Enabling elevation information on a road network for routing applications

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Agenda

• How network analysis is being used
• Look at the 3D future!
Transportation and Logistics
Key Industries

- Insurance
- Local Government
- Public Safety
- Retail
- Telco
- Transportation
- Utilities
- Health
Logistics in Trucking and Distribution

- Reduce cost
  - Mileage reduction
  - Fuel reduction
  - Time savings (field and office)
- Reduce emissions
  - Support environmental responsibility
- Increase safety
  - Avoid unsafe areas
  - Monitor and correct driver behavior
- Raise operational awareness
  - Visualize trends and patterns
Delivery Routing
Sears Capacity Planning

SEARS Product Repair Services

Maintain Daily Start, End, Seed Points

Select Associates

Select Location

Refresh Layers Legend

Zoom Out Zoom In
Schindler Elevator Territory Planning
Starbucks relies on server technology from Esri to make more informed market and site analysis decisions.
Petco

Improves location selection and mitigates the risks of expansions with GIS

“We have successfully avoided the downside risk associated with several locations, which more than pays for our investment in the Esri solution”

Shawn Hanna, Director of Financial Analysis
Cisco - Global Premium Depots
Accurate Service Capabilities
GIS – CISCO Service Availability

**Older Capabilities**
- As-the-crow-flies calculation
- Manually map install base
- Dependent on TPL analysis
- Zip code accuracy
- Sub-optimized inventory
- Sub-optimized depot locations

**Newer Capabilities**
- Real world conditions
  - Driving time calculations
  - Road infrastructure network
  - Posted and average speed limits
  - Depot Administrative time
- Automatic install base assignment
- Street level accuracy
- Modeling capabilities
Public Works and Facility Management

Wastewater Asset Management
- Geocom Informatik
  - Liechtenstein

Pavement Management
- Cityworks
  - Utah

Work Management
- Debris Clean-up
  - Missouri

Work Order Heat Maps
- Cityworks
  - Missouri

Historical Drainage Reporting
- Midland GIS
  - Missouri

Online Sewer Analytics

Sewer Line Risk Analysis
- Innovyz
  - New England
ArcGIS Network Analyst Extension
Solving transportation problems
NA Deployed in various ways

• In Desktop
  – Traditional client since mid 80s
• Server
  – Data and solvers
• Online services
  – Access anywhere via web clients
• Runtime
  – Embed routing services in devices
  – Disconnected routing
Evolution of 2D Networks

• Network extension for workstation ArcINFO since mid 1980s.
  – End point connectivity model and support for directional impedances.
  – Only planar networks supported
  – Two part turn tables

• What about:
  – Ramps
  – Bridges
Evolution of 2D Networks

- Early 90’s we added support for non-planar network features (bridges/tunnels) via node elevation fields
  - F_Zlev and T_Zlev

- World is more complex than that...
Evolution of 2D Networks

• In 2005, ArcGIS Network added support for complex connectivity and turning movements.
Evolution of 2D Networks

• Turn delays – at specific intersections or global turn penalties

Total Time: 25 Seconds
Evolution of 2D Networks

- Restriction and descriptor attributes can model width, height and weight limits

10′- 6”
Evolution of 2D Networks

• Support for sophisticated U-turn policy
How 2 D networks were used for 3 D

- Spatial offsets were used to model 3D features

- Or, the node elevation capability was exploited to model the different levels of building
  - Corridors in each floor of a building given the same elevation value
  - Different floors connected via connector lines
3D Networks

- In 2010, ArcGIS 10 added support for vertical lines in a geodatabase.
  - Network connectivity was enhanced to use true 3D X,Y,Z coordinates and the vertical lines could be used to model elevators or mine shafts.
3D Network Applications

- 3D buildings
  - Airports, hospitals, amusement parks
- 3D roads
  - Mines
  - Truck with slope restrictions
  - Electric cars – minimize power consumption
  - Bicycle
  - Wheelchair
3 D Networks - Buildings

• Initial use was to model Buildings
Facility Management
Emergency Route
An Analytical Revolution

Indoor mapping will transform retail in the same way that freeways did in the 1950’s.
Indoor GIS at UC
Dashboard for hotspot analysis and patterns
3D Network Applications

• 3D buildings
  – Airports, hospitals, amusement parks
• 3D roads
  – Mines
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  – Electric cars – minimize power consumption
  – Bicycle
  – Wheelchair
How to make a 3D Road Network

- Need true X, Y, Z coordinates for the roads

- USGS has the National Elevation Dataset
  - 1/3 arc second resolution for 95% of the USA
    - Provides 10 meter or better resolution
3D Surface with 2D Roads
3D Surface with 2D Roads- Details
Adding 3D Coordinates

• Use the GP tool Interpolate Shape to add Z information to the 2D features to make 3D features
3D Roads
3D Roads
Making a routable 3D network

- Having 3D line features is not enough for connectivity!

- Intersections with bridges and tunnels are a problem
  - Use the Z-levels to **fudge** the data to maintain correct connectivity
    - Move Z coordinate 5 meters up for each z-level via VBA
Honoring Z Levels in 3D
3D Attributes

• Having 3D features is not enough for “3D routing”!

• Need more intelligent attributes
  – 3D length in meters
  – Terrain variability
    • roughness
  – Slope in percentage
Using Terrain variability

- Knowing the 3D length by itself is not enough
- Need to categorize the difficulty in traversing the street due to terrain
  - How many uphill meters are there?
Using Terrain variability

- The network edges were calibrated with an attribute called UphillMeters
  - The number of meters uphill (not including downhill) along an edge
  - This is a directional impedance attribute

- The network can now be used for finding suitable paths for different modes such as bicycles, pedestrian, wheel chair, etc
Using Slope

- Having the slope of the line is not enough!
- Slope is directional, so need a bi-directional attribute
- Also, slope is too coarse by itself
### Computed 3D Line Attributes

A screenshot of a software interface showing the attributes of a line. The identified line has the following attributes:

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>FT_Weekday</td>
<td>24</td>
</tr>
<tr>
<td>FT_WeekdayMinutes</td>
<td>0.23575</td>
</tr>
<tr>
<td>FT_Weekend</td>
<td>25</td>
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<tr>
<td>FT_WeekendMinutes</td>
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<td>Shape_Length</td>
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<td>Z_Min</td>
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<td>Z_Max</td>
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<td>Z_Mean</td>
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<td>Length3D</td>
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<tr>
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<td>Max_Slope</td>
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<td>Vertex_Ctr</td>
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<td>AvgSlopeDirection</td>
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<tr>
<td>TF_Uphill</td>
<td>13.1322</td>
</tr>
</tbody>
</table>

Identified 1 feature.
**Attributes for 3D routing**

![Network Identify](image)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Along</th>
<th>Against</th>
</tr>
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<tbody>
<tr>
<td>Source</td>
<td>Streets3D</td>
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<tr>
<td>Oneway</td>
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<td>WeekdayFallbackTravelTime</td>
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<tr>
<td>WeekendFallbackTravelTime</td>
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<tr>
<td>Meters3D</td>
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<tr>
<td>Slope</td>
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<tr>
<td>UphillMeters</td>
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<tr>
<td>MaxUpHillSlope</td>
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</tr>
<tr>
<td>MaxDownHillSlope</td>
<td>Traversable</td>
<td>Traversable</td>
</tr>
</tbody>
</table>
Parameterized Slope Attribute

- MaxUphillSlope
  - a restriction with a parameter set to 20 percent

- MaxDownHillSlope
  - a restriction with a parameters set to -20 percent

- The network can now be used for finding paths restricted to a specified maximum slope such as 15%
Shortest Paths with slope restriction
Future work

• 10 meter accuracy is too coarse when finding paths for people with disabilities

• Lidar data can be used for more 3D accuracy
  – 0.3 meter resolution
  – Presents a new set of challenges in assigning 3D coordinates to the roads (e.g., bridges and ramps)
  – Larger data volumes
3D Calibrating issues with Lidar
Limited mobility applications

- People with limited mobility may use wheelchairs or scooters to get around.
- A network with more attribution than 3D geometry is needed:
  - Curb cuts
  - Cross-walks
  - Divided roads
  - Building ramps
How far can I go on “electricity”
1, 2, 3 Miles Driving reach

[Map of the San Francisco area highlighting a 1, 2, 3 miles driving reach]
0.1, 0.2, 0.3 KwH Driving reach
Conclusion

• Terrain can be used to calibrate road networks with true 3D coordinates
  – Additional attributes can be derived to make effective use of the additional 3D information
• Routing applications can be developed to
  – Minimize slope (e.g., trucking – minimize fuel)
  – Minimize uphill (e.g., running/bicycle – minimize effort)
  – Electric car’s range anxiety can be dealt with
• More work needed to calibrate large scale networks