Dynamic delivery of geospatial data to mobile devices

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Citizens require up-to-date spatial data!

It is difficult for traditional raster-based map services to provide map tiles in a dynamic manner since the updating of the whole database is time consuming.
The cartographic quality of many web based maps are sometimes disappointing.

Overloaded with location information, geotag and symbol

Too complicated to read and understand
The workflow and drawbacks for traditional tile based map

Static GIF or JPEG tile maps

Raster-based grid Retrieval

Update the whole database

Very large tile based geospatial database

Semantic objects are reduced to an incoherent bunch of pixels

Inefficient spatial queries of spatial objects

Time consuming compiling results in out of date data
A dynamic framework for real time processing of geospatial data

- Vector-based map
- Openstreetmap xml data
- Dynamic visualization
- On the fly Generalization
- Streaming process
- progressive transmission
Generalization of OpenStreetMap data

For the small screen of mobile device

- Lower detail and less points is enough
- Delivers map visualizations more efficiently

OpenStreetMap is a case study
Stream vector-base geospatial data from OSM
Progressive transmission

--- Waiting a short time to get initial dataset and then gradually transmit additional levels of detail.

However, there are several issues:
• Processing the whole dataset will cost time and can not be used for dynamic data (such as VGI)
• Mobile screens are often too small to represent all detail, some details do not adapt to the low resolution
• User requirements for the location context vary over the time
Literatures Review

- Longin Jan Latecki and Rolf Lakaamper *Convexity Rule for Shape Decomposition Based on Discrete Contour Evolution* Computer Vision and Image Understanding.
- Rosemarijn Looije, Guido M Te Brake, Mark A Neerincx *Usability engineering for mobile maps* Volume: 07, Publisher: ACM Press, Pages: 532-539.
ASSUMPTIONS

1. Only a small area of OSM XML processed (<1km²)

2. We do NOT write our own generalization technique
   {Douglas Peucker, Latecki Method}

3. OSM is very dynamic - static tile-based approaches are very slow

4. Feature representation in OSM is very variable in some regions

5. A mobile device is the target for visualization (Android platform)

6. Only Open Source software/libraries are considered
Our model + data structure for progressive transmission

Application Process
- User Selects the OSM in a small area
- Streaming OSM XML data by OSM API
- Process Data based on Opensource XML Tool
- Deliver increasing Levels of details (LoD) to LBS
- Reduced map visualization with progressive transmission

Figure 2: Schematic diagram of the implementation of our progressive transmission model.
We use shape representation and complexity measure to guide processing.

Request vector data for current location

Partly over-detailed representation

Simplified version as temporary work datasets

Should Undergo Simplification
Using Complexity score and kmean to guide simplification

Kmean=0.05800859  
N=77  
(C,A):  
Circularity=0.861512427  
Area Ratio=0.011622088  

Simple  
Simplify  
(Over-represented)
Over-representation of polygons/lines is common in spatial data management.

Version A (360 Nodes)

Version B (765 Nodes)

Area difference < 1%
**Complexity Measurements**

For Polygon

**Circularity, Area Ratio** (convex hull, Perimeter Ratio) L. J.

**K-mean( )** Refer to: Latecki and R. Lakmper.

Convexity rule for shape decomposition based on discrete contour evolution.

For Polyline

**DP**: Refer to: Douglas Paucker algorithm

We found polygons which contains large number of vertices. However, only a few of these vertices are really significant to describe the overall shape when progressively adding the details

--- Y. Fangli el. Paper in ACM SIGSPATIAL GIS 2010
The large and complex objects get more details during selective progressive transmission procedure

<table>
<thead>
<tr>
<th>R20%</th>
<th>R40%</th>
<th>R60%</th>
<th>R80%</th>
<th>Full detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPa = 13 nodes;</td>
<td>NPa = 80 nodes;</td>
<td>NPa = 291 nodes</td>
<td>NPa = 337 nodes</td>
<td>NPb = 103 nodes</td>
</tr>
<tr>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
<td><img src="image4" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td>NPb = 11 nodes</td>
<td>NPb = 11 nodes</td>
<td>NPb = 13 nodes</td>
<td>NPb = 103 nodes</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R20%</th>
<th>R40%</th>
<th>R60%</th>
<th>R80%</th>
<th>Full detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPa = 11 nodes;</td>
<td>NPa = 21 nodes</td>
<td>NPa = 111 nodes</td>
<td>NPa = 281 nodes</td>
<td>NPb = 103 nodes</td>
</tr>
<tr>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
<td><img src="image7" alt="Image" /></td>
<td><img src="image8" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td>NPb = 11 nodes</td>
<td>NPb = 13 nodes</td>
<td>NPb = 16 nodes</td>
<td>NPb = 20 nodes</td>
<td></td>
</tr>
</tbody>
</table>

\[ Npa = \text{number of vertices in larger blue polygon}; \quad Npb = \text{number of vertices in smaller blue polygon}; \quad \text{Number of polygonal objects} = 43 \]
**Initial conceptual performance of progressive transmission and full detail transmission**

- **The full detail**: if always send the full data, the loading time will be quite long.
- **LoD** can send progressively, users can stop the refinement at any time when sufficient details have been provided.
- **Initial version detail**: send immediately.

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**Generalization Process time**

- **Case1** with 200 nodes
- **Case2** with 600 nodes
- **Case3** with 1500 nodes

---

**Data amount**

**Time**
Example of Progressive transmission on mobile phone

Gradually add detail to the display until the users’ requirements are met.
An initial example of Html5 version

23427555

HTML 5 Canvas rendering example for real time XML data
Experimental Setup of user satisfaction test

- The 10 datasets selected include single polygon datasets and multi-polygon datasets.

- Users were given 10 sample maps in five levels, a ten point rank scale was used in the questionnaire from (1 - “strongly disagree with the representation” to 10 - “strongly satisfied with the map”).

- We ran our progressive transmission software for 10 input datasets. To ensure each user evaluated the same level $L_k$ of the map we configured our client software to pause at 5 distinct levels.
Over-represented example – users liked all versions of the map

Final (mean score 7.9 out of 10)

Reduced by 40% (8.0 out of 10)

Reduced by 80% (8.1 out of 10)
Under-represented – users did not like over simplified maps

Final (mean score 8.6 out of 10)

Reduced by 40% (6.5 out of 10)

Reduced by 80% (2.5 out of 10)
Results

Table 1: This table outlines the mean of all user scores for each level Li of each of the 10 map datasets used in the user trials

<table>
<thead>
<tr>
<th>Set</th>
<th>Final</th>
<th>R20</th>
<th>R40</th>
<th>R60</th>
<th>R80</th>
</tr>
</thead>
<tbody>
<tr>
<td>C42</td>
<td>8.5</td>
<td>7.6</td>
<td>7.9</td>
<td>4.4</td>
<td>3</td>
</tr>
<tr>
<td>D14</td>
<td>8.6</td>
<td>7.2</td>
<td>5.3</td>
<td>3.9</td>
<td>3</td>
</tr>
<tr>
<td>N1</td>
<td>8.6</td>
<td>8.5</td>
<td>6.5</td>
<td>4.1</td>
<td>4.2</td>
</tr>
<tr>
<td>N2</td>
<td>8.2</td>
<td>7.3</td>
<td>5.9</td>
<td>3.8</td>
<td>3.2</td>
</tr>
<tr>
<td>N3</td>
<td>8</td>
<td>7.7</td>
<td>5.9</td>
<td>3.7</td>
<td>3.2</td>
</tr>
<tr>
<td>N4</td>
<td>7.9</td>
<td>8</td>
<td>8.2</td>
<td>8.1</td>
<td>8.1</td>
</tr>
<tr>
<td>N6</td>
<td>6.3</td>
<td>6.2</td>
<td>5.1</td>
<td>3.9</td>
<td>3.1</td>
</tr>
<tr>
<td>N7</td>
<td>7.9</td>
<td>7.9</td>
<td>8</td>
<td>6.4</td>
<td>3.9</td>
</tr>
<tr>
<td>R16</td>
<td>6.1</td>
<td>6.2</td>
<td>4.9</td>
<td>3</td>
<td>2.2</td>
</tr>
<tr>
<td>R50</td>
<td>6</td>
<td>4.7</td>
<td>4.1</td>
<td>3.2</td>
<td>2.3</td>
</tr>
</tbody>
</table>

• For single polygon examples, a low number of nodes used to represent the polygon, these shapes lose their shape characteristics quickly.

• For multi-polygons the satisfaction with the maps at different levels of refinement are more spread out.
Results

Table 2: This table outlines the standard deviation of all user scores for each level Li of each of the 10 map datasets used in the user trials

<table>
<thead>
<tr>
<th>Set</th>
<th>Final</th>
<th>R20</th>
<th>R40</th>
<th>R60</th>
<th>R80</th>
</tr>
</thead>
<tbody>
<tr>
<td>C42</td>
<td>1.27</td>
<td>1.90</td>
<td>1.37</td>
<td>1.58</td>
<td>0.94</td>
</tr>
<tr>
<td>D14</td>
<td>1.07</td>
<td>1.23</td>
<td>2.06</td>
<td>1.85</td>
<td>1.15</td>
</tr>
<tr>
<td>N1</td>
<td>0.97</td>
<td>1.18</td>
<td>1.35</td>
<td>1.45</td>
<td>2.04</td>
</tr>
<tr>
<td>N2</td>
<td>1.03</td>
<td>2.11</td>
<td>0.32</td>
<td>1.69</td>
<td>1.14</td>
</tr>
<tr>
<td>N3</td>
<td>1.25</td>
<td>0.48</td>
<td>0.99</td>
<td>1.70</td>
<td>1.99</td>
</tr>
<tr>
<td>N4</td>
<td>2.02</td>
<td>1.83</td>
<td>1.75</td>
<td>1.91</td>
<td>1.91</td>
</tr>
<tr>
<td>N6</td>
<td>2.26</td>
<td>2.04</td>
<td>1.20</td>
<td>1.37</td>
<td>2.08</td>
</tr>
<tr>
<td>N7</td>
<td>0.74</td>
<td>0.57</td>
<td>0.67</td>
<td>1.96</td>
<td>1.52</td>
</tr>
<tr>
<td>R16</td>
<td>1.52</td>
<td>1.75</td>
<td>1.37</td>
<td>1.83</td>
<td>1.14</td>
</tr>
<tr>
<td>R50</td>
<td>1.83</td>
<td>1.89</td>
<td>1.66</td>
<td>1.87</td>
<td>2.06</td>
</tr>
</tbody>
</table>

• However the standard deviations of these satisfaction ratings in table2 show a wide spread of scores for each level.

• This is potentially caused by the fact that these datasets are well represented (sufficient nodes).
Current work on location-aware selective progressive transmission

The **bold points** (which are connected in the graph) represent those hotels are dominated in terms of price and distance to the beach by at least one hotel which is part of the Skyline.

Such a Skyline could be useful for a travel agency; it helps users to get a big picture of the interesting options.

From the Skyline of locations, we progressively send more detail to interesting locations to help users make a quick decision and further details send later to refine their inquiries.
Progressive spatial queries of the interesting locations using online skyline computing

Nearest neighbor algorithm for progressive identification of skyline points
Grouping spatial context using skyline

However, for spatial related objects shown as below, if one shop is on the skyline but others are far away from skyline- the grouping must consider about the special case:

- **A**: expensive
- **B**: expensive
- **C**: cheap

**Skyline grouping**

Topological grouping
Conclusion

• In our experiments we attempted to quantify how satisfied users were with progressively-generated maps.

• Over represented examples exhibit greater user satisfaction at greater data reduction percentages. The generalised versions remove insignificant vertices from the polygons. But the polygons retain their overall structure.

• Initial results indicate a significant relationship between levels of detail (LOD) and usability of the corresponding progressively transmitted maps. Findings also show the potential use of shape complexity data metrics to improve the user experience of progressive transmission.
Future work

• **Additional user testing and statistics analysis**
  - Is there potential for user preference towards heavily generalised versions of the input dataset
  - OSM is an inhomogeneous dataset - testing with National Mapping Agency data.

• **Generalization Research and Integration of line features**
  - We are currently working on tests to include line features
  - We are investigating using web-services for generalisation (REF)

• **Map appearance and aesthetics**
  - The projection of the map on mobile display and the aspects of visual appearance, such as colour and texture, will also be considered
Open Discussion on Wireless Sensor Network

Potentially related topics:

- The latency of network or QoS means to progressive transmission over the wireless network.
- Location-aware skyline queries for sensor network distribution.
- Low power cost strategy with selective progressive sampling for large scale structural health monitoring (SHM).

Ying, F. and Mooney, P. and Corcoran, P. and Winstanley, A.C. **How little is enough? Evaluation of user satisfaction with maps generated by a progressive transmission scheme for geospatial data** In proceedings of the 14th AGILE International Conference on Geographic Information Science, Utrecht, The Netherlands, April 18-21, 2011


