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PERFORMANCE TESTING OF WEB MAP SERVICES IN THREE DIMENSIONS – X, Y, SCALE

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ABSTRACT

The paper deals with the performance testing of web mapping services. The paper describes map service tests in which it is possible to determine the performance characteristics of a map service, depending on the location and scale of the map. The implementation of the test is tailored to the Web Map Service specifications provided by the Open Geospatial Consortium. The practical experiment consists of testing the map composition acquired from OpenStreetMap data for the area of southwestern Slovakia. These tests permit checking the performance of services in different positions, verifying the configuration of services, the composition of a map, and the visualization of geodata.

The task of this paper is to also highlight the fact that it is not sufficient to only interpret a map service performance with conventional indicators. A map service's performance should be linked to information about the map's scale and location.

KEY WORDS

- Web Map Service,
- performance testing,
- map scale,
- response time.

1. INTRODUCTION

Spatial information can be accessed in many ways. A Web Map Service (WMS) is one of the most commonly used ways to access geodata for a wide range of users. It enables the distribution of spatial information across the Internet in a simple way and provides many benefits. Spatial data is available wherever there is a connection to the Internet. This is possible because almost all geographical information systems support the addition of maps through a WMS. The responsibility for the data remains with their administrators so they are always up to date. The Service provides data visualization, but the source data itself are not available in this type of service. It is necessary to publish a service with sufficient performance to satisfy the user.

The performance of web applications can be expressed through characteristics such as response time, latency, throughput or the number of errors. These characteristics of conventional applications have values that are dependent on the number of users, the type of operation which is being performed, the volume of the data being processed, and a number of other parameters (hardware, software, network, etc.). Two indicators are added to map services (compared to traditional web applications), namely, the performance depending on the map scale and the performance depending on the location. These parameters are especially important if the map service works with heterogeneous data which have a diverse density of objects,

or if the map is a composition consisting of more layers which are available in different scales.

2. STATE OF THE ART

Performance testing itself is part of an issue which includes tests such as acceptance/qualification testing, installation testing, alpha and beta testing, conformance testing/functional testing/correctness testing, reliability achievement and evaluation, regression testing, performance testing, stress testing, recovery testing, configuration testing and usability testing (Abran, Moore, 2004). The results of the tests describe different attributes. Performance belongs among the Quality of Service (QoS) attributes. We distinguish the following attributes (INSPIRE PG, 2007), (W3C, 2003):

- Performance – represents how fast a service request can be completed. This attribute is related to values measured by testing tools, the response time (the time measured from sending a request to receiving a full response), and latency (time measured from sending a request to receiving a first response (JMeter, 2012)).
- Reliability* – represents the ability of a web service to perform its required functions under the stated conditions for a specified time interval. Reliability is the overall measure of a web service's ability to maintain the quality of its service.

- Scalability* – represents the capability of increasing the computing capacity of a service provider's computer system and the system's ability to process more user requests, operations or transactions in a given time interval.
- Capacity* – capacity is the limit of the number of simultaneous requests which should be provided with a guaranteed performance. This attribute is related to the term "Throughput" (the number of requests per time unit, which is sometimes known as the overall performance).
- Accuracy* – represents the error rate generated by the web service.
- Accessibility* – represents whether the web service is capable of serving the client's request.
- Availability* – The web service should be ready (i.e., available) for immediate use. Availability is the probability that the system is up.
- Interoperability – Web services should be interoperable between the different development environments used to implement services so that developers using those services do not have to think about which programming language or operating system the services are hosted on.
- Security – Web services should be provided with the required security. Security for web services means providing authentication, authorization, confidentiality, traceability/auditability, data encryption, and non-repudiation.
- Integrity – Integrity for web services should be provided so that a system or component can prevent unauthorized access to, or modification of, computer programs or data.
- Robustness – Web services should be provided with a high degree of robustness. Robustness here represents the degree to which a web service can function correctly even in the presence of invalid, incomplete or conflicting inputs.
- Exception Handling – Web services should be provided with the functionality of exception handling. Since it is not possible for the service designer to specify all the possible outcomes and alternatives (especially with various special cases and unanticipated possibilities), exceptions should be handled properly. Exception handling is related to how the service handles these exceptions.
- Network-related QoS requirements – To achieve a desired QoS for web services, the QoS mechanisms operating at the web service application level must operate together with the QoS mechanisms operating in the transport network which are rather independent of the application. In particular, the application level of QoS parameters should be mapped appropriately to the corresponding network level's QoS parameters. Basic network level QoS parameters include network delay, delay variation, and packet loss.

Bad performance will affect the attributes marked with an asterisk.

The performance testing of web applications is a longstanding issue and is documented by a number of publications. The performance testing of WMS is especially discussed in (Horák et al., 2009)

and (Kliment, Cibulka, 2011). Results comparing the performance of various mapping servers and configurations are discussed in (Anderson, Deoliveira, 2007) and (WMS Benchmarking, 2011).

There are many methods used to increase the performance of map services. It is possible to use appropriate formats, data warehousing, editing the data model, etc. Methods such as load balancing, high availability, cluster computing, and others can also increase the performance of operations. Some of these techniques are described in (Yang et al., 2005).

The improvement of the performance of map services from the client's point of view can also be achieved by storing map tiles loaded on the client or by a procedure known as "prefetching." One such algorithm is discussed in (Yeşilmurat, İşler, 2011). The disadvantage of these methods can be the increased utilization of systems, both on the client side and the server side.

Testing is carried out by gradually sending requests to a service and recording the characteristics of the services. This can be performed by one or more concurrent users. During the test the values of the response time, latency, bandwidth or error rate are recorded. The values of these parameters are dependent on many factors, for example, the number of concurrent users, the type of operation, or the "think time" which defines the breaks between the requests. The measured values are usually plotted on charts, which show the dependence of the values with respect to the testing time, the number of users, or the type of operation.

3. MAP SERVICE PERFORMANCE CHARACTERISTICS

The heterogeneous geodata of a map service can affect the values of the above parameters. Data from map services tend to have different levels of resolution, which may be dependent on the map scale and on the geographical area of the services. Therefore, it is appropriate to define the following outputs of any map service performance testing:

- The dependence of the service performance on the map scale. The dependence of the response time or latency on the map scale is a valuable output of the testing. This dependence indicates whether the service is configured correctly and whether a service is smoothly usable at different scales. Ideal and bad response time dependencies on a map scale are shown in Figure 1.

Fig. 1 Ideal (on the left) and bad (on the right) dependencies of response time on a map scale.

- The dependence of service performance on the position of the requests within the bounding box of the service. Based

on these test results we can decide whether a service has a satisfactory performance, for example, in urban or rural areas, or in similar places with different densities of objects. If possible, the service should have the same characteristics in all locations. In the case of one map scale, the results can be interpreted with a two-dimensional performance model (x, y, performance). This model can be interpreted in different ways, e.g., using cartodiagrams, isolines or hypsometry. In the case of different map scales this would be a three-dimensional map service performance model (x, y, scale, performance).

4. TESTING METHODS

The record of the map service characteristics listed above requires the development of testing procedures and scenarios that can record the required data. Tests of map services in three dimensions require recording classical performance characteristics (response time, latency, etc.) as well as the map scale (or resolution) and the bounding box of the requests, or its centroid. We need to become familiar with a map service interface in order to record these specific values. This paper is focused on WMS testing. The interface of the WMS is described below.

Web Map Service

A WMS is used for accessing geographic data. The data are available via the service to view in raster form, but the source data are not available. The International Standard (OGC WMS, 2006) defines a “map” as a portrayal of geographic information as a digital image file suitable for display on a computer screen. A map is not the data itself. These maps are usually provided in image formats such as PNG (Portable Network Graphics), GIF (Graphics Interchange Format) or JPEG (Joint Photographic Experts Group). A server with a WMS can contain raster data or vector data, which are often stored in databases. Web map services support three operations:

- GetCapabilities – used to obtain the service’s metadata,
- GetMap – used to obtain images of maps,
- GetFeatureInfo – used to identify the contents of a map.

We are testing the performance of providing the maps; therefore, we are testing the GetMap operation. We are using the following parameters to carry out this operation in the case of HTTP (Hypertext Transfer Protocol) GET (OGC WMS, 2006):

- VERSION (mandatory) – version of the service; for example, the highest is 1.3.0.
- REQUEST (mandatory) – name of the request, in this case, GetMap.
- LAYERS (mandatory) – comma-separated list of the map layers.
- STYLES (mandatory) – comma-separated list of the layer styles.
- BBOX (mandatory) – coordinates of the requested map, in the order min. X, min. Y, max. X, max. Y (bounding box)

- CRS (mandatory) – (CRS – Coordinate Reference System) coordinate reference system code.
- WIDTH (mandatory) – map image width in pixels.
- HEIGHT (mandatory) – map image height in pixels.
- FORMAT (mandatory) – output map format.
- TRANSPARENT (optional) - background type of the map; the possible values can be true or false.
- BGCOLOR (optional) - color for the background in the form 0xRRGGBB.
- EXCEPTIONS (optional) - format in which the server provides exceptions.
- TIME (optional) - time value of the required layer.
- ELEVATION (optional) - elevation of the required layer.

A complete description of the WMS and its operations is available at (OGC WMS, 2006).

It is necessary to store the location of the requests contained in the BBOX parameters in order to record the performance of the service depending on the position. Determining the relationship between the map scale and performance requires the computation of the scale of the digital map. The map scale of the desired image can be calculated from the parameters BBOX and WIDTH or HEIGHT. The calculation can be performed as shown in Figure 2 and with the help of the following formulas (OpenLayers, 2012):

Fig. 2 Geographic bounding box of a GetMap request and the height and width of the map image.

$$R = \frac{\max X - \min X}{WIDTH} = \frac{\max Y - \min Y}{HEIGHT} \quad (1)$$

$$M = R * IPU * DPI \quad (2)$$

where: M – scale denominator,
R – resolution,
IPU – inches per map unit (for example, for meters IPU ≈ 39.3701, for degrees IPU ≈ 4374754),
DPI – dots per inch.

The practical experiment involves testing the WMS with OpenStreetMap data showing the whole territory of Slovakia. The layer tested was established as a group of eight sub-layers whose description can be found in Table 1. The styles of the sub-layers were divided into categories that were available at different map scales.

Tab. 1 Description of the WMS layers.

Layer name	No. of categories	Max Scale	Label	No. of features
forest	1	none	No	8,303
waterways	1	150,000	Yes	3,590
water	1	500,000	No	207
building	26	10,000	No	1,484,606
roads	33	4,000-none	Yes	129,359
railway	3	14,000-260,000	No	3,135
poi (point of interest)	10	5,000	No	32,618
location	8	5,000-1,200,000	Yes	35,376

The testing was performed only on a part of Slovakia. The location is shown with a dotted line in Figure 3.

Fig. 3 The area subjected to performance testing.

The area was chosen to include the densely built-up parts of large cities as well as villages with a low density of objects. The left boundary was chosen to include the capital city of Slovakia – Bratislava. Nitra is situated at the right side of the bounding box, and the upper part includes the city of Trnava. Municipalities, small towns and a rural area are situated in the central part of the bounding box. The Little Carpathians can be found in the upper left part of the area studied. The geographical demarcation (latitude and longitude) of the area is approximately 17.1, 48.0, 18.15, 48.4 degrees.

The WebTest testing tool, which was developed for the dissertation of the author, was used for the testing. The map scales of 1:2,000, 5,000, 10,000, 25,000, 50,000 and 100,000 were tested in the first part of the test. Only one user was simulated in these tests. The classical parameters as well as the location of the requests (parameter BBOX) and map scale were recorded during the test. This information makes it possible to determine the performance of the map service both in a horizontal as well as in a vertical direction.

The map scale of 1:25,000 was selected for the second set of the tests because most heterogeneous results on this scale were obtained in the horizontal direction. This map scale was subjected to further testing in which 20 concurrent users were simulated.

5. RESULTS

The test results show that the urban areas are the areas with the highest response time. The worst times were measured in the center of Bratislava. The minimum response times were collected in the rural area, while the best performance of the map service was obtained in the southern part of the Little Carpathians. The resulting response times for the tested map scales are shown in Table 2.

Tab. 2 Response times.

Scale 1 : M	Count of the users	Count of the GetMap requests	Average response time	Response time rural area	Response time urban area
2,000	1	19,584	1.10	1.08	1.21
5,000	1	19,146	1.12	1.09	1.22
10,000	1	19,105	1.12	1.06	1.28
25,000	1	78,113	0.27	0.19	0.40
50,000	1	10,561	0.32	0.22	0.38
100,000	1	9,080	0.35	0.35	0.35
25,000	20	9,062	3.17	2.52	4.08

The relationship between the performance in an urban area and a rural area is not visible on a map scale of 1:100,000. The major differences between the performance in an urban area and a rural area were reported on the map scale of 25,000. This scale was subjected to testing in which the 20 concurrent users were simulated. The response time was logically increased, but the difference between an urban area and a rural area was diminished.

The test area has a sufficient number of points to interpolate a two-dimensional map service performance model for the one map scale. The performance model for the scale of 25,000 is shown in Figure 4.

Fig. 4 2D performance map for scale 1:25,000.

6. CONCLUSIONS

The performance of a web map service is one of the parameters which ensure smooth and seamless use within a Spatial Data Infrastructure (SDI). An example is the Infrastructure for Spatial Information in Europe (INSPIRE), which has fixed quality parameters (performance, capacity, availability). Any service that is published for a larger number of users should be subjected to performance testing to verify its ability to meet the needs of future users for parallel access and work with the service.

The practical testing has shown that the response time of the tested service on an unfavorable scale can be doubled in areas with different densities of objects. Also, there can be large differences in the response time of different map scales. Consequently, it is insufficient to characterize the performance of a map service by the conventional indicators used for the description of a web application's performance. The end point of the service often hides heterogeneous

data. These data can be heterogeneous both in a horizontal as well as in a vertical direction. This should be taken into account in performance testing. If we want to describe and declare the performance of a map service exactly, it is necessary to take into account the map scales with which the data of the service are provided as well as the location of the request. The results of the map service performance testing should include the dependence of the performance on the map scale in areas with a high or low density of objects. To describe the map service performance, a 2D or 3D performance model can be used.

The benefits of this testing are very high if we are doing map service tuning. In this way it is possible to detect the bad setting of a map service, composition or scales. An incorrect setting can be repaired, based on the results of three-dimensional performance tests. Improvements in the performance can be made through changes in the data structures, tuning the spatial indexes, or adding derivative or generalized layers. We can also use various other methods.

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