MWGen: A Mini World Generator

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Problem Description

- Moving objects with transportation modes
  - Inferring outdoor transportation modes from GPS data [1,2,3]: Geolife Project in Microsoft
  - Advanced trip planning [4], different modes (e.g., $Walk \rightarrow Bus$) and constraints (e.g., less than two bus transfers)

Problem Description

- Example trips
  1. *Indoor* → *Walk* → *Car*
  2. *Bus* → *Walk* → *Indoor*

- Global Work: Represent and manage moving objects with different transportation modes in a database system and provide efficient query processing.
Problem Description

- The goal: Generating moving objects in different environments where (1) the precise location in each environment and (2) transportation modes are managed.

- Existing data generators for moving objects
  1. free space: GSTD [1], BerlinMOD [2]
  2. road network: [3]
  3. indoor: [4]

Method

1. Preliminary
2. Framework
3. Trip plannings
4. Moving objects generation
5. Experimental results
Available environments

1. Road Network
2. Region-based Outdoor
3. Bus Network and Metro Network
4. Indoor

Transportation modes

\[ TM = \{Car, Taxi, Bike, Walk, Bus, Metro, Indoor\} \]
Data representation (location and moving objects)

1. \( D_{\text{genloc}} = \{(oid, (loc_1, loc_2)) | oid \in D_{\text{int}}, loc_1, loc_2 \in D_{\text{real}}\} \)

2. \( mo = <u_1, u_2, ..., u_n> \) where \( u_i = (t, gl_1, gl_2, m) \), \( gl_1, gl_2 \in D_{\text{genloc}}, m \in D_{\text{TM}} \)

\( mo = <u_1(t_1, \text{Indoor}_\text{loc1}, \text{Indoor}_\text{loc2}, \text{Indoor}), ..., u_i(t_i, \text{Pave}_\text{loc1}, \text{Pave}_\text{loc2}, \text{Walk}), ..., u_n(t_n, \text{Road}_\text{loc1}, \text{Road}_\text{loc2}, \text{Car})> \)
Method - Framework

- **Framework**

**MWGen Workflow**

- **Input:**
  1. a set of roads represented by lines
  2. floor plans
  3. parameters such as road width

- **Output:**
  1. Environments: Road Network, Region-based Outdoor, Bus Network, Metro Network, and Indoor
  2. Moving objects with multiple transportation modes such as *Indoor → Walk → Bus → Walk*
Method - Framework

roads \rightarrow \text{Road Network}

\text{Region-based Outdoor}

roads + parameters \Rightarrow \text{Bus Network}

\text{Metro Network}

floor plans \rightarrow \text{Indoor}

1. Road Network: roads and junctions
2. Region-based Outdoor: pavements and zebra crossings
3. Bus and Metro Network: routes, stops and moving buses (metros)
4. Indoor: rooms, corridors, staircases and doors.
Method - Framework

\[ \text{roads} \rightarrow \text{Road Network} \]
\[ \text{Region-based Outdoor} \]
\[ \text{roads} + \text{parameters} \Rightarrow \text{Bus Network} \]
\[ \text{Metro Network} \]
\[ \text{floor plans} \rightarrow \text{Indoor} \]

- An Environment
  1. the object set
  2. indices (B-tree and R-tree)
  3. a graph for routing

- Space
  1. managing each environment
  2. location mapping (e.g., bus stop)
  3. an interface between moving objects and underlying geographic objects such as roads, bus routes and rooms
Trip Planning

- One environment:
  1. shortest path searching in a road network
  2. shortest path searching for pedestrians (a large polygon with obstacles)
  3. routing in a bus network (combine bus and walk movements);
     routing in a metro network
  4. indoor navigation (precise path inside a building)

Time Complexity Analysis

- Multiple environments (graphs and location mapping):
  1. Indoor $\rightarrow$ Walk $\rightarrow$ Car $\rightarrow$ Walk
  2. Walk $\rightarrow$ Bus $\rightarrow$ Walk $\rightarrow$ Indoor
Moving Objects Generation: paths + speed values

- Car
- Walk
- Indoor

Graph showing
- X-axis: X
- Y-axis: Y
- T-axis: T
- Roads
- Walking areas
- Buildings
Method - Experimental Results

Results

Input

<table>
<thead>
<tr>
<th>Roads</th>
<th>Berlin (3,250); Houston (4,575)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor plans</td>
<td>office building, shopping mall, university... (8 in total)</td>
</tr>
<tr>
<td>Parameters</td>
<td>road width, pavement width, etc.</td>
</tr>
</tbody>
</table>

Output

<table>
<thead>
<tr>
<th></th>
<th>Berlin</th>
<th>Houston</th>
</tr>
</thead>
<tbody>
<tr>
<td>X Range</td>
<td>[0, 44411]</td>
<td>[0, 133573]</td>
</tr>
<tr>
<td>Y Range</td>
<td>[0, 34781]</td>
<td>[0, 163280]</td>
</tr>
<tr>
<td>No. Vertices in $P$</td>
<td>116,516</td>
<td>437,279</td>
</tr>
<tr>
<td>Bus Routes</td>
<td>89</td>
<td>92</td>
</tr>
<tr>
<td>Metro Routes</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>Buildings</td>
<td>4,996</td>
<td>5,992</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Berlin</th>
<th>Houston</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trip No.</td>
<td>Time (h)</td>
<td>Size (GB)</td>
</tr>
<tr>
<td>4k</td>
<td>0.32</td>
<td>0.052</td>
</tr>
<tr>
<td>500k</td>
<td>39.75</td>
<td>6.35</td>
</tr>
</tbody>
</table>

Moving objects with different transportation modes:

Walk + Indoor + Car (Taxi, Bus, Metro)
### Time Cost (sec) for Outdoor Trip Planning

<table>
<thead>
<tr>
<th></th>
<th>Berlin</th>
<th>Houston</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region-based Outdoor</td>
<td>0.78</td>
<td>2.4</td>
</tr>
<tr>
<td>Bus Network</td>
<td>0.13</td>
<td>0.23</td>
</tr>
<tr>
<td>Metro Network</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
</tr>
</tbody>
</table>

### Time Cost (sec) for Indoor Navigation

<table>
<thead>
<tr>
<th>Location</th>
<th>Berlin</th>
<th>Houston</th>
</tr>
</thead>
<tbody>
<tr>
<td>officeA</td>
<td>0.25</td>
<td>0.27</td>
</tr>
<tr>
<td>mall</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>hotel</td>
<td>1.57</td>
<td></td>
</tr>
<tr>
<td>university</td>
<td>0.123</td>
<td></td>
</tr>
<tr>
<td>cinema</td>
<td></td>
<td>0.32</td>
</tr>
<tr>
<td>hospital</td>
<td></td>
<td>0.35</td>
</tr>
<tr>
<td>trains station</td>
<td></td>
<td>0.1</td>
</tr>
</tbody>
</table>
Berlin: Pavements

Method - Experimental Results
Berlin: Roads + Bus Routes
Berlin: Roads + Metro Routes
Berlin: A Close View (pavements, zebra crossings, bus routes, roads)
Method - Experimental Results
Conclusions

- **Conclusion**
  
  We developed a tool called MWGen that can

  1. create the following environments road network, region-based outdoor, bus network, metro network, and indoor based on roads and floor plans;
  2. provide trip plannings in one environment and multiple environments;
  3. generate moving objects with multiple transportation modes based on the result of trip plannings.

- **Future Work**
  
  1. Creating moving objects by considering human movement patterns such as home↔work, work↔work, nearest neighbor searching.

- **Transportation Mode Web Page:**
  
  http://dna.fernuni-hagen.de/secondo/TransportationMode/TM.html
Thank you!