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Advanced Spatial Data Management for Enterprise Applications

ORACLE

Introduction

Oracle Spatial 11*g*, an option for Oracle Database 11*g* Enterprise Edition, provides advanced spatial capabilities to support geospatial applications, location-based services, and enterprise spatial information systems. Oracle Spatial extends the core location features included in every Oracle database with Oracle Locator.[1] Its advanced data manipulation and spatial analysis features include spatial data mining functions, geometric unions and intersections, and linear referencing. It also includes a GeoRaster datatype to store and manage image and gridded raster data and metadata, network and topology data models, geocoding and routing engines, and APIs for quick and easy deployment of mapping, geocoding, and routing services. These significant capabilities address business-critical requirements of the public sector, defense, logistics, energy exploration, business geographics, and life sciences domains.

Oracle Spatial 11*g* Release 1 introduced significant functionality. The spatial geometry data type was enhanced to support 3-dimensional (3D) data, and 3D data types support storage and management of point clouds and terrain models, found in domains such as urban planning, homeland security, or LIDAR-based map production. Oracle Spatial 11*g* introduced support for geospatial web services standards, to provide a secure, scalable service-oriented architecture platform. The GeoRaster datatype and Network Data Model were enhanced to handle data sets larger by orders of magnitude with high performance, and became easier to use.

Oracle Spatial 11*g* Release 2 introduces enhancements that support more completely a wide range of requirements from applications across several different domains such as

1 Oracle Locator, a feature of Oracle Database 11*g* (Express Edition, Standard Edition, Standard Edition One, and Enterprise Edition), provides core spatial features for business applications and partner-based GIS. Features include vector data storage and management, indexing, spatial relationship analysis, coordinate systems support (including support for the EPSG model), and more.

raster processing, truck routing, and utility and logistics network applications; simplify application development; and boost performance. These include a GeoRaster Java API; raster reprojections and ground control point-based georeferencing; a 3D visualization framework; Network Data Model modeling and analysis enhancements; geocoding and routing enhancements; and more.

In general, this white paper focuses on features included only with Oracle Spatial; however, some features included both in Oracle Locator and in Oracle Spatial are also described. Oracle Locator, a feature of the Oracle Database (Express Edition, Standard Edition, Standard Edition One, and Enterprise Edition), provides core location functionality such as a spatial vector data type, R-tree indexing, and spatial relationship operators. Please refer to separate white papers and documentation for more information about Locator features, and detailed listings of Locator and Oracle Spatial features.[2] Combined with the performance, scalability, and security of Oracle Database, Oracle Spatial 11*g* is the most advanced spatial database platform available for enterprise class deployments.

3D Data Type Support

Oracle Spatial provides native storage, querying, and retrieval for 3-dimensional (3D) data, including points, lines, surfaces, triangulated irregular networks (TINs - an alternative to rasters), and point clouds. Spatial R-tree indexing and SQL operators and analysis functions for 3D data are also provided.

Very large 3-dimensional datasets such as urban models, point clouds, and terrain models can be stored and managed in open Oracle Spatial data types, with security, scalability, and high performance. 3D datasets are often found in urban planning and design, government, homeland security, military, oil and gas exploration, transportation engineering, gaming and simulation, geo-

2 For descriptions of features in Oracle Locator, please refer to *Oracle Locator: Location-Enabling Every Oracle Database - Technical White Paper* and *Oracle Locator – Feature Overview*.

For complete comparative listings of features included in Oracle Locator and in Oracle Spatial, please refer to Appendix B of the *Oracle Spatial Developer's Guide 11g Release 2 (11.2).*

engineering, medical applications, business intelligence (for example, real estate and advertising), and LIDAR-based map production.

Oracle Spatial 11*g* Release 2 now provides a modeling, visualization and simulation infrastructure for 3-dimensional data. A set of metadata tables describes themes, scenes, textures, viewpoints, light sources, non-geographic data, and other elements used to visualize 3D content. This metadata support enables a consistent way to combine all 3D, raster, vector, and non-geometric data into a unified visualization framework. Information may be logically grouped into themes to simplify the development, analysis, use, and maintenance of 3D applications. Performance of the 3D analysis operations has also been improved.

Spatial Web Services

Oracle Spatial 11*g* Release 1 introduced a web services platform to access, incorporate, publish, and deploy geospatial services, such as for routing, geocoding, business directory, catalog, geospatial feature, and mapping. Because of tight integration with Oracle Database and Oracle Fusion Middleware, this is a transactional service-oriented architecture platform with enterprise-class security.

Oracle Spatial conformance to the Open Geospatial Consortium (OGC) and ISO TC211 standards has been enhanced. Oracle Spatial 11*g* Release 1 (11.1.0.7) complies with the OpenGIS Web Feature Service Interface Standard (WFS) 1.0.0.

This release is designed to support the following XML-based geospatial web services standards: OGC OpenLS 1.1, Web Feature Service – Transactional 1.0, Web Feature Service 1.0, and Catalogue Service 2.0, on a variety of client technologies and platforms.

Oracle Spatial 11*g* Release 2 also includes full support for database transactions on WFS-T feature tables through SQL (with no restrictions on using WFS-T transactions), and full support for Oracle Database Workspace Manager and WFS feature tables.

Oracle Database and Oracle Fusion Middleware provide security – including authorization, authentication, and transport confidentiality and integrity. Java and PL/SQL client APIs are provided.

Spatial Functions

Over 400 spatial functions perform calculations on geometries, such as area of a polygon and length or perimeter of a geometry. These functions can be used, for example, to determine the total area of all counties around a given county, the length of an interstate highway, or the length of a provincial border.

Other functions can generate new geometries such as buffers, unions, intersections, and more. They can be used, for example, to define sales regions by creating a 5 mile buffer around all sales offices, identify the new geometry representing the union of two sales regions, or find the intersection between two sales regions.

New functions in the current release include interior point, concave hull, and generation of triangulated irregular networks through Delaunay triangulation. Cross-endian operations for transportable tablespaces are also supported.

Whole Earth Geometry Model for Geodetic Coordinate Support

A Whole Earth geometry model takes into account the curvature of the Earth's surface when performing calculations on geodetic data. Thus, Oracle Spatial functions return accurate lengths and areas for both projected and geodetic data. Oracle supports over 30 of the most commonly used distance and area units, e.g. foot/square foot, meter/square meter, kilometer/square kilometer, and so on.

Projections and Coordinate Systems

To represent and integrate spatial information effectively and accurately, Oracle Spatial provides comprehensive tools for managing coordinate systems and projections. Over 4000 commonly used mapping coordinate systems are supported; users can also define new coordinate systems. Oracle Spatial also provides support for converting data freely between different coordinate systems – it enables explicit map projection transformations of vector objects from one coordinate system to another. These transformations can be on a geometry-level basis or an entire layer at a time.

Coordinate systems support is based on the European Petroleum Survey Group (EPSG) data model and data set. Although created by the oil and gas industry, this industry model provides benefits of standardization, expanded support, and flexibility for all industries, GeoRaster data vendors, and GIS users in general.

Oracle Spatial 11*g* Release 1 introduced support for 3D coordinate systems, which are based on the height dimension, in addition to longitude and latitude or projected x, y coordinates as appropriate. With Oracle Spatial 11*g* Release 2, reprojection of rasters is supported. Also with this release, coordinate system transformations execute faster than with previous releases.

Linear Referencing Support

Oracle Spatial supports the storage of "measurement" information associated with a linear geometry. This allows many attributes or events to be associated with a specified segment on a linear geometry. Attributes or events are stored in tables separately from the geometry, and the geometry does not have to be duplicated in the attribute tables. Linear referencing is often used in the transportation, utilities, and telecommunication industries.

Functions to manipulate linear referenced geometries are also included, such as locating points along a linear feature, clipping a piece of a linear feature (dynamic segmentation), snapping to the closest point of a linear feature of a given point, and conversion between standard and linear referenced geometries.

Spatial Aggregates

SQL has long had aggregate functions, which are used to aggregate the results of a SQL query. Spatial aggregate functions operate on a set of geometries rather than just one or two geometries. An aggregate function performs a specified aggregate operation on a set of input geometries, and returns a single geometry object. For example, the following statement returns the state boundary of Tennessee generated from all of the counties in Tennessee:

```
select sdo_aggr_union(sdoaggrtype(geom,0.5)) state
from geod_counties
where state_abrv='TN';
```

Other supported aggregate functions include union, centroid, and convex hull; users can also define other aggregate functions. The use of spatial aggregates improves performance and simplifies coding.

In Oracle Spatial 11*g* Release 2, internal tests of aggregate union computations have shown performance improvements of 50 times compared with the previous release, on data sets of typical size. Tests have also shown that the magnitude of the performance improvements increases with size of data sets.

GeoRaster Support

Oracle Spatial includes a data type that natively manages georeferenced raster data, such as satellite imagery, airborne photographs, and gridded data, in Oracle Database. The GeoRaster feature of Oracle Spatial provides georeferencing of rasters; an XML schema for metadata management; and basic operations like pyramiding, tiling, and interleaving. GeoRaster also supports industry standard image compression techniques, including JPEG baseline (lossy) and DEFLATE (lossless). Image compression can reduce user storage costs significantly, given the

very large sizes of remote sensing imagery data sets. The result is the ability to manage larger data sets by orders of magnitude with greater performance and ease of use. Other proprietary compression techniques are supported through third party plugins. Applications in environmental management, defense/homeland security, energy exploration, and satellite image portals will all benefit from this powerful functionality.

Oracle Spatial 11*g* Release 1 provided many new subprograms and other enhancements, including advanced mosaic, GeoRaster object or layer union, statistical analysis, partial raster update, and GeoRaster templates and related functions. GeoTiff, JPEG 2000, and Digital Globe RPC file formats are supported for loading and exporting GeoRaster objects. JPEG files can be loaded without decompression. GeoRaster also supports the use of Oracle SecureFiles, a new high performance LOB data type, which improves GeoRaster performance significantly.

More metadata and data types are supported. GeoRaster supports a generic polynomial georeferencing model, which includes direct linear transportation and rapid positioning capability georeferencing for non-rectified imagery. It also supports bitmap masks, multiple NODATA values and value ranges, and has limited sparse data type support.

Oracle Spatial 11*g* Release 1 GeoRaster provided enhanced ease of use, reliability, and manageability. GeoRaster DML triggers are created and monitored by the system automatically. Internal changes that monitor DDL events on raster tables and activities on GeoRaster system data enhance the manageability, reliability, robustness, and usability of GeoRaster. Raster data versioning with Oracle Workspace Manager, and raster data row-level security with Oracle Label Security are supported.

In Oracle Spatial 11*g* Release 2, a new Java API for GeoRaster has been introduced. It supports all the functions currently available in the existing PL/SQL interface, including all the query, manipulation, and raster management features in GeoRaster. In addition, this API includes calls to support the development of extraction, transformation, and loading (ETL) tools, Web applications, and raster processing applications. This new feature simplifies the development of Java applications that use, access, and manipulate raster and gridded data sets stored in Oracle Spatial.

The GeoRaster data type is supported by all the leading third party GIS and image processing tool vendors. This data type is also now supported by Geospatial Data Abstraction Layer (GDAL), the leading open source geospatial Extract-Transform-Load tool/API available for raster data. GDAL natively supports importing and exporting over 50 raster formats to and from SDO_GEORASTER, including GeoTIFF, JPEG2000, ECW, NITF, HDF, and many more. GDAL is a high performance C++ tool that supports large file sizes. It includes C/C++, Java, and Python APIs to access GeoRaster; and utilities to translate raster formats, warp rasters, generate contours from DEM rasters, and many other raster operations.

Additional enhancements include support for raster reprojections (to over 4,000 coordinate systems supported by Oracle Spatial); Ground Control Point-based georeferencing and native

storage (enabling data collection and processing applications to georeference raw, or non-rectified, and processed, or rectified, raster data); blocking size optimizer; irregular polygon-based clipping in queries; and grid point interpolations.

For more information about Oracle Spatial GeoRaster, please refer to separate white papers at oracle.com/technology/products/spatial.

Network Data Model

A data model is provided to store network (graph) structures persistently in Oracle Database. It explicitly stores and maintains network connectivity and provides network analysis capability such as shortest path, nearest neighbors, within cost, and reachability. Applications requiring network solutions include transportation, utilities, and oil and gas.

The Network Data Model includes: a PL/SQL API for managing network data in the database; a Java API for performing network analysis, and creating and applying network constraints.

Oracle Spatial 11*g* Release 1 introduced the ability to load partitioned networks into memory on demand, which overcomes the limitations of in-memory analysis. Large networks can be partitioned into manageable sub-networks and incrementally loaded into memory as needed for performant and scaleable analysis. Partitioning utilities are also available for large spatial networks. Thus, users can now analyze very large networks in Oracle Spatial without loading the entire network into memory.

In Oracle Spatial 11*g* Release 2, the Network Data Model is now integrated with the Oracle Spatial routing and geocoding engines, enabling applications using those engines to perform analysis using Network Data Model functions. The Network Data Model load on demand API can work directly with commercial street network data from Navteq, in Oracle Delivery Format (ODF).

A new demo kit that includes JSP and Java files enables application developers to quickly and easily deploy routing and other network analysis, using data stored in the Oracle Spatial Network Data Model. Users can visualize analysis results in a web browser. The demo works with Navteq ODF network data, and uses the Network Data Model load on demand API, Oracle Fusion Middleware MapViewer, and the Oracle Spatial geocoding engine. Please visit the Oracle Technology Network at oracle.com/technology/products/spatial to download the demo kit.

The Network Data Model also includes a number of modeling and analysis enhancements that more completely support a wider range of requirements of utility networks, logistics, and other applications dependent upon network-based analysis.

The following enhancements allow users to easily model a wider range of networks:

- Model and represent any point along a link for all analysis functions, such as specific addresses in street networks.

- Model partial-link paths (subpaths).
- Customize link and node costs.
- Support path analysis with multiple link/node costs (distance/time/hops).
- Perform partitioning of logical networks (for example, social and biochemical pathway networks) based on metrics appropriate to the application.

The following enhancements provide users with more network analysis capabilities:

- Compute the shortest route connecting a given set of nodes.
- Generate a polygon representing the region that can be reached from a given node with a specific cost. A typical application is the generation of drive-time/drive-distance polygons.
- Generate the shortest path on a hierarchical network, where links are prioritized by category (e.g., highways, local roads), to support queries such as finding the route between two addresses that favors highways over local roads as much as possible.
- Compute a buffer based on network cost; the buffer representation contains coverage and cost information.
- Compute K shortest paths between two nodes.

For more information about Oracle Spatial Network Data Model, please refer to separate white papers at oracle.com/technology/products/spatial.

Topology Data Model

Oracle Spatial includes a data model and schema that persistently store topology in Oracle 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 when involving relationships such as adjacency, connectivity, and containment. Land management (cadastral) systems and spatial data providers benefit from these capabilities.

Application developers and DBAs can version topologies stored in the Oracle Spatial topology data model using Workspace Manager, a feature of Oracle Database. Feature level spatial transactions against persistent topology in the database are supported. A feature insert or update occurs as a single operation, simplifying the process of updating and maintaining topology datasets, and keeping code streamlined.

Spatial Analytic Functions

Oracle Spatial supports spatial analysis and mining in Oracle Data Mining (ODM) applications. ODM allows automatic discovery of knowledge from a database, with techniques such as discovering hidden associations between different data attributes, classification of data based on some samples, and clustering to identify intrinsic patterns.

Spatial data can be materialized for inclusion in data mining applications. Data at a specific location is often influenced by data in the neighborhood. The spatial analysis and mining features in Oracle Spatial let users exploit such spatial correlation in the following ways:

- binning data into regions – determine if southeastern US customers in a certain age or income category are more likely to prefer regular or diet soda
- materializing spatial correlation (neighborhood influence) – in assessing the value of a house, examine the values of similar houses in a neighborhood
- colocation mining – determine if colocation of a pizza restaurant franchise with a video store results in higher sales
- spatial clustering – determine regions where crime rates are high, to decide where to deploy additional police
- location prospecting – identify the best locations for opening new hospitals based on the population of patients who live in each neighborhood

For more information about spatial analytic functions, please refer to a separate white paper at oracle.com/technology/products/spatial.

Geocoder

Geocoding is the process of associating geographic references, such as addresses and postal codes, with location coordinates (longitude and latitude). With Oracle Spatial, a fully functional geocoding engine is provided. It provides international address standardization, geocoding POI matching by querying geocoded data stored in Oracle Database, reverse geocoding, batch geocoding, and other geocoding subprograms. Its unique unparsed address support adds great flexibility and convenience to customer applications. SQL, Java, and XML APIs for geocoding are provided, and it can be deployed either at the middle tier (Oracle Fusion Middleware) or at the database server tier.

Sample data is available online. Data sets in the format supporting Oracle Spatial 11*g* are also available from leading data providers. For more information, please visit www.oracle.com/technology/products/spatial , and navigate to Resources – Partner Data. Or visit www.oracle.com/technetwork/database/options/spatial/spatial-partners-data-087203.html.

In addition to support for standard address geocoding based on interpolation, the Oracle Spatial 11*g* Release 2 geocoder now supports point-based geocoding where data sets include the exact location of addresses, intersections, and points of interest. Point-based geocoding is becoming increasingly popular because it allows for more accurate results and can be used in situations where interpolation is not possible.

For more information about the Oracle Spatial geocoder, please refer to a separate paper at: oracle.com/technology/products/spatial.

Routing Engine

A scalable routing engine provides driving distances, times, and directions between addresses (or locations that have been geocoded in advance). It is provided as a Java client library that can be easily deployed in J2EE servlet containers. 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. It also provides driving distances, times, and directions between addresses for over a dozen Western European countries, including Germany, United Kingdom, France, and more, to support logistics, transportation, and location-based services applications.

Sample data is available online. Data sets in the format supporting Oracle Spatial 11*g* are also available from leading data providers. For more information, please visit www.oracle.com/technology/products/spatial , and navigate to Resources – Partner Data. Or visit www.oracle.com/technetwork/database/options/spatial/spatial-partners-data-087203.html.

With Oracle Spatial 11*g* Release 1, the routing engine provides driving directions in Western European languages including German, French, Spanish, and Italian. Generation of turn-specific geometries is supported, which helps with location services applications that require turn-specific point of interest data. Computed routes can be returned as a set of edges that can be used for further analysis.

With Oracle Spatial 11*g* Release 2, the routing engine is based on the Oracle Spatial Network Data Model, which enables support for restrictions and conditions required for advanced routing applications. For example, Oracle Spatial now supports truck routing data sets to produce driving directions that include restrictions based on roads, weight, height, time of day, and other conditions applied to commercial and logistics applications.

Semantic Database Management

Oracle Spatial 11*g* includes advanced semantic data management capability, with native support for RDF/RDFS/OWL/SKOS standards from the World Wide Web Consortium. Based on a graph data model, RDF triples are persisted, indexed and queried, similar to other object-

relational data types. This semantic data store enables application developers to benefit from an open, scalable, secure, integrated, efficient platform for RDF and OWL-based applications. Semantic technologies are designed to extend the capabilities of information on the Web and enterprise systems to be networked in meaningful ways, with application areas such as life sciences, defense and intelligence, enterprise application integration, and CRM/ERP.

For more information about semantic data management capabilities, please refer to separate white papers at oracle.com/technology/tech/semantic_technologies.

Enterprise Features Supporting Spatial in Oracle Database 11*g*

Oracle Database 11*g* provides powerful, reliable support for an organization's mission-critical applications. These enterprise features enrich Oracle's spatial capabilities via a flexible Internet deployment architecture, object capabilities, and robust data management utilities that ensure data integrity, data recovery, and data security. This level of support can only exist in the homogenous environment of an enterprise database solution, and cannot be effectively replicated in a hybrid solution that marries an external location-based solution with a traditional enterprise solution, no matter how tightly integrated the two components may appear.

Oracle Spatial takes full advantage of expanded database size limits, high-performance VLDB maintenance utilities, replication, workspace manager (versioning), faster backup and recovery, and partitioning. Only users of Oracle's native spatial datatype can take full advantage of features such as partitioning, replication, parallel index builds and queries, and spatially-driven multi-level security. The full range of Oracle utilities (e.g. SQL*Loader) are also available to ease migration and help upgrade applications that use the spatial features. Some of these key enterprise features are described below.

Partitioning Support for Spatial Indexes

Oracle's database architecture includes partitioning, in which a single logical table and its indexes are broken up into one or more physical tables, each with its own index. Spatial indexes associated with partitioned tables can be partitioned; range partitioning is the partitioning scheme supported for spatial indexes.

Partitioning offers significant performance, scalability, and manageability benefits, including the following:

- Reduced response times for long-running queries; partitioning can reduce disk I/O operations.
- Reduced response times for concurrent queries; I/O operations run concurrently on each partition.
- Easier index maintenance, because of partition-level create and rebuild operations.
- Ability to rebuild indexes on partitions without affecting the queries on other partitions.

- Ability to change storage parameters for each local index independent of other partitions.
- Partitions can also be split, merged, and exchanged.

Parallel Spatial Index Creation

Spatial indexes and index partitions can be created in parallel. R-tree index creation can be subdivided into smaller tasks that can be performed in parallel, making use of unused hardware (CPU) resources. For certain spatial data sets and index types and parameters, parallel index creation can substantially increase index build performance and provide a significant time savings. Large non-point datasets (commonly used in many standard GIS applications) can show dramatic performance improvements.

Parallel Spatial Queries

Spatial queries can run in parallel on partitioned spatial indexes, improving the performance of "within distance", "nearest neighbor", and "relate" queries. Performance scales with the number of CPUs used to execute a query. This helps location service and land management applications, which need to execute high volumes of spatial queries quickly.

Replication

Oracle's Advanced Replication capabilities can be used for location data. For example, distributed systems that involve geographically dispersed yet logically replicated web sites, can take advantage of synchronized replication of spatial data objects across multiple databases.

Note: Advanced Replication multimaster configuration is offered with the Enterprise Edition database only. Refer to the *Oracle Database Advanced Replication* manual for more information about Advanced Replication features.

Database Workspaces

Oracle Workspace Manager, a feature of Oracle Database, provides a virtual environment (workspaces) that allows current, proposed and historical values for data to be managed in the same database. Workspaces can be shared and used to: isolate a collection of changes to production data until they are approved and merged into production; keep a long term history of changes to data; and create multiple data scenarios based on a common data set for "what if" analysis.

Open Standards

Oracle consistently works to help shape, drive, implement and support the latest open standards in the spatial and location services areas. Oracle is a founding, Principal Member of the Open

Geospatial Consortium (OGC) and participates actively on the Technical Committee. Oracle is also committed to supporting the new OGC Geographic Markup Language (GML) as well as Open Location Service interfaces. The object-relational model used for geometry storage by Oracle Spatial also conforms to the specifications associated with SQL92 representation of points, lines, and polygons.

Oracle Spatial 11*g* Release 1 (11.1.0.7) complies with the OpenGIS Simple Features Specification for SQL, Revision 1.1, Types and Functions Alternative. Oracle Spatial supports the SQL/MM types and operators, as specified in *ISO 13249-3, Information technology - Database languages - SQL Multimedia and Application Packages - Part 3: Spatial*. Oracle Spatial operators corresponding to those defined in this standard, as well as the SDO_NN and SDO_WITHIN_DISTANCE operators, can be used on data stored in the SQL Multimedia root type.

Standards compliance testing for Oracle Spatial is ongoing, and compliance with more recent versions of standards or with new standards might be announced at any time. For current information about compliance with standards, see www.oracle.com/technology/products/spatial.

Support from Leading Geospatial and Location Services Vendors

Oracle Spatial is directly integrated with the leading geospatial and location services technology vendors worldwide. The breadth of partner support provides developers with their choice of best of breed tools to meet their requirements.

Support from leading systems integrators, both from the geospatial and enterprise IT domains, provides customers with choices for fast deployment of customized solutions to meet their specific requirements.

With Oracle Spatial 11*g* and partner tools, developers can rapidly deploy scalable, secure enterprise geospatial and location service solutions.

A list of partners is available at oracle.com/technology/products/spatial.

Conclusion

Oracle Spatial provides advanced spatial capabilities for Oracle Database 11*g*, addressing the business-critical needs of customers in traditional geospatial domains such as defense, homeland security, land management, transportation, as well as a broad range of domains from finance and retail to life sciences. In repeated studies, IDC has found that Oracle is the most widely used enterprise spatial database server, used in 80-90% of medium-sized and large enterprise spatial information systems.[3] Customers and partners rely on Oracle to deliver performance, scalability, security, and ease of use for their spatial applications. Oracle Spatial is supported by all the leading geospatial and location services vendors and systems integrators.

Oracle Spatial with Oracle Database Enterprise Edition is the solution for users who have geospatial applications requiring advanced server-side spatial analysis and processing. Oracle Spatial 11*g* introduced the world's first native support for 3-dimensional data in a database management system. Oracle Spatial supports storage and management of urban models, point clouds, and terrain models found in domains such as urban planning, homeland security, or LIDAR-based map production. Oracle Spatial 11*g* is also a geospatially-enabled web services platform, supporting major XML-based standards from OGC.

Oracle Spatial supports all data types found in geospatial and location-enabled business applications. An open GeoRaster format supports the image storage and management requirements from the public sector, defense, and energy exploration domains. Network and topology data models meet the needs of applications in transportation, utilities, land management, life sciences, and location services. A server-side geocoder and routing engine support the deployment of location-based services, and spatial analysis functions enhance business applications. With Oracle Spatial 11*g*, users can manage larger datasets with better performance than ever before, with less complexity. Oracle Spatial 11*g* Release 2 introduces enhancements that support more completely a wider range of customer requirements, simplify application development, and boost performance.

With every release since its introduction over ten years ago, Oracle Spatial has added advanced spatial data management capabilities to relational database management systems. Oracle Spatial 11*g* continues this mission. With the unmatched enterprise data management capabilities of Oracle Database 11*g*, it continues to be the world's leading database management platform for geospatial and enterprise spatial systems.

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3 IDC, *Worldwide Spatial Information Management Software 2008-2012 Forecast and 2007 Vendor Shares, Sonnen and Vesset, September 2008*

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