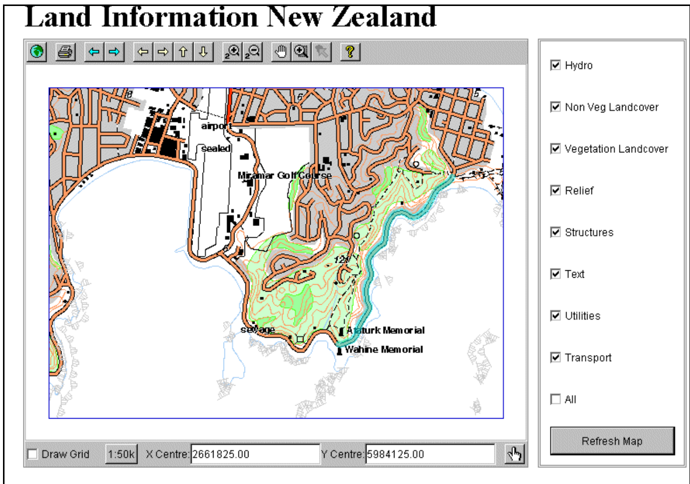

Figure 13 – LINZ web mapping

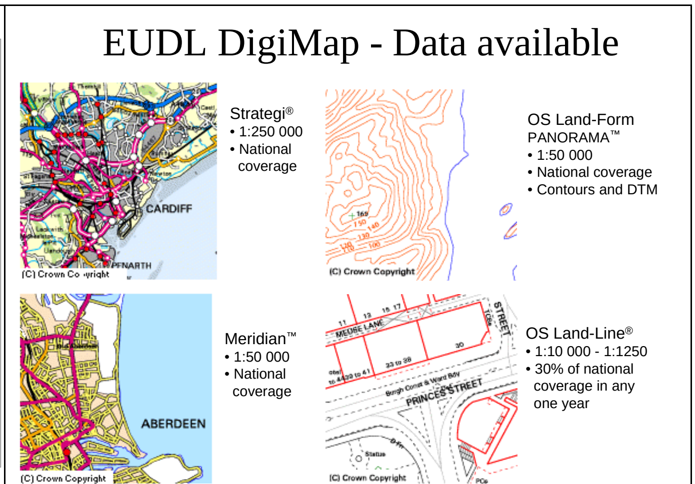

Figure 14 – Digimap web mapping data

6. INTEROPERABILITY

6.1 OGC Web Mapping

The OpenGIS Consortium (http://www.opengis.org/) brings together software suppliers, spatial data suppliers, and major government agencies to define protocols and interfaces for interoperability. In particular, it has defined three APIs (GetCapabilities, GetMap, and GetFeatureInfo), that together allow spatial data from multiple sources to be displayed together in a web browser. These APIs evolved in Web Mapping Testbed 1 (WMT1) and subsequently refined and adopted as the *OpenGIS Web Map Server Interface Implementation Specification*.

In WMT1, transportation data from a Laser-Scan Gothic object database was combined with satellite imagery, terrain models, flood predictions, and emergency capabilities, in a simulation of a hurricane landfall over Mobile, Alabama (Figures 15,16). Once again, the active object selection and representation of Gothic allowed clear display. In the future, WHIAs will be a central way of disseminating such emergency information, and presenting it to the user in a clear manner.

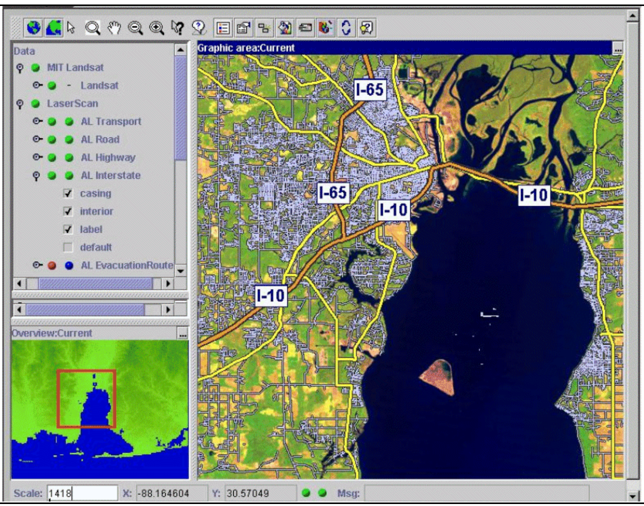

Figure 15 – OGC Web Mapping Testbed

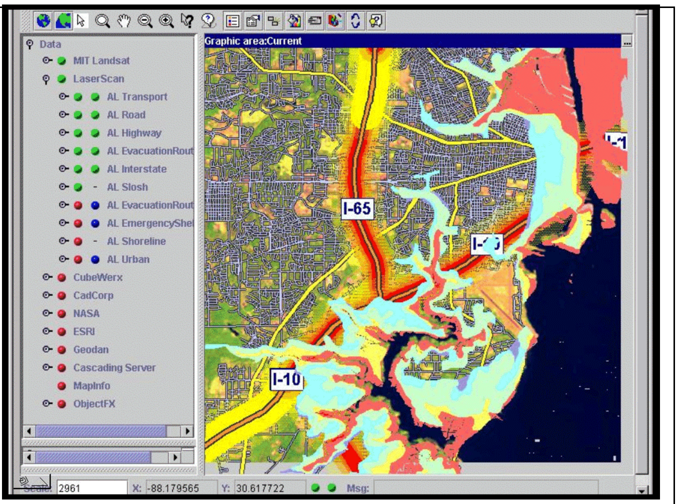

Figure 16 – OGC WMT1 - Flood alert

7. MOBILE MAPPING

7.1 WAP maps

The small screen of current WAP phones limits their use for presenting location information graphically, but with intelligent object selection and representation as described in earlier sections of this paper, useful results can be shown. Figures 1 and 17 show a WAP phone displaying information from CamWAP (http://wap.CamMap.com), an alternative view of the CamMap web mapping site. This uses the same active object dataset, but different display methods, to enhance clarity on the low-resolution monochrome screen. An example is the use of automatic text haloing (Figure 18) to erase background and clear space for the important text labels. The CamWap implementation builds on research collaboration between Laser-Scan and the Department of Geography at Edinburgh University.

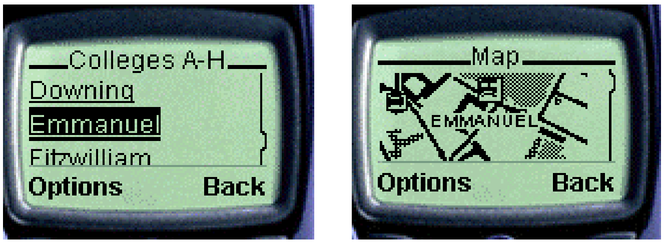

Figure 17 – CamWAP- lookup college to get map

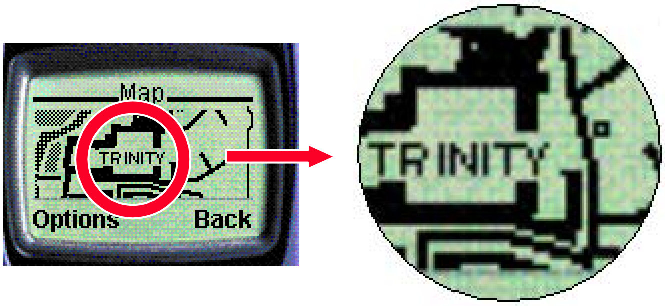

Figure 18 – Text Halo for clarity

7.2 Future mobile maps

The limitations of WAP and current mobile phone screens will not hold us back for long. The future WHIA will have a screen at least as capable as a modern palmtop, and hence the development of mobile mapping must concentrate on clear presentation on screens of about a megapixel.

8. CONCLUSION

The rise of the Internet has already changed the way that many users access spatial information. No longer is the printed map the primary medium. The union of the mobile phone with the PDA and other new technology will produce the 'WHIA', a Wireless Handheld Information Appliance. WHIAs will become over the next few years the central medium for information retrieval, particularly location-related information in the form of active maps.

This shift from paper hardcopy to mobile screen softcopy will greatly affect the nature of the cartographic business. Major parts of the knowledge and skill of human cartographers will need to be embedded in real-time generalisation software (using active representation and intelligent spatial feature generalisation) and in pre-prepared generalised 'usages' within digital databases.

Active object technology in the information server is crucial to on-demand retrieval and clear presentation of the requisite information in the form of an active map on the WHIA, tailored to the user's current need.

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