Extending SLD and SE for cartograms

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Abstract

Thematic maps are intended to provide statistical information associated with a certain geographic area. Despite the recent development in the area of the map services on the Web, we realize that the standards proposed by Open Geospatial Consortium (OGC), namely the Styled Layer Descriptor and Symbology Encoding, do not yet offer specific functionality for creating thematic maps. This objective of this work is to propose an extension to these standards in order to allow the creation of cartogram maps. This extension was implemented in GeoServer, a well known and largely used map server.

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

1. INTRODUCTION

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

Several types of maps can be distinguished according to the type of information they represent. Physical maps are intended to represent aspects of the physical geography of a given area, such as, characteristics of relief in a given region, as well as rivers and type of vegetation in that 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, aim to present statistical information related to a geographic location [3]. They are an appealing visual solution for the representation of different types of georeferenced information, in order to facilitate their interpretation. Depending on how the information is presented in the map, different types of thematic maps can be distinguished. Section 3 of this document presents and describes some of the main types of thematic maps.

There are already geographic information systems (GIS) that allow the representation of information in thematic maps. As examples, we highlight the 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 some OGC standards in order to facilitate the creation of thematic maps, namely extensions to the Styled Layer Descriptor (SLD) and Symbology Encoding (SE) standards, because they are responsible for defining the representation of the objects on the map. However, some types of thematic maps where 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.

The objective of this work is to propose an extension to the SE standard in order to allow the definition of cartograms maps. The extension was implemented on an existing open source map server, the GeoServer[1]. GeoServer is one of the most used and well known open source map servers. For the implementation, an open source Java library, that implements an algorithm for building cartograms, was used. So, this work mainly consists of an integration work, integrating ScapeToad[2] into GeoServer.

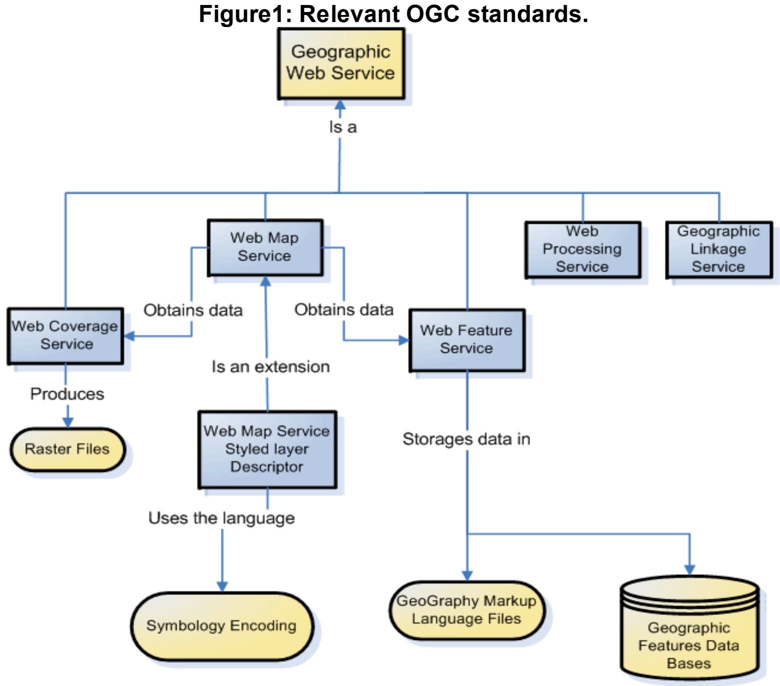
With this extension it is possible to build cartograms using a numeric attribute present in that map layer.

2. STANDARDS FOR MAP SERVICES

The Open Geospatial Consortium (OGC) is an international consortium responsible for the specification of standards that allow interoperability between geographic information systems. In that scope there are standards more relevant to the specification of services to create map images: Web Map Service (WMS) [11], Web Feature Service (WFS) [16], Geography Markup Language (GML) [4], Web Coverage Service (WCS) [18], Web Processing Service (WPS) [19], Geographic Linkage Service (GLS) [17], Web Map Service Styled Layer Descriptor (SLD) [6] and Symbology Encoding (SE) [7].

Figure 1 shows the existing relations between these concepts. It can be observed that a WMS service can interact with a WFS service or a WCS service to obtain information for map creation. WFS services can store information in geographic databases or simply in files coded according to the GML standard [20]. On the other hand, WCS services store information in raster data files [18]. WMS services use the standards SLD and SE for the definition of the styles by which the geographic information will be rendered on the map image. Finally, although the WPS and the GLS services do not have a direct interaction with the rest, they are involved in the access and manipulation of geographic data with the perspective of creating maps.

Figure1: Relevant OGC standards.



1 http://geoserver.org
2 http://scapetoad.choros.ch/

This document gives more emphasis to the WMS, SLD and SE standards, as they are the most relevant in the context of creating thematic maps.

2.1. Web Map Service

WMS is a standard proposed by the OGC [11]. It defines an interface for a service, based on HTTP requests, capable of dynamically producing map images from geographic information. Usually the maps produced by this service are rendered in pictorial formats, such as Portable Network Graphics (PNG), Graphics Interchange Format (GIF) or the format proposed by the Joint Photographic Experts Group (JPEG). Using image rendering formats that support transparency (for example the PNG format) it is possible to overlay them, creating complex map images. This service can also produce map images in vector-based format such as Scalable Vector Graphics (SVG) or Web Computer Graphics Metafile (CGM).

The geographic information contained in the maps that is 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. We define a style as 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.).

This standard defines three elementary operations:

1. GetCapabilities: This operation returns a XML file, containing service metadata, which informs the client about the service capabilities. The capabilities include the layers served by the service and the styles that are applicable to these layers.
2. GetMap: This operation returns a map image with dimensions, layers and layer styles defined through its parameters.
3. GetFeatureInfo: This is an optional operation that returns information about a given point in a given map previously obtained with the GetMap operation. The returned information format is specified using a parameter of the operation.

The WMS standard is essential to create open source GIS because it defines a service capable of produce and return map images.

2.2. WMS Styled Layer Description

The WMS Styled Layer Descriptor (SLD) [6] is an extension to the WMS standard. Its purpose is to allow the user to define its own styles for the map rendering. The basic WMS standard gives only the option to choose a layer style from its identifier that is previously provided by the service. The use of styles is obligatory, and it’s made trough the parameter Styles of the operation GetMap. So 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 language Symbology Encoding Specification (SE). The SLD standard specifies how the SE language can be used with WMS services through an XML document also named Styled Layer Descriptor (SLD).

The SLD document also allows the definition of map layers in it. For that purpose there is an element named InlineFeature in the XML document. The layers specified this way use the GML language [4].

2.3 Symbology Encoding

SE [7] is an OGC standard that consists in a language based in XML. This language allows the definition of the styles that will be used in the representation of

the different features present on the map. The SLD document will use this language so that the map services can interpret the styles defined by the user.
The SLD document contains several sections, and the most important are:

- FeatureTypeStyle: This section is the root of the document and indicates what is the feature type to which that the style will be applied.
- Rule: This section is found inside the FeatureTypeStyle section. Its purpose is to group rendering instructions. The elements Filter and ElseFilter can be placed inside the Rule section. Their function is to chose, using a condition, to which features the rendering instructions will be applied. The SLD document can contain one or more Rule sections.
- Symbolizer: These elements are placed inside the Rule sections. They describe how a feature is rendered in the map. They define characteristics like shape, color or opacity. There are several types of symbolizers that are used according to the elements the user wishes to represent on the map: lines, polygons, points or text.

Using the SE language the user can define how the different objects will be represented on the map. The next Section discusses the possibilities of creating thematic maps using this language.

3. THEMATIC MAPS

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 to 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 different styles can be created to represent the different elements, present in the map. These styles can be 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 the purpose is the creation of thematic maps. It is possible to represent some statistical information using the actual SLD and SE specifications, but they have some limitations and in some cases a high level of complexity that make them quiet hard to use when the purpose is to create thematic maps [1,12]. There are different types of thematic maps according to how information is represented on the map. Next, is discussed some of the most important types of thematic maps, and the possibilities to create them using SLD and SE standards.

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 that is intended to represent. So they offer an appealing way to visualize the variation of a single attribute in a given region. Figure 2 shows an example of a choropleth map.

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

To create these types of thematic maps using the SLD and SE specifications, a rule containing a filter for each class of values can be defined [1]. Each rule defines its own PolygonSymbolizer with a certain color associated. Each color representing a specific class of values. However it would take a rule with a different color for each class. If there is a significant variation of values, and at the same time a great number of classes, the SLD document may become too large and complex.

Figure 2: Example of a choropleth map.

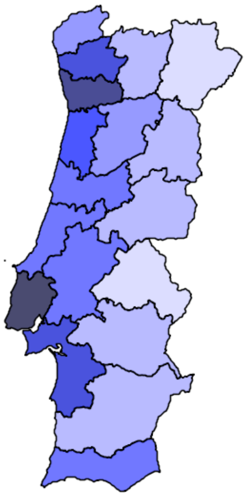


Diagram maps are maps where charts are placed in some specific locations in the map, presenting statistical information associated with these sites. Different types of diagrams can be used, like bar charts, pie charts, line charts, etc. Figure 3 shows an example of a diagram map.

In a regular way, the SE standard does not offer mechanisms that allow the creation of these maps. However, it is possible to use an external server to generate images that represent the charts. Using the PointSymbolizer element, present in the current SE language, these images can be placed on the map. 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.

In short, 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.

Figure 3: Example of a diagram map.

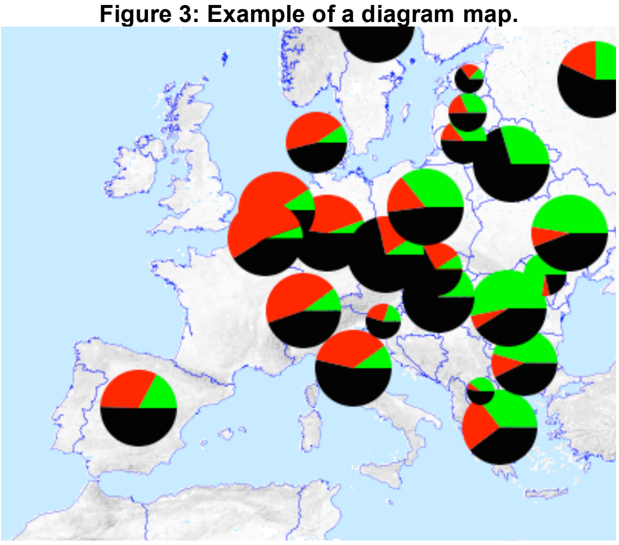
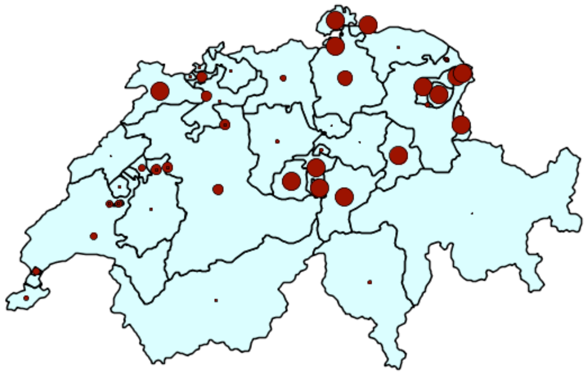


Figure 4: Example of a proportional symbol map



Proportional Symbol Maps are maps that show symbols, in specific locations, with a size that varies proportionally 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 [1]. Figure 4 shows an example of a proportional symbol map.

Overlayed 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 (overlayed or juxtaposed) according to some attribute value that is intended to represent.

It is possible to create overlayed symbol maps with the SLD and SE standards using two rules with a filter each [1]. For each rule, a PolygonSymbolizer is associated, which is an element present in the SE language. Its size varies according to one 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.

On the other hand, the OGC standards do not offer mechanisms to create juxtaposed symbols maps, because there are no mechanisms on the SE language to place two symbols side by side.

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 [8, 5, 15, 14]. 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 most important regions of the map.

ScapeToad is an open source library that allows the creation of cartograms. It uses the ESRI shapefile format for input and output of geographic information. ScapeToad implements the diffusion algorithm proposed by Gastner & Newman [10] 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.

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

Table1: Comparison between the different types of thematic maps.

	Difficulty of creation using SLD and SE standards
Choropleth	Moderate
Diagrams	Hard
Proportional Symbols	Easy
Overlayed Symbols	Easy
Juxtaposed Symbols	Impossible
Cartogram Maps	Impossible

Table 1 summarizes the possibility of creating the different types of thematic maps using the OGC standards. Proportional Symbols and Overlayed 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 one can devise some strategies for creating them using external sources to build the chart images, so they are considerate hard to create. Juxtaposed Symbols maps and cartograms are not possible to be created using these standards.

4. EXTENSIONS TO THE OGC STANDARDS FOR THEMATIC MAPS

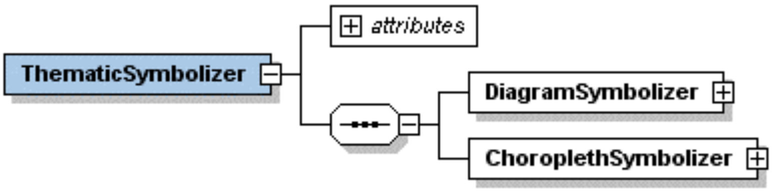
Due to the limitations of the SLD and SE specifications for the creating of thematic maps, there were proposals for extending these specifications in order to allow an easier definition of styles with the objective of creating such maps. The next sections present and discuss the most important studies in this regard.

4.1 Thematic Symbology Encoding Specification Proposal

Dietze and Alexander proposed an extension to the SE standard named Thematic Symbology Encoding Specification [12]. This extension allows the definition of diagram maps, using pie charts, bar charts, or line charts. With this extension it is also possible the definition of choropleth maps. The definition of thematic maps is done by introducing a new Symbolizer called ThematicSymbolizer. This Symbolizer must appear inside the element Rule, like the other Symbolizers. As shown in Figure 5, the element ThematicSymbolizer has two main sub-elements: DiagramSymbolizer and ChoroplethSymbolizer. The element DiagramSymbolizer is responsible for the definition of diagram maps. It contains a sub-element named DiagramType that allows the specification of the diagram one wishes to draw on the map. Another important sub-element is ThematicClass. Its purpose is to describe one or more classes, each one representing an element on the diagram. It also indicates the property of the feature from which it gets the value that will be represented.

The ChoroplethSymbolizer element allows the definition of choropleth maps, in an easier than the current SE language.

Figure 5: The element ThematicSymbolizer.



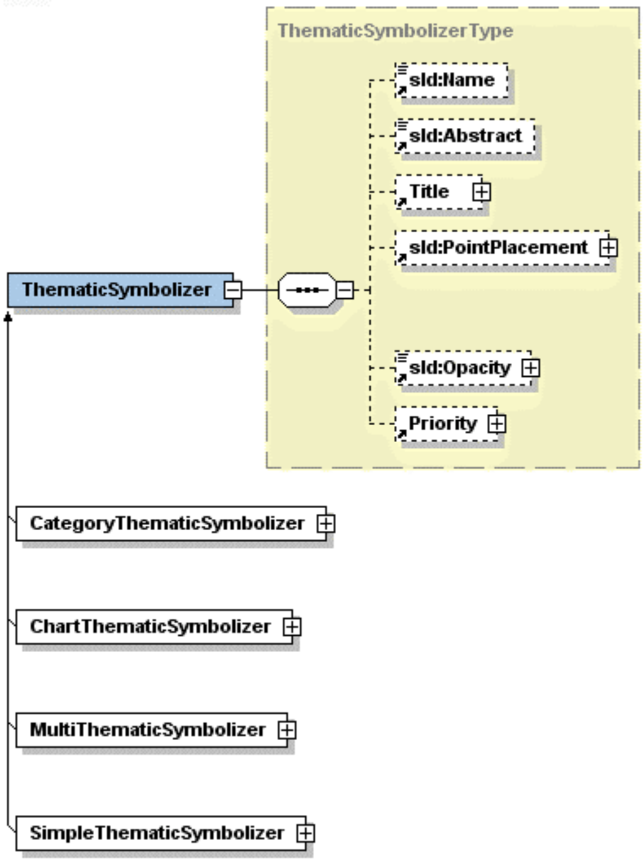
4.2 SLD-T Proposal

Abson sae-Tang and Olivier Ertz proposed another extension to the SE standard, called SLD-T [1]. This proposal also defines a new Symbolizer called ThematicSymbolizer, which has several specializations that inherit from it and are used depending on the type of thematic map one intends to represent. Figure 6 shows the different types of ThematicSymbolizers.

The MultiThematicSymbolizer is used to create thematic maps that combine different presentation techniques (for example combining choropleth with proportional symbols). The sub-element Priority is important to the creation of proportional symbol maps, as it allows defining the order in which the symbols are drawn. Another important sub-element is PointPlacement that will be relevant to the definition of juxtaposed symbols, as it allows drawing two symbols side by side.

Another element that inherits from ThematicSymbolizer is the SimpleThematicSymbolizer. This symbolizer allows the creation of thematic maps without classification. Examples of these maps are proportional symbol maps in which the represented data is not divided into categories.

Figure 6: The element ThematicSymbolizer and its specializations.



Finally the ChartThematicSymbolizer is used to create diagram maps. The diagrams can be pie charts or bar charts, so there are two types of ChartThematicSYmbolizer: BarChartSymbolizer and PieChartSymbolizer.

4.3 QGIS MapServer

QGIS Mapserver[3] is an open source implementation of a WMS server developed in the Institute of Cartography from ETH Zurich. It implements an extension to the SLD and SE standards in order to enable the creation of various thematic maps such as diagram maps, choropleth maps or proportional symbols maps.

This extension introduces a new type of Symbolizer named DiagramSymbolizer. Its purpose is to allow the definition of different types of diagram maps and also proportional symbol maps. It supports different types of diagrams by choosing one of the predefined names. When one wants to create a proportional symbol map, instead of choosing the type of the diagram, a symbol is specified in SVG format using the sub-element SVGSymbol.

This extension also defines an element Classification that can be placed inside the element Rule. The Classification element allows the partition of the values of a given attribute of the layer creating classes. This way the creation of choropleth maps is easier.

QGIS Mapserver also proposes to extend the element Mark, found inside element Graphic, adding a new element: SvgSymbol. With this extension the user can define its own symbols, in SVG format, to place on the map.

4.4 Comparing the proposals

Table 2 shows a comparison between the presented studies about the types of maps that each one directly supports. It can be observed that all the three proposals offer specific functionality to the creation of choropleth maps and diagram maps. SLD-T goes further giving 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. It can also be observed that none of these studies have support for the creation of cartogram maps.

Table 2: Types of thematic maps that each studies directly supports

	Thematic Symbology Encoding	SLD-T	QGIS
Choropleth	Supports	Supports	Supports
Diagrams	Supports (pie, bar, lines)	Supports (pie, bars)	Supports (bars, lines, pie, ring)
Proportional symbols	Does not support	Supports	Does not support
Overlayed symbols	Does not support	Supports	Does not support
Juxtaposed symbols	Does not support	Supports	Does not support
Cartograms	Does not support	Does not support	Does not support

[3] http://karlinapp.ethz.ch

5. TECNOLOGY FOR MAP SERVERS

There are several implementations of map servers that support the OGC standards. The next sections present the best known.

5.1 Deegree

Deegree is an open source framework implemented in Java that allows the creation of infra-structures of geographic information systems [13,9]. It is structured to allow the various components run on different web servers. Its entire architecture was built based on the OGC standards.

The currently recommended version is Deegree 2. It includes web services that implement some of the main OGC standards such as WMS 1.1.1 and 1.3, including operations for SLD, WFS 1.1.0 and WPS.

5.2 GeoServer

GeoServer is an open source server, implemented on Java, for the access and management of geographic information. It is implemented using the library GeoTools that supports the most recent OGC standards as well as access to different types of storage media for spatial information like the ESRI Shapefiles and PostGIS/MySQL data bases [9].

Currently, the latest version of GeoServer (2.0) implements the WMS 1.0 and WFS 1.1.1 standards, including the operations for the SLD.

5.3 MapServer

MapServer is another open source framework that allows the creation of applications for the manipulation of geographic data [2]. It is build using C language. It allows the creation of images of maps from various sources of geospatial data (for example ESRI ArcGIS Shapefiles), vector and raster.

MapServer can operate in two distinct modes: CGI and MapScript. When used in CGI mode, it functions as a Web server that processes requests from clients and produces the desired map images. When used in MapScript mode, it works as an API accessible from different programming languages such as Perl, Python, PHP, Ruby or Java.

The MapServer framework also supports the most important OGC standards, including WMS (versions 1.0.0, 1.0.7, 1.1.0, 1.1.1 and 1.3.0) and the operations for the SLD and WFS 1.0.

6. PROPOSAL: CARTOGRAM SYMBOLIZER

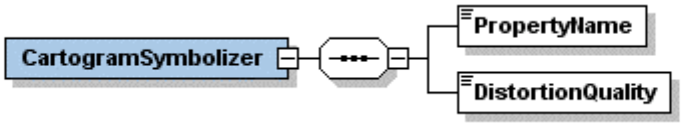
This work presents a new extension to the SLD and SE standards to allow the definition of cartogram maps. It consists of a new element in the SE language. It is a new type of symbolizer that must be placed inside the element Rule, like all the others symbolizers. Figure 7 shows the structure of this new element.

The CartogramSymbolizer element contains two sub-elements: PropertyName and DistortionQuality. 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 DistortionQuality defines the quality of the resulting cartogram map. It must receive an integer between 1 and 100. To create the cartograms an implementation of the Gastner & Newman diffusion algorithm was used [10]. 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 presence of this element inside the element Rule will indicate the server that the layer must be deformed using the Gastner & Newman algorithm. The rest of the symbolizations rules will be applied normally to the deformed layer. The CartogramSymbolizer works differently from the rest of the symbolizers in the way that the standard symbolizers describe how a feature is drawn on the map, but on the other hand the CartogramSymbolizer is applied to all the features, because the entire layer is will be deformed.

Figure 7: The structure of the CartogramSymbolizer element.



7. IMPLEMENTATION

In order to implement the CartogramSymbolizer extension the open source java library ScapeToad was used. 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.

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

GeoServer uses the GeoTools library to parse the SLD documents, so an extension to this library was made in order 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 must be transformed to a shapefile. Then it calls the ScapeToad to perform the distortion algoritm, 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.

8. RESULTS

With these extension implemented to the GeoServer it is possible to create cartograms using the CartogramSymbolizer element in the SLD document.

Figure 8: Cartogram of Portugal Territory

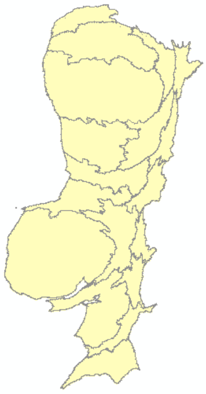


Figure 9: Territory of the U.S.A.

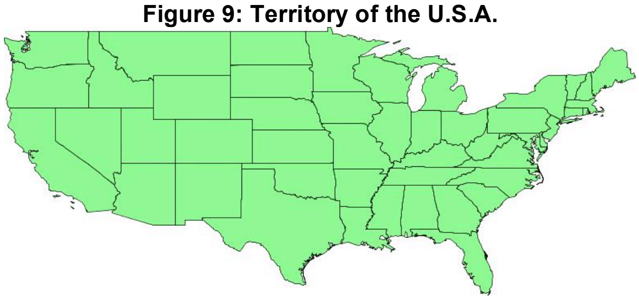


Figure 10: Cartogram of the population of the USA

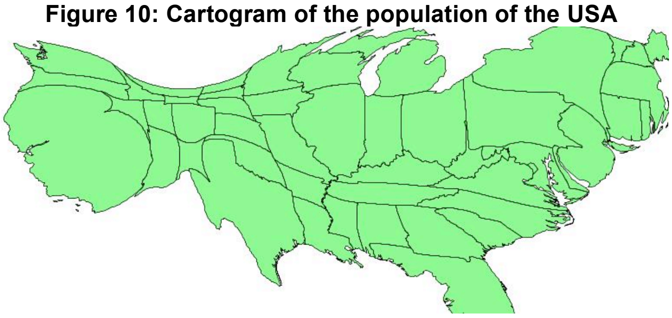


Figure 8 represents a map obtained using the CartogramSymbolizer element. In this case the layer has an attribute that corresponds to the population of each district of the Portuguese territory. Choosing this attribute to perform the deformation the service returns a map presenting the area of the districts proportional to the population. It can be observed that the majority of the Portuguese population is concentrated on the coast, especially in the regions of Lisbon and Porto.

Figure 10 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 shown in the figure 9.

Figure 11: Choropleth map of the Switzerland territory.

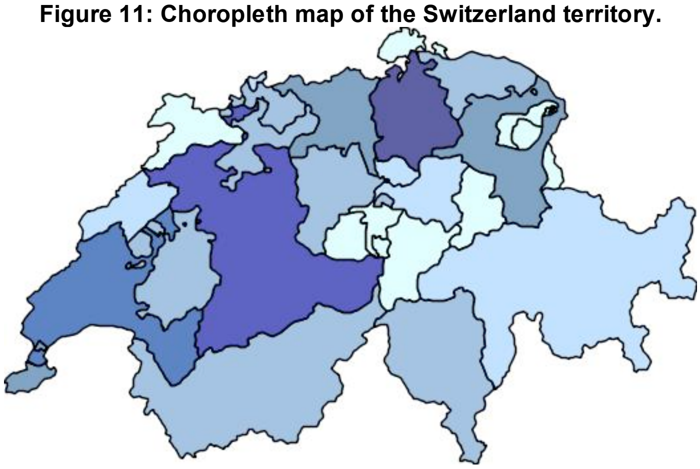


Figure 12: Cartogram map of the Switzerland territory.

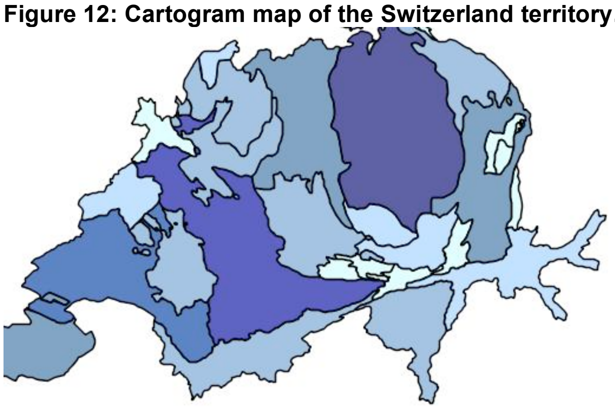


Figure 11 shows a choropleth map representing the population of the different regions of Switzerland. With our extension it is possible to add the CartogramSymbolizer element to the SLD document, and the rest of the rendering rules will be applied normally to the deformed layer. Figure 12 shows the resulting map of adding the CartogramSymbolizer to the SLD document that specified the style of the previous map. As can be seen in Figure 12 the map is deformed and the remaining rendering rules were applied normally.

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.

10. CONCLUSIONS

Despite recent developments in the area of map services on the web, it appears that 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 type of thematic maps not considered by these studies: cartograms. The extension was implemented in one the most used implementations of the WMS service: GeoServer. With this extension it is possible to deform a layer, provided by the service, choosing a numeric attribute of that layer.

With this work, it can be concluded, that it is possible to add extensions to the SLD and SE standards to give new styling options in order to create different types of map, presenting different types of information. These standards are not prepared for the existence of possible extensions implemented by the different map servers. It could very advantageous if the standards admitted the existence of different types of Symbolizers, and the servers would just need to give this information in the service metadata.

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