Scalable Vector Graphics – Web Standard for Cartography

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Abstract. Scalable Vector Graphics (SVG) represents the well-known standard used for description of two-dimensional vector graphics in the world of web technologies. This paper tries to sketch out the possibilities of SVG in cartography. The cartographic potential of SVG is supported by particular SVG drawing elements and their attributes, that are able to cover requirements on map symbols and their parametrization by graphical variables. There are also another properties of SVG important for cartography and map making – transformations, grouping of elements, labeling or support of various types of multimedia (sound, animation, raster graphics). It is also necessary to emphasize other very important characteristics of SVG – it is completely open standard and technology (from views of license, accessibility, extensibility etc.). This paper describes not only particular part of SVG standard, but also selected libraries working with SVG maps and some examples of implementation of SVG in the Geomatics section in the University of West Bohemia in Plzeň (Czech Republic).

Keywords: Scalable Vector Graphics, vector, Internet, map, web cartography

Introduction

The development of the format Scalable Vector Graphics (SVG) started around the year 1999. It was based on existing formats of vector graphics connected to the format Extensible Markup Language (XML). The first SVG standard (version 1.0) was published in 2001. In the half of the first decade of 21st century the SVG format was viewed with distrust. Many experts (not only in cartography) started to exploit similar technologies such as Adobe Flash.

There are two main reasons for the revival of SVG format and related technologies:

1. While applications for computers used another formats, the mobile technologies were still focused on SVG, because it has been simple and open. Also devices with low performance (e.g. mobile phones) have been able to process SVG graphics.

2. SVG was incorporated to the set of technologies related to HTML 5. SVG represents the part of HTML 5 focused on 2D vector graphics. It means new opportunity – many web pages and multimedia applications connected with SVG which will be based on HTML 5.

The contemporary SVG brings a chance for cartographers to interconnect the actual trend (HTML 5 technologies) with cartography, its product and research. Moreover SVG (thanks to its properties) can solve questions connected with maps on the Internet such as reliance on proprietary libraries or incompatibility.

This article should introduce SVG, describe its cartographic potential and show selected application in cartography. It is divided into three main sections. The important properties and specifics of SVG format (including history and relations to other technologies and standards) are described in the part "Introduction to SVG". The section "Cartographic Potential of SVG" introduces particular elements of SVG standard and shows their opportunities in a process of map construction and presentation. Following part of this paper calls "Examples of SVG Maps". It is focused on various examples of maps in SVG format that were developed in the projects of Geomatics Section of the University of West Bohemia in Plzeň (Czech Republic).

Scalable Vector Graphics

1.1 Introduction to SVG

The acronym SVG stands for Scalable Vector Graphics. It is an XML-based format for two-dimensional graphics. SVG represents a subset (with specific elements and attributes) of general XML (Extensible Markup Language). The SVG standard is managed by World Wide Web Consortium (W3C) and its SVG Working Group (http://www.w3.org/Graphics/SVG/) that also publishes SVG standard document (Dahlström et al., 2011). The schemes for a validation of SVG documents are also found in SVG standard as DTD (Document Type Definition) and W3C XML Scheme files.

The development of SVG started around 1999. The experts of W3C re-used experience of older vector formats based on XML – VML (Vector Markup Language) and PGML (Precision Graphics Markup Language) that were coordinated by commercial companies such as Microsoft or Autodesk

(VML) or Adobe and IBM (PGML). The first SVG standard was published in 2001. The current version of SVG is called as 1.1 (Dahlström et al., 2011).

According to SVG Working Group (as the main development and management body) the second version of SVG (SVG 2.0) is under development. It will add new features to SVG, as well as more closely integrating with HTML (Hypertext Markup Language), CSS (Cascading Style Sheets), and the DOM (Document Object Model).

The SVG document is (just as any XML document as well as HTML) a plain text composed of particular elements organized to a tree structure with the root element <svg>. The relation with another standards based on XML and the principle of scripting and linking ensures interconnections with many web technologies such as HTML, ECMA (European Computer Manufacturers Association) script, DOM, CSS, XPath (XML Path Language), XSLT (Extensible Stylesheet Language – Transformation) or multimedia files. Because of plain text format a SVG document is editable in any text editor being able to process ASCII (American Standard Code for Information Interchange) document (from simple tools like NotePad to advanced code and/or WYSIWYG software packages like Emacs or Inkscape).

Relation to XML and HTML facilitates the viewing of SVG graphics. Formerly the plug-in modules of web page browsers were necessary. Now there is a native support. The table published on Wikipedia (http://en.wikipedia.org/wiki/Comparison_of_layout_engines_%28SVG%29) shows a compatibility of particular web browser engines. The main web browser producers (Google, Mozilla Foundation, Microsoft or Apple) support the essential SVG elements.

Many publication compares SVG format and other similar technologies (VML, PGML, Flash...). Perspectives of cartographers are captured in Neumann & Winter (2001) or Becker (2009) – focused on Flash as the main rival of SVG.

1.2 SVG and HTML 5

The world of web technologies and the Internet was in last years supplemented by the fifth version of Hypertext Markup Language (HTML). Development of HTML 5 started in 2007 and both organizations responsible for the course of development (W3C and WHATWG – Web Hypertext Application Technology Working Group) expect the completion of standard in 2022.

The HTML 5 does not have any official specification up to now (except WHATWG living standard edited by Ian Hickson; http://whatwg.org/html). W3C has published just the documents related to

HTML5 as W3C Working Drafts. The plan announced in September 2012 (http://dev.w3.org/html5/decision-policy/html5-2014-plan.html) describes the progress of development and version HTML 5.1 (W3C Recommendation in 2016) and 5.2. Originally authors do not suppose any new version upgrades.

The HTML 5 represents very important milestone in the development of web pages because it interconnects the language describing particular parts of web pages (including SVG) with style language (CSS, version 3), script languages (ECMA script), multimedia and other components (e.g. various Application Programming Interfaces).

HTML 5 brings many improvements to previous HTML versions such as support of semantics (including microdata formats), combination of different markup languages, multimedia support, Local & Session Storage, geolocation, offline applications or web databases.

HTML 5 has not been designed just for programmers and coders. Also cartographers can exploit benefits of HTML 5, above all the relation among web page components, graphics (Canvas and SVG as graphics tools for HTML) and interactive tools managed by scripts.

Combination of HTML 5, SVG and other components allows to develop map without advanced map libraries. It enables to create sophisticated map outputs (e.g. complicated thematic and statistic maps) that cannot be formed in map libraries and by similar tools.

Cartographic Potential of SVG

This part of the paper describes SVG format from the view of cartography. It means a list of selected SVG elements that could be very helpful during a process of map application development such as possibilities of spatial data migration to SVG, transformation of graphics or defining user's symbols. This section describes fundamental graphical elements, their parametrization and labeling and tools for another operations (transformation, scripting, graphical features /gradient, masking etc./). This part of the articles is based on Eisenberg, 2002 and Dahlström et al., 2011.

The cartographic potential of SVG was mentioned in many various resources. As far back as in 2001 the capabilities of SVG in cartography were described in Neumann & Winter (2001) published in International Cartographic Conference in Beijing, China. These authors also have been cooperated on carto:net project and web site (www.carto.net). These web pages contain many examples, fragments of code and links to articles focused on SVG in cartography.

Other research of relation of SVG format and cartography is mainly focused on concrete case studies showing particular cartographic solutions based on SVG. From the large quantity of various materials it is possible to select a paper describing an interconnection of SVG and WMS (Web Map Service) standard (Köbben, 2007), design of server solution based on SVG (Neumann & Jenny, 2007), article solving question of labeling SVG maps (Kulyukin, V. et al., 2010), works of the author of this article focused on a generation of maps in SVG format via XSLT styles and SVG cartographic products such as Atlas of International Relationships or maps for the VisualHealth project (Čerba, 2008, Čerba, 2010a, Čerba, 2010b, Čerba & Čepický, 2012). Some of articles about SVG applications contain also a general description of SVG (e.g. Hedge, 2004 or Becker, 2009).

There is a huge number of various publications focused on interconnection between cartography and SVG format. The broad scope of publications and ways of research support the importance of SVG in cartography.

2.1 SVG Drawing Tools

The drawing tools are divided into two groups. SVG contains elements of basic graphical primitives such as lines, polylines, polygons, circles, ellipses or rectangles. The coding of these symbols is summarized and shortly described in table 3-1 (Table of shape elements) in Eisenberg, 2002. The simple map symbols of geometric character can be created with using of these features. They are usually not very suitable for drawing complicated composed shapes (e.g. areal symbols in choropleth maps or cartograms). They are not used in a process of generating of SVG from spatial data (details of the process of generating SVG maps in Čerba, 2008, Čerba, 2010a, Čerba, 2010b, and Čerba & Čepický, 2012), because the description of parameters (elements and attributes) is specific for each element.

SVG standard contains more universal drawing element. It calls <path> and is able to create any graphic feature with using a list of coordinates and simple commands represented by one letter. The commands are included in list of coordinates that is content of attribute d. The element <path> uses following commands – M (moving of drawing tool), L (line), H (horizontal line), V (vertical line), and Z (closing of polygon). Users can also deal with advanced commands such as A (elliptical arc), Q (Quadratic Bezier's curve), T (Smooth quadratic Bezier's curves), C (Cubic Bezier's curve), S and (Smooth cubic Bezier's curves). These features are focused mainly on general graphics and they are not used in cartography very often. The element <path> is able to work with absolute (commands are written as upper cases) and relative (commands are written as upper cases) coordinates as well as using a compressed form of coding.

2.2 Other SVG elements

Above-mentioned elements represent corner-stones of each SVG graphics, including maps and other cartographic products. The drawn primitives and “paths” can be modified and supplemented in various ways by transformation, grouping, labeling, adding raster graphics, graphical features (filters, gradients, patterns...), animations, scripting and interactivity.

The transformations and work with coordinate system is the crucial activity of a development of a map in SVG format. SVG uses the coordinate system of graphics with the origin in top left corner of a draw. Unfortunately this approach is not useful for most cartographic activities. Cartographers need to use transformation attribute to adjust to original data coordinate system.

Users can define not only a size of a picture (or map) but also its segmentation. Following fragment of code shows the SVG document with height 10cm and width 20cm. The canvas of SVG document is divided into 300 pixels (height) and 600 pixels (width). The origin of axes starts in point 1000, 1000.

```
<svg width="20cm" height="10cm" viewBox="1000 1000 600 300">
```

In some cases it is necessary also to change directions of axes. Users can apply the attribute transform. SVG enables four types of transformations – translation, rotation, change of scale size and skew. Transformations can be composed in content of transform attribute or SVG can deal with affine 9-elements transformation matrix.

The best practice how to use transformations is to prepare as many as possible features of map out of the canvas and than to transform them to the right position and scale. Unfortunately it is not possible to use this type of transformation for labels and composed symbols of map.

The grouping is also very useful in cartography. It can be used in various ways:

- The same styling of more elements (using the same graphics variables for more map symbols).
- Definition of composed cartographic symbols that can be described only one time and applied many times.
- Transformations of particular part of map.

SVG offers three grouping elements – <g> – creating of group of SVG elements that can be affected by the same attributes, <defs> – common definitions and <symbol> – definition of graphics that is used in map repeatedly (with possibility of changing their attributes such as color or size). The element <symbol> is able to work with its own coordinate system and view box. Predefined parts of map are included to draw by element <use> and attribute xlink:href that contains URI (Uniform Resource Identifier) of element.

Text elements are important for any map, but the text processing ranks among the shortcomings of SVG standard. There are some limits that must be taken into consideration. The main restriction consists in missing possibilities of working with paragraphs (line wrapping). Cartographers can reduce this restriction by combination of SVG and HTML, because paragraphs are not usually a part of map drawing, but they just complete the map as additional components.

Label of map symbols are realized by the element <text>. Its behavior can be affected by various attributes. They specify position, alignment, outlining, family of fonts, size, weight, underlining, word or letter spacing. The <tspan> element enables a modification of text direction, including following a curve or applying to shapes (text along a path). This property is very helpful in the process of labeling of water flows or mountain ranges.

Because SVG is a subset of XML standard, it support UTF (UCS Transformation Format) encoding of characters. It means that SVG is able to deal with any type of alphabet.

SVG contains many other graphical elements that can make a map more attractive. There are graphic filters (used for example for adding shadows or lighting effects to map symbols, including text labels, for changing of color schemes or for combination of rasters and vector graphics). The particular parts of map do not need to be covered just by single color. User can implement patterns, linear or radial gradient (transition among two or more colors). It is also possible to use masks or clips.

SVG does not mean just a static vector map. SVG has various possibilities of features related to animations and interactivity. Animations in SVG are based on another W3C standard – Synchronized Multimedia Integration Language (SMIL). It allows adding an animation element to any SVG feature. SVG is able to animate a change of colors, size, orientation (through animation of transformation) and motion. Animation elements work with many attributes being able to define essential properties of animation (e.g. starting and ending time of animation, duration or repetition).

The interactivity (a possibility to influence a visualization by user) represents the second main attribute of dynamic maps. SVG (similarly to other XML-based format) uses ECMA script (known also as Java script). It ranks among the most important web technologies. ECMA script allows (together with DOM) to define any processing of any SVG element.

2.3 SVG Libraries

The drawing of map in SVG by writing a code or drawing in some editor is very difficult, slow and inefficient. Therefore there are technologies that are able to transform spatial data as well as attribute data to the form of SVG map by automated way.

The next chapter and publications (Čerba, 2008, Čerba, 2010a, Čerba, 2010b and Čerba & Čepický, 2012) show possibilities of XSLT in the process of generation of SVG maps. The another way how to create a SVG map is to use a library based on ECMA script (or any other script language) and to include the script to web page.

The library Polymaps (http://polymaps.org/) represents such ECMA script library using SVG. It allows anybody to create any vector graphics including maps. Polymaps support not only raster tiles but also a vector tiles in SVG (via GeoJSON – open format for encoding geographic data).

The jVectorMap (http://jvectormap.com) is also based on ECMA script. It does not use any proprietary format (e.g. Flash), but it support except SVG also VML format. Users can download not only script files but also predefined maps (or data) of selected countries and apply mapping techniques (choropleth, proportional symbols). The jVectorMap allows anybody to work with selected projection (e.g. Mercator projection or Lambert Conformal Conic Projection).

D3 (http://d3js.org/) means Data-Driven Documents. It is also ECMA script library using HTML, CSS and SVG. It serves as a tools for a visualization of data, including spatial data. The gallery of the project contains some cartographic products such as choropleth maps, proportional symbol maps or non-continuous cartograms. But the portfolio of visualization methods is broader (e.g. various types of graphs, charts or diagrams).

Google Chart Tools represents one of the not much known service or product of Google company. It can be attached to the web page by ECMA script. The visualization is based on SVG or VML. Google Chart Tools are divided into particular instruments such as Google Geochart that allows the users to work with maps and spatial data. The Interactive World Maps (a plugin for WordPress) are also based on Google Geochart.

The Raphaël—JavaScript Library (http://raphaeljs.com/) is very similar to D3 library. It offers a huge number of various visualization techniques, including maps. It uses SVG as well as VML format.

The set of ECMA script libraries is very numerous and contains many other products like SVGMap.

Case Studies – SVG in Geomatics section of the University of West Bohemia

This sub-chapter shows selected applications of SVG format in cartographic activities of Geomatics section of the University of West Bohemia,. These activities could be divided into three main groups – classes of Computer Cartography, final thesis of students and projects.

The course Computer Cartography is intended mainly for students of cartography specialization of geomatics. It is based on processing spatial data set by XSLT templates and processor and their presentation in a form of thematic maps in SVG format. Lectures of SVG format and its cartographic potential account for the important part of this course. The workshop "HTML 5, CSS 3 & SVG 1.1 in Cartography" (gis.zcu.cz/tmp/Workshop/Workshop_v2.pdf), that was presented in the The Internet and Geospatial Technologies: A workshop jointly supported by the ICA Commission on Maps and the Internet and the ICA Commission on Open Source Geospatial Technologies In conjunction with AutoCarto 2012 as well as in the University of Nebraska in Omaha, is also a part of the course of Computer Cartography.

SVG is used also in many final thesis of students of geomatics. They use SVG as a tool for visualization of particular task such as interactive map of the railway network in the Czech Republic, multimedia representation of the oldest map of Bohemia, modelling of changes of electoral districts and their effect on results of elections, multimedia plan of Komarno city (Slovakia) or possibilities of SVG in cartographic visualization of dynamic phenomenons.

SVG format was also used in two projects with a participation of Geomatics section. The Atlas of International Relationships (Waisová et al., 2007) represents the traditional printed cartographic publication, but the maps were constructed in SVG (via XSLT transformation) and after that converted to PDF (Portable Document Format) format. The project VisualHealth was focused on a support of prevention of selected diseases through cartographic products. There were used various approaches how to build fitting maps including thematic maps in SVG format (Čerba, 2010b).

Conclusion

SVG format has very diverse using in cartography. It can used in “traditional” cartography to final editing of maps. For example SVG format is used in the Geomatics section of the University of West Bohemia to finalize the maps generated in GIS software. Such maps are modified in open-source vector graphics editor Inkscape (with using SVG format), transformed to PDF and printed or archived.

The cartographic potential of SVG is important for connection with digital maps above all interconnecting vector graphics, rasters, text elements, multimedia and interactive components. This paper summarizes essential cartographic capabilities of SVG (parts 2.1 and 2.2) and shows libraries applicable to digital maps construction (part 2.3) and examples of SVG using (part 3).

The number of various applications, research articles and SVG maps support the importance and significance of SVG in cartography. It documents also the interest in courses and workshops focused on SVG and related technologies.

SVG maps and cartographic applications cannot substitute (and even do not want to substitute) other ways of building of digital and multimedia maps. They represent one alternative that is applicable in some specific cases such as web statistic and thematic maps, solution for mobile devices or cartographic products with specific and unique graphic design.

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