BIOGRAPHICAL INFORMATION

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SPECIFIC RESPONSIBILITIES

Xavier Lopez joined Oracle in March 1998 and directs product management for the Spatial Technologies group. Xavier leads Oracle's efforts to incorporate location technologies across Oracle's database, application server, e-Business technologies. He has fifteen years of experience in the area of GIS and spatial databases.

PAST EXPERIENCE

Mr. Lopez has extensive background in the deployment of spatial technology with the Massachusetts Water Resources Authority and Massachusetts Department of Environmental Protection. Mr. Lopez has been active in numerous academic and government sponsored spatial information research initiatives. He is the author of a book on government spatial information dissemination practices and has published numerous research papers and book chapters on spatial technologies. Xavier served in U.S. Peace Corps Nepal during 1986-89.

EDUCATION

1998 University of California, Berkeley, (Chancellor's Postdoctoral Fellow)
1996 University of Maine, Ph.D, Spatial Information Engineering
1992 Birkbeck College, Univ. of London, Dept. of Geography (Fulbright Fellow)
1991 Massachusetts Institute of Technology, Master of City Planning
1984 University of California, BA Geography, Davis, BA

PROFESSIONAL MEMBERSHIPS

Geographic Information Technology Association (GITA), Board of Directors
International Geographic Information Foundation (IGIF), Board of Directors
Journal of Urban and Regional Information Systems (URISA), Editorial Board
GeoWorld, Editorial Board
National Academies of Science, Study Member

DATABASE DRIVEN GIS:
DELIVERING REAL-TIME, MISSION CRITICAL, LOCATION SERVICES

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Abstract: This paper describes how database technology has evolved as a platform to support a new generation of spatial applications and services. While early attempts to integrate generic GIS capability to existing IT framework has proven to be costly and unsustainable, new advances in database technology now enable users to manage all their spatial data in the database and make it accessible to a large range of business applications. This paper highlights an *information-centric* approach to delivering high-end applications facilitates timely and cost-effective development, resulting lower management and training costs, reduced IT churn, and increased public satisfaction. It highlights the emerging approach taken by the leading enterprise software vendors to deliver open, Internet-based spatial platform for delivery of GIS and location-enabled enterprise applications.

INTRODUCTION

Interest in spatial information is on the rise. This interest is both stimulated and realized by the increasing use of geographic information systems, Internet mapping, global positioning systems, location based services, and navigation systems. The increasing availability of georeferenced data, combined with continued progress in information technology is making the use of spatial data mainstream throughout commercial, scientific and government decision-making. Success in making spatial data available across a broader spectrum of corporate IT applications lies with location-enabling common business applications. These include: customer care, business intelligence, supply chain, financial, and other application.

However, the broad use of GIS data across various sectors of an organization has not been straightforward. Over the past decade, many government agencies have found that their GIS systems cannot be successfully integrated with their enterprise systems due to inherent technology, design and organizational constraints. The result has been islands of spatial information and technology that undermine the organization's ability to add value to its information and technology investments. It has also led to increased training and development costs and the inability to share valuable information assets across the organization. Attempts to integrate applications – a GIS application and a customer care application, for instance – become difficult and expensive. Most importantly, these public organizations have not effectively leveraged their investments in the development of spatial information. A newer approach is called for – one that makes location an inherent capability of an organization's IT infrastructure.

LOCATION ENHANCED BUSINESS APPLICATIONS

The Internet has redefined the ways that location information is collected, managed, queried and disseminated. Location-based services are now deployed on large, professionally managed servers and accessed via Internet browsers and mobile interfaces. Smaller numbers of large servers are being used to consolidate databases, resulting in lower costs, improved reliability, heightened security, and dramatic improvement in quality of services. The only way to truly make location applications scale to meet the requirements of Internet and wireless deployments is to embed spatial capability natively into the database, which can then be accessed by virtually any device.

In the past decade the spatial information industry has undergone significant changes, evolving rapidly from a closed GIS-based niche application to an “open” enterprise application for disseminating location-enhanced business information. While the market for highly specialized GIS continues to grow at annual rates of 10 - 15%, there will be even faster growth for location-enabled capability within in mainstream business applications (call centers, data warehousing, customer relationship management, service delivery, e-commerce) (IDC 2002). Application developers can leverage a spatial platform to support a wide variety of location –enabled solutions:

- **Geographic Information Systems (GIS)**: Query topographic data for flood plain and basic land management. Combine with population data in a single database to support disaster preparation and relief.
- **Utilities Infrastructure**: Maintain spatial database of the entire network including individual poles, lines, hydrants, or distribution centers. Overlay road and housing data for “dig safe” queries. Manage “long transactions” through version management.
- **Energy Exploration and Distribution**: Maintain virtual maps of underground oil or gas deposits. Determine where to locate drill sites, refineries, or storage facilities.
- **Supply Chain Management**: Optimize the flow of goods through the supply chain (product mix, inventory, distribution, warehousing, and shipment routes). Add a location dimension to a supply chain so that suppliers can directly review and take action on information that affects them.
- **Customer Relationship Management (CRM)**: Enable organizations to understand, anticipate, and respond to their customer needs, in a cost-effective manner. An Internet-centric business model can use electronic storefronts and self-service to expand service delivery, shorten response time, improve efficiencies, and reduce costs for the fastest ROI.
- **Data Warehousing/Business Intelligence**: Analyze all transactions being collected in ERP systems (customer purchasing, sales, asset characteristics by time and place) to derive insight and enhanced decision making.

- **Wireless Location-Based Services**: Enable Internet and wireless service providers to enhance their content offerings with the delivery of geocoded information through a variety of location aware devices. New types of services include looking up addresses, online geocoding, finding travel directions, and identifying the nearest hotels, gas stations, and other places of interest.
- **Field Service/Telematics**: Enhance and/or enable the delivery of diverse multimedia services to a car or fleet. These services include driving directions, real time weather and traffic (E511), and a range of personalized concierge services enhanced by location data. Intermodal transportation and Intelligent Transportation Systems are relevant, related areas.

SPATIAL PLATFORMS FOR GIS, ASSET MANAGEMENT, AND LBS

In an era of desktop and client server environments, each department maintained its own "island of spatial information" that was locally maintained and used for specific purposes. Hence, it is not uncommon for many agencies to maintain multiple mapping, engineering, and analysis applications that are not interoperable. With the introduction of spatial databases, it is now possible to consolidate spatial information assets on large servers that are professionally managed and accessed through a network via a browser, just like other data assets. A smaller numbers of large servers are used to consolidate databases, resulting in lower costs, improved reliability, heightened security, and dramatic improvement in quality of information.

By effectively managing spatial and attribute data in a single platform—with common storage, indexing, query optimization, security, and user management—a spatial database reduces processing overhead and eliminates the complexity of coordinating and synchronizing disparate sets of location and attribute data. Immediate realizable benefits include:

- Spatial data and all types of attribute data can be stored in a single server
- Seamless geographic coverages—no tiling
- Better management of spatial data—SQL access
- Elimination of hybrid GIS architectures and schemas
- Greatly reduced complexity of systems management
- Standard spatial types: proprietary data structures are avoided
- Scalability, data security, replication, partitioning, bulk load utilities
- Support by leading GIS and location technology tool vendors
- Breaking the size barriers—support for tens of terabytes of data
- Support for both short and long transactions (version management)
- OGC conformance certification
- Ready support for Geographic Markup Language (GML)

SPATIAL DATABASE FEATURES

As traditional GIS technologies hit their own scalability and reliability limits, users are increasingly turning to database centric spatial computing. Spatial databases allow organizations to handle spatial data just like any other data. From the perspective of

IT and data management, spatial no longer has to be special. This is important since mainstream IT applications all use standard relational database technology as their fundamental data management solutions. Managing GIS data in an open, spatial DBMS enables GIS users to overcome the inherent limitations of file-based storage, it eliminates the proprietary encoding of spatial data; and provides an open standard interface (SQL) to query, retrieve and analyze spatial data. Standard features of spatial databases include:

- Spatial indexing: Usually R-tree or quadtree indexing
- Spatial operators that determine the interaction of geometric features
- Relationship operators
- Open, standard SQL access to spatial operations
- Spatial referencing system
- Whole Earth geometry model
- Spatial functions such as buffer generation, centroids, area and length calculations, and aggregate functions (e.g. unions and user defined aggregates)
- Linear referencing system
- Coordinate transformations
- Function-based spatial indexes
- Partitioning support for spatial indexes
- Support for parallel index builds
- Support for parallel spatial queries

Spatial databases, like Oracle Spatial, move spatial processes and operations directly into the database engine, thereby increasing performance and security. With every release, database vendors incorporate new spatial features that increase performance and broaden range of applications. Recent advances in spatial databases are advancing the concept of spatial platform into broader areas with new features like:

- **Network Data Model**: A data model is provided to store network (graph) structure in some spatial databases, like Oracle Database 10*g*. It explicitly stores and maintains connectivity of link-node networks and provides network analysis capability such as shortest path, connectivity analysis. Applications requiring network solutions include transportation, transit, utilities and life sciences. For transportation applications, the network data model also supports a routing feature.
- **Navigation Routing Engine**: A spatial database now supports navigation routing (driving distances, times, and directions between addresses). Other features include: preference for either fastest or shortest routes, returning summary or detailed driving directions, and returning the time and distance along a street network from a single location to multiple destinations.

- **Topology Data Model**: This is a data model and schema that persistently store topology in a relational database. This is useful when there is a high degree of feature editing and a strong requirement for data integrity across maps and map layers. Another benefit is that topology-based queries typically perform faster for queries involving relationships such as adjacency, connectivity, and containment. Land management (cadastral) systems and spatial data providers benefit from these capabilities.

- **Raster Data Management**: A new data type natively manages georeferenced raster imagery (satellite imagery, remotely sensed data, gridded data). This feature provides georeferencing of imagery, XML schema for metadata management and basic operations like pyramiding, tiling, and interleaving. Applications in environmental management, defense/homeland security, energy exploration, and satellite image portals will benefit.

- **Geocoding Engine**: Geocoding is the process of associating geographic references, such as addresses and postal codes, with location coordinates (longitude and latitude). A fully functional geocoding engine is now available as part of the industry's leading database. It provides international address standardization, geocoding and POI matching by querying geocoded data stored in the spatial database. Its unique unparsed address support adds great flexibility and convenience to customer applications.

- **Spatial Analytic Functions**: New server-based spatial analysis capabilities include classification, binning, association, and spatial correlation – essential for business intelligence applications. This technology enables application developers to deploy spatial data mining operations on a variety of point-based features.

What make these advances in spatial database technology groundbreaking is that they are accessible through open interfaces using SQL. By adhering to emerging industry standards such as OpenGIS, ISO-TC211, and SQL-MM, it is now possible to have multiple client tools access this information. It is no longer necessary to force all departments to standardize their tools and applications. Instead, what is standardized is the underlying data model. For example, it is possible to embed mapping capability into a utilities' asset management or SCADA application. By storing all spatial data in an open, OGC conformant schema, it is possible to use simple web browsers to access mapping in the Planning department, network data in the Engineering department, and land management data in the assessor's office. The ability to centralize all your spatial information assets in a common IT environment enables government to leverage its investments in spatial data – much like it has with other types of corporate information. In short, spatial data simply becomes another type of data that is stored in a standard relational database.

LOCATION ENABLED ENTERPRISE APPLICATIONS

In the past, databases were simply used as repositories of digital data, performing basic indexing and querying functions. However, database technology has rapidly evolved. Databases have now become platforms for deploying enterprise applications like e-commerce, CRM, digital libraries to hundreds and thousands of customers – all on the Internet. With the introduction of spatial databases, location can now be incorporated into corporate e-Business applications like Customer Relationship Management (CRM), Enterprise Resource Planning (ERP), and Business Intelligence (BI).

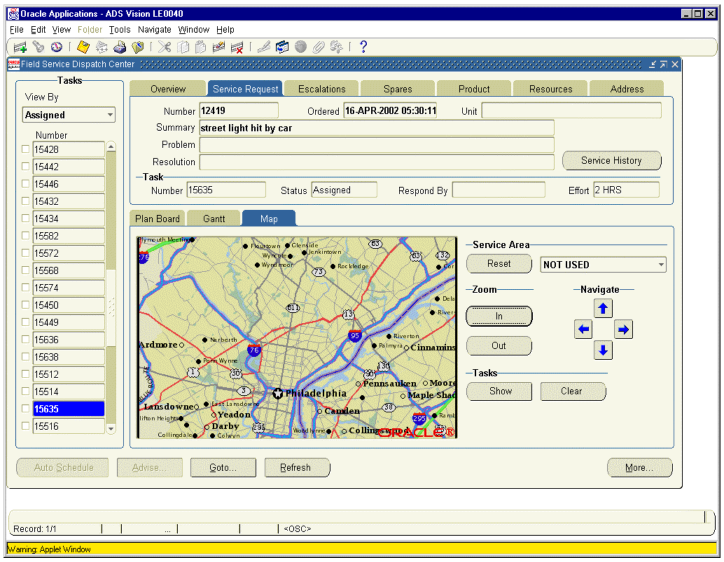

Figure 1: Location-enabled CRM Field Service application

The figure above illustrates the integration of mapping capability directly into a CRM field service application. Organizations have demonstrated that effectively managing location can provide strategic differentiation when managing customer information and efficiently managing corporate assets, both critically important in business.

Spatial databases can support a variety of GIS, asset management, network, and visualization tools and applications. In doing so, they enable the re-purposing of "location awareness" across a broad spectrum of an organizations spatial and non-spatial applications. Utility providers, for example, now recognize that they will compete on the basis of how effectively they can integrate their CRM and field service operations with those of customers and suppliers to create a positive business experience. By integrating enterprise information with location-enhanced customer information, utilities obtain comprehensive business intelligence, and value builds exponentially. Service providers can now use real customer information to determine service expansion, improve service delivery, and determine load demands. On the customer end, by automating information integration and interpretation, the customer is able to deal with a much richer set of location-enhanced information for better decision-making. With the introduction of event-driven e-Business, utilities can send fresh information as it becomes available or as users roam into a new location, rather than waiting for customers to check in with the service. Customers, mobile operators, and partners can react immediately to the changed location of a handset user by delivering personalized services for his/her new roaming region.

ORGANIZATIONAL BENEFITS

As mentioned earlier, embedding lightweight spatial capability into existing corporate applications holds tremendous potential. However, location-enhanced data warehouse and CRM applications must be able to leverage the underlying spatial capabilities of the leading database products. For example, handling location data within a spatial database provides significant organizational benefits – increasing operational efficiency while reducing cost:

- **Savings**: Provide complete, low-cost, entry-level location services capability using a spatial database to location-enable enterprise apps. Developers can integrate spatial features directly into business and location-based applications at relatively low cost and with minimal training
- **Consolidation**: Consolidate all geospatial data types (vector, raster, grid, imagery, network, topology) in a single, open, standards-based data management environment. This in turn reduces cost, complexity and overhead of managing separate, isolated, proprietary systems.
- **Simplification**: Reduce training, software, support and application integration costs inherent in multiple stove-piped geospatial and enterprise systems
- **Risk Reduction**: Application developers can use existing database and GIS technology investment s to location-enable their applications.

Spatial databases can lower costs by as much as 90% per transaction compared to using separate, isolated, proprietary GIS systems. For the State of Arkansas, its GeoStor system has produced savings of more than $2 million dollars in its first 18 months of operation, and continues to generate dramatic savings by cutting the costs of spatial data publishing and other transactions at a rate of 90% per transaction.

All these advantages are driving forces for the creation of a new class of location enhanced business applications that help to integrate silos of information using a common database infrastructure. These benefits are increasingly compelling IT managers to consolidate their information resources -- managed centrally by small group of experts while enabling users to view and edit information using simple Web browsers. Since user departments maintain different types of location-based information (street addresses, land records, network infrastructure, SCADA) they all benefit from the increased ability to standardize and share this information.

PROGRESS THROUGH INTEROPERABILITY

Interoperability standards make possible the integration of spatial databases with the market's leading GIS tools and mapping applications. Spatial databases, like Oracle Locator and Spatial, are directly integrated with the leading GIS mapping and location services technology vendors. Through the combination of a spatial database and partner tools, it is possible for developers to rapidly deploy scalable and secure enterprise GIS and location service solutions. Vendors consistently work to influence and support the latest open standards, particularly in the area of geographic information and location-based services.

CONCLUSION

With the advent of spatially capability from the leading database vendors, the era of managing spatial data in hybrid systems or files based systems has come to a close. Storing spatial data in an enterprise-class server enables GIS, CAD, AM/FM applications to leverage advanced database features like: parallel query, replication, partitioning, security, scalability, none of which are supported in file-based or hybrid middle-ware systems. Second, spatial data is now stored in an open format, using rows and columns or arrays as opposed binary elements optimized for vendor specific applications. Third, spatial data can be managed, queried, and displayed using SQL from any enterprise application like financial, data warehouse, supply chain, CRM, and industry standard reporting tools. Finally, centralizing management reduces the overhead of managing different systems, eliminates training on different applications, and minimizes application integration costs. This means that public organizations can maximize the utilization of public resources, a necessary competitive tool in the public sector today and in the future

REFERENCES

IDC 2002, *Spatial Information Management, Competitive Analysis*, D. Sonnen and H. Morris, International Data Corp. December 2002. Framingham, MA.