Making Sense of Location: Tracking, Visualizing & Analyzing Moving Objects in 2D, 3D & 4D

Location Intelligence On-premise and in the Cloud

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Safe Harbor Statement

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Tracking and Tracing – Analysis of Moving Objects

• Lots of use cases involving moving objects transmitting location data
  – Smart Cities, Public Transport, Traffic Services, ...
  – Internet of Things (IoT)
  – Industry 4.0 / Supply Chain Management
  – Location-based Services, eg. Targeted Marketing based on location of consumer
Agenda

1. Geospatial Data in the Database
2. Using the Database for Tracking and Tracing
3. Visualizing Results on a Map
4. Advanced Analysis using Road Networks
5. Wrap-up
What is Spatial Data

Integral part of almost every database

• Business data that contains or describes location
  – Geographic features (roads, rivers, parks, etc.)
  – Assets (pipe lines, cables, transformers,
  – Sales data (sales territory, customer registration, etc.)
  – Street and postal address (customers, stores, factories, etc.)

• Anything associated with a physical location

• Described by coordinates or implicitly as text (place name), ...

• Location is a “universal key” relating otherwise unrelated entities
Required database capabilities for geospatial analysis

• Data type to store points, lines, areas, solids, ...
  – In two or three dimensions
  – Taking into account coordinate system

• Topological Operators
  – Point-in-polygon, intersecting linestrings, overlapping areas, ...

• Geometric Functions
  – Calculating areas, distances, buffer zones, ...

• Spatial Indices
  – Fast access to relevant data
Storing spatial data in SDO_GEOMETRY

Table Counties

<table>
<thead>
<tr>
<th>ID</th>
<th>NAME</th>
<th>BOUNDARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMBER</td>
<td>VARCHAR2</td>
<td>SDO_GEOMETRY</td>
</tr>
</tbody>
</table>

SDO_GTYPE NUMBER
SDO_SRID NUMBER
SDO_POINT SDO_POINT_TYPE
SDO_ELEM_INFO SDO_ELEM_INFO_ARRAY
SDO_ORDINATES SDO_ORDINATE_ARRAY
Creating Geometric Objects

• Creating point data ...

```sql
select sdo_geometry('POINT (10 50)', 4326) from dual;
```

```
SDO_GEOMETRY
-----------------------------------------------
SDO_GEOMETRY(2001, 4326, SDO_POINT_TYPE(10, 50, NULL), NULL, NULL)
```

• Alternatively ...

```sql
select sdo_geometry(2001, 4326, sdo_point_type(10,50,null), null, null) from dual;
```

```
SDO_GEOMETRY
-----------------------------------------------
SDO_GEOMETRY(2001, 4326, SDO_POINT_TYPE(10, 50, NULL), NULL, NULL)
```
Accessing Coordinates in SDO_GEOMETRY

• Which points describe the boundary of Germany?

```
SQL> select k.id, k.x, k.y from
countries c,
table(sdo_util.getvertices(c.geometry)) k
where country_name='GERMANY';

<table>
<thead>
<tr>
<th>ID</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14,7200450</td>
<td>51,582406</td>
</tr>
<tr>
<td>2</td>
<td>14,7554651</td>
<td>51,603937</td>
</tr>
<tr>
<td>3</td>
<td>14,7570239</td>
<td>51,644129</td>
</tr>
</tbody>
</table>
```

Accessing Coordinates in SDO_GEOMETRY
Example: Spatial SQL Queries

• Which German Länder are touching North-Rhine Westphalia?

```sql
select l1.name
from laender l1, laender l2
where l2.name='NRW' and
sdo_relate(
    l1.boundary, l2.boundary,
    'mask=touch'
)= 'TRUE'
```

• Using spatial (R-Tree) index for query optimization
  – Two-step filter process
  – Checking interaction between minimum bounding rectangle first, then detailed test
Geospatial Product Portfolio

- **Oracle Database**
  - Basic capabilities for spatial data management

- **Oracle Spatial and Graph**
  - Priced option for Geocoding, Routing, High-Performance Query and Analytics, and more
  - Includes RDF Graph capabilities (triple store, SPARQL queries, inferencing and ontology support, ...)
  - Includes property graph analytics engine

- **Oracle Fusion Middleware MapViewer**
  - Java-based map rendering engine built on HTML5

- **Big Data and NoSQL support**
  - Built on open standards (OGC, ISO 191xx, ...)
  - Partnerships with data providers, SIs, ISVs, ...
Oracle’s Spatial and Graph Strategy
Enabling spatial analysis use cases on every platform

Oracle Database
Spatial and Graph Option

Oracle Big Data
Spatial and Graph

Cloud
Services

Exadata
Non-Engineered Systems

Big Data Appliance
Commodity Hadoop
Spark

Database Cloud Service
Exadata Cloud Service
ADW/ATP-S (coming up)
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Location tracking in Oracle 12.2

- New APIs in Oracle 12.2
- Tracking many moving objects against many regions
- Enhanced “point-in-polygon” analysis
  - Tracking multiple objects simultaneously through parallelism
  - Designed to scale to millions of objects
- Java API and PL/SQL API for event capture and processing
  - Using Advanced Queuing in database for performance and async. processing

Diagram:
- Application
  - Location Generator
  - Event Notification
  - Message Queues
  - Processor
  - Trajectory Storage
- Oracle Spatial and Graph Database
Location Tracking API workflow

• Create regions of interest in database as polygon geometries

• Initialize the location tracking server
  – Initialization of 3 queues: one for receiving location objects, one for receiving location messages, and one for storing the notifications after the locations are processed
  – Each location object (moving item) has many location messages, can be persisted

• PL/SQL APIs to create location objects and insert location messages

• Java Applications can use AQ Java API to insert data into the input queues
  – JMX queues used for maximum performance

• Alerts are sent to output queue
  – Subscription to output queue for further processing
Location Tracking – Use cases

- Raise alert when object enters area-of-interest
- Raise alert when object leaves area-of-interest (Geofencing)
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Visualizing Relevant Events in Context

- HTML5-based visualization component
  - Included in Spatial and Graph license
- Rendering dynamic maps
  - Data from database
  - Data from external sources (WMS, WFS, GeoRSS, WMTS)
  - Integration of Google Maps, etc.
- Available as plug-in for Apex
  - Geolocation Showcase
- Many 3rd Party Tools available as well
  - eg. Luciad RIA, working with OracleJET
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Tracking und Tracing based on Road Network

• Object position not sufficient in all cases, but position on road network required
  – eg. exact route needed, despite GPS inaccuracies/errors
  – eg. route planning, calculating (remaining) drivetime

• Road network as reference dataset needed
  – Commercially available from HERE, Tomtom
  – OpenStreetMap converter available from CISS TDI

• Required database functionality
  – Support for linear coordinate systems
  – Network data model (graph), routing engine
Routing based on Network Data Model

• Entire road network stored as nodes and edges of a graph
  – With or without road segment geometry
• Connectivity and cost (e.g. drivetime) per road segment
• Enabling network analysis
  – Using graph algorithms
  – Based on directed or undirected graph
  – Optionally taking cost into account
• Data Management API
  – Caching, Partitioning, load-on-demand, ...
Network Data Model: Analysis

- Shortest path analysis
- Nearest neighbor analysis
- Within cost analysis
- Network Buffer (forward and reverse)
- Reachable/Reaching nodes
- K-shortest paths analysis
- Traveling salesman problem
- Multiple TSPs/Single Depot (new)
INM Spatial Data Warehouse

Institute for Emergency Medicine and Management in Medicine

• Emergency Services Planning in Bavaria
  – State-wide planning and optimization
  – Site planning for ambulance bases, What-if analysis, ...

• Based on 2TB data warehouse of emergency mission data
  – Location and status information plus medical data

• Combined with road network data, hospital locations, helicopter bases, ...
  – Including individual speed profiles per road segment

• Calculating drive-time areas, hospital service areas, ...
  – Simulation model, ensuring compliance with legal mandate
INM Spatial Data Warehouse

Determining drivetime area based on road network
Wrap-up
“While hardcore GIS professionals may start their work in other applications, when they want to solve spatial problems in production and with web- and IoT-scale data, Oracle gives them the platform to do so.”

Analysts: Rowan Curran with Holger Kisker, Ph.D. and Emily Miller
September 1, 2016
More resources

- Further information on oracle.com
  - www.oracle.com/goto/spatial

- Blogs
  - https://blogs.oracle.com/oraclespatial

- Developer forums on OTN
  - https://community.oracle.com/community/database/oracle-database-options/spatial

- Social Media
  - LinkedIn: „Oracle Spatial and Graph“ group
  - Google+: „Oracle Spatial and Graph SIG“
  - Twitter: @SpatialHannes, @agodfrin, @JeanIhm
Q&A
Integrated Cloud
Applications & Platform Services