

MOBILE MAPPING ON-DEMAND, USING ACTIVE REPRESENTATION AND GENERALISATION

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ABSTRACT

Tomorrow's user will expect to retrieve everyday information easily wherever they are, via their hand-held wireless appliance (integrated phone plus Internet 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 dynamic representation, automatic generalisation and active feature selection to present the vital information to the user without unnecessary clutter.

This paper overviews the underlying technologies, reviews example implementations, analyses the impact of this new requirement on the cartographic industry, and highlights the importance of active object technology in achieving the necessary presentation.

1. INTRODUCTION

1.1 Overview

Although they have been greatly over-hyped, mobile information presentation technologies such as WAP show the way forward for communication of information to the individual. When combined with complementary technologies such as GPS and handheld computers (PDAs), they will provide the heart of the next generation wireless handheld information appliance. In addition, interoperability protocols from the OpenGIS consortium provide the framework for bringing together location data from multiple servers, to be combined on the browser for maximum value.

Recent advances in geospatial technology have shown that Object-Oriented mapping software based on an active object spatial database provides unique capabilities suitable for the presentation of location information to the mobile user. The paper uses the Laser-Scan Gothic object database and LAMPS2 mapping system as exemplars. Examples are taken from a range of current and prototype Internet web mapping solutions, concentrating on their strengths for mobile mapping.

Active objects in a spatial object database respond dynamically to the current needs of the user in a range of ways:

- Dynamic representation implemented as object display behaviours allows individual objects to draw themselves differently according to their surroundings;

- Active object generalisation methods and software agent behaviours derive appropriate map features for current scale and need;
- Object database views are the means by which geographical feature objects can decide for themselves whether they should be included in a specific map product;
- Multiple alternative geometries allow a single attributed object to adapt its shape and position rapidly to suit the current scale and need.

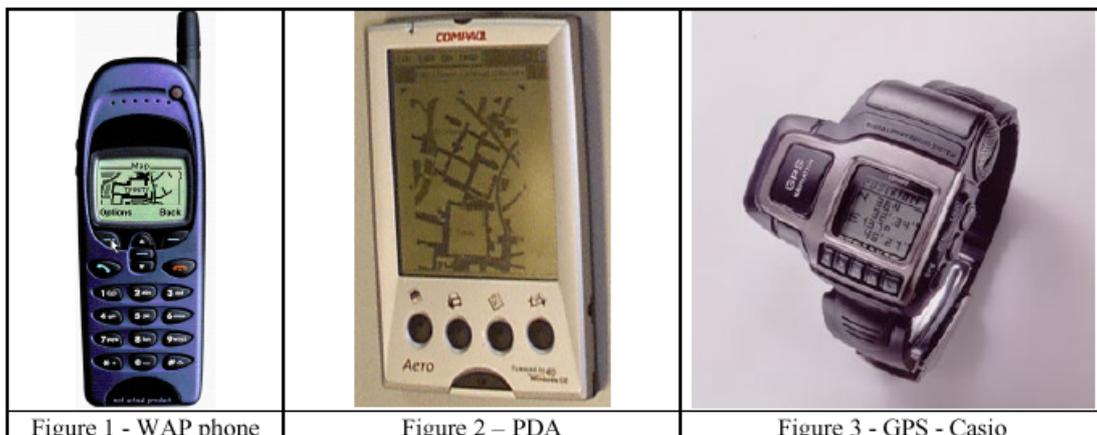
Distributing the knowledge of selection, generalisation and representation into object behaviours in this way overcomes many of the problems previously encountered in embedding the skill of the human cartographer into a software solution.

1.2 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. 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, and of ‘mobile mapping’ and ‘location based services’ (LBS).

1.3 The Wireless Handheld Information Appliance (WHIA)

If the growth of the Internet has been dramatic, that of the cellular telephone has been explosive. Recent figures suggest that of the 500 million mobiles in use in 2001, almost 400 million were sold in 2000. Although recent well-publicised layoffs by major phone manufacturers show that that rate of growth is not sustainable, the new technology already in the pipeline will continue to drive future sales. 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. In addition to voice (which will remain a main information channel), other visual aspects are developing. WAP (Wireless Application Protocol), was the first such and was hyped beyond its limited but useful capabilities. Other more capable technologies include the DoCoMo iMode phones in widespread use in Japan. A WAP phone is shown at Figure 1, being used for ‘WAP mapping’, within the limits of its screen resolution of 100x50 monochrome pixels.



The expansion of the information retrieval role for the mobile phone 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. The high costs of the G3 licenses and the bursting of the ‘dotcom bubble’ mean that large-scale availability of G3 services may be further away than previously thought.
- 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 the 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.

1.4 Hand-held devices

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, such as the Psion 5mx, Palm V, and Compaq Aero (see Figure 2). 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).

The future will bring a new generation of devices, the “Wireless Handheld Information Appliance”, or WHIA. This will meld features from mobile phones, PDAs, palmtops and GPS with new screen technologies to give a single optimal tool for communication, location, and information retrieval, which will be 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).

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 Location questions and answers

The WHIA will give the answers to the set of location questions: “Where am I? Where is the nearest...? How do I get to...?”, and various techniques can be used individually or in combination to deliver the answers:

- Synthesised voice (“at next junction, turn left”). This is particularly important for hands free situations, such as while driving. The Yeoman Navigation system

(<http://www.yeomangroup.plc.uk/>) is a leading example of use of synthesised voice for in-car navigation.

- Text messaging, e.g. by the SMS Short Message Services “in 250m turn left, then ...”
- Graphical map displayed on screen. In many cases, the map will need to be much more schematic or diagrammatic than conventional cartography, to put forward the vital information in the small screen.
- Graphical map plus instructions sent to device for printing to paper, or by fax to a nearby location. Generation of high-quality map content tailored to the request and provided in formats such as Adobe PDF, is an important intermediate step in this process.

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

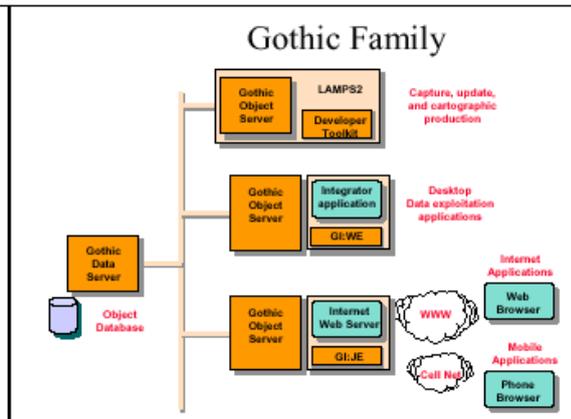


Figure 5 – Laser-Scan Gothic Family

2. ACTIVE OBJECTS

2.1 What are Active Objects?

The Object-Oriented (O-O) paradigm swept through the software industry many years ago. O-O is a logical way of modelling the real world within a computer system. All modern software 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 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 [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
- Topological structure – knows about connectivity, adjacency
- Object database views allow intelligent selection of subsets of objects for current purpose
- Active representation provides appropriate cartography (see below)
- Active object generalisation methods derive appropriate map features for current scale and need
- Validation methods ensure data integrity
- Open architecture allows access from workstation, desktop, web browser, or mobile browser

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 – 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 label to match length of road

All of these techniques are applicable to Web mapping and mobile 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]. 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 & Matrikelstyrelsen (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.

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 Internet browser or 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 (see Figure 10).

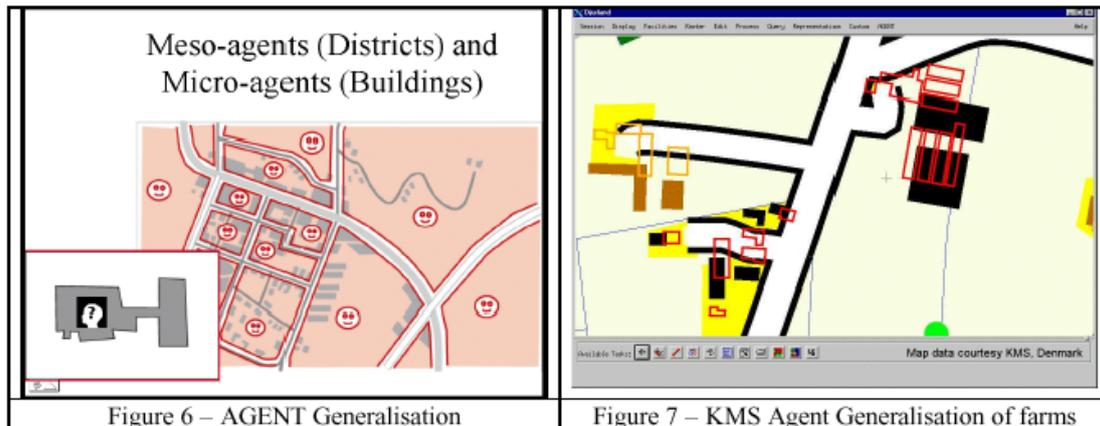
4.2 Agent Generalisation

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

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 6 shows co-operating meso-agents handling urban blocks, communicating with the micro-agents that are the buildings and roads.

The fruits of the project have been implemented in the Laser-Scan Gothic LAMPS2 mapping

software, and are now being productised and commercialised. The first customer is Kort & Matrikelstyrelsen, which is relying on the active agent capabilities for applying its rules on building generalisation, including handling of rural farms. Figure 7 shows the original data in outline and the generalised output in solid, including the effects of aggregation, elimination, typification, and displacement.



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).

The philosophy underlying the AGENT project generalisation mechanism is for the designer to define how the map should appear rather than defining how to achieve it (declarative rather than imperative). Each agent then tries to improve its happiness during an agent life-cycle, which encompasses:

- Measures – implemented as object methods, these assess the tangible state of the feature.
- Constraints – implemented as objects, these return the degree of unhappiness for each aspect of state.
- Algorithms – implemented as methods, these change the state, and (hopefully) improve the situation
- Plans – dynamic lists of values, these determine the choice and order in which algorithms are executed.
- Re-evaluate – part of the lifecycle method, this determines if the previous plan was a success or not, and if not will backtrack the state in order to try another plan.

See the paper referenced at the head of this section and [Ruas 2000] for more information on the Agent project. Like the active object generalisation techniques described in the previous section, these agent techniques are to be used at present 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 Internet browsers or WHIAs.

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.

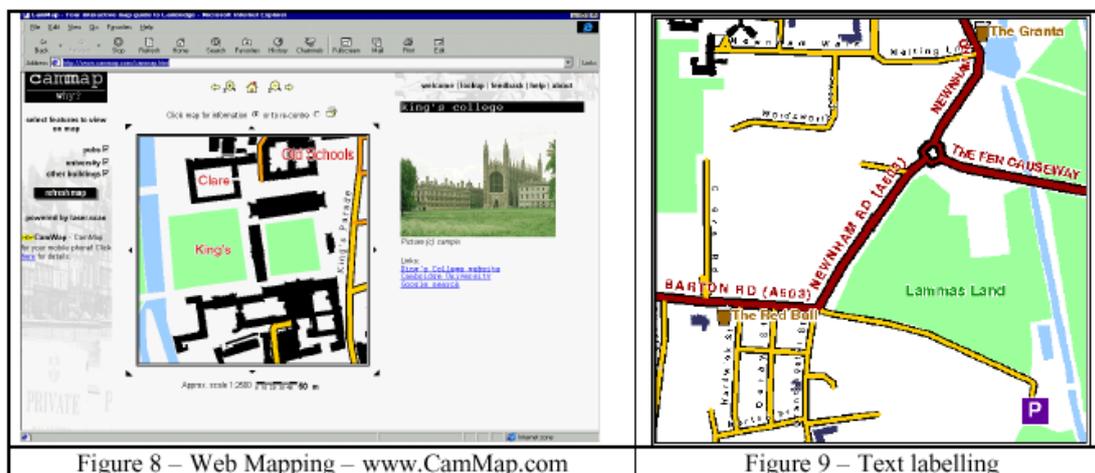
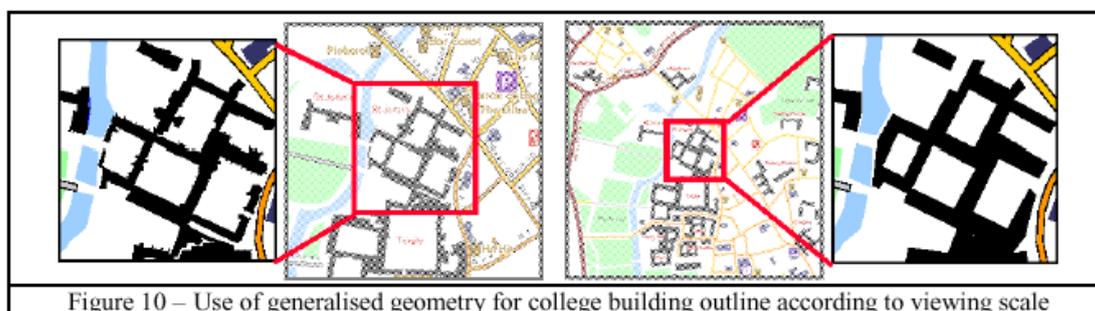


Figure 9 shows intelligent generalisation and positioning of text labels. Road numbers have been suppressed where there is insufficient room. Road and pub names have been positioned so that they don't fall over the edge of the window or over important detail. Figure 10 shows automatic selection of an 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.



5.2 Location Mapping

A commercial web site (<http://knowheremaps.com/>) has been launched to provide location mapping from an object database. 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, the user can request a print-quality map which is delivered in Adobe Acrobat PDF format, for printing at A4 (Figure 11). Both map types are produced using active object representation and generalisation from a continuous object database. The selection of content for the map is determined each time to suit the request, and dynamic label generation and positioning is applied.

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, and will shortly be available as high quality Adobe PDF for viewing and printing. 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 12). 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 in the future, for those countries that have the foresight to release their mapping in this way.



Figure 11 – Knowheremaps PDF map

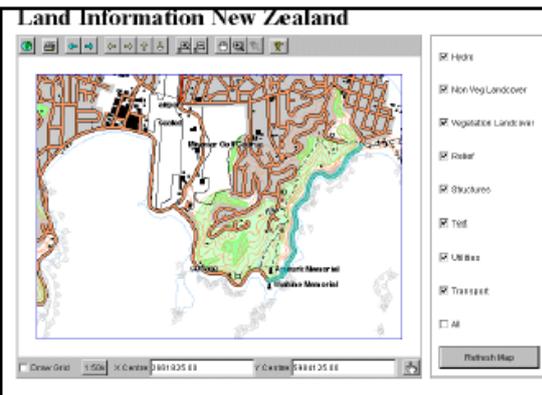


Figure 12 – LINZ web mapping

5.4 EDINA Digimap

EDINA Digimap, which is hosted at Edinburgh University Data Library (EUDL), provides on-line access to OS digital mapping (250,000 map sheets worth) for the UK Higher Education Community (Universities and Colleges).

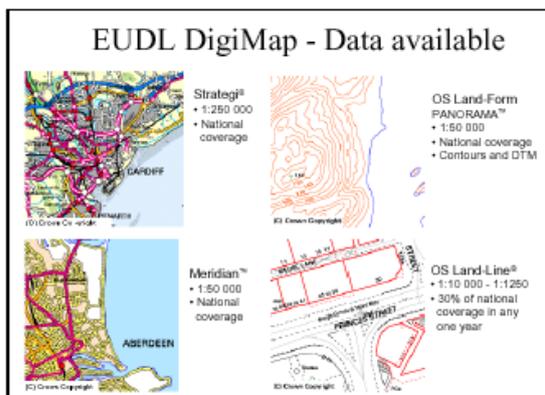


Figure 13 – Digimap web mapping data

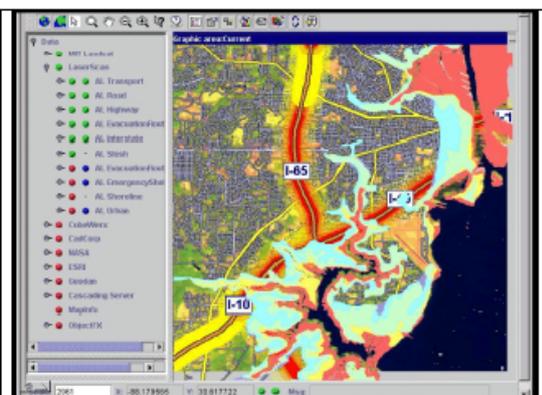


Figure 14 – OGC Web Mapping Testbed - Flood

The current system is a limited prototype and EDINA is currently re-engineering Digimap to use Laser-Scan Gothic software, for deployment in 2001. The active object dataset (Figure 13) 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 dataset and active object representation are key to providing good cartographic quality for demands for arbitrary sized areas of mapping at different scales.

An important capability of the Digimap system is that when the user has browsed and chosen the needed area, scale and content, then the results can be provided in different media forms. In addition to the browser screen, the map (complete with legend and other marginalia) can be downloaded in PostScript or Acrobat (PDF) format for quality printing, or as feature data in common formats (Shape, DGN, MapInfo, NTF) for further analysis in a GIS.

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 from other servers, in a simulation of a hurricane landfall over Mobile, Alabama (Figure 14). Once again, the active object selection and representation of Gothic allowed clear display. In the future, Internet Browsers and WHIAs will be a central way of disseminating such emergency information, and presenting it to the user in a clear manner.

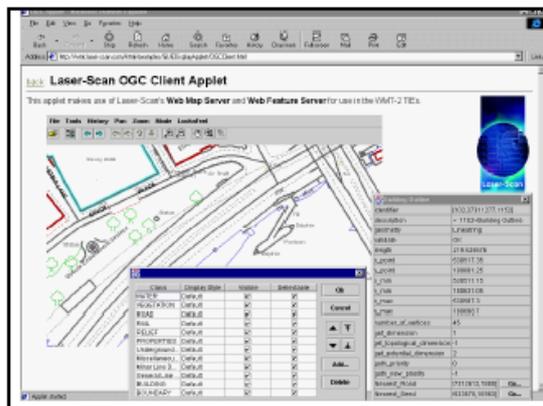


Figure 15 – OGC WMT2 – Feature access

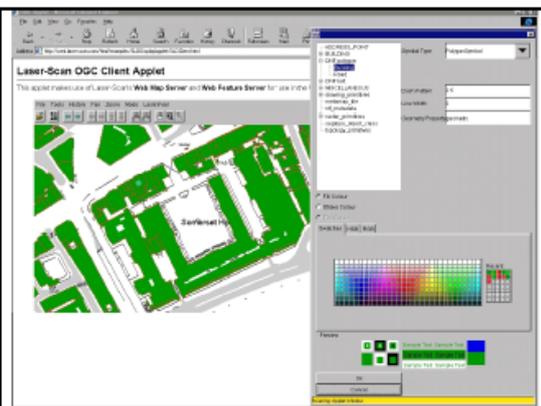
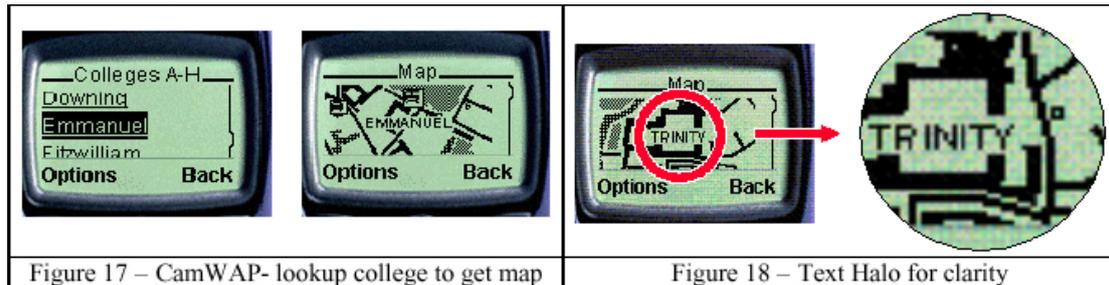


Figure 16 - OGC WMT2 Portrayal styles

The recently completed Web Mapping Testbed 2 (WMT-2) has advanced the specifications in the areas of feature retrieval, portrayal and symbology, catalogue metadata and security. The separation of the architecture into a Map Server and a Feature Server lays the foundation for update over the web. Figure 15 shows OSGB data being served from an object database using OGC protocols, and with feature query. Figure 16 shows an interface for setting the graphical portrayal from a web browser, and display of OSGB DNF object data.

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. CamWAP 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.

7.2 Mobile cartography

For maximum usability, the cartography for small screen mobile devices must be different to that of paper maps in a number of ways:

- Content tailored to current request and to user's profile
- Irrelevant detail suppressed, and lesser information generalised.
- Important detail exaggerated for clarity
- Diagrammatic or schematic, rather than artistic representation
- Dynamically aligned to direction of travel or to important landmark rather than North up.

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, providing the 'mobile Internet'. 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.

Object-Oriented generalisation and software agent techniques provide an exciting new framework for generation of clear derived mapping products from detailed master spatial 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 Internet browser, mobile phone, or WHIA, tailored to the user's current need.

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