Oracle’s Spatial Technologies
(In a Nutshell)
Presenter

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In the Past
Challenge of Integrating GIS & MIS

GIS/Design

MIS

Spatial Data

Tabular Data

Geo Engineering Server

Enterprise Data Server
Evolution of GIS

Past

- Monolithic GIS
  - Proprietary Files

<table>
<thead>
<tr>
<th>Application</th>
<th>Proprietary APIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional DBMS</td>
<td></td>
</tr>
</tbody>
</table>

| Standalone |

Today

- Spatially Enabled Database

<table>
<thead>
<tr>
<th>Application</th>
<th>Open APIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map Server</td>
<td></td>
</tr>
</tbody>
</table>

| Proprietary Middleware |

| Internet Platform |

- Spatially Enabled Database
Oracle’s Core Spatial Capabilities

Spatial Data Types
- Points
- Polygons
- Lines
- All Spatial Data Stored in the Database (vector, raster, topology)

Spatial Indexing
- Fast Access to Spatial Data

Spatial Analysis Through SQL

```sql
SELECT a.customer_name, a.phone_number
FROM policy_Holders a
WHERE sdo_within_distance( a.geom, hurricane_path_geom,
    'distance = 10 unit = mile' ) = 'TRUE';
```
# Spatial Columns in Traditional Database Tables

<table>
<thead>
<tr>
<th>ROAD_ID</th>
<th>NAME</th>
<th>SURFACE</th>
<th>LANES</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fisher Cir.</td>
<td>Asphalt</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Coop Ct.</td>
<td>Asphalt</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>85Th St.</td>
<td>Asphalt</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
R-Tree Spatial Indexing

Which of millions of roads in the U.S. interact with this county?

- First compares geometry approximations, so result is not exact.
- Interior optimizations are applied to candidate set.
- Geometry comparisons are done only where required.
Spatial Operators

- Full range of spatial operators
  - Implemented as functional extensions in SQL
  - Topological Operators
    - Inside Contains
    - Touch Disjoint
    - Covers Covered By
    - Equal Overlap Boundary
  - Distance Operators
    - Within Distance
    - Nearest Neighbor
Spatial Query Via SQL

Find all buildings within 500 meters of building 902

```
SQL> SELECT a.building_id
2> FROM base_buildings a,
3>    base_buildings b
4> WHERE b.building_id = 902
5> AND SDO_WITHIN_DISTANCE(
6>    a.Location, b.Location,
7>    'distance=500 unit=meter')
8>   = 'TRUE';
```
Spatial Functions

- Database Server Side Spatial Functions
  - Union, Difference, Intersect, etc.
  - Spatial Aggregates
  - Buffer
  - Point at bearing
  - To_GML
  - Geometry Validations
  - Length
  - Area
  - Distance
  - Etc…
Longitude/Latitude Data Considerations

Whole Earth Model

- P1 and P2 are 1 degree apart (about 111 Km apart)
- P3 and P4 are 1 degree apart (about 10 Km apart)
- Natively operate on Longitude/Latitude data
Coordinate Systems

• Whole Earth model (latitude/longitude)
  • Ellipsoidal computations
  • Accurate distance and area calculations (unit support)
  • Support for geometries that span the poles and the 180 meridian

• Projected coordinate systems
  • Cartesian computations
  • For example: UTM, State Plane, and many more…

• Non-Earth coordinates (e.g., floor plan)

• New - EPSG support - Oracle 10g Release 2
Ship Track That Crosses the 180 Meridian
Linear Referencing Systems (LRS)
What Is Linear Referencing (LRS)?

Commonly used in many GIS applications such as:
• transportation (road network)
• utilities (pipeline and gas lines)
LRS Concepts

Clip from measure 5 to 20
A.K.A. Dynamic Segmentation

(5,10,0) → (15,5,11.2) → (30,10,27) → (40,5,38) → (50,15,53.8) → (55,20,60)

(53,17) is located at measure 52
A.K.A. Locate Point
Pipeline Asset Management Example

System requirements

- Linear reference each section of the pipeline and store:
  - associated diameters locations
  - valve locations

Pipeline Table

<table>
<thead>
<tr>
<th>PIPE_ID</th>
<th>GEOMETRY</th>
<th>INSTALL_DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUS1105</td>
<td>lrs geom</td>
<td>05-Feb-1997</td>
</tr>
<tr>
<td>SUS1106</td>
<td>lrs geom</td>
<td>08-Feb-1997</td>
</tr>
<tr>
<td>SUS1107</td>
<td>lrs geom</td>
<td>09-Feb-1997</td>
</tr>
</tbody>
</table>
Pipeline Asset Management Example (continued)

Pipeline Section Table

<table>
<thead>
<tr>
<th>Section #</th>
<th>Pipe_ID</th>
<th>Start M.</th>
<th>End M.</th>
<th>Diameter</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>203</td>
<td>SUS1105</td>
<td>230.56</td>
<td>243.17</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>204</td>
<td>SUS1105</td>
<td>243.17</td>
<td>275.84</td>
<td>0.48</td>
<td></td>
</tr>
<tr>
<td>205</td>
<td>SUS1105</td>
<td>275.84</td>
<td>302.21</td>
<td>0.43</td>
<td></td>
</tr>
</tbody>
</table>

Pipeline Valve Table

<table>
<thead>
<tr>
<th>Pipe_ID</th>
<th>Measure</th>
<th>Valve ID</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUS1105</td>
<td>230.56</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>SUS1105</td>
<td>243.17</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>SUS1105</td>
<td>275.84</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

Note: No explicit vertices are needed to define the pipeline sections or valves
LRS Application

• **US Airspace Boundary Crossing Application**
  - Spatial functions to calculate intersection of flight paths and US airspaces.
  - Linear Referencing to interpolate the time and altitude for entry/exit points of US airspace.
  - Accurately charge foreign carriers for the amount of time in US airspace.
Spatial Aggregate Functions - Example

Generate New York state boundary by aggregating counties

```sql
SELECT SDO_AGGR_UNION(sdo_aggr_type(a.geometry, 0.5))
FROM counties
WHERE state = 'New York';
```
SDO_AGGR_CONVEXHULL

• Snap a rubber band around contaminated wells
• Dynamically generate new region
• Further analysis with new region, e.g.
  • Search for chemical plants within 5 miles of new region
GIS and Image Processing Vendors Natively Integrate Oracle Spatial
Advanced Spatial Features
Available in Oracle
Oracle Spatial 10g New Features Summary

• GeoRaster data type
• Persistent Topology data type
• Network Data Model
• Spatial Analysis and Mining
• Geocoder in the database
• Routing Engine
Raster Data and Cell Size

Coarser resolution

Finer resolution
## Raster/Vector Data Differences

<table>
<thead>
<tr>
<th>Vector Data</th>
<th>Vector Coordinates</th>
<th>Raster Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Vector Data" /></td>
<td>$-74.1651749, 41.339141$</td>
<td><img src="image2" alt="Raster Data" /></td>
</tr>
<tr>
<td><img src="image3" alt="Vector Data" /></td>
<td>$-74.1651749, 41.339141$, $-73.4284481, 40.678193$, $-72.9792214, 41.6862282$</td>
<td><img src="image4" alt="Raster Data" /></td>
</tr>
<tr>
<td><img src="image5" alt="Vector Data" /></td>
<td>$-74.1651749, 41.339141$, $-74.1651749, 39.559004$, $-72.9792214, 39.559004$, $-72.9792214, 41.339141$</td>
<td><img src="image6" alt="Raster Data" /></td>
</tr>
</tbody>
</table>
Grid Raster Data

Value Attribute Table (VAT) maps numeric values to the meaning of that value.

An example value attribute table for geological raster data:

<table>
<thead>
<tr>
<th>CELL VALUE</th>
<th>GEOLOGICAL PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Quaternary</td>
</tr>
<tr>
<td>2</td>
<td>Tertiary</td>
</tr>
<tr>
<td>3</td>
<td>Paleocene-Cretaceous</td>
</tr>
<tr>
<td>4</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>5</td>
<td>Gondwana</td>
</tr>
<tr>
<td>6</td>
<td>Early Palaeozoic</td>
</tr>
<tr>
<td>7</td>
<td>Proterozoic</td>
</tr>
<tr>
<td>8</td>
<td>Early Proterozoic</td>
</tr>
<tr>
<td>9</td>
<td>Archaean</td>
</tr>
<tr>
<td>0</td>
<td>Blank Cell (no data)</td>
</tr>
</tbody>
</table>

Stored cell values:

```
2 5 4 9 1 9 7 6
6 1 1 1 1 6 6
1 3 8 7 9 7 9 1
3 1 8 3 3 5 9 1
3 3 3 9 8 7 9 1
0 3 3 9 9 1 0 0
0 8 8 9 9 1 0 0
0 0 2 9 1 0 0 0
```
**Grid Raster Data**

**COLORMAP** associates stored numeric values with colors for display

An example **COLORMAP** table for geological raster data

<table>
<thead>
<tr>
<th>CELL VALUE</th>
<th>Red</th>
<th>Green</th>
<th>Blue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>255</td>
<td>255</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>82</td>
<td>123</td>
<td>67</td>
</tr>
<tr>
<td>3</td>
<td>142</td>
<td>230</td>
<td>98</td>
</tr>
<tr>
<td>4</td>
<td>96</td>
<td>121</td>
<td>228</td>
</tr>
<tr>
<td>5</td>
<td>145</td>
<td>231</td>
<td>243</td>
</tr>
<tr>
<td>6</td>
<td>255</td>
<td>51</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>203</td>
<td>188</td>
<td>224</td>
</tr>
<tr>
<td>8</td>
<td>195</td>
<td>135</td>
<td>75</td>
</tr>
<tr>
<td>9</td>
<td>204</td>
<td>102</td>
<td>255</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Geological Map of India (Grid Raster Data)

- Quaternary
- Tertiary
- Paleocene-Cretaceous
- Mesozoic
- Gondwana
- Early Palaeozoic
- Late Proterozoic
- Early Proterozoic
- Archaean
Raster Data Concepts – (Digital Imagery)

• **Digital Imagery** - a specialized type of raster data

  - Examples include:
    - Satellite imagery
    - Airborne photographs
    - others…
Some bands may accentuate different features
Blocking

- One image can be Gigabytes in size
- Index very large rasters into smaller blocks
- Blocked data is also interleaved
  - Band sequential (BSQ)
  - Band interleaved by pixel (BIP)
  - Band interleaved by line (BIL)
Pyramids

- Pyramid level 2
- Pyramid level 1
- Pyramid level 0 (raw data)
GeoRaster - Features/Functionality

- Store, index, and retrieve raster data
- Store, maintain, and retrieve GeoRaster metadata
- Analysis functionality:
  - Generate pyramids
  - Copy
  - Change format: Interleaving, blocking
  - Subset: Crop, cut, clip by band or layer
  - Scaling: Enlarge or reduce
  - Generate the spatial extent of an image
  - Tile adjacent images to build a mosaic of the data
  - Georectified/Georeferenced images supported
GeoRaster: Compression
New in Oracle 10g Release 2

• Natively support two industry standard compression techniques
  • JPEG (lossy)
    – JPEG-B (abbreviated baseline JPEG format)
    – JPEG-F (full-format baseline JPEG format)
  • DEFLATE (lossless)
    – (a.k.a. ZIP)

• All GeoRaster operations work on compressed/uncompressed GeoRaster objects
  • Automatic decompression on sub-set operations
Advanced New Feature

Geocoder

• Geocoding Engine included in the database
• Generates latitude/longitude (points) from address
• Supports:
  • International addressing standardization
  • Formatted and unformatted addresses
  • Transaction and batch capabilities
• Base data available from NAVTEQ & TeleAtlas
  • Navteq partners (eSpatial and ADCI)
  • Download sample data from NAVTEQ
• Servlet model – new in 10g Release 2
• Working with Gempi for Brasil support
Advanced New Feature

Router

- Routing algorithms included in the database
- Generates driving directions
- XML API
- Base data available from NAVTEQ & TeleAtlas
  - Download sample data from NAVTEQ
- Working with Gempi for Brasil support
Advanced New Feature
Persistent Topology

Object View

Topology View
Topology Example

• Land parcel features
  • Land Parcel 1 associated with face F1
  • Land Parcel 2 associated with face F2
  • Both faces include edge E3.

• Stream features
  • Stream 1 associated with edge E3 (and edges E1 and E5)
Hierarchical Feature Model: Example

- Parcel features are stored in a level 0 feature layer
  - Each parcel is derived from topological primitives (faces).
- Neighborhood features are stored in a level 1 feature layer:
  - Each neighborhood is derived from a list of parcels.
- School District features are stored in a level 2 feature layer:
  - Each school district is derived from a list of neighborhoods.
Advanced New Feature
Network Data Model

• Open Data Model For Graph Analysis In the Database

• Supports Network solutions (Tracing & Routing)
  • Transportation and Transit Solutions
  • Field Service, Logistics
  • Location based Services
  • and Telematics

• Bio-Info Pathways (Life Sciences)
  • Biological Pathways
  • Protein-Protein Interaction
Advanced New Feature
Spatial Analysis and Mining

- Everything is related to everything else, but nearby things are more related than distant things.
  
  Tobler’s first law of geography
Spatial Analytic Functions

• Discovery based on Spatial Patterns
  • Cluster analysis
  • Location prospecting
Example

```
SELECT SDO_SAM.AGGREGATES_FOR_GEOMETRY(
    'GEOD_COUNTIES', 'GEOM',
    'sum', 'totpop',
    SDO_GEOMETRY(2001, 8307,
        SDO_POINT_TYPE(-73.943849, 40.6698,NULL),
        NULL, NULL),
    'distance=3 unit=mile')
FROM DUAL;
```

<table>
<thead>
<tr>
<th>COUNTY</th>
<th>ST</th>
<th>TOTPOP</th>
<th>BY WINDOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queens</td>
<td>NY</td>
<td>1951598</td>
<td>00.5437756</td>
</tr>
<tr>
<td>Kings</td>
<td>NY</td>
<td>2300664</td>
<td>31.0430579</td>
</tr>
<tr>
<td>New York</td>
<td>NY</td>
<td>1487536</td>
<td>00.0188785</td>
</tr>
</tbody>
</table>

723570.362
Standards Are Important
SQL/MM Methods and OGC Standards

• GET_WKB() – Get Well Known Text
• GET_WKT() – Get Well Known Binary

```sql
set long 500;
SELECT A.GEOM.GET_WKT()
FROM polygon_table a
WHERE id = 1;

A.GEOM.GET_WKT()
----------------
POLYGON ((146.0 66.0, 148.0 66.0, 148.0 68.0, 146.0 68.0, 146.0 66.0))
```
Make Sure Your Spatial Strategy Leverages Important Core Database Features

- **Table partitioning**
  - For scalable solutions, maintenance and performance

- **Label Security**
  - Row level security policies on your data

- **Spatial Analysis via SQL**
  - Use non-proprietary spatial data types
  - Spatial applications don’t always need a GIS

- **Spatial Analysis inside stored procedures, triggers and functions**

- **Replication**

- **Native database long transaction support**

- **Grid computing architecture**
Oracle Application Server 10g
MapViewer
Oracle Application Server 10g MapViewer

• Web Map Server
  • Standard feature of the Oracle Application Server
  • Integrated with Oracle Spatial and Oracle Locator
• Easily publishes data stored in Oracle’s native spatial data type (SDO_GEOMETRY) to the web
• Provides the following API’s:
  – XML
  – Java
  – JSP Tag library
  – OGC Web Map Service
Oracle Application Server 10g MapViewer
Native Support For Map Visualization

Title

Themes

Legend

Footnote
OGC Compliant Web Map Service (WMS)

• Style, Theme and Map definitions stored in the database (in SVG and XML formats)

• Supports the following requests:
  • GetMap
  • GetFeatureInfo
  • GetCapabilities

• Application Server Map Visualizers can:
  • Generate OGC WMS compliant maps
  • Render OGC WMS compliant maps generated by another OGC compliant WMS
  • Render vector and raster data on maps generated by another OGC compliant WMS
# Oracle10g Locator & Spatial Features

## Oracle Locator 10g release 2
- All Data Types
- Spatial Operators
  - Topological
  - Distance
- Distance Function
- SDO_UTIL package
- Coordinate Transformation
- Long Transactions
- Table Partitioning*
- Object Replication*
- Oracle Label Security

## Oracle Spatial 10g release 2
- All Locator features
- GeoRaster Data Type
- Topology Data Type
- Network Data Model
- Geocoding
- Routing
- Linear Referencing
- Spatial functions
  - aggregates
  - buffer, centroid, union, etc

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**Bundled Feature**
Standard & Enterprise Edition

**Licensed Option**
Enterprise Edition Only
Spatial Applications Don’t Always Need a GIS

• Every organization wants to cut costs
• Oracle Spatial Technologies Bundle
  • Oracle Locator
    – Oracle Standard Edition
    – Oracle Enterprise Edition
  • Oracle Application Server MapViewer
    – Java Edition
    – Standard Edition
    – Enterprise Edition
• Leverage what you own