19c ORACLE Database

Spatial Analytics with Oracle Database 19c

Technical Feature Overview

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INTRODUCTION

Oracle provides the industry's leading spatial database management platform. Oracle Database includes advanced features for management and analysis of spatial data.

Oracle's mission is to help people see data in new ways, discover insights, and unlock endless possibilities. Spatial analysis is about understanding complex interactions based on geographic relationships – answering questions based on where people, assets, and resources are located. Spatial insights enable you to provide better customer service, optimize your workforce, locate retail and distribution centers, evaluate sales and marketing campaigns, and more.

The geospatial data features are designed to support the most complex requirements found in Geographic Information Systems (GIS), enterprise applications, and location-enabled business and web applications. These features include native support for geocoding, a routing engine, and spatial web services conformant with Open Geospatial Consortium (OGC) and ISO standards. Support for advanced spatial models and types include a network data model, georaster (for geo-referenced imagery and gridded data), topology, 3D, including triangulated irregular networks (TINs) and point clouds (supporting LIDAR data), and linear referencing. These features provide a complete platform for geospatial applications in many domains, including defense, land management retail, insurance, and finance.

With Oracle Database 19c, spatial operations are faster, cloud-ready and more developer friendly. With GeoJSON support, a location tracking service to track millions of objects against thousands of regions, more accelerated spatial functions, and an interactive map visualization component, it is the most advanced spatial platform Oracle has ever offered.

The new Spatial Studio web application is a self-service, visual, no-code tool that makes it easy for analysts to perform mapping and spatial analysis. New spatial features include spatial support for distributed and Oracle XA transactions for cloud applications with distributed architectures; expanded spatial JSON support; Oracle REST Data Services support for spatial operations in Oracle Database for modern RESTful development; support for sharded databases with spatial data types; expanded spatial web services features for scalability and usability for WFS, CSW, and WCS; performance enhancements for operations on spatial point data; server side raster loading tool and more image processing and analytics functions.

Oracle's spatial capabilities are part of the database kernel, and geospatial deployments natively harness Oracle Database features for scalability, security, partitioning, and parallelism. They reduce application logic and support real world analysis by moving complex spatial logic into the database. The processing power and bandwidth of Oracle Exadata Database Machine is exploited, realizing extreme performance capabilities that are orders of magnitude over what was previously possible.

This white paper provides an overview of the spatial features in Oracle Database. The appendices list major and new features.

Oracle's spatial features are completely integrated with the performance, scalability, and security of Oracle Database, making it the most advanced spatial database platform available for enterprise class deployments, in the Cloud and on premises.

SPATIAL FEATURES OVERVIEW

Vector Performance Acceleration

Vectors are 2-dimensional and 3-dimensional sets of vertices, for instance latitude, longitude and height that describe geometries, such as points, lines, polygons, surfaces and solids. Geometries often represent real world objects. Vector operations evaluate spatial relationships between geometries, including within-distance, nearest-neighbor, and geometry interactions, such as touch, overlaps, contains, covers, distance, and buffer zone generation around geometries.

Vector acceleration capabilities substantially improve the performance of vector operations. Vector acceleration provides enhanced computational algorithms along with CPU and memory enhancements that improve the performance of spatial index creation, geometric computations in functions and spatial operator secondary filter operations.

Spatial features support a broad range of applications

Vector Geometry Functions

Oracle Database provides over 400 functions to perform calculations on geometries, such as area of a polygon, length or perimeter. These functions are 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 generate new geometries such as buffers, unions, intersections, and much 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.

Other functions 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

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

Projections and Coordinate Systems

Oracle provides comprehensive tools for managing coordinate systems and projections to represent and integrate spatial information effectively and accurately. Over 4000 commonly used mapping coordinate systems are supported; users can also define new coordinate systems. Support for implicitly and explicitly transforming data between different coordinate systems is also provided – 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 supports 3D coordinate systems, which include height or a "z" coordinate, in addition to longitude and latitude or projected x, y coordinates as appropriate; reprojection of rasters is also supported.

Spatial Aggregates

SQL has long had aggregate functions, which are used to aggregate the results of a SQL query. Oracle's spatial aggregate functions perform a specified aggregate operation on a set of input geometries, and return 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.

Linear Referencing Support

Attributes and events can be stored and associated with a specified segment on a linear geometry. Attributes and 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. Oracle's Linear Referencing System functions support 3D geodetic data.

White papers address a variety of industry and business topics,

3D Data Type Support

Oracle Database 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 3D datasets such as urban models, point clouds, and terrain models can be stored and managed in the open Oracle 3D 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-engineering, medical applications, business intelligence (for example, real estate and advertising), and LIDAR-based map production.

A modeling, visualization and simulation infrastructure for 3D data is provided. 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.

Rich 3D and Point Cloud analysis and visualization. 3D parametric (freeform) curves are supported. The Java API in-memory functions support 3D projected and geodetic geometry types. The distance between two 3D points approximates and accounts for the height of those points in the calculation. 3D visualization and analytical tools can take advantage of metadata views for 3D themes, scenes, and view frames. Pyramiding is supported for Point clouds and TINS to support visualization at different levels of granularity. Contour lines can be generated from point clouds. 2D points can be projected onto a TIN to determine point heights. Linear Referencing System functions support 3D geodetic data.

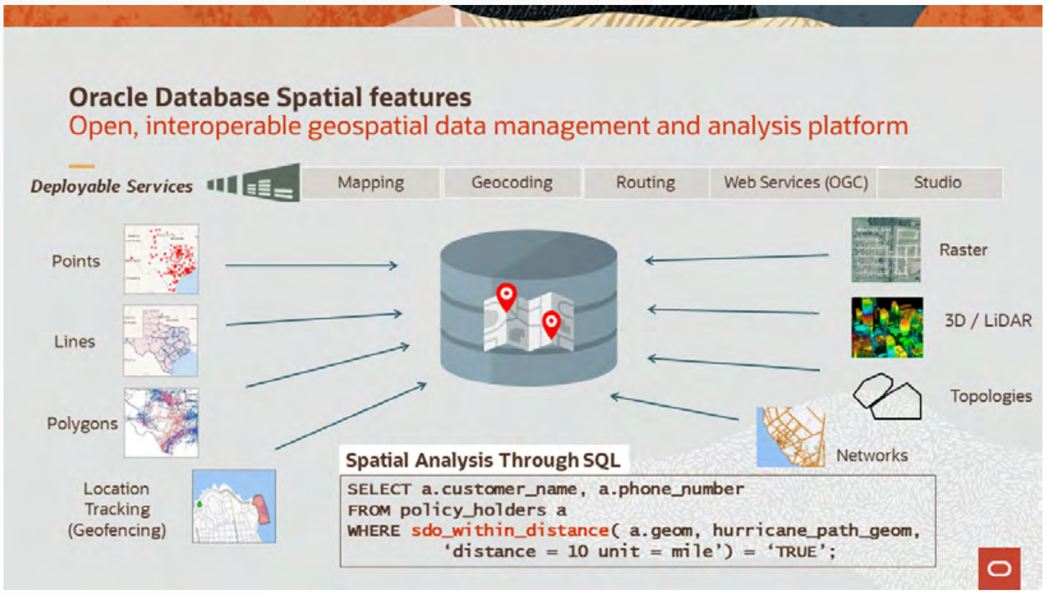
Parametric Curve Support

2-dimension and 3-dimension parametric curves, also called non-uniform rational B-splines (NURBs), are supported. The Oracle Database spatial type, SDO_GEOMETRY, now supports mathematically precise representation of freeform curves that can be reproduced exactly. NURBs are used to simplify the design and modeling of roads, highways, and rail.

Topology Data Model

A data model and schema 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. Topology-based queries typically perform faster than the alternative for 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 topology data model using Workspace Manager, a feature of Oracle Database. Feature level spatial transactions against a 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 simplify application logic.



Spatial data types and models in Oracle Database

GeoRaster Support

Geometries can be represented by vectors or rasters, or both. Image processing systems typically refer to raster data as images, for instance in satellite imagery and airborne photographs. Raster data used in GIS is normally called gridded data. Oracle's GeoRaster type can store, index, query, analyze, and deliver raster image and gridded data and its associated metadata.

GeoRaster stores multidimensional grid layers and digital images that can be referenced to positions on the Earth's surface or to a local coordinate system. What differentiates GeoRaster is the ability to perform raster analysis on extremely large images and data sets, provide in-place image processing and analysis with no development required, and provide parallelized image processing with simple invocation of PL/SQL procedures.

GeoRaster is used with data from any technology that captures or generates raster data and images, such as remote sensing, photogrammetry, and geospatial thematic mapping. It is used in a wide variety of application areas, including environmental monitoring and assessment, geological engineering and exploration, natural resource management, defense, emergency response, telecommunications, transportation, urban planning, and homeland security.

GeoRaster is designed to deliver enterprise-class data management capability to large image processing and GIS solutions and business applications. Developers can integrate this powerful data management technology with the leading image processing and raster/grid analysis tools and various business applications.

Native Support for Raster File Formats, Compression, Core Operations

GeoRaster loading and native storage is flexible, cost-effective and performant. The file formats GeoTiff, JPEG 2000, and Digital Globe RPC are supported for loading and exporting GeoRaster objects. GeoRaster associates location with the geometries in a raster by assigning location values to a matrix of cells that cover the raster and storing the cells as an array. Native JPEG 2000 compression provides high compression ratios and image quality. JPEG files can be loaded without decompression. Oracle SecureFiles provides transparent lossless compression. Alternatively, GeoRaster-specific industry standard image compression techniques, including JPEG baseline (lossy) and DEFLATE (lossless) can be used and an open plug-in architecture allows additional third party compression techniques. Automatic blocking size optimization chooses a block size for georasters that minimizes storage while optimizing retrieval and processing. GeoRaster supports raster image and raster data at differing sizes and degrees of resolution through pyramiding, and very large images with tiling. Three types of interleaving are supported to optimize access to the data in the raster.

GeoRaster supports relational raster data tables (RDTs) to allow users to specify default alpha channel and pyramid level in its metadata. It includes a resampling algorithm that supports resolution unit specification and parallel processing in many operations, and adds additional loading and exporting capabilities.

Raster Algebra and Analytics

GeoRaster supports raster algebra operations that work on individual raster cells, or pixels to generate new maps from two or more raster layers. Raster algebra operations enable applications to implement sophisticated analytical algorithms, such as a Normalized Difference Vegetation Index (NDVI), and Tasseled Cap Transformation (TCT). Raster operation performance is also substantially faster and can be parallelized to scale up to 100s of times faster for large data sets. Statistical analysis functions can dynamically compute complete statistical values for a GeoRaster object or individual statistical values. Image classification, time series analysis, and raster GIS modeling are supported with the capability to merge multiple bands or layers of different GeoRaster objects into a single GeoRaster object.

Fast, Sophisticated Image Processing

GeoRaster provides advanced image processing and serving capabilities. These include Ground Control Point georeferencing, reprojection (to over 4000 supported coordinate systems), rectification, orthorectification, image scaling, stretching, masking, filtering, image segmentation, NDVI computation, Tasseled Cap

Transformation, image appending, bands merging, large-scale advanced image mosaicking, and virtual mosaic. The operations described here are most commonly used to process and serving geospatial images, particularly raw satellite imagery and airborne photographs.

More image processing can be handled in the server instead of the client, and some processing is parallelized. This enables improved performance of image processing on a much larger scale, with larger data sets, which are increasingly being used in government and commercial applications as more raster data becomes available. Customizable memory control further improves performance.

GeoRaster uses industry standard resampling and interpolation methods for image and raster transformations and operations. Transformations between 2D or 3D ground coordinates and 2D cell coordinates, and vice-versa are supported. Non-rectified images (not geometrically corrected for uniform scale) can be georeferenced with GeoRaster’s flexible functional fitting polynomial georeferencing model. Irregular polygon-based clipping in queries returns a precise subset of a GeoRaster object. Grid point interpolations infer values at spatial positions between or within cells. Irregularly shaped regions inside an image can be defined with bitmap masks.

Easy and Manageable Administration

GeoRaster provides ease of development, ease of use, and manageability. GeoRaster DML triggers are created and monitored by the system automatically. Users can monitor resource-intensive operations on GeoRaster system data. Partial raster updates are supported. GeoRaster templates are supported to develop GeoRaster applications, such as extraction, transformation, and loading (ETL) tools and image processing systems that work with GeoRaster objects. Raster data versioning with the Workspace Manager feature of Oracle Database, and raster data row-level security with Oracle Label Security are supported.

Java API

A Java API supports query, manipulation, and raster management. It also supports the development of ETL tools, Web applications, and raster processing applications – simplifying the development of Java applications that use, access, and manipulate raster and gridded data sets stored in Oracle Database. It supports features such as ground control point (GCP) storage and manipulation, GCP georeferencing, reprojection, grid interpolations, and getCellValue. The Java API supports all server-side functions and procedures and includes a Virtual Mosaic API.

Loading and Exporting Raster Data

The GeoRaster data type is supported by all leading third party GIS and image processing tool vendors. Geospatial Data Abstraction Layer (GDAL), the leading open source geospatial ETL tool and API available for raster data also supports it. GDAL natively supports importing and exporting over 50 raster formats to and from SDO_GEORASTER. 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.

GeoRaster includes an ETL wizard tool to automate and enable concurrent batch loading and exporting of various image and raster files using GDAL. The tool can load and export large numbers of raster and image files in batches, and do so concurrently. This tool supports all raster formats supported by GDAL.

Spatial Analytic Functions

Oracle supports spatial analysis and mining in Oracle Data Mining (ODM), a component of Oracle Advanced Analytics. ODM allows automatic discovery of knowledge from a database, such as discovering hidden associations between various 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 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) – examine the values of similar houses in a neighborhood when assessing the value of a house
- colocation mining – determine if locating a pizza restaurant franchise with a video store results in higher sales
- spatial clustering – determine the regions where crime rates are high, 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

Geocoding

Geocoding is the process of associating geographic references, such as addresses and postal codes, with location coordinates (longitude and latitude). Oracle's spatial features include full geocoding capabilities in Oracle Database. It provides international address standardization, geocoding points of interest (POI) and matching them to geocoded data stored in Oracle Database, reverse geocoding, batch geocoding, and other geocoding capabilities. 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's spatial data type are also available from leading data providers. For more information, please visit the Oracle Spatial and Graph website on oracle.com and navigate to the Partners link.

The geocoding feature supports standard address geocoding based on interpolation and 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.

The geocoding feature includes point address geocoding support for countries that don't have address ranges and language support for countries that have addresses in multiple languages. Reverse geocoding can be performed without specifying a country code.

Routing Engine

A routing engine provides driving distances, times, and directions between addresses or between locations that have been geocoded in advance. The routing engine is provided as a Java client library that can be easily deployed in JEE servlet containers. It supports preference for either fastest or shortest routes, and provides summary and detailed driving directions, and the time and distance along a street network from a 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, and France to support logistics, transportation, and location-based services applications.

Sample data is available online. Data sets in the format supporting Oracle's spatial type are also available from leading data providers. For more information, please visit the Oracle Spatial and Graph page on oracle.com and navigate to the Partners tab.

The routing engine provides driving directions in Western European languages, including German, French, Spanish, and Italian. Turn-specific geometries can be generated for location services applications that require turn-specific point of interest data.   Computed routes can be returned as a set of relationships between points that can be used for further analysis.

The routing engine supports restrictions and conditions that are required for advanced routing applications, such as truck-specific routing. It can provide truck-specific routing based on roads, weight, height, time of day, and other conditions applied to commercial and logistics applications and logical turn restrictions. It can compute the drive times based on truck speed limits, which often differ from car speed limits. It can also provide information on truck services, such as weigh stations and truck stops along a route. Finally, it can handle logical turn restrictions involving more than two way points in the route geometry. These enhancements yield more accurate results for logistics and truck routing applications.

A routing engine servlet supports lightweight location-based queries related to speed limit and traffic speed.

Spatial Web Services

A web services platform enables users to access, incorporate, publish, and deploy geospatial services, including services for geocoding, routing, mapping, business directory, catalog, and geospatial feature transactions. Oracle's spatial features are tightly integrated with Oracle Database and Oracle Fusion Middleware to provide a transactional service-oriented architecture platform with enterprise-class security. They provide security, including authorization, authentication, and transport confidentiality and integrity.

Oracle has supported the Open Geospatial Consortium (OGC) and ISO TC211 standards for many releases. It supports these XML-based geospatial web services standards: OGC OpenLS 1.1, Web Feature Service – Transactional (WFS-T) 1.0, Web Feature Service 1.1.0, Catalog Service for the Web (CSW) 2.0.2, and Web Coverage Service (WCS) 2.0.1 on a variety of client technologies and platforms.

Web Feature Services (WFS) enable query and retrieval of geographic feature information in vector format, encoded in GML. Oracle includes full support for database transactions on WFS-T feature tables through SQL without restriction. It also supports Workspace Manager versioning and WFS feature tables. Java and PL/SQL client APIs are provided.

Catalog Services (CSW) are used to locate, manage, and maintain distributed geospatial data applications, and services. Web Coverage Service (WCS) support enables retrieval of coverages, or raster data such as satellite imagery or DEMs.

Oracle provides a unified framework and Web-based administrative console for WFS, WCS, and CSW, for easy deployment, administration, and diagnosing. This menu-driven user interface simplifies registration of spatial layers. It allows users to browse existing spatial layers, eliminating the need for a DBA to run PL/SQL scripts to publish spatial layers. It includes a tutorial on configuring and using WFS, and includes a sample request and response page for WFS queries. The user interface can also be used as a client to other WFS servers.

WFS, WCS, and CSW can support reading and publishing data from multiple data sources in the same WebLogic Server instance, making it easy to scale web services applications. The administration console user interface allows users to manage multiple data sources for WFS, WCS, and CSW.

A new metadata application profile defined by ISO for OGC CSW 2.0.2 is now supported. This enables easy exchange of spatial data and metadata among applications and organizations. Oracle’s CSW services can interoperate with other services and query languages that also implement the ISO profile.

XML full text indexes can be created on metadata profile data, enabling XQuery full text queries that search on XML documents efficiently by combining text and structured search. This improves CSW query performance significantly.

Network Data Model Features Overview

Network Data Model (NDM) stores physical and logical network data structures commonly used in transportation, utilities, and oil and gas. It explicitly stores and maintains network connectivity and provides network analysis capability, including shortest path, nearest neighbors, within cost, and reachability.

NDM has a PL/SQL API for managing network data in the database, and a Java API for performing network analysis and creating and applying network constraints.

NDM users can benefit from the speed of in-memory analytics with networks that are larger than available memory. NDM supports partitioning large networks into manageable sub-networks and can automatically load network partitions into memory as needed for efficient in-memory analysis.   Partitioning utilities are also available.

NDM is integrated with the Oracle geocoding and routing engine; applications using these features can perform analysis using NDM functions. NDM supports commercial street network data from Nokia (Navteq), in Oracle Delivery Format (ODF).

NDM includes a number of modeling and analysis features that meet the requirements for utility networks, logistics, transportation, and other network-based applications.

MODELING FEATURES

- Model and represent any point along a link for all analysis functions, such as specific addresses in street networks with any number of properties on the nodes and links.
- Model partial-link paths (subpaths).
- Customize link and node properties: e.g., costs.
- Perform path analysis with multiple link and node properties (e.g., distance/time/hops costs).
- Perform partitioning of logical networks, for example social and biochemical pathway networks, based on metrics appropriate to the application.

NETWORK ANALYSIS FEATURES

- 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 and drive-distance polygons.
- Generate the shortest path on a hierarchical network, where links are prioritized by property (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.

NDM includes an example with JSP and Java files for application developers to quickly and easily deploy routing and other network analysis using data stored in NDM. Users can visualize analysis results in a web browser. The example works with Nokia ODF network data, and uses the NDM load on demand API, Oracle Fusion Middleware MapViewer, and the Oracle geocoding engine. Download the example from the Oracle Technology Network at oracle.com/technetwork/database/options/spatialandgraph/spatial.

NDM feature and time modeling enhancements simplify application development and support real-world analysis by moving complex spatial logic into the database.

Feature Modeling, Analysis, and Editing

NDM simplifies feature editing and analysis by providing a feature analysis function that associates feature representations with network elements. Feature modeling bridges the gap between concrete objects of interest in real world and abstract network elements.

Feature modeling simplifies application development by associating real world objects with network elements. For example, if a utility network application needs to find affected households when a substation experiences a power failure, it is necessary to associate the application features (substations, power lines and transformers) with network elements (links and nodes). Feature modeling maintains these relationships through feature metadata, simplifying application development and maintenance.

Network feature editing (NFE) lets you create and manage an NFE model. An NFE model extends the feature modeling capabilities by enabling you to visualize and manipulate features using Java Swing components and a PL/SQL API. You can also define features on the top of an existing network.

Network Modeling with Time; Multimodal Transportation Routing

NDM adds support for modeling networks having a time dimension. Users may associate time properties with nodes and links, and specify temporal inputs in network analysis queries.

Most real-world networks have a time element. Travel times on road segments vary with the time of day. Utility networks experience different demand loads based on seasonal demand and the time of day. Analytic and planning applications can benefit from more accurate representation of real-world conditions. NDM supports queries such as finding the fastest travel route for a specified time of day. NDM supports modeling and analysis of multimodal transportation networks, and computing the fastest paths on multimodal transportation networks.For more information about Network Data Model, please refer to the white paper on the Oracle Spatial and Graph page on oracle.com.

GeoJSON Support

Oracle supports the use of GeoJSON objects to store, index, and manage geographic data that is in JSON (JavaScript Object Notation) format, directly in Oracle Database. GeoJSON is an open standard format designed for representing simple geographical features, with their non-spatial attributes. It is based on JSON, a lightweight data interchange format that has become a standard for reading and publishing data in web, Big Data, and Internet of Things environments.

You can convert data from GeoJSON objects to Oracle spatial SDO_GEOMETRY objects, and from SDO_GEOMETRY objects to GeoJSON objects. You can use spatial operators, functions, and a special SDO_GEOMETRY method to work with GeoJSON data. If the application requires a JSON data store, GeoJSON data can be embedded into that JSON store; these JSON documents can then be spatially indexed and used in spatial queries. The GeoJSON features leverage capabilities in Oracle Database to store, manage, and index JSON documents. Developers can access JSON through REST services or other APIs, and use SQL to query JSON documents, providing flexible application development and powerful SQL analytics for modern development environments.

JSON supports a larger range of geometry types and coordinate systems beyond those included in the GeoJSON standard, including 2D and 3D, solid, surface, and LRS geometries. You can convert these additional geometry types between JSON and SDO_GEOMETRY formats.

Oracle REST Data Services (ORDS), a Java application that allows developers to easily create RESTful services with Oracle Database, now supports spatial operations.

Location Data Enrichment

Oracle includes a place name data set, with hierarchical geographical data from HERE, that you can load into the database and search using the new SDO_UTIL.GEO_SEARCH function. The data set includes commonly used textual location data such as place names, addresses and partial addresses, and latitude and longitude information.

Location tags are extracted from customer text data, matched with well known place names using Oracle Text, and enhanced with other geographic information associated with the well known place names. The results can be stored as additional attributes with the original data. This feature enables you to process less structured geographic and location data so that the information can be categorized, compared, filtered, and associated with other data. For example, data with only partial names can be enriched to include city, county, state, and country, allowing it to be joined or analyzed with other data sets that may have state level information. This is especially useful when comparing Big Data results with structured information in operational systems and data warehouses.

Spatial Index Improvements

Spatial indexes support all partitioning methods, including list, interval, and hash partitioning; previously, this was restricted to range partitioning. This enables improved performance.

Additionally, Spatial indexes can be system-managed. The main benefit is simplified spatial index management. This is most beneficial in cases of partitioning, because this new index type eliminates the need for most, if not all, index partitioning management operations. Full support is provided for almost all Oracle Database base table partitioning models. Customers are strongly encouraged to use this index type for all new spatial indexes created, regardless of whether the spatial table or the spatial index is partitioned.

Index Type Optimized for Point Data

Point only data sets commonly used for location services, such as moving objects, point of interest, and yellow page data, can be massive, and applications often require fast update and query performance. Performance using R-tree indexes can be challenging when large numbers of concurrent DMLs are performed on spatial tables.

An alternative index type, the composite B-tree index, can significantly improve the performance of spatial index creation and DML operations for large volumes of updates for point only data sets, with 20 – 30 times faster index creation, and 10 times faster updates. Performance for DML operations and queries using composite B-tree indexes is 3 – 4 times faster compared to the 12.2 release.

Map Visualization of Geographic Data

The spatial visualization feature is an HTML5-based mash up component that allows developers who are familiar with SQL and JavaScript to incorporate a wide variety of map styles and spatial analysis into business applications. Its mapping engine visualizes data in Oracle Database, and allows developers to combine this data with external web services such as WMS, WFS, GeoRSS streams, and WMTS. Developers can define their own third party map tile layer using a plug-in interface, and there is support for third party GeoJSON files. Dynamic tile layers enable large data sets to be visualized in an interactive manner, with the ability to explore individual features if needed.

These capabilities are also available to users of the spatial features of Oracle Database. The map visualization feature must be deployed in a JEE container or in Oracle Java Cloud Service.

Location Tracking Server

A location tracking server enables you to define regions of interest, track the movement of objects into or out of those regions, and receive notifications when certain movements occur. As location becomes an increasingly important aspect of our lives, and as location-sensing devices become ubiquitous, there is an increasing demand for applications to be able to monitor subscriber location data continuously. The monitoring of the location data may translate into alerts being generated in the system.

For example, a trucking company may want to monitor its network of 10,000 trucks as they move along their specified routes towards their destinations. They may want to track the movement of trucks within a specified range of the route and expect notifications to be generated to detect undesirable deviations the vehicles from their desired routes. Proactive location-based services (LBSs) generalize such applications that track locations of subscribers inside or outside a specified region of interest for various purposes, such as location-based advertising and notifications about friends nearby.

The location tracking server provides a simple framework for setting up a location tracking network within the database through a PL/SQL interface.   An API is provided for continuous location monitoring of objects within a tracking network. A queuing mechanism handles incoming location updates and tracking requests and for outgoing relevant notifications, using Oracle Advanced Queuing. This delivers efficient, continuous location monitoring for thousands of relevant objects within the database.

ORACLE EXADATA DATABASE MACHINE

Engineered systems provide high performance, high bandwidth, and massive parallelism with enormous capacity to address the challenges faced by high volume workloads. Combining advanced spatial analysis with Oracle Exadata Database Machine performance and scalability delivers an ideal platform for the most demanding applications.

Oracle's spatial features fully use the balanced hardware and highly parallelized architecture of Oracle Exadata. It can achieve performance results over 150x faster than other spatial database machines and solutions. Real customer scenarios, test results, and strategies have maximized performance for massive spatial and graph computations and data ingest.

Oracle's spatial features are engineered to natively leverage the parallelism, partitioning, indexing and the scalability features of Oracle Exadata without application changes. The fully-parallelized joins and aggregations of Oracle Exadata coupled with the extreme I/O bandwidth and high performance of Exadata Storage server provide the processing power needed for server-based geo-processing applications. OLTP index compression improves query performance by compressing and increasing memory residence for spatial indexes. Exadata Hybrid Columnar Compression increases memory residence for large spatial data sets as well as the rule sets used in inferencing.

For more information, including customer scenarios, test results, and strategies with Oracle Exadata and Oracle Database spatial features, please refer to the Oracle Spatial and Graph page on oracle.com.

ENTERPRISE FEATURES SUPPORTED IN ORACLE DATABASE

Oracle Database 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's spatial features take full advantage of expanded database size limits, high-performance VLDB maintenance, utilities, replication, versioning of geospatial data (Workspace Manager), faster backup and recovery, and partitioning. Only users of the native geospatial data type in Oracle Database can take full advantage of features such as partitioning, replication, parallel spatial index builds and queries, and geospatial-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

The Oracle 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. Spatial indexes support list, interval, and hash partitioning.

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 that can be split, merged, and exchanged.

Parallel Index Creation

Spatial indexes and index partitions can be created in parallel. Geospatial R-tree index B-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 Load, Query and Inference

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 GoldenGate can replicate data in the native geospatial data types. It supports SDO_GEOMETRY, SDO_GEORASTER, SDO_TOPO_GEOMETRY. Distributed systems that involve geographically dispersed yet logically replicated web sites, can take advantage of synchronized replication of spatial data objects across multiple databases.

Database Workspaces and Long Transactions

Workspace Manager, a feature of Oracle Database, provides a virtual environment (workspaces) that allows current, proposed and historical spatial data values 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. Workspace Manager is supported by most GIS vendors.

Sharded Database Support

Database tables with Oracle Spatial SDO_GEOMETRY columns and spatial indexes, operators, and functions can be used with Oracle Sharding. Spatial tables can be sharded across different databases, and spatial indexes can be created on sharded tables, so that spatial queries get routed to the correct shard.

This allows customers who desire the horizontal scalability and geographic distribution of data enabled with Oracle Sharding to include spatial data types. Applications that run on a sharded database architecture can achieve linear scalability, extreme data availability and geographic data distribution. Sharding is an architectural pattern popularized by Internet and online companies that need very high scalability and absolute availability.

Spatial Support for Distributed Transactions

In a distributed database, portions of the database are stored in multiple physical locations. Distributed transactions update data among multiple database nodes. The use of spatial R-tree indexes is now supported in distributed and Oracle XA transactions, which will be useful for several cloud-based applications that use distributed web architectures.

Oracle REST Data Services Support for Spatial Operations

REST is today's dominant software architectural style for creating modern, scalable web services for cloud environments. Oracle REST Data Services (ORDS) is a middle tier Java application that allows developers to easily access data in Oracle Database through REST, and turn them into RESTful services. ORDS maps HTTP uniform resource identifiers to a query or object in Oracle Database, runs the appropriate SQL, and returns output as JSON. ORDS supports Oracle Spatial types and operations, so using REST, SQL queries can be issued on SDO_GEOMETRY data, which is automatically converted to JSON.

ORDS is included with both Oracle Database and Oracle SQL Developer installations. It is supported in WebLogic, Tomcat, Glassfish, and also as a standalone application running Jetty in embedded mode.

SUPPORT FOR ORACLE MULTITENANT

Oracle Multitenant is an Oracle Database technology that enables database consolidation without changes to applications. Designed for the Cloud, it allows many databases to be managed as one, while retaining the isolation and resource prioritization of separate databases. The multitenant architecture consolidates multiple Oracle Databases (each referred to as a pluggable database) to run under a single occurrence of Oracle Database software (referred to as a multitenant container database). Architectural separation is enforced between each pluggable database (user data and metadata) and its multitenant container database (Oracle metadata). Pluggable databases are compatible with traditional Oracle Databases not in a multitenant container database.

Oracle's spatial features function transparently in a multitenant architecture; spatial applications benefit from the efficient administration of one multitenant container database, and the separation and resource prioritization allowed by multiple pluggable databases.

OPEN STANDARDS

Oracle consistently works to help shape, drive, implement and support the latest open standards in the spatial and location services database areas. Oracle is a founding and Principal Member of the Open Geospatial Consortium (OGC). Oracle is a World Wide Web Consortium (W3C) member and active contributor and/or editor in various technical working groups, such as the W3C RDF, SPARQL, OWL and RDB2RDF working groups and the OGC GeoSPARQL Working Group.

Multiple versions of Oracle Spatial and Graph comply with the OGC Simple Features Specification for SQL, Revision 1.1, Types and Functions Alternative; OGC OpenLS 1.1, Web Feature Service – Transactional (WFS-T) 1.0, Web Feature Service (WFS) 1.1.0, Web Coverage Service (WCS) 2.0.1, and Catalog Service for the Web (CSW) 2.0.2. Oracle Spatial and Graph also 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's 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's spatial features 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, visit the Oracle Spatial and Graph page on oracle.com.

SPATIAL PARTNERS

Oracle builds and maintains active partnerships with the leading data providers; systems integrators; and geospatial tool, application, and service providers. Oracle's longstanding commitment to depth and breadth of partnerships provides users flexibility and the widest possible choices. Developers and IT managers can select best of breed tools and applications to meet their industry and organization-specific requirements and rapidly deploy scalable, secure enterprise geospatial and location service solutions. Support from leading data providers and systems integrators, both from the geospatial and enterprise IT domains, provides customers with choices for fast deployment of customized solutions to meet their needs.

All of the most widely used GIS software technologies available in the industry support Oracle's spatial features. The leading geospatial data vendors provide data products in Oracle's spatial format with worldwide coverage, and integrators around the globe provide expertise and experience at delivering Oracle-based spatial solutions.

For a complete list of partners and links to sample data, free downloads, and other resources, visit the Oracle Spatial and Graph page on oracle.com.

CONCLUSION

Oracle provides advanced spatial capabilities for Oracle Cloud and Oracle Database 19c. It addresses the business-critical needs of customers in traditional geospatial domains such as defense and intelligence, homeland security, land management, transportation, as well as a broad range of business domains requiring location technologies, including finance, retail, life sciences, publishing and media companies. Features from native 3D point cloud, raster, topology, and network models to geocoding, routing, web services, JSON and REST interfaces, and map visualization make this a complete, advanced geospatial platform. Oracle users include several of the largest organizations in the world that use mission-critical, location-enabled enterprise systems.   Customers and partners rely on Oracle to deliver performance, scalability, security, and ease of use for their spatial applications. Oracle's spatial features are supported by all the leading geospatial and location services vendors and systems integrators.

With Oracle's spatial offerings, developers, database professionals, and analysts can use a comprehensive suite of spatial data management, analytics, and visualization tools to integrate spatial analysis and mapping into applications on enterprise grade data management infrastructure – Oracle Database and Oracle Exadata. Innovative technologies of Oracle Cloud Gen 2 and Oracle Autonomous Database, the industry's only self-driving, self-securing, and self-repairing database, are available to spatial applications.

With every release since its introduction twenty years ago, has delivered the most advanced spatial data management capabilities to database management systems. With the unmatched enterprise data management capabilities of Oracle Database 19c, it continues to be the world's leading database management platform for enterprise spatial systems, on premises and in the cloud.

APPENDIX 1: SPATIAL FEATURES

- Vector Performance Acceleration: from 5-900 times faster execution of spatial operations and more efficient use of CPU, memory, and partitioning
- Vector geometry type native to Oracle Database
- Vector operators and functions: 400+ functions to analyze and generate geometries through SQL access
- R-tree indexing
- Projections and coordinate systems: support for 4000+ commonly used coordinate systems, implicit and explicit transformations by layer or geometry, geodetic model, user-defined coordinate systems
- GeoRaster support for imagery and raster data: Virtual Mosaic, raster algebra analytical algorithms and operations, image processing (parallel for high performance), Java and PL/SQL APIs, GDAL loader support with ETL Wizard
- 3D data model – native support for 3D geometries, surfaces and point clouds (LIDAR data).
- Spatial Web Services: support for OGC and ISO geospatial standards – Web Feature Service (WFS) 1.1.0, Web Map Service (WMS), Catalog Service for the Web (CSW) 2.0.2, Web Coverage Service (WCS) 2.0.1, Open Location Services 1.1, with unified administration console/UI
- Geocoding engine
- Routing engine
- Spatial analysis and mining functions
- Topology data model
- Linear referencing system
- Network Data Model– a storage model to represent graphs and networks in link and node tables, including feature, time, and multimodal transporation modeling
- Parametric Curves (NURBs): mathematically precise representation of free form curves that can be reproduced exactly for 2D and 3D data
- GeoJSON support and REST APIs: spatial data access for modern development environments
- Location data enrichment services: API with bundled geographic hierarchy and place names data set, to search and categorize large collections of unstructured text records with location tags for analysis
- Map visualization: HTML5-based mash up component for spatial visualization of geographic data in Oracle Spatial and Graph or from external services. (Must be

deployed in a JEE container or in Oracle Java Cloud Service)

- Spatial index optimization for point data: composite B-tree indexes for improved performance on index update and creation for point only data
- Spatial indexes: support for all index partitioning methods and system managed indexes for improved performance and simplified management
- Location tracking server tracks the movement of objects in and out of regions of interest on a massive scale for logistics and IOT

APPENDIX 2: NEW SPATIAL FEATURES IN ORACLE DATABASE 18C/19C

New Spatial Features in 18c

- Support for R-Tree spatial indexes in distributed and Oracle XA transactions
- JSON support expanded: ability to convert data between JSON and all the types supported by SDO_GEOMETRY, support for larger range of geometries including 2D, 3D, solid, surface, and LRS geometries
- Oracle REST Data Services support for spatial operations on Oracle spatial data
- Support for sharded databases with spatial data types
- Spatial Web Services: administration console enhancements
- Spatial Web Services: WFS, CS-W, WCS can support reading data from multiple data sources in the same WebLogic Server instance
- Spatial Web Services: Support for CSW 2.0.2 - ISO Metadata Application Profile
- Spatial Index now optional for spatial operations
- Performance enhancements for spatial indexes for point data (composite B-tree)
- Routing Engine: new servlet for lightweight location-based queries related to speed limit and traffic speed
- New Utility Functions: SDO_UTIL.GETFIRSTVERTEX and SDO_UTIL.GETLASTVERTEX
- Enhanced concave hull support

New Spatial Features in 19c

- New JSON support in addition to GeoJSON
- Data can be in NFS files, HDFS, and Object Store.

- Data can be from a JOIN view or some other complex view.
- Data can be stored in an external table using text format for geometry.
- Support for distributed transactions. R-tree index updates were not supported for distributed transactions before Release 19c.
- The location tracking server is updated to support INSIDE/OUTSIDE/TRANSIT states and have improved scalability.
- Map Visualization
  - Define tile layer dynamically in the V2 API (instead of pre-built in the server and stored permanently in metadata view).
  - Specify or change rendering style as needed.
  - Server generates tile images just like regular tile layers.
  - Large and complex queries supported, without unnecessary storage and management overhead.
  - Offline map cache for detached applications.
  - Vector tiles for thematic data.
- GeoRaster
  - Raster algebra support: All subprograms in the SDP_GEOR_RA package and the Java API support putting the result data in a temporary BLOB so that users can do raster analysis and cartographic modeling on-the-fly to support various real time applications.
  - GeoRaster must be enabled at schema level. (In previous releases, GeoRaster is enabled for the whole database.) This change enhances database security for the cloud.

ORACLE CORPORATION

Worldwide Headquarters
500 Oracle Parkway, Redwood Shores, CA 94065 USA

Worldwide Inquiries
TELE + 1.650.506.7000 + 1.800.ORACLE1
FAX + 1.650.506.7200
oracle.com

CONNECT WITH US

Call +1.800.ORACLE1 or visit oracle.com. Outside North America, find your local office at oracle.com/contact.

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Integrated Cloud Applications & Platform Services

White Paper **Spatial Analytics with Oracle Database 19c**
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Contributing Authors: [OPTIONAL]