Analysis .vs. Documentation -

A Comparison of Complementary Geographical Tasks

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1. Introduction

Although interactive map applications are sometimes called geographic information systems (i.e., GIS) and they both manipulate and display spatial data, there are important distinctions between interactive maps which are primarily for geographical documentation, and geographic information systems which are primarily for geographical analysis. Tools for geographical analysis are general purpose and necessarily complex, while tools for geographical documentation are task specific and simple. Further illustrating this complementary relationship, typical analysis/documentation tools access atomized/integrated spatial data that is multimedia sparse/rich, spans a large/small geographic area, is described by integrated/atomized metadata, and is indirectly/directly modified by users with significant/insignificant training.

In addition to comparing geographical analysis and geographical documentation, this paper suggests the use of

- SVG (Scalable Vector Graphics) and GML (Geography Markup Language) as the common format for geographical documentation,
- RDF (Resource Description Framework) to directly link geographical documentation elements to their source data to promote automated updates of geographical documentation, and
- FDL (Free Documentation License) as a license that puts spatial information in the public domain while not dictating any change to the author’s ownership wishes concerning content (e.g., Web pages and audio).

2. Geographical Documentation

'All maps are local' is a variant of the late Speaker of the House Tip O'Neil's generalization of politics. It is hard to imagine a local group that does not have unique requirements for their geographical documentation. Even if geographical documentation is compiled at the national level, localities modify it according to their needs. For example, the U.S. Census Bureau compiles data about the nation's road system. However that data does not include road restrictions (e.g., weight limit, horizontal and vertical clearance) needed by U.S. states when issuing oversize/overweight load transportation permits. As another example, the U.S. Geological Survey's Center for Biological Informatics compiles geographical data concerning the nation's invasive species. However that data is not detailed enough at the local level to assist parks and recreation departments in implementing a species management policy. In these and many other examples, the salient requirement of geographical documentation is extendibility.

Characteristics that promote the creation and use of extendible geographical documentation are listed below. Notes on implementation of geographical documentation using SVG (Scalable Vector Graphics), GML (Geography Markup Language), RDF (Resource Description Framework) and FDL (Free Documentation License) are included to put the characteristics in the realm of practice rather than conjecture.

1. <u>Protection against IP claims</u> – Intellectual Property claims are barriers to extending geographical documentation. The use of copyrights to promote sharing and extending information is already a successful practice in open source software development but it has not yet been widely applied to geographical documentation.

Implementation note: The GNU FDL (Free Documentation License) [4] seems to be a good fit for geographical documentation. From the FDL, its recommended use is for instruction or reference material. The full FDL is listed in Appendix C.

2. <u>Standard formats</u> – Standard data formats are a prerequisite to sharing and extending information.

Implementation note: SVG (Scalable Vector Graphics) [5] is an application of XML (eXtensible Markup Language) defined by W3C (World Wide Web Consortium). A sample SVG document is listed in Appendix D. Note that the location information is written in geographic coordinates (i.e., latitude and longitude) in a particular datum (e.g., NAD83). Upon presenting this data graphically, the <svg> element's viewBox attribute and the <g> element's transform attribute instruct the SVG viewer application to transform the coordinates to an equidistant cylindrical projection. This is a "just in time" projection strategy similar to the U.S. Geological Survey's move to 'seamless' geographical data. Geographic coordinates enable cartographers to easily cut and paste data among maps that employ different map projections.

SVG documents are as easy to post as HTML documents. No map servers are necessary, because each client performs its own map processing.

Also note how the SVG elements can be extended with the <metadata> element. The GML (Geography Markup Language) schema supports the inclusion of geography specific information in the SVG document.

3. <u>Widely available documentation tools</u> – The Web browser has become the documentation tool of choice. Geographical documentation does not require anything different. Some additional geographical documentation tools might be convenient, but they must defer to the central role of the Web browser.

Implementation note: There has been talk of an SVG viewer being built into the major browsers. Currently, however, these browsers require a plug-in to view SVG documents. Adobe offers a free SVG viewer plug-in. [6]

4. <u>Document management tools</u> – Integrating changes to geographical documentation from a variety of sources having various levels of accuracy is a mundane but crucial task.

Implementation note: The W3C has also defined RDF (Resource Description Framework) [7] that can be metadata linking SVG elements to their source data, promoting automation of geographical documentation updates. The open source software development community has developed tool chains to assist with managing the integration of frequent contributions from a variety of sources of varying quality. A similar open source map tool chain would be an important development to geographical documentation. CVS (Concurrent Version System) [8] is a version control utility that could be common to both open source software and SVG documents. To CVS, text is text regardless of whether it is source code or an SVG document.

5. Support – Creating geographical documentation is a multidisciplinary task that might involve surveying, cartography, Web page authoring, audio recording/editing, video recording/editing, system administration, debugging, and analysis skills. Ideally, the people with the geographical expertise are the people creating the geographical documentation.

Implementation note: A moderated on-line discussion with their peers following a class-like itinerary seems like it would be a low cost and effective way to provide support to people creating geographical documentation.

6. Resolution – Improved location resolution increases the applicability of geographical documentation. For example, the geographical documentation for a botanical garden requires resolution sufficient to uniquely locate each specimen.

Implementation note: The geographic coordinate horizontal resolution of the SVG document listed in Appendix D is 1.0E-7 degrees (i.e., 1.1 cm or 0.44 inches). The vertical resolution is 0.2 meters.

7. Multimedia – The major Web browsers are capable of playing multimedia content, which is suitable for geographical documentation as well.

Implementation note: The tags that link elements in HTML documents to multimedia files, do the same in SVG documents.

8. Multi-dimensional filtering – Most interactive maps are capable of filtering points of interest according to category (e.g., show all the Italian restaurants) and location (e.g., show all the Italian restaurants within five miles of current location). However interactive map users would benefit by expanded filtering capabilities. For example, a botanical map might offer these filtering options.

- location (x, y, z)
- time (e.g., show flowers that are currently in bloom)
- tag (e.g., a specimen)
- type (e.g., show only species/genus/family/order/class/phylum/kingdom)
- theme (e.g., show plants with known medicinal uses)
- target (e.g., show only the documentation written for children ages 10-13)
- technique (e.g., show only the documentation that has an audio component)
- tour (e.g., show plants which are part of the "local history of American Indians" tour)

Implementation note: Metadata elements in the documentation define the filtering data. When implemented on a Palm handheld, I compiled the filtering data into lookup tables to avoid slow searches through documents.

9. Multi-skill user interface – A major barrier to the acceptance of geographical documentation in museums has been the user interface. Because training sessions for museum visitors are impractical, user interface simplicity is paramount. On the other hand, users familiar with the application may want more capabilities and therefore a more complex user interface. To cover this range of users a geographical documentation viewer application should have different user interface modes.

Implementation note: Sony handheld computers have a promising user interface device: the jog dial. Controlled by just one finger, it is similar to a volume adjustment dial, but it is also a pushbutton. I have implemented a prototype slide show viewer that is controlled entirely by the jog dial. Rolling the dial forward/backward advances/reverses the slide show, and pressing the dial starts/pauses it. I am hopeful that museum visitors would find this one-finger operation intuitive after a brief (e.g., 10 second) demonstration.

3. Comparison of Geographical Analysis and Geographical Documentation

characteristic	geographical analysis	geographical documentation
data size	typically large	typically small
data orientation	atom-oriented data object-oriented metadata	object-oriented data atom-oriented metadata
data modification	Indirect	direct
multimedia support	Sparse	rich
required user expertise	significant	insignificant

3.1 Data Size

Geographical analysis tools can gather large amounts of geographic data from many sources. Geographic documentation typically focuses on local information, and therefore typically requires less geographic data.

3.2 Data Orientation

To efficiently access large amounts of geographic data, geographical analysis tools use database strategies that atomize geographic information into small pieces dispersed among many tables. The result is efficient machine access but inefficient human access due to the tedious nature of mentally traversing the database tables to integrate the small pieces of geographic information into a recognizable object, such as a road. In geographical documentation, the geographic information is integrated into recognizable objects in a text format.

For geographical analysis, metadata is often applied to the map data as a whole (e.g., all location measurements in a map abiding by a single horizontal location accuracy specification, such as a 95% confidence interval of 15 meters). In geographical documentation, in order to promote small but frequent improvements in map accuracy, metadata is applied to individual map components. With atomized metadata, further acquisition effort can be applied where it is most needed (e.g., along a stretch of trail that has particularly inaccurate measurements).

3.3 Data Modification

When geographical information consists of recognizable objects in text form, people can modify it with just an ordinary text editor as opposed to a specialized utility.

3.4 Multimedia Support

Although the result of geographical analysis is typically text interspersed with still pictures, geographical documentation can be presented as a combination of text, still pictures, audio and video. However in most cases moderation is the key, especially when a user is viewing geographical documentation at the actual site of interest (e.g., the grounds of a historical house). On site, the documentation should enhance the user's connection with the site rather than distract from it. A good metric for the presentation quality of on-site documentation is the percentage of time it doesn't occupy the user's senses. So if a user has to look at a presentation all the time, that presentation scores zero. Using this metric, an entirely audio presentation is best. Or if pictures are necessary, a slide presentation should beep or momentarily vibrate with each new slide to allow the user to look at the site most of the time and only briefly look at new slides as they appear.

3.5 Required User Expertise

Creating geographical documentation is similar to creating Web pages, a common skill. The expertise required for geographical analysis is significantly greater, as ESRI's (Environmental Science Research Institute) "time and materials rate schedule" illustrates; [9] their GIS consulting fees are as high as $279 per hour.

4. Objections to SVG/GML/RFD/FDL Geographical Documentation

4.1 Inefficient

Using the SVG format for geographical documentation will result in extremely large files. Writing out the complete latitude and longitude values for every geographical coordinate is particularly wasteful.

It may seem wasteful, but transparency is often helpful. And if file sizes become overwhelming, gzip compression is an option because SVG viewers also accept gzip compressed SVG files (i.e., SVGZ). Most compression algorithms, including gzip, excel at compressing duplicate strings such as the most significant portions of close latitude and longitude values. For comparison, the tables below show the sizes of U.S. Census Bureau TIGER line files, and the SVG as well as the SVGZ files created from them.

1,181,970	11/25/02	4:14p	TGR51680.RT1
295,050	11/25/02	4:14p	TGR51680.RT2
39,420	11/25/02	4:14p	TGR51680.RT4
73,022	11/25/02	4:14p	TGR51680.RT5
7,566	11/25/02	4:14p	TGR51680.RT6
380	11/25/02	4:14p	TGR51680.RT7
322,240	11/25/02	4:14p	TGR51680.RTA
5,952	11/25/02	4:14p	TGR51680.RTC
170,496	11/25/02	4:14p	TGR51680.RTH
662,931	11/25/02	4:14p	TGR51680.RTI
71,440	11/25/02	4:14p	TGR51680.RTP
234	11/25/02	4:14p	TGR51680.RTR
258,400	11/25/02	4:14p	TGR51680.RTS
177,380	11/25/02	4:14p	TGR51680.RTT
100,380	11/25/02	4:14p	TGR51680.RTZ
3,366,861	bytes		15 file(s)

964,309	1/12/04	9:20p	bwc.road.t.svg
59,239	1/12/04	9:21p	bwc.hydro.t.svg
21,872	1/12/04	9:20p	bwc.rail.t.svg
14,302	1/12/04	9:21p	bwc.pipe.t.svg
4,826	1/12/04	9:21p	bwc.power.t.svg
1,064,548	bytes		5 file(s)

89,773	1/13/04	5:37p	bwc.road.t.svgz
7,384	1/13/04	5:37p	bwc.hydro.t.svgz
3,638	1/13/04	5:37p	bwc.rail.t.svgz
1,672	1/13/04	5:37p	bwc.pipe.t.svgz
1,124	1/13/04	5:37p	bwc.power.t.svgz
103,591	bytes		5 file(s)

Integrating the atom-oriented data used by geographical analysis into an object-oriented form for geographical documentation forfeits the speed advantages offered by spatial indexing.

Yes, the spatial indices in database tables are lost in the conversion from atomized data to integrated data. Fortunately spatial indices are easy to recreate and store in spatial lookup tables (i.e., R-tree and intersection indices) that reference into segments of the integrated data. I used this 'spatial lookup table into integrated object' approach in the implementation of a directed graph library that turned out to be faster than the directed graph implementation in the popular GRASS GIS. To be fair, I suspect the 'spatial lookup table into integrated object' approach is much slower in accommodating graph changes, but prompt handling of infrequent geographical documentation changes is unnecessary.

4.2 Incomplete

What about surveying/acquisition applications and other map creation applications?

To promote geographical documentation, acquisition and map creation applications should be inexpensive (preferably no charge), easy to use, and eclectic in the sense that they should be part of a system that anticipates a wide range of data quality and is able to choose the best or judiciously weight calculations on the aggregate.

I have developed three acquisition and map creation applications, for use with the Palm, Windows, or Linux OS (Operating System). All are presently stable prototypes; that is they contain no known design or implementation errors, but their designs are simplified for testing concepts rather than hardened for distribution and support.

	ODE (Outdoor Data Entry)	Pathman	DGW (Directed Graph Wizard)
Description	a Palm OS application that interfaces to a Web browser displaying a user defined HTML form and that stores the entered information along with geographic information and quality assessment data when the user 'submits' the form	a PalmOS application in conjunction with a PC (Windows or Linux OS) application that averages multiple acquisitions of path data to increase the accuracy of the path's location information	a PC (Windows OS) application that assists with the task of conflating disparate sources of map data
Purpose	1) reduce field-data entry keystrokes 2) automatically acquire quality assessment data	extend the averaging techniques commonly used on point data so that they can also be used on path data	increase the automation of creating SVG/FDL base maps
Expense	no charge	no charge	unavailable
Easy to Use	Yes, the user sees just an ordinary HTML form with some combination of input text fields, push buttons, check boxes and selection lists. And it is easy for the user to open a different form that suites the data entry task, so forms can be very task specific and short, rather than general and long.	There is no graphical user interface. It is a command line utility, forfeiting a graphical user interface for multi-OS (Windows or Linux OS) capability.	No. There is a graphical user interface, but it seems the nature of the task prevents total automation and requires some (presumably less as the application evolves) manual intervention.
Eclectic	Yes. Based upon hidden fields in the user designed HTML form, ODE can automatically save data such as time, date, username, location, direction (assuming electronic compass is available), hardware configuration, GPS signal level, and GPS Dilution of Precision. All of which can be used in data quality assessment.	Yes. The Palm OS application logs GPS receiver NMEA (National Marine Electronics Association) messages, including GPS signal level and GPS Dilution of Precision information. In addition, the PC application requires a minimum of two acquisition-passes over each path (e.g., out and in) so repeatability is available for data quality assessment as well.	Yes. The present U.S. Census Bureau map data is labeled well, but with poor location accuracy. The present U.S. Geological Survey DLG (Digital Line Graph) and DOQ (Digital Orthophoto Quadrangle) and DEM (Digital Elevation Model) map data has better location accuracy, but poorer labeling, and it does not include the NOAA's (National Oceanic and Atmospheric Administration) bathymetry data.

Geographical documentation concerning a location is often most valuable when presented at that location. To accommodate this, geographical documentation viewer applications on portable devices are necessary. However there are so many varieties of portable devices, it seems that it would be difficult to support them.

Portable devices will play an important role in geographical documentation, especially when smartphones become more popular. Concerning a development strategy for the many varieties of portable devices, I think the buffet analogy holds.

In the buffet analogy, food (geographical documentation) is delivered to one table (delivered in one format). Then customers (platform-dependent applications) go to that table and take the food (geographical documentation) they want (they can present) and leave the rest. Therefore a $79 Palm PDA downloads the subset of the geographical documentation it can present, which is text, still pictures and vector maps.

There are a couple advantages to this one-format/many-conduits strategy.

- <u>It sets up a potential growth spiral.</u> A common format of geographical documentation simplifies the work of geographical documentation authors, which encourages more authors and results in more geographical documentation, which attracts more software developers and results in more supported hardware, which broadens the use of geographical documentation, which encourages more authors, ...

- <u>It promotes both cooperation and competition.</u> Developers cooperate by designing geographical documentation viewers that read a common format. And they compete because only the market imposes constraints on the features and prices of geographical documentation viewers.

4.3 Unfounded

What is the point in implementing centimeter resolution geographic coordinates when there is virtually no existing map data with that accuracy and surveying equipment with that accuracy is too expensive?

The centimeter location resolution is presently useful for defining relative positions among close objects (e.g., plants in a botanical garden) even though the absolute positions may have many meters of error.

It is likely carrier detection capabilities will soon extend beyond today's survey quality GPS receivers and be in consumer quality GPS receivers as well. Then, centimeter accuracy will become the norm, and so will geographical documentation with centimeter resolution.

4.4 Scalable Vector Graphics?

SVG is for 2D graphics. Why use it for geographical documentation, which is inherently 3D?

Although coordinates in SVG documents have just two dimensions (i.e., x and y), a third dimension (i.e., z or altitude) can be added in metadata, or it can be appended to the x or y coordinate. In my SVG implementation, I scaled the altitude to be a six digit integer with a resolution of 0.2 meters and with a range from –11050 meters (value 0) to 8949.8 meters (value 999999), covering the altitudes of the Earth's lowest and highest known surfaces (-11034 meters in the Pacific Ocean's Mariana trench and 8850 meters at Mount Everest). I appended the resulting integer to the y-coordinate. Because appending any number to the y-coordinate cannot change it more than the initial y-coordinate resolution, which is about one centimeter, the changes in the SVG viewer's presentation due to the extra y-coordinate digits are unperceivable. So why bother appending the z-component?

The primary motivation for using the SVG format is that it admirably handles the extendibility required by geographical documentation. The fact that high quality SVG viewers are available that can be controlled by JavaScript is a huge bonus, and I suspect that garden-variety SVG viewers will suffice in many geographical documentation tasks.

The OGC (Open GIS Consortium) has defined GML (Geography Markup Language) for defining geographic information. The transformation language of XSL (extensible Styles Language) automates the translation from GML to SVG. So why not save geographical documentation entirely in GML as opposed to using it to extend SVG?

The translation from GML to SVG complicates the implementation of SVG's interactive capabilities (e.g., JavaScript) and its graphics capabilities (e.g., filter effects).

Why vector maps? I prefer raster maps.

With SVG, raster and vector maps are not exclusive. Raster background(s) in an SVG map can be very useful.

4.5 Free Documentation License?

I don't want to lose ownership of the Web pages and multimedia content I create. How does the use of FDL in the SVG document affect the ownership of the Web pages and multimedia content in geographical documentation?

The Web pages and multimedia content are external to the SVG document. Just as linking to a Web page does not diminish its author's copyrights, the SVG document with the FDL does not diminish your copyrights to your Web pages or multimedia content by linking to them.

I don't want to lose ownership of the JavaScript code I write. How does the use of FDL in the SVG document affect the ownership of the JavaScript code?

As with the Web pages and the multimedia content, the JavaScript is external to the SVG document. Therefore the SVG document with the FDL does not diminish your copyrights to your JavaScript, but SVG and JavaScript source is easily viewed and that makes some developers uncomfortable. For those who embrace openness, GPL (the GNU General Public License) for the JavaScript and FDL for the SVG document seem to be the ideal combination for sharing geographical documentation.

What about geographical documentation I want to keep private? How does the use of FDL in the SVG document affect that?

Even though there is a requirement to retain the FDL in all derivative work, there is no requirement to publicly exhibit that derivative work. If you wish to keep your geographical documentation private, you keep it to yourself.

5. Conclusion

The proper use of "geographic" and "geographical" was not initially clear to me. The "-al" suffix implies a process or action (e.g., a seltzer bottle is a comic prop that is not comical unless used in a funny way). But I was not sure if action was what I wanted to imply until I read the derivation of the word 'documentation': documentum is the Latin term for lesson. So literally, the definition of geographical documentation is "lessons that promote the study of Earth, its features and its life."

I have suggested the use of

- SVG (Scalable Vector Graphics) and GML (Geography Markup Language) as the common format for geographical documentation,
- RDF (Resource Description Framework) to promote automated updates, and
- FDL (Free Documentation License) as a license that puts geographical documentation in the public domain while not dictating any change to the author's ownership wishes concerning content (e.g., Web pages and audio).

I hope the legal, design and implementation issues I have suggested form a framework solid enough to illustrate how geographical documentation can achieve its definition.

Appendix A. References

[1] http://www.ngdc.noaa.gov/seg/tools/gis/gisdefs.shtml
[2] http://www.geo.ed.ac.uk/home/research/whatisgis.html
[3] http://www.fgdc.gov/nsdi/docs/communications/final_gis.pdf
[4] http://www.gnu.org/licenses/licenses.html#FDL
[5] http://www.w3c.org/Graphics/SVG/
[6] http://www.adobe.com/svg/viewer/install/main.html
[7] http://www.w3.org/RDF/
[8] http://www.cvshome.org/
[9] http://www.in.gov/ingisi/intranet/esri_02/services.pdf

Appendix B. Glossary

CSS – Cascading Style Sheet
CVS – Concurrent Versions System
DEM – Digital Elevation Model (U.S. Geological Survey)
DG – Directed Graph
DGW – Directed Graph Wizard application
DLG – Digital Line Graph (U.S. Geological Survey)
DOQ – Digital Orthophoto Quandrangle (U.S. Geological Survey)
DTD – Document Type Definition
ESRI – Environmental Systems Research Institute
FDL – The GNU Free Documentation License
FGDC – Federal Geographic Data Center
GD – Geographical Documentation
GIS – Geographic Information System
GML – Geography Markup Language
GPL – The GNU General Public LIcense
GPS – Global Positioning System
GRASS – Geographical Resources Analysis Support System
NMEA – National Marine Electronics Association
NOAA – National Oceanic and Atmospheric Administration
ODE – Outdoor Data Entry application
OGC – Open GIS Consortium
OS – Operating System
PC – Personal Computer
PDA – Personal Digital Assistant
RDF – Resource Description Framework
SVG – Scalable Vector Graphics
SVGZ – Scalable Vector Graphics compressed by gzip
TIGER - Topologically Integrated Geographic Encoding and Referencing (U.S. Census Bureau)
W3C – World Wide Web Consortium
XML – eXtensible Markup Language
XSL – eXtensible Styles Language

Appendix C. GNU FDL

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Version 1.2, November 2002

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Appendix D. Sample SVG (Scalable Vector Graphics) Document

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<?xml-stylesheet type="text/css" href="style.css"?>

<svg viewBox="37.3329430 -79.2713490 0.1357970 0.1823730"
   preserveAspectRatio="xMidYMid"
   xmlns="http://www.w3.org/2000/svg"
   xmlns:xlink="http://www.w3.org/1999/xlink"
   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:gml="http://www.opengis.net/gml"
   xmlns:crs="http://www.ogc.org/crs"
   xmlns:gd="http://www.eduneer.com/gd"
   onload="initMap(evt)" onmousemove="showCoordinates(evt)" onresize="resetXform()"
onscroll="resetXform()" onzoom="resetXForm()" >

   <metadata>
      <rdf:RDF>
         <rdf:Description>
            <crs:CoordinateReferenceSystem transform="rotate(-90)"
                rdf:resource="http://www.example.org/srs/epsg.xml#4326"/>
         </rdf:Description>
      </rdf:RDF>
   </metadata>

   <title>bwc.road.t.svg</title>
   <desc>
      datum: NAD83
      projection: cylindrical equidistant
      sources:
         US Census Bureau TIGER (Topologically Integrated Geographic Encoding and Referencing)
         USGS SDTS (Spatial Data Transfer Standard) DLG (Digital Line Graphics)
   </desc>

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       Free Documentation License".
   -->

   <defs>
      <path id="GdRoads0000" d="
         M 37.4527630 -79.1899970
         L 37.4530200 -79.1912240
         L 37.4522920 -79.1921210
      "/>
      <path id="GdRoads0001" d="
         M 37.4061650 -79.1728990
         L 37.4061550 -79.1727040
         L 37.4061450 -79.1724120
         L 37.4061450 -79.1721680
         L 37.4061520 -79.1719190
      "/>
      <path id="GdRoads0002" d="
         M 37.4631410 -79.1933480
```

```
      L 37.4644290 -79.1931720
      L 37.4649710 -79.1930650
    "/>
    <path id="GdRoads0003" d="
      M 37.4446410 -79.2080480
      L 37.4433410 -79.2075480
      L 37.4424410 -79.2076480
    "/>
    <path id="GdRoads0004" d="
      M 37.4076250 -79.2152060
      L 37.4073340 -79.2157110
    "/>
    <path id="GdRoads0005" d="
      M 37.4061650 -79.1728990
      L 37.4062710 -79.1729350
      L 37.4063970 -79.1729230
      L 37.4065540 -79.1729190
    "/>

    <!-- path definitions removed for brevity -->

  </defs>

  <g transform=
    "translate(37.4008415,-79.1801625)
    rotate(-90)
    scale(1,0.7944057)
    translate(-37.4008415,79.1801625)" >

    <script type="text/ecmascript" xlink:href="gdsvg.js"/>

    <use xlink:href="#GdRoads0000" class="GdRoadsLocal" title="" >
      <metadata>
        <gd:road>
          <gd:classification>USCB 41</gd:classification>
        </gd:road>
      </metadata>
    </use>

    <use xlink:href="#GdRoads0001" class="GdRoadsLocal" title="" >
      <metadata>
        <gd:road>
          <gd:classification>USCB 41</gd:classification>
        </gd:road>
      </metadata>
    </use>

    <use xlink:href="#GdRoads0002" class="GdRoadsLocal" title="" >
      <metadata>
        <gd:road>
          <gd:classification>USCB 41</gd:classification>
        </gd:road>
      </metadata>
    </use>

    <!-- paths removed for brevity -->
    <use xlink:href="#GdRoads1529" class="GdRoadsLocal" title="Wyndale Dr" >
      <metadata>
        <gd:road>
          <gd:addressesLeft>
            399
            388
```

```
        368
        356
        301
        199
        0
      </gd:addressesLeft>
      <gd:classification>USCB 41</gd:classification>
    </gd:road>
  </metadata>
</use>
<text class="LblGdRoadsLocal">
  <textPath xlink:href="#GdRoads1529" id="LblGdRoads1529">Wyndale Dr</textPath>
</text>

<use xlink:href="#GdRoads1530" class="GdRoadsLocal" title="Wythe Rd" >
  <metadata>
    <gd:road>
      <gd:addressesLeft>
        0
        0
        1401
        1453
        1499
        1601
        1699
      </gd:addressesLeft>
      <gd:classification>USCB 41</gd:classification>
    </gd:road>
  </metadata>
</use>
<text class="LblGdRoadsLocal">
  <textPath xlink:href="#GdRoads1530" id="LblGdRoads1530">Wythe Rd</textPath>
</text>

<use xlink:href="#GdRoads1531" class="GdRoadsLocal" title="Yale St" >
  <metadata>
    <gd:road>
      <gd:addressesLeft>
        101
        143
        199
      </gd:addressesLeft>
      <gd:classification>USCB 41</gd:classification>
    </gd:road>
  </metadata>
</use>
<text class="LblGdRoadsLocal">
  <textPath xlink:href="#GdRoads1531" id="LblGdRoads1531">Yale St</textPath>
</text>

<use xlink:href="#GdRoads1532" class="GdRoadsLocal" title="Yancey St" >
  <metadata>
    <gd:road>
      <gd:addressesLeft>
        1401
        1536
        1599
      </gd:addressesLeft>
      <gd:classification>USCB 41</gd:classification>
    </gd:road>
  </metadata>
</use>
```

```
<text class="LblGdRoadsLocal">
   <textPath xlink:href="#GdRoads1532" id="LblGdRoads1532">Yancey St</textPath>
</text>

<use xlink:href="#GdRoads1533" class="GdRoadsLocal" title="Yeardley Ave" >
   <metadata>
      <gd:road>
         <gd:addressesLeft>
            499
            399
            301
            201
            101
         </gd:addressesLeft>
         <gd:classification>USCB 41</gd:classification>
      </gd:road>
   </metadata>
</use>
<text class="LblGdRoadsLocal">
   <textPath xlink:href="#GdRoads1533" id="LblGdRoads1533">Yeardley Ave</textPath>
</text>

<use xlink:href="#GdRoads1534" class="GdRoadsLocal" title="York St|N York St" >
   <metadata>
      <gd:road>
         <gd:addressesLeft>
            499
            438
            399
            299
            201
            199
            101
         </gd:addressesLeft>
         <gd:classification>USCB 41</gd:classification>
      </gd:road>
   </metadata>
</use>
<text class="LblGdRoadsLocal">
   <textPath xlink:href="#GdRoads1534" id="LblGdRoads1534">York St</textPath>
</text>

<use xlink:href="#GdRoads1535" class="GdRoadsLocal" title="Yorkshire Cir" >
   <metadata>
      <gd:road>
         <gd:addressesLeft>
            101
            111
            121
            131
            140
            148
            148
            155
            175
            189
            198
            199
         </gd:addressesLeft>
         <gd:classification>USCB 41</gd:classification>
      </gd:road>
   </metadata>
```

```
</use>
<text class="LblGdRoadsLocal">
   <textPath xlink:href="#GdRoads1535" id="LblGdRoads1535">Yorkshire Cir</textPath>
</text>

<use xlink:href="#GdRoads1536" class="GdRoadsLocal" title="Yorktown Ave" >
   <metadata>
      <gd:road>
         <gd:classification>USCB 41</gd:classification>
      </gd:road>
   </metadata>
</use>
<text class="LblGdRoadsLocal">
   <textPath xlink:href="#GdRoads1536" id="LblGdRoads1536">Yorktown Ave</textPath>
</text>

<use xlink:href="#GdRoads1537" class="GdRoadsLocal" title="Yorktown Ave" >
   <metadata>
      <gd:road>
         <gd:addressesLeft>
            2201
            2305
            2362
            2363
         </gd:addressesLeft>
         <gd:classification>USCB 41</gd:classification>
      </gd:road>
   </metadata>
</use>
<text class="LblGdRoadsLocal">
   <textPath xlink:href="#GdRoads1537" id="LblGdRoads1537">Yorktown Ave</textPath>
</text>

<use xlink:href="#GdRoads1538" class="GdRoadsLocal" title="Young Pl" >
   <metadata>
      <gd:road>
         <gd:addressesLeft>
            3501
            3539
            3563
            3599
         </gd:addressesLeft>
         <gd:classification>USCB 41</gd:classification>
      </gd:road>
   </metadata>
</use>
<text class="LblGdRoadsLocal">
   <textPath xlink:href="#GdRoads1538" id="LblGdRoads1538">Young Pl</textPath>
</text>

<use xlink:href="#GdRoads1539" class="GdRoadsLocal" title="Zenobia St" >
   <metadata>
      <gd:road>
         <gd:classification>USCB 41</gd:classification>
      </gd:road>
   </metadata>
</use>
<text class="LblGdRoadsLocal">
   <textPath xlink:href="#GdRoads1539" id="LblGdRoads1539">Zenobia St</textPath>
</text>

<use xlink:href="#GdRoads1540" class="GdRoadsLocal" title="Zenobia St" >
```

```
            <metadata>
                <gd:road>
                    <gd:classification>USCB 41</gd:classification>
                </gd:road>
            </metadata>
        </use>
        <text class="LblGdRoadsLocal">
            <textPath xlink:href="#GdRoads1540" id="LblGdRoads1540">Zenobia St</textPath>
        </text>


        <polyline class="GdGrid" points="
            37.350000000 -79.271349000
            37.350000000 -79.088976000
        "/>
        <polyline class="GdGrid" points="
            37.375000000 -79.271349000
            37.375000000 -79.088976000
        "/>
        <polyline class="GdGrid" points="
            37.400000000 -79.271349000
            37.400000000 -79.088976000
        "/>
        <polyline class="GdGrid" points="
            37.425000000 -79.271349000
            37.425000000 -79.088976000
        "/>
        <polyline class="GdGrid" points="
            37.450000000 -79.271349000
            37.450000000 -79.088976000
        "/>
        <polyline class="GdGrid" points="
            37.332943000 -79.250000000
            37.468740000 -79.250000000
        "/>
        <polyline class="GdGrid" points="
            37.332943000 -79.225000000
            37.468740000 -79.225000000
        "/>
        <polyline class="GdGrid" points="
            37.332943000 -79.200000000
            37.468740000 -79.200000000
        "/>
        <polyline class="GdGrid" points="
            37.332943000 -79.175000000
            37.468740000 -79.175000000
        "/>
        <polyline class="GdGrid" points="
            37.332943000 -79.150000000
            37.468740000 -79.150000000
        "/>
        <polyline class="GdGrid" points="
            37.332943000 -79.125000000
            37.468740000 -79.125000000
        "/>
        <polyline class="GdGrid" points="
            37.332943000 -79.100000000
            37.468740000 -79.100000000
        "/>
    </g>
</svg>
```

Appendix E. Sample Schema

```xml
<?xml version="1.0" encoding="UTF-8"?>

<xsd:schema targetNamespace="http://www.eduneer.com/gdt"
   xmlns="http://www.w3.org/2001/XMLSchema"
   xmlns:gml="http://www.opengis.net/gml"
   xmlns:gd="http://www.eduneer.com/gd"
   xmlns:xlink="http://www.w3.org/1999/xlink"
   elementFormDefault="qualified"
   version="3.0">

   <annotation>
      <appinfo>gd.xsd v0-0 2004-01</appinfo>
      <documentation xml:lang="en">
         GML schema for Geographical Documentation of Transportation features

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      </documentation>
   </annotation>

   <!-- ================================================================
   global element declarations
   ================================================================== -->
   <element name="road" type="RoadType" />
   <element name="addressList" type="AddressListType" />
   <element name="way" type="WayType" />

   <!-- ================================================================
   imports
   ================================================================== -->
   <import namespace="http://www.w3.org/1999/xlink" />

   <!-- for GML feature, geometry, measures, units, gmlBase, and baseTypes schemas -->
   <import namespace="http://www.opengis.net/gml" schemaLocation="../../base/feature.xsd"/>

   <!-- ================================================================
   type definitions
   ================================================================== -->
   <simpleType name="AccuracyListType">
      <list itemType="float"/>
   </simpleType>

   <simpleType name="AddressListType">
      <list itemType="integer"/>
   </simpleType>

   <simpleType name="WayType">
      <restriction base="xsd:integer">
         <enumeration value="1"/>
         <enumeration value="2"/>
      </restriction>
   </simpleType>
```

```
    <complexType name="RoadType">
        <complexContent>
            <extension base="gml:AbstractFeatureType">
                <sequence>
                    <element name="accuracyHorizontal" type="AccuracyListType" minOccurs="0"/>
                    <element name="addressesLeft" type="AddressListType" minOccurs="0"/>
                    <element name="addressesRight" type="AddressListType" minOccurs="0"/>
                    <element name="classification" type="string" minOccurs="0" maxOccurs="unbounded"/>
                    <element name="laneCount" type="integer" minOccurs="0"/>
                    <element name="number" type="string" minOccurs="0"/>
                    <element name="way" type="WayType" minOccurs="0" maxOccurs="1" default="2"/>
                </sequence>
            </extension>
        </complexContent>
    </complexType>
</schema>
```

Appendix F. Sample CSS (Cascading Style Sheet)

.GdInterpretation { fill:none; stroke:orange; stroke-width:0.0001 }
.GdTours { fill:none; stroke:gold; stroke-width:0.0005 }
.GdPaths { fill:none; stroke:black; stroke-width:0.0001 }
.GdDirtPaths { fill:none; stroke:brown; stroke-width:0.00001 }
.GdRoads { title:road; desc:a-road; fill:none; stroke:crimson; stroke-width:0.0001 }
.GdRoadsPrimary { title:primary-road; desc:a-primary-road; fill:none; stroke:crimson; stroke-width:0.0003 }
.GdRoadsSecondary { title:secondary-road; desc:a-secondary-road; fill:none; stroke:seagreen; stroke-width:0.0002 }
.GdRoadsLocal { title:local-road; desc:a-local-road; fill:none; stroke:slategray; stroke-width:0.0001 }
.GdRoadsRamp { title:on-off-ramp; desc:an-on-off-ramp; fill:none; stroke:orange; stroke-width:0.0002 }
.GdRails { title:railroad; desc:a-railroad; fill:none; stroke:silver; stroke-width:0.0001 }
.GdMiscTrans { title:ground-transport; desc:a-ground-transport; fill:none; stroke:lime; stroke-width:0.00002 }
.GdPipelines { title:pipeline; desc:a-pipeline; fill:none; stroke:lime; stroke-width:0.00002 }
.GdPowerlines { title:powerline; desc:a-powerline; fill:none; stroke:yellow; stroke-width:0.00002 }
.GdHydrography { fill:none; stroke:blue; stroke-width:0.00001 }
.GdHypsography { fill:none; stroke:sandybrown; stroke-width:0.0001 }
.GdBorders { fill:none; stroke:peachpuff; stroke-width:0.0001 }
.submaps { fill:none; stroke:green; stroke-width:0.001 }
.Label { font-size:22; font-family:Verdana }

Appendix G. Change Log

2004 feb 17 gjs – added comments about RDF
2004 jan 29 gjs – switched order of coordinates in SVG document to (lat,lng) as opposed to (lng,lat)
2004 jan 22 gjs – changed definition of geographical documentation structure from DTD to schema
2004 jan 22 gjs – added metadata to the complementary comparison
2004 jan 22 gjs – added appendices E, F and G
2004 jan 16 gjs – created