WEB-BASED SPATIAL INFORMATION MANAGEMENT SYSTEMS

M. Bertolotto[1], J.D. Carswell[2], L. McGeown[3], J. McMahon[3],

[1]Department of Computer Science, University College Dublin, Ireland, michela.bertolotto@ucd.ie
[2] Digital Media Centre, Dublin Institute of Technology, Ireland, jcarswell@dit.ie
[3] e-Spatial Solutions, Dublin, Ireland, info@e-spatialsolutions.com

ABSTRACT

In this paper we discuss the innovative software solutions offered by e-Spatial[TM] technology for the deployment of web-based and mobile spatial information management systems. This technology has been developed within the Oracle 9i Database environment and allows users to build and deploy spatially enabled Internet applications on any Oracle supported hardware platform and on any device running a Java Virtual Machine (e.g., standard web browsers, PDAs and other mobile devices). The paper focuses on a Land Information Management System (LIMS) application developed for the Irish Department of Agriculture. The application utilises the e-Spatial[TM] Information Server to deliver a spatially enabled Internet solution for the tracking and management of land information based on land usage, land classifications and land ownership changes over time. The developed land information management system provides a seamless Oracle 9i Spatial database environment for the combination of multiple land information datasets. Integrated database topology ensures the integrity of the topology relationships within the spatial database. The normal edit (e.g. create, modify, and delete) and spatial analysis functions associated with a traditional GIS based land management applications, are deployed as Java stored procedures in the Oracle Spatial database.

KEYWORDS: Web-based GIS; Land information management systems; Location-based services.

1. Introduction

To date users wishing to utilize commercial (web-based) GIS applications (such as Arcview/ArcInfo and ArcIMS; MapInfo and MapInfo MapXtreme, Intergraph GeoMedia WebMap, etc.) in connection with their Oracle database, are required to use proprietary application-specific software. In this paper we discuss the architectural issues of e-Spatial[TM] technology, a timely alternative to traditional proprietary GIS packages for Oracle users (Bertolotto et al., 2001). Such technology comprises a software solution for deploying web-based spatial applications within an Oracle 9i Database environment that fully exploits the complete integration of spatial and non-spatial data repositories offered by Oracle Spatial. e-Spatial[TM] technology extends the functionality of an Oracle Spatial database by providing a wide range of advanced spatial data handling and management functions (e.g., real-time data display, collecting, manipulating, querying, etc. using standard web browsers) typically provided by specialised GIS packages, without requiring any proprietary application-specific source code.

These functions together with all data are stored in the enterprise database and can be accessed from any PC or mobile device using functionality built into the database itself. Indeed, one of the greatest advantages of this software is that it is seamlessly integrated into the database instead of being developed as a separate application. This has been achieved by implementing all management information and spatial analysis functions as stored procedures. This characteristic makes the package specifically suited for interactive real-time analysis and decision making in applications such as utility and government mapping, navigation systems, GPS applications and the emerging mobile location-based applications.

The two main components of this technology are the *i*SMART[TM] application development technology and the *i*-Spatial[TM] Information Server (*i*SIS), both implemented within an Oracle 9i Spatial database environment. *i*SMART[TM] is an intelligent Oracle application database development technology that allows database administrators and software engineers to design, build and deploy spatially enabled Internet applications without requiring any proprietary or application specific source code. *i*SIS is a Java plug-in component of *i*SMART[TM]. It consists of a database management application program that exploits the spatial functionality inherent to an Oracle Spatial database.

In this paper we show the potentiality and performance of e-Spatial[TM] technology by describing a working system that deploys it. The Land Information Management System (LIMS) application, developed for the Irish Department of

Agriculture, utilises the Spatial Information Server platform to deliver a spatially enabled Internet solution for the tracking and management of land information based on land usage, land classification and land ownership changes over time.

The developed system provides a seamless Oracle 9i Spatial database environment for the combination of multiple land information datasets. Integrated database topology ensures the integrity of the topology relationships within the spatial database. The normal editing and spatial analysis functionality associated with traditional GIS based land management applications are included, for example:

- Vector data manipulation (pan, scroll, zoom, locate, window queries, etc.);

- Vector and attribute data entry and editing;

- Spatial and attribute data analysis (polygon overlay and network tracing);

- Thematic mapping (display of query results with assigned symbology);

- Raster/Vector integration.

This system allows for a wide variety of spatial analysis functionality and therefore provides an effective decision making tool.

The remainder of this paper is organized as follows. Section 2 gives a brief overview of e-Spatial[TM] technology. Section 3 describes in detail the functionality of the land information management system that has been developed for the Irish Department of Agriculture, while Section 4 presents some operational results of this system. Finally, Section 5 discusses our concluding remarks and further issues that are currently under investigation.

2. e-Spatial[TM] technology

The two major components of *e*-Spatial[TM] technology architecture are the *i*SMART[TM] database development technology and the *i*-Spatial[TM] Information Server (*i*SIS) (Bertolotto et al. 2001). *i*SMART[TM] is an intelligent Oracle application database development technology that allows database administrators and software engineers to design, build and deploy spatially enabled (as well as standard) Internet applications without requiring any proprietary or application specific source code. It therefore allows to reduce overall system development and deployment costs. All *i*SMART[TM] applications are automatically generated on-the-fly directly from the Oracle database and can be used and modified on-line without having to log-off existing Internet applications or writing any client application code. The *i*SMART[TM] architecture is illustrated in Figure 1.
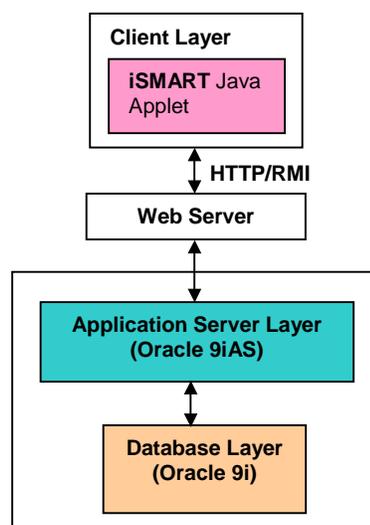

Figure 1. The three *i*SMART[TM] architecture components: client layer, application server layer and database layer.

The application server currently used by *i*SMART[TM] is Oracle 9iAS. This layer contains several Enterprise Java Beans (EJBs) responsible for communication with the client layer and for querying the database layer tables. The structure of a user application developed using *i*SMART[TM] is stored in the form of a hierarchy of objects and panels (corresponding to buttons, textfields, etc. and forms to be displayed on the user's screen) in the Application Specific Metadata tables. Panel (entity) EJBs are responsible for retrieval of such information.

The *i*-Spatial[TM] Information Server consists of a database management application program that enhances the spatial functionality of an Oracle Spatial database. More details about the e-Spatial[TM] architecture can be found in (Bertolotto et al., 2001).
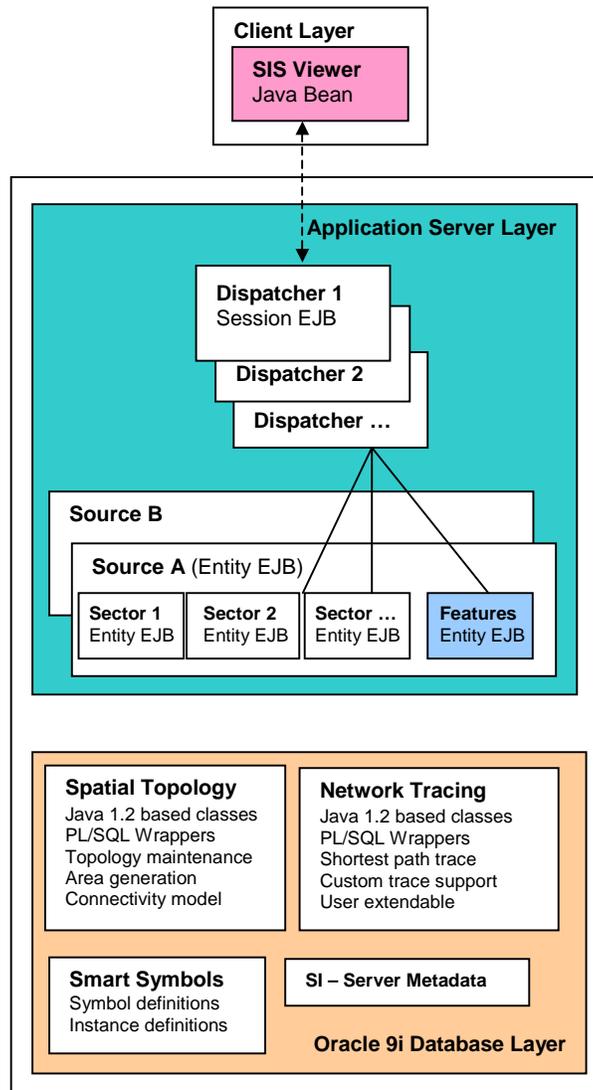

Figure 6. The *i*SIS architecture components: the client layer, the application server layer and the database layer.

The spatial data model used by e-Spatial[TM] technology is the Oracle Spatial object-relational model. The main advantage provided by this model is the automatic reconstruction of topological properties upon update : if a spatial element is updated (for example, by a remote user accessing the application web site in the field), all spatially related elements are automatically changed accordingly to guarantee consistency. More details about the advantages of this approach can be found in (Bertolotto et al., 2002).

Finally, another advantage of e-Spatial[TM] technology is the ease of use of its application development environment. In order to facilitate current users of GIS applications that have been integrated in the widest range of information systems, e-

Spatial[TM] technology also provides a user-friendly environment that allows building and customising the application by means of drag-and-drop functionality to add objects, such as buttons, textfields, tables, combo boxes, etc. to panels and sub-panels in a hierarchical fashion (see (Bertolotto et al., 2001) for more details). In this way, even non-expert users can easily build their own spatially enabled application. Additional development tools include: the Pyramid Builder, a utility designed to load scanned aerial/satellite photos and topographic maps into the database; the Feature Builder, a utility that allows users to define new data sources and the feature classes that the source controls; and Visual*i*, a tool specifically designed to allow any user to build a customised graphic user interface for both standard management information systems and spatial applications without writing any source code.

3. A land information management system

In this section the Land Information Management System (LIMS) implemented using *e*-Spatial[TM] technology is described. The LIMS application, developed for the Irish Department of Agriculture, is a web-based spatial information system that serves 125,000 farmers in the territory of the Republic of Ireland. A functional overview is provided in the following.

The functionality provided by the LIMS system include:

- View farmers' details online
- Locate a parcel/area using different criteria
- Digitising
- Spatial queries
- Printing

Accessing the system requires all users to logon with a valid name and password. Different security restrictions are applied to different groups of users (e.g., only viewing/querying, viewing and editing, etc.).

In the following we describe how the system is used after authorised logon. At first the user is prompted with a homepage from which several different options can be chosen. For example, the Farmer/Locate screen can be entered to view farmer details and locate parcels (Figures 3 and 4). A remote user can view the claimant's details to retrieve associated information. To access details the user is required to enter a herd number and select a year from a drop-down list (Figure 3).
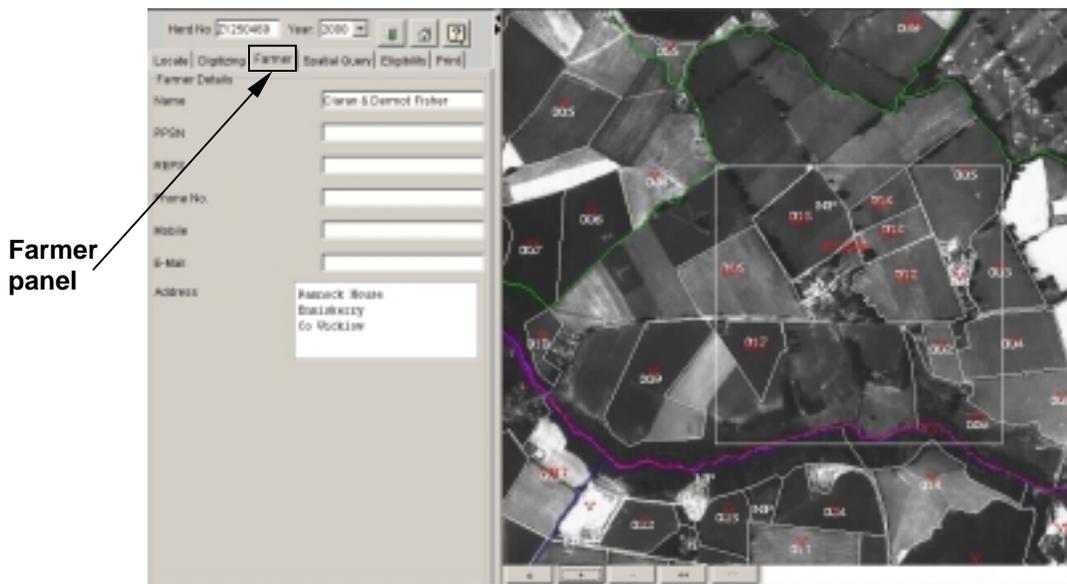

Figure 3. Screenshot of the Farmer panel.

By clicking on the locate button (Figure 4) it is possible to locate a parcel/area using several different criteria: cadastral locate (specifying a county), Ordnance Survey locate (entering map numbers), coordinate locate (enter x and y map coordinates), LPIS number (land parcel ID).
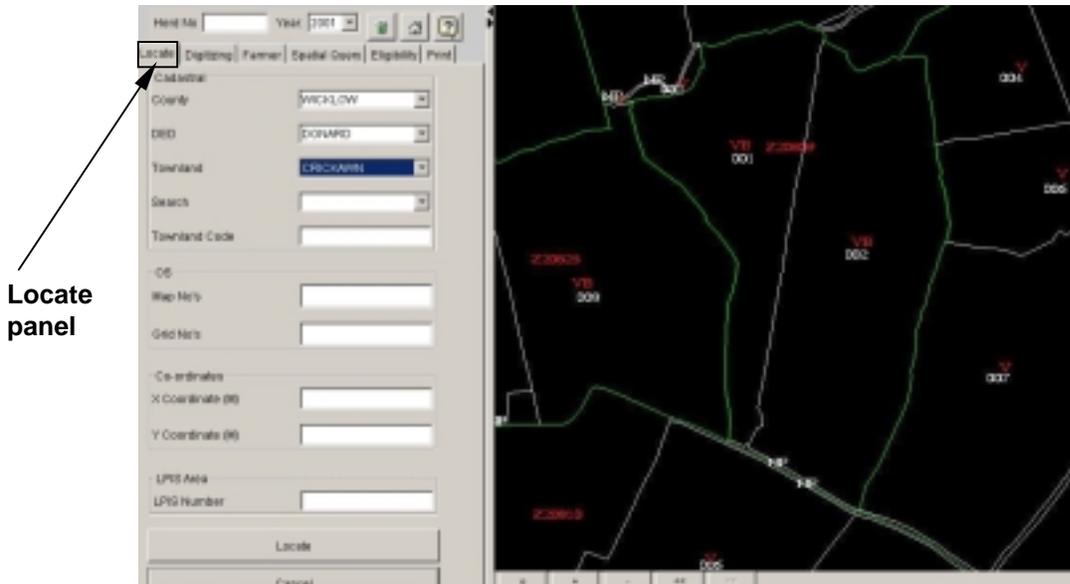

Figure 4. Locate panel: example of locate functionality using the cadastral details.

Alternatively, the user could enter a herd number and a year to display all parcels where the specified herd is located. One specific parcel can then be selected and viewed (Figure 5).
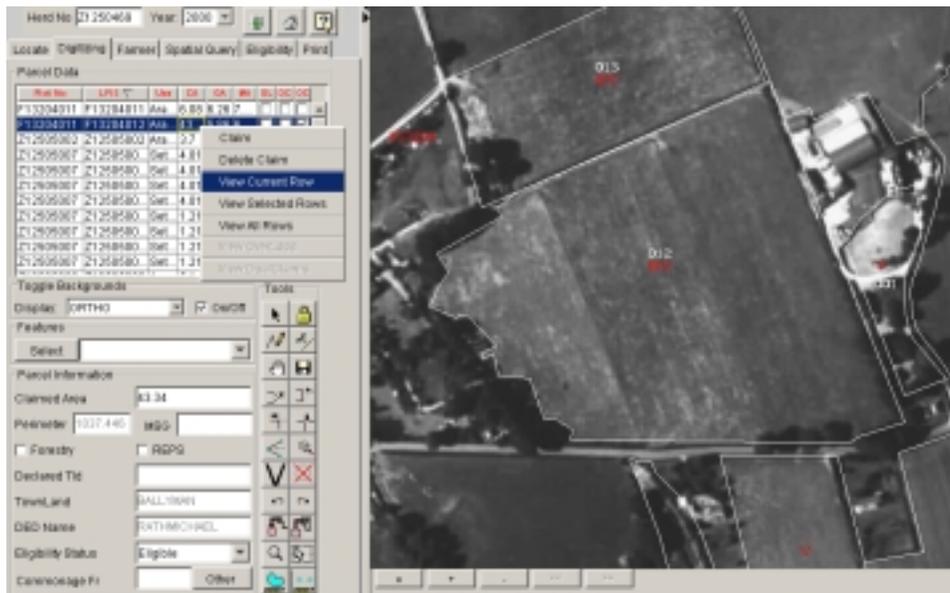

Figure 5. Alternative locate method: the user enters a herd number and year; then clicks on the Digitising tab (Parcel Data will have been populated with plot and parcel data for the chosen herd number); the specific parcel is then selected and viewed by right clicking on it and choosing the *View Current Row* option.

The on-line digitising functionality is accessible directly from the result screen of the locate search described above by clicking the digitising tab (see Figure 6).
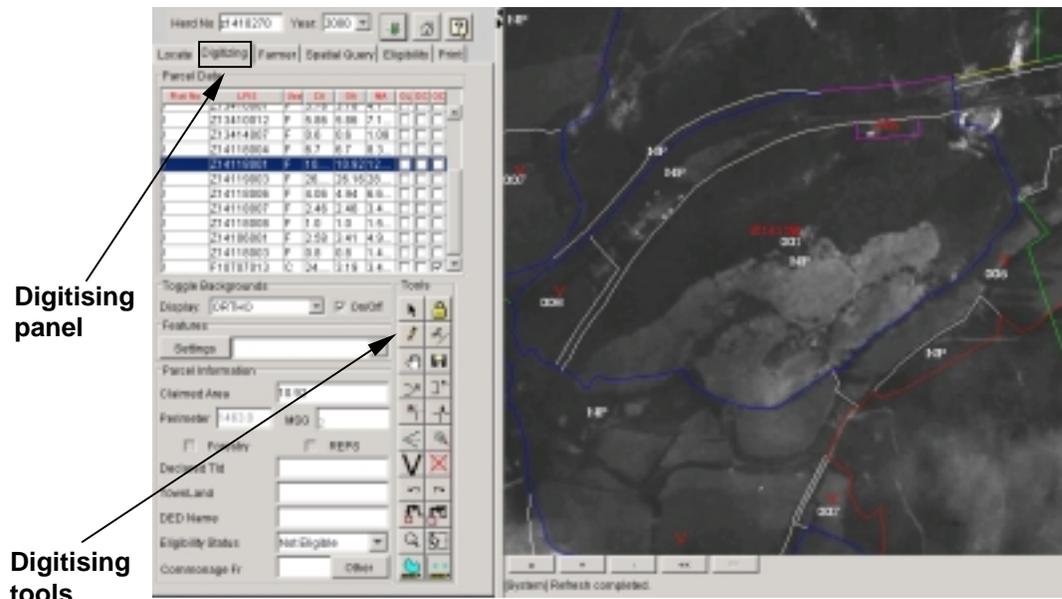

Figure 6. Digitising panel: besides viewing parcel data and changing visualisation settings, the user can utilise standard digitising and validation tools.

Once the user has digitised a new parcel boundary, topology updating algorithms are automatically invoked within the Oracle 9i Spatial database. Immediate printing capabilities of graphical/attribute editing updates represent additional benefits of the system.

Spatial query functionalities of the system include: retrieving parcels of a given shape, area, centroid coordinates; buffer queries; window queries; topological queries (e.g., based on overlapping, containment, etc.). Thematic queries are also allowed where re-symbolisation of an area on a map is based on its attributes. In Figure 7 the Spatial Query panel is illustrated.

To enable printing capabilities the Print tab is selected. Two different modes are available: on-line printing and batch printing. Using the on-line mode, users can print (see Figure 8):

- Screenshots: prints what is currently visible in the viewer;

- On-screen parcels: prints a parcel based on its LPIS number, which is entered into the relevant field.

- On-screen herd numbers: prints a farmer's entire herd at a zoom level and paper size chosen by the user;

- On-screen townlands: prints a townland map with any required background depending on user preference.
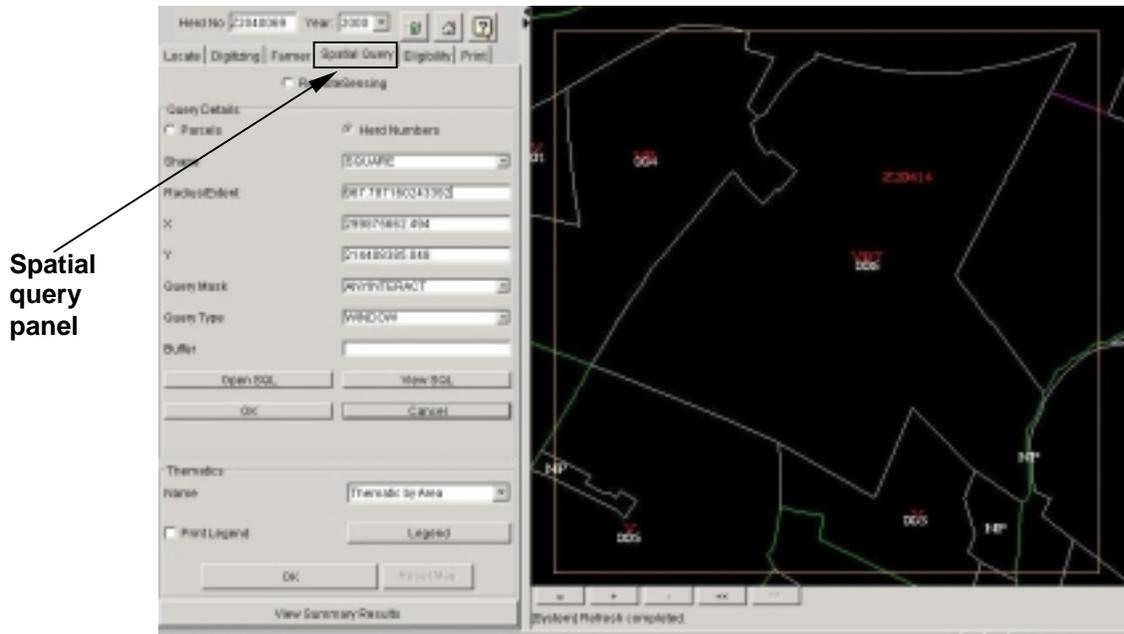
Figure 7. Spatial query panel: the user can enter query details such as the shape of the geometry, the distance from specified map coordinates, the query type (window, buffer, etc.), the topological relations (overlap, touch, equal, anyinteract, etc.). The corresponding automatically generated SQL statement can be viewed and manually edited if required.
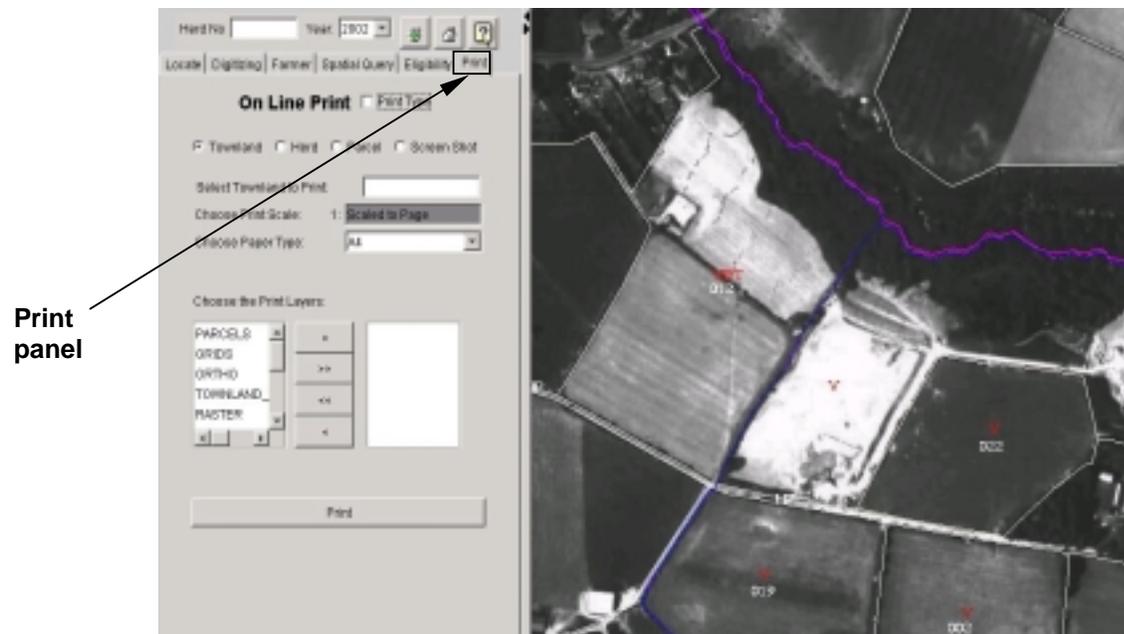
Figure 8. Printing panel with on-line option: a wide range of parameters can be selected by the user (zoom levels, paper size, background settings, etc.).

4. Performance

In this section we provide some operational results of the Land Information Management System developed for the Irish Department of Agriculture. This system (on-line since February 2002) serves 125,000 farmers in the territory of the Republic of Ireland for a total of 700,000 field parcels. Table 1 shows typical dataset sizes in terms of number of bytes and number of records.

Type of Dataset	Size of Datasets	No of Records
Orthophotography	80GB	24,000
OS Maps in Raster Format	180GB	24,000
Geometries	12GB	7,000,000

Table 1. Typical dataset sizes.

In the first two weeks of on-line operation the system generated 200,000 maps. The average number of spatial users is 16, with a peak number of 64. The average response time for a locate query is 7 seconds without caching capabilities. Cached locate queries require on average 2 seconds. Updates (e.g. posting a new geometry) require an average time of 5 seconds including recalculation of topology within the database. Further testing of processing times under load is currently on-going.

5. Conclusions

This paper presents an application of e-Spatial^{TM} technology, an innovative software solution that extends Oracle Spatial databases by adding spatial information management functionality that can be used within web-enabled applications accessed via any device that supports the Java Virtual Machine (e.g., standard web browsers, PDAs and 3G mobile phones). A major advantage of this technology is that it does not require the use of complex GIS proprietary application specific software.

The use of the Oracle Spatial database environment allows for a unified way of handling both spatial and non-spatial data within the same database. Typical GIS applications (e.g., ArcInfo, MapInfo, etc.) store the two types of data separately. Besides reducing the complexity of system management by eliminating the hybrid architecture of typical GIS data models, additional specific benefits (from the point of view of data management) of exploiting the Oracle Spatial unified approach include:

- The possibility for users to access full function spatial information systems based on industry standards with an open interface to all data (e.g., SQL);

- The capability of storing spatial data in enterprise-wide database management systems thereby enabling the spatial development of several more enterprise applications;

- The complete integration of management information and spatial data repositories that allows for web enabling the development of geo-spatial applications providing additional analysis and reporting functionality.

From a data management point of view, a critical issue involves guaranteeing the preservation of topological consistency (Egenhofer and Franzosa, 1991). The integrated Oracle 9i topology management functionality completely controls topology within the iSMART^{TM}+iSIS platform: if a spatial element is updated, all spatially related elements are automatically changed accordingly to guarantee consistency.

Using e-Spatial technology, no application code is ever installed on the client side, thereby eliminating any redundant code. The thin client applet supports an unlimited number of users and an unlimited number of applications. With the database generating all requested information (including both application functionality and attribute data) on the fly, only the minimum data required is downloaded to the client, which leads to the most economical usage of bandwith and resources for real-time response.

In this paper we have shown the potentialities and performance of *e*-Spatial[TM] technology as deployed in the land information management system developed for the Irish Department of Agriculture. This system serves 125,000 farmers in the territory of the Republic of Ireland and after two weeks of on-line operation, it generated 200,000 maps. This application provides a seamless Oracle 9i Spatial database environment for the combination of multiple land information datasets. The normal edit (e.g. create, modify, and delete) and spatial analysis functions associated with a traditional GIS based land management applications, are deployed as Java stored procedures in the Oracle Spatial database. Integrated database topology ensures the integrity of the topology relationships within the spatial database. The automatic preservation of topological properties makes this system a reliable decision-making tool. Statistical data analysis (e.g., land use, land classification and land ownership changes over time, etc.) can also be easily compiled using standard Oracle reporting functionality. Implementation and testing to make the land management information system available also on hand-held mobile devices are currently under development.

In the past spatial information was utilised within specialised applications and exclusively by expert high-end users. Recently, thanks to the diffusion of desktop GIS and the Internet, its integration within the widest range of applications is becoming a common requirement. Therefore, a pressing need relates to providing non-expert users with easy-to-use environments where they can visualise, query and manipulate spatial data without requiring any specific GIS, programming, or database management background. To this purpose, additional tools to build and customise graphic user interfaces that facilitate interaction with the iSMART[TM]+iSIS platform have also been developed. Such tools provide a user-friendly environment based on drag-and-drop functionality, without requiring any specific programming skills. In this way, even non-expert users can easily build their own spatially enabled applications.

Finally, while existing systems are restricted to using all the data contained within each data layer with no ability to switch on/off specific subsets of spatial data, *e*-Spatial[TM] allows users to select the particular data they wish to view and query. This ability to switch on and off data and also define exactly what the users need to query greatly improves the speed with which the individual query is completed. This characteristic also conforms to the information-on-demand approach discussed by several authors in the context of web-based vector map generalization (Bertolotto and Egenhofer, 2001; Buttenfield, 1999; Cecconi and Weibel, 2000). The potentialities of the application of *e*-Spatial[TM] technology in this context are currently under investigation.

6. Acknowledgements

7. References

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