

# Extensions to Styled Layer Descriptor and Symbology Encoding standards

Emanuel Rita

IST/INESC-ID

**Abstract.** Thematic maps provide statistical information associated with a certain geographic area. Despite the recent developments in the area of the map services on the Web, we have that the standards proposed by Open Geospatial Consortium (OGC) do not yet offer specific functionalities for creating thematic maps. In this paper, we propose a new extension that allows the creation of cartograms. The creation of cartograms was not considered in the previous studies. We implemented this extension in the GeoServer, a well known and largely used map server. With this work we also implemented another extension to allow GeoServer to get external data to create thematic maps.

**Keywords:** Thematic map, Cartogram, Styled Layer Descriptor, Symbology Encoding.

## 1 Introduction

A map is a visual representation of a surface area from planet Earth. Thus, maps are representations of a three-dimensional space on a two dimensional surface.

We can distinguish several types of maps according to the type of information they represent. Physical maps represent aspects of the physical geography of a given area, such as characteristics of the relief in a given region, rivers and the type of vegetation in this area. Political maps are maps that represent political and administrative regions. Usually, these maps use lines to identify boundaries between different regions and points to identify specific locations or other issues arising from human activities on the territory. Thematic maps, which are the main focus of this work, present statistical information related to a geographic location [2]. They are an appealing solution for the representation of different types of georeferenced information, in order to facilitate their interpretation. Depending on how the information is presented on the map, we can distinguish different types of thematic maps. Section 3 of this document presents and describes the main types of thematic maps.

Some geographic information systems (GIS) allow the representation of information in thematic maps. As examples, we highlight Google Earth and Microsoft Visual Earth, both proprietary solutions. In the other hand there are open source GIS based on the standards proposed by the Open Geospatial Consortium (OGC). These standards allow an easier interoperability between different solutions. However, none

of the open source solutions allow an easy creation of thematic maps. This is due to the fact that there are no explicit features in the OGC standards for the creation of thematic maps.

There are studies that proposed extensions to OGC standards in order to facilitate the creation of thematic maps, namely extensions to the Styled Layer Descriptor (SLD) and Symbology Encoding (SE) specifications, because they are the standards responsible for defining the representation of the objects on the map. However, some types of thematic maps were not considered by these studies. For example, none of them supports the creation of cartogram maps. Cartograms are maps where the represented regions are deformed so that its areas are proportional to a given statistical variable.

This paper proposes an extension to the SE standard in order to allow the definition of cartograms maps. We implemented this extension in an existing open source map server, namely GeoServer<sup>1</sup>, relying on an open source Java library that implements an algorithm for building cartograms, called Scapetoad<sup>2</sup>. We also extended the SLD in order to allow the user to get data from an external source. With this extension we can build cartograms using a numeric attribute present in the layer we wish to deform, or using a numeric attribute that can be obtained from an external service.

## 2 Standards for Map Services on the Web

The Open Geospatial Consortium (OGC) is an international consortium responsible for the specification of standards that allow interoperability between geographic information systems. Among these standards there are some that allow the manipulation of data with the objective of creating map images.

In this document we will give more emphasis to the Web Map Service, Styled Layer Descriptor and Symbology Encoding standards, as they are the most relevant in the context of creating thematic maps.

Web Map Service (WMS) is a standard proposed by OGC [8]. It defines an interface for a service, based on HTTP requests, capable of dynamically producing map images from geographic information. It responds with an image that can be in several types such as Portable Network Graphics (PNG), Graphics Interchange Format (GIF) or the format proposed by the Joint Photographic Experts Group (JPEG).

The geographic information contained in the maps that are served by a WMS is organized in different layers. So, a map request that is made to the service is composed by the request of several different layers, using some identifier. The layers requested to the service can be rendered using styles that are offered by the WMS service. The style defines how the information is visually presented in the map (for example, the color of the polygons, color and thickness of the lines, labels font, etc.).

---

<sup>1</sup> <http://geoserver.org/>

<sup>2</sup> <http://scapetoad.choros.ch/>

The WMS Styled Layer Descriptor [4] is an extension proposed by the OGC, to the WMS standard. Its purpose is to allow the user to define its own styles to the map rendering. The basic WMS standard gives only the option to choose a layer style that is provided by the service, through an identifier. The user does not have the possibility to specify its own styles. To allow the definition of its own styles it is necessary a language to specify them, the XML language Symbology Encoding Specification (SE) [5]. The SLD standard specifies how the SE language can be used with WMS services through an XML document named Styled Layer Descriptor (SLD).

### 3 Thematic Maps and Their Creation with OGC Standards

Thematic maps are a solution for representing different types of statistical information with a relation to some specific geographic location. For example, they can show data referent population density, birthrate, mortality, etc.

Using the OGC standards it is possible to create maps showing different types of information. For example using SLD and the SE language we can create different styles to represent the different elements that are present in the map, based on the attributes of the features present in a specific layer.

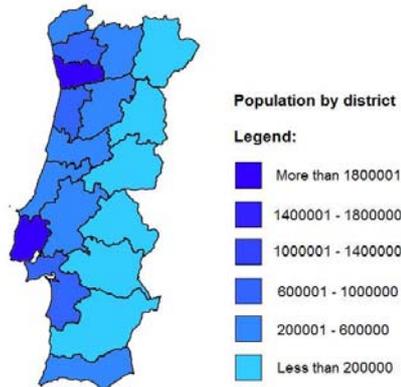
However, using these standards to specify styles for map creation is very limited when we want to create thematic maps. It is possible to represent some statistical information using the actual SLD and SE specifications, but they have several limitations and in some cases a high level of complexity that makes them hard to use when the purpose is to create thematic maps [1, 9].

There are different types of thematic maps according to how information is represented on the map.

Choropleth maps are maps where the geographical area is divided into different regions each of these regions is distinguished from others by a color or different shades of color, depending on a particular attribute. They offer an appealing way to visualize the variation of a single attribute in a given region. Fig. 1 shows an example of a choropleth map that represents the population of the districts of the Portuguese territory. The zones represented with a darker blue are more populated than the zones represented with a lighter blue, as showed on the legend.

Typically, one creates intervals within the range of values that the attribute can take, and each of those intervals is assigned a different color.

To create these types of thematic maps using the SLD and SE specifications, we can define a rule containing a filter for each class of values. Each rule defines its own PolygonSymbolizer with a certain color associated. Each color represents a specific class of values. However it takes a rule with a different color for each class. If there is a significant variation of values, and at the same time a large number of classes, the SLD document may become too large and complex. Furthermore the various colors will have to be set manually, and one must have prior knowledge of the range of the values of the attribute in question.



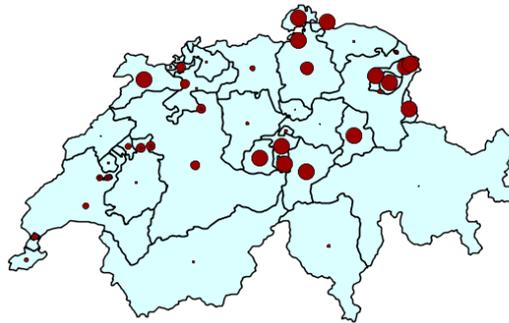
**Fig. 1.** Example of a choropleth map showing the population of the different districts of the Portuguese territory.

Diagram maps are maps where we put charts in some specific locations on the map, presenting statistical information associated with these sites. We can use different types of diagrams like bar charts, pie charts, line charts, etc. Fig. 2 shows an example of a diagram map, representing the age distribution in European countries.

The SLD standard does not offer mechanisms allowing the creation of these maps. However it is possible to use an external server that generates images that represents the charts, and using the `PointSymbolizer` element that exists in the SLD document we can place these images on the map. The Google Chart API is an example of a web service capable of creating chart images. It receives HTTP requests with the necessary parameters for the creation of the desired chart. The service returns a chart image that can be placed on the map. This way is possible to create diagram maps using the `PointSymbolizer` element. Still, although it is possible to devise some alternative solutions for creating diagram maps based on OGC standards, these were not specifically developed for the generation of such maps.



**Fig. 2.** Example of a diagram map representing the age distribution in European countries.



**Fig. 3.** Example of a proportional symbol map.

Proportional Symbol Maps are maps that show symbols, in specific locations, with a size that varies in proportion to the attribute that is intended to represent. This way it is easy to make visual comparisons between the differences of the values of a single attribute represented on the map.

Using the SLD and SE specifications it is possible to create this type of thematic map. They can be created using a `PointSymbolizer` to define a symbol and its size may vary according to some attribute of the feature using the sub-element `Size`. Fig. 3 shows an example of a proportional symbol map. It represents the population in the different regions of Switzerland. The size of the red symbol varies according to the size of the population on that region.

Overlaid and juxtaposed Symbols Maps allow an easy visualisation of several different attributes that refer to a single location on the map. They are based on placing proportional symbols (overlaid or juxtaposed) according to some attribute value that we wish to represent.

It is possible to create overlaid symbol maps with the SLD and SE standards using two rules with a filter each. For each one we associate a `PolygonSymbolizer`. Its size varies according to an attribute of the feature. The order of rules is important because it will determine the order in which the symbols will be drawn on the map. However, the OGC standards do not offer mechanisms to create juxtaposed symbols maps.

Cartograms maps are based on the redrawing of a given map, deforming its regions so that its areas or the distances across regions are proportional to a given statistical variable [6, 3, 12, and 13]. The advantage of these maps is that they can give more emphasis to areas of greatest relevance and hide less important regions. This way it is easier to analyse the map in the most important regions.

ScapeToad is an open source library that allows the creation of cartograms. It uses the ESRI shapefile format for input and output of maps. ScapeToad implements the diffusion algorithm proposed by Gastner & Newman [7] to adapt the geometric shapes present in a map according to a statistical variable defined by the user, keeping the topological relations between the geometries involved.

**Table 1:** Comparison between the different types of thematic maps.

	<b>Difficulty of creation using SLD and SE standards</b>	<b>Attributes that can be represented</b>
<b>Choropleth</b>	Moderate	Only one
<b>Diagrams</b>	Hard	Several
<b>Proportional Symbols</b>	Easy	Only one
<b>Overlaid Symbols</b>	Easy	Several
<b>Juxtaposed Symbols</b>	Impossible	Several
<b>Cartogram Maps</b>	Impossible	Only one

The OGC standards, namely the SLD and SE standards, do not allow the creation of cartogram maps. They do not offer mechanisms to deform the geometric shapes associated with the map according to some attribute.

Table 1 summarizes the possibility of creating the different types of thematic maps using the OGC standards, and their possibility to represent several attributes. Proportional Symbols and Overlaid Symbols are the easiest thematic maps that can be created with the standards. Choropleth are considered of moderate creation difficult, because, although they can be created, the SLD document may become too large and complex if they have a large number of intervals within the range of values. Diagram maps cannot be created using only the SLD functionalities, but we can devise some strategies for creating them using external sources to build the chart images. Juxtaposed Symbols maps and cartograms are not possible to be created using these standards.

#### **4 Extensions to the OGC Standards for Thematic Maps**

Due to the limitations of the SLD and SE specifications for the creation of thematic maps, there are proposals for extending these specifications in order to allow an easier definition of styles with the objective of creating such maps. The most relevant studies are the Thematic Symbology Encoding Specification proposed by Dietze et al. [9], SLD-T proposed by Abson sae-Tang and Olivier Ertz [1], and the extensions implemented in QGIS Mapserver (an open source implementation of a WMS server developed in the Institute of Cartography from ETH Zurich). Table 2 shows a comparative analysis of these cases, according to the types of maps that each one directly supports, by offering new functionalities for its creation.

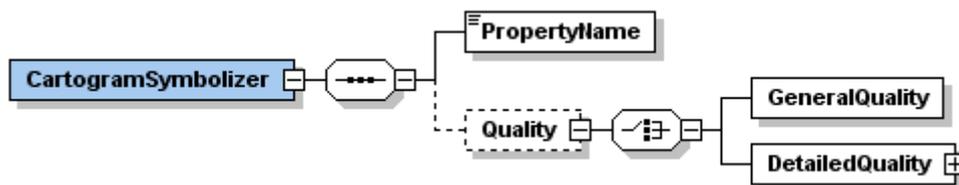
	<b>Thematic Symbology Encoding</b>	<b>SLD-T</b>	<b>QGIS</b>
<b>Choropleth</b>	Offers creation support	Offers creation support	Offers creation support
<b>Diagrams</b>	Offers creation support (pie, bar, lines)	Offers creation support (pie, bars)	Offers creation supports (bars, lines, pie, ring)
<b>Proportional symbols</b>	Does not offer creation support	Offers creation support	Does not offer creation support
<b>Overlaid symbols</b>	Does not offer creation support	Offers creation support	Does not offer creation support
<b>Juxtaposed symbols</b>	Does not offer creation support	Offers creation supports	Does not offer creation support
<b>Cartograms</b>	Does not offer creation support	Does not offer creation support	Does not offer creation support

**Table 2:** Types of thematic maps that have specific creation support by each of the presented studies.

As we can observe, all the three proposals offers specific functionality to the creation of choropleth maps and diagram maps. SLD-T goes further giving direct support for the creation of proportional symbol maps, overlaid symbol maps and juxtaposed symbol maps, although the two first can be created with the actual SLD and SE standards. We can also observe that none of these studies have support for the creation of cartogram maps.

## 5 Cartogram Symbolizer

Here we present a new extension to the SLD and SE specification to allow the definition of cartogram maps, i.e. CartogramSymbolizer. It consists of a new element in the SE XML language. It is a new type of symbolizer that must be placed inside the element Rule, like all the others symbolizers. Fig. 4 shows the structure of this new element.



**Fig. 4.** The structure of the CartogramSymbolizer element.

The CartogramSymbolizer element contains two sub-elements: PropertyName and Quality. The sub-element PropertyName is used to specify the attribute of the layer from which the layer will be deformed. It must be a numeric attribute. The sub-element Quality is optional and defines the quality of the resulting cartogram map. As showed in Fig.4 the Quality sub-element also contains two sub-elements: GeneralQuality and DetailedQuality. GeneralQuality allows defining the quality of the cartogram in a general way, using an integer that varies from 1 to 100. To create the cartograms we use an implementation of the Gastner & Newman diffusion algorithm [7]. The quality value will define the precision of the execution of the algorithm. Lower values will result in larger distortion grid and fewer iterations of the diffusion algorithm. In the other hand, higher values will result in a denser distortion grid and more iterations of the algorithm. Higher quality will also increase the computation time. The sub-element DetailedQuality is used to define the quality of the cartogram in a detailed way: it is composed of sub-elements that define the size of the distortion grid and the number of iterations. If the Quality element is not used in the SLD, it will be used a value of Quality of 50.

The presence of this element inside the element Rule will indicate the server that the layer in question must be deformed using the Gastner & Newman algorithm. The rest of the symbolizations rules will be applied normally to the deformed layer.

## 6 Implementation of the Cartogram Symbolizer

In order to implement the CartogramSymbolizer extension we used an open source Java library called ScapeToad. ScapeToad implements the Gastner & Newman algorithm for the creation of cartograms. The objective of the implementation work was to integrate this library into an existing implementation of a map server.

We chose GeoServer for this work, one the most used open source map servers that implements the OGC standards. The fact that GeoServer is written in Java makes the integration with ScapeToad easier.

GeoServer uses the Geotools library to parse the SLD documents, so we did an extension to this library to add the new CartogramSymbolizer.

When GeoServer receives a GetMap request it uses Geotools to parse the SLD document. A tree is returned representing the document. GeoServer then checks, for each layer present in the request, if there is a CartogramSymbolizer element in the tree. If there is, that layer must be deformed.

Because ScapeToad receives shapefiles as input, the layer in question must be transformed to a shapefile. Then it calls the ScapeTod to perform the distortion algorithm, which will create a new shapefile with the deformed layer. Finally GeoServer replaces the original layer with this new one. After this, the creation of the map continues normally.

## 7 External Data

Using the cartogram Symbolizer extension the user is able to obtain a deformed map from a WMS. However, this is only possible by choosing an attribute of the layer that is being requested. So the data from which the map will be deformed must be present in the layer. This is a limitation of the SLD standard itself, in the sense that all symbolizations can only depend on the attributes present in the requested layer.

Taking this limitation in consideration, the next step of this work is to understand how can we extend the standard in order to get external attribute data.

We considered that the WMS could get the attribute, from a Geographic Linkage Service (GLS) [11]. GLS is an OGC standard for a service that returns attribute data in the GDAS format. GDAS [10] is another OGC standard that defines an XML data format used by the GLS to express the attribute data. The obtained attribute, can then be used in all the symbolizers that are present in the SLD document.

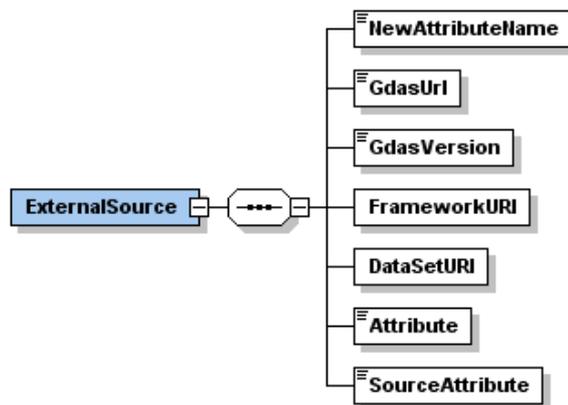
We introduced a new element named ExternalSource. It has several sub-elements that will gather the necessary information to make a GET request of the operation GetData present in the GLS standard [11]. This element is placed inside the NamedLayer element of the SLD.

As showed in Fig. 5 the ExternalSource element consists of several sub-elements:

- **NewAttributeName:** The name of the new attribute that will contain the obtained data.
- **GdasUrl:** Element that indicates the URL of the service, from which the data will be obtained.
- **GdasVersion:** Element that indicates the version of the service.
- **FrameworkURL:** The URL that identifies the Framework. A Framework is a geospatial dataset that partitions the surface of the earth into a set of management units. Municipalities, postal codes, telephone area codes, and watersheds are all examples of spatial frameworks. It has three sub-elements that identify the framework: Domain, Name and Version.
- **DatasetURL:** The URL that identifies the URL. A dataset is a set of values that describes a particular framework. Examples of datasets can be the population or the temperature of a given region. It has two sub-elements that describe it: Domain and Name. It also as sub-element named Attribute that indicates the attribute, contained in that dataset, which will be used to deform the map layer.
- **Attribute:** Name of the attribute that will be obtained from the GLS service.
- **SourceAttribute:** It is used to select an attribute of the layer that will be used to merge the values obtained from the GLS with the features present in the layer. Each value obtained from the GLS service has an ID that identifies it. This way, the values are associated to the features that have the value of the SourceAttribute equal to this ID.

Using this extension the user has the ability not only to create cartograms based on an attribute present in the layer, but also to obtain data from a GLS service and create a cartogram based on this data. The new attribute can also be used with all the other symbolizers present on the SE language, making the creation of maps more flexible. This approach assumes that the user must have some knowledge about the attributes present in the layer and also the available attributes and its IDs, on a GLS service. This is necessary to establish relationships between the values of the obtained attribute and the features present in the layer. The layer must have an attribute that uniquely identifies each feature, and the user must also know an attribute that can be obtained from a GLS service whose IDs correspond to the values of that attribute present on the layer.

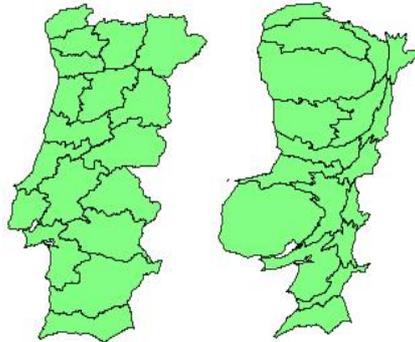
With this extension, we show that it is possible to extend the SLD protocol in order to get new data from an external source, this way making the creation of maps more flexible, in the sense that the WMS service only has to provide the geographic data, and the user that requests the map can provide the attribute data.



**Fig. 5.** The structure of the ExternalSource element.

## 8 Results

With these extension implemented to the Geoserver we can create cartograms by using the CartogramSymbolizer element in the SLD document.

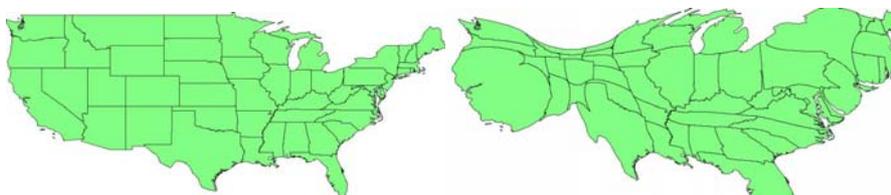


**Fig. 6.** Cartogram of Portugal Territory

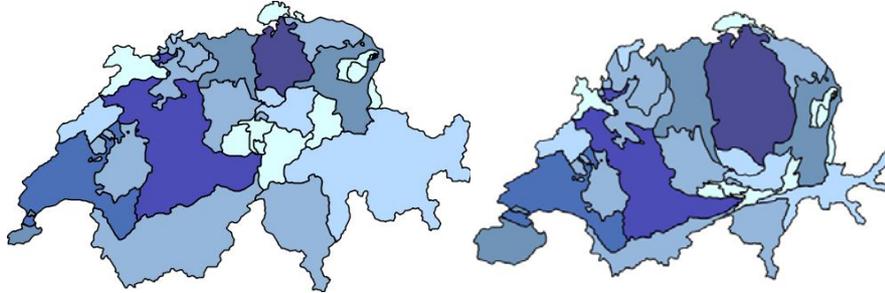
Fig. 6 shows on the right a map obtained using the CartogramSymbolizer element and the original map on the left. In this case the layer has an attribute that corresponds to the population of each district of the Portuguese territory. Choosing this attribute to perform the deformation the service returns a map presenting the area of the districts proportional to the population. As we can see, there majority of the Portuguese population are concentrated on the coast, especially in the regions of Lisbon and Porto.

Fig. 7 shows another example of the creation of cartograms using this extension. This map represents the territory of the USA with its states deformed according to their population. The original layer is the figure on the left.

A cartogram can be easily combined with other types of thematic maps, as shown in Fig. 8. It shows, on the left, a choropleth map representing the population of the different regions of Switzerland. With our extension we can add the CartogramSymbolizer element to the SLD document, and the rest of the rendering rules will be applied normally to the deformed layer. In Fig.8, the figure on the right shows the map obtained by adding the CartogramSymbolizer to the SLD document which specified the style of the choropleth map on the left side of the image. As we can see the map is deformed and the remaining rendering rules were applied normally. It is easy to combine a cartogram with another thematic map that was previously defined with SLD. One simply needs to add the CartogramSymbolizer to the SLD.



**Fig. 7.** Cartogram of U.S.A. Territory.



**Fig. 8.** Choropleth map of the Switzerland territory.

## 9 Future Work

This work proposed to add a new type of the element Symbolizer to the SE standard that allows the definition of a type of thematic map that could not be created using the actual OGC standards. The studies presented in Section 4 of this document also proposed the introduction of new types of Symbolizers, in order to add new rendering options that allow the creation of different types of thematic maps. In other words, in order to allow different forms of specifying the style of map creation, using the SLD and SE standards, it would be necessary to define and implement other types of Symbolizers, other than those already present in the standards.

It would be an interesting functionality to the SE and SLD standards if they could support extensions, in the way that each implementation would be free to support and implement any new type of Symbolizers. The clients would need only to ask the server in question about which types of Symbolizers it supports, as well as a description of them. This information could be present in the metadata returned by the WMS with the GetCapabilities operation.

There are also other types of thematic maps that were not considered on this study, for example Heat Maps. Heat Maps are a type of thematic map that use a colour graduation with the purpose of representing a statistical variable in a continuous way. They represent information through colour variation like choropleth maps but, while these represent it in discrete way through well defined regions, Heat Maps represent it in a continuous fashion in non delimited areas. In the future work we can devise some strategies to implement them and create a new Symbolizer in the SE language in order to define these maps.

## 10 Conclusions

Despite recent developments in the area of map services on the Web, the standards proposed by OGC do not offer specific functionality for the creation of thematic maps. There are already studies that proposed extensions to the OGC standards in

order to facilitate the creation of such maps. However, some types of thematic maps were not considered, such as cartograms. This work proposed an extension to the SLD and SE standards, aiming the creation of thematic maps, particularly these types that were not considered by the previous studies, e.g. cartograms. We implemented this extension in one the most used implementations of the WMS service, i.e. GeoServer. With this extension it is possible to deform a layer, provided by the service, choosing a numeric attribute of that layer. We also extended the SLD in order to allow it to obtain data from an external service, and maps based on this data. This way, the SLD standard gets more flexible, in the sense that the maps can be created using data that is not present on the web map service.

We can conclude with this work that it is possible to add extensions to the SLD and SE standards while keeping the functional compatibility with the reference versions. This makes it possible to provide new styling options in order to create different types of maps, presenting different types of information. By default, these standards are not previewing the existence of possible extensions implemented by more specialized map servers. It could very advantageous if that could be incorporated in the standards by admitting the existence of different types of Symbolizers, and thus the servers would just need to give this information in the service metadata.

## References

1. Abson Sae-Tanf, Olivier Ertz (2007). Towards Web Services Dedicated to Thematic Mapping, *IICT/geo SYSIN. Free and Open Source Software for Geospatial (FOSS4G)*.
2. Borden Dent, Jeff Torguson, Thomas Hodler (2008). *Cartography: Thematic Map Design*, McGraw-Hill.
3. Daniel A. Keim, Stephen C. North, Christian Panse, Jörn Schneidewind (2002). Efficient Cartogram Generation: A Comparison Export. Information Visualization, *IEEE Symposium on In IEEE Symposium on Information Visualization*, Vol. 0.
4. Dr. Markus Lupp (2007). Styled Layer Descriptor profile of the Web Map Service Implementation Specification, version 1.1.0, OpenGIS Implementation Specification, 05-078r4, OpenGIS Consortium.
5. Dr. Markus Müller (2006). Symbology Encoding Implementation Specification, version 1.1.0, OpenGIS Implementation Specification, 05-077r4, OpenGIS Consortium.
6. E. Raisz, (1934). The rectangular statistical cartogram *Geographical Review*, Vol. 24, Nr. 2, pp 292-296.

7. M.T. Gastner, M. Newman, (2004). Diffusion-based method for producing density equalizing maps. *In Proceedings of the National Academy of Sciences of the United States of America*, 101(20): 7499-7504.

8. Jeff de la Beaujardiere (2006). OpenGIS Web Map Server Implementation Specification, version 1.3.0, OpenGIS Implementation Specification, 06-042, OpenGIS Consortium.

9. L. Dietze, Alexander A. Zipf, (2007) . Extending OGC Styled Layer Descriptor (SLD) for Thematic Cartography – Towards the ubiquitous use of advanced mapping functions through standardized visualization rules, *University of Applied Sciences Mainz, University of Bonn Meckenheimer Allee. 4th Int. Symp. on LBS and Telecartography.*

10. Peter Schut (2004). “Geolinked Data Access Service (GDAS)”, version 0.9.1, OpenGIS Project Document, 04-010r1, OpenGIS Consortium.

11. Peter Schut (2009). Geographic Linkage Service (GLS) Specification, version 0.12, OpenGIS Project Document, 08-006r2, OpenGIS Consortium.

12. W. Tobler, (2004). Thirty five years of computer cartograms. *Annals of the Association of American Geographers*, 94(1): 58-73.

13. E.B. Wolf, (2005). Creating contiguous cartograms in ArcGIS 9. *In Proceedings of the 25th Annual International ESRI User Conference.*