GIMA

Geographical Information Management and Applications

Master of Science Thesis

TOWARDS IMPROVING THE USABILITY OF VIRTUAL GLOBES BASED APPLICATIONS

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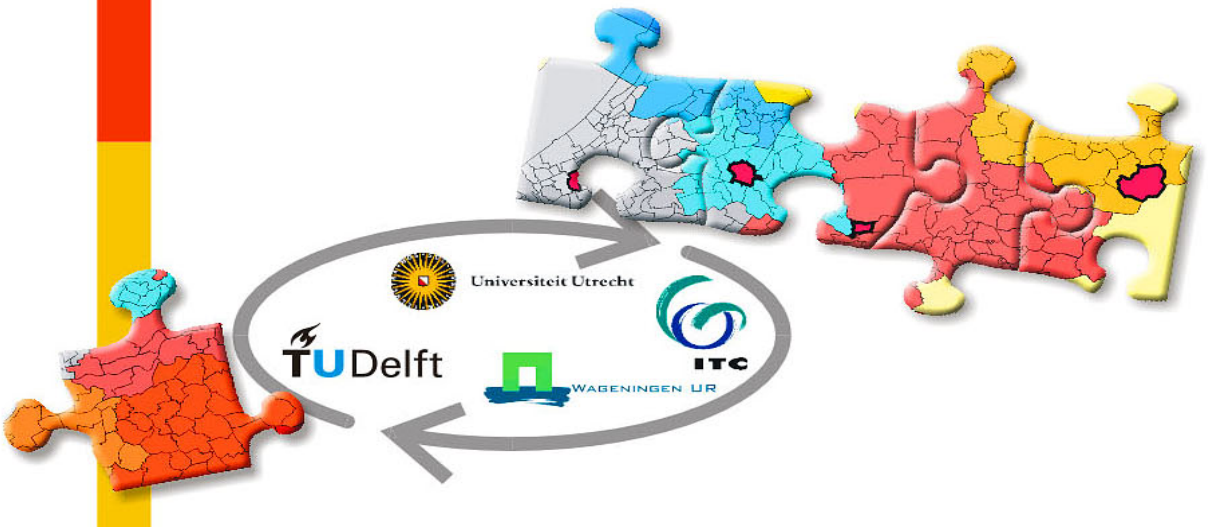

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Virtual globes (VG) can be described as a 3D software models representing the surface of the planet earth. Virtual globes based applications (application or system designed and built specifically for use with Virtual Globe) use virtual globes' functionalities for any user requiring a map to show some particular information. VGs based applications are growing constantly but their full capabilities are not yet well known or exploited and they need further development in order to improve their usability and use.

The present thesis research is intended to analyze the current usability of VGs based applications, considering the "trendiest tendencies" for improving applications, such as *mashup*s, in a user-friendly way. This research work lists common and readily available VGs based applications and current usability issues employing professionals and scientists with an appropriate background as testers.

Three usability factors: efficiency, effectiveness and satisfaction were tested using a variety of useful proven methods: performance tests, questionnaires, reaction adjectives, thinking aloud technique and guided interviews for non functional requirement analysis (qualimetry). Results pointed to some elements of the Satisfaction aspect as requiring further improvements.

Specific usability analysis using guided interviews were performed, with the purpose of obtaining usability elements requiring improvement in the visualization and representation of statistical data.

The proposed conceptual design of the Thesis consists on a mashup that combines the content of the INE Website (Bolivian National Statistical Office) and the Google Earth application. On the basis of the results from the usability tests conducted, specific improvements included on the proposed conceptual design are suggested.

KEYWORDS

Usability, Virtual Globes, Mashups, Applications, Statistical Data Dissemination, Conceptual Design, Qualimetry.

CHAPTER I

INTRODUCTION

1.1. BACKGROUND

Since GIS appeared, the way of working with it has been continuously and widely changing. At the very beginning, very strong technical skills and scientific knowledge were required in order to work with GIS. Nowadays, thanks to the enormous improvement of technology, almost anyone can take advantage of using these tools. GISs are increasingly friendly to use, so, not much knowledge is needed to solve most of low complexity problems. This fact has been widely described (e.g. Turner, 2006). In his article, the author also shows that just a few years ago, access to GIS as a tool was limited to very specialized group of people.

Nowadays, this manner of working has evolved, rendering a new generation of science: "Neogeography", which combines *"the complex techniques of cartography and GIS and places them within reach of users and developers*" (Turner, 2006) supported by the development of a growing number of easily accessible tools. This fact becomes evident after analyzing current literature, with the result of a huge amount of diverse types of tools and applications, developed to manage geographic data in such a way that they are readily available to basically anyone who is able to work properly with a computer and has an access to internet.

Turner defines Neogeography as "new geography", stating that it "*consists of a set of techniques and tools that fall outside the realm of traditional GIS, Geographic Information Systems. Essentially, Neogeography is about people using and creating their own maps, on their own terms and by combining elements of an existing toolset. Neogeography is about sharing location information with friends and visitors, helping shape context, and conveying understanding through knowledge of place*" (Turner, 2006).

O'Reilly (2005), defined neogeography as "*a diverse set of practices that (mostly) fall outside the professional geographic domain, rather than making claims on scientific standards*". He stated that neogeography is focused on intuitive, expressive, absurd or even artistic personal applications of the "reality"; he also declared that these types of practices in general do not conform to the cartographic protocols, but they take into account the importance of the geographic sciences.[1]

"*While geographic information systems (GIS) remained as expensive programs, and its use restricted to highly-trained specialists, tools like MapQuest and Yahoo! Maps brought easy-to-use mapping tools to the public. The release of Google Maps demonstrated to web developers and users the expanding possibilities of navigation and opened a floodgate of interest in online mapping*" (Turner, 2006). Great advances in the development of "Virtual Globes" open a huge and new field for uses and application in the scientific field.

Blower *et al,* (2007), define virtual globes as "*software applications that display a three-dimensional representation of the entire Earth, usually based on satellite imagery, upon which new information can be superimposed*". A virtual globe (VG) can be described as a 3D software model representing the surface of the planet earth. Usually a virtual globe gives de user the possibility to freely move around the surface of the earth in a virtual environment using different

[1] ZDNet Website <http://blogs.zdnet.com/BTL/index.php?p=1565> retrieved on December, 2009.

tools. Compared to a conventional globe, virtual globes have the additional capability of representing many different views on the surface of the earth.

Nowadays VGs are widely used by general public, mainly because their intuitive and easy to use properties. Currently more than 42 VGs can be found over the Internet, as reflected on Section 2.6 in this document; from those the most popular and widely used are: Google Earth and Google Map, NASA World Wind and ArcGIS Explorer. Chapter II presents more information about these examples.

Virtual globes based applications can be defined as computer programs using virtual globes' functionalities as the main tool employed for any uses requiring a map to show some particular information. VGs based applications are growing constantly as they seem to be attractive and powerful tools for practical applications at first sight. Their usefulness for research, business, professional and educational purposes is not yet exploited in the perspective of their potential for saving money, time and efforts while trying to obtain primary information from earth's surface data and for making many types of analysis of information.

In spite of these facts, users are not fully aware of its power, prospective based applications, functions and functionality. Improving usability of developing applications is just starting to be known and understood. Even though virtual globes tools are relatively easy to use, their full capabilities are still not well known or exploited.

Virtual globes (VGs) users need additional and specialized software to complete their work as VGs provide just limited tools for analyzing certain tasks in a complete form. It constitutes a practical limitation and increases working time and efforts. Many VGs based applications need further development in order to improve their usability and become widely used tools around the world.

A *mashup* can be defined as "a Web application that combines data or functionality from two or more sources into a single integrated application, implying easy and fast integration of applications"[2].

Thanks to *mashup*s, users are now able to create their own software-based applications that best fit their needs; by combining several data sources, users can improve their results. Yee (2008) states: "*mashups are starting to forge this sought-after access and integration of data and tools not only in the context of blogging but also to any point of interaction between users and content*". This thesis research is focused on those applications, including VGs combined with different web-based data sources results.

Thesis research presented here highlights the usability engineering of VGs based applications, both current and potential, considering the "recent tendencies" for improving applications, such as *mashup*s, in a user-friendly way.

Tuttle *et al.* (2008) state that, until recently, GIS, remote sensing, and digital cartography were mostly restricted to those who could afford expensive software packages as well as understanding how to deal with a range of different data formats and projections. VGs have allowed neogeographers lacking expensive software and a high level of geospatial training to start using, accessing and publishing data, in such a manner, thus making it available, for example, to geographers in developing countries such as Bolivia.

[2] Wellsphere Website <http://stanford.wellsphere.com/general-medicine-article/cdc-releases-on-line-environmental-health-tracking-system/746954> Retrieved on February, 2010.

Research of this thesis is focused on two main aspects:

1. The "use and abuse" of VGs based applications, including the description of the most common and available based applications and their current usability analysis.
2. The conceptual design of a VG based application using a *mashup* combining national (Bolivian) statistical data with a Google Earth interface, in order to analyze the possibilities of developing an improved VG based application.

1.2. MOTIVATION AND PROBLEM DESCRIPTION

1.2.1. PROBLEM IDENTIFICATION

Lack of sufficient scientific evidence of the usability of VGs based applications, does not allow improvement of their capabilities and use.

This statement is supported by an extensive review of the available literature and web searching. Available scientific usability of VGs studies is extremely specific and directed to unique applications. Since there is an ample field for research on this topic, this evident lack of information became the motivation for the present research.

1.2.2. PROBLEM CONTEXT

This research was focused on the analysis of the current and potential usability of VGs based applications, thus enabling fundamental and/or key aspects for usability improvement of these applications, stressing its use in scientific, business, professional and academic environments with emphasis on geographical data.

After scrolling the Web, it became evident that there is a tendency to use VGs mainly for fun and social purposes; there is only few documentation and VGs based applications for use in professional or scientific environments, as natural resources management, land use planning, merchandise distribution, etc.

The researcher considers that VGs are very useful tools that can highly contribute to the development of applications based on them, since there is a certain vacuum in professional and scientific fields regarding the use of these tools; this fact supports the idea that it is worthwhile to consider developing and exploiting them, since "*there is no a bigger challenge today than connecting the people who study and investigate the earth, with the vast quantities of available earth data that can be converted in information critical for knowledge development and for informed decision-making*"[3].

The present research intends to highlight the possibilities and limitations of using VGs based applications for real scientific research and professional applications in the geographic information data management field. Main target users, for this study, are professionals and scientists; mainly due to the fact that VGs are free or low cost tools available on the Internet and currently used for amusement or for simple and basic purposes and rarely as a reliable professional and scientific tool. This research intends to transform this situation, highlighting the real possibilities of finding innovative formal applications for these increasingly popular tools, namely in the professional and academic scientific work, especially where availability and software costs become a limiting factor (i.e. in developing countries like Bolivia).

[3] Geosoft Website <http://www.geosoft.com/opensource/> retrieved on January, 2010.

1.3. RESEARCH OBJECTIVES

Overall objective is to assess the current usability of VGs based applications, suggesting capability improvement and use, followed by the development of a conceptual design of a VG based application, focused on national statistical data dissemination.

Specific objectives are listed as follows:

1) To identify and/or define the types of uses (mapping, marketing, tourism, etc) currently using VGs based applications.
2) To establish basic usability elements, metrics (qualimetrics) methods and techniques for measuring and validating the current usability of VGs based applications used in scientific research and/or specialized uses.
3) To determine the conceptual variables (factors) needed for improving the usability of VGs based applications, as main tools for scientific research and/or practical applications.
4) To develop a conceptual design of an improved VG based application for statistical data dissemination.

1.4. RESEARCH QUESTIONS

In order to determine the components, structure and relations for measuring the current usability of VGs based applications and to arrive at useful conclusions for improving them, the following research questions are established.

A. Which are the types of uses (mapping, marketing, tourism, etc) currently using VGs based applications?
B. Who are currently using VGs based applications?
C. What is the most used purpose of VGs based applications?
D. Is it possible to measure the usability of VGs based applications? If so, what are the best and suitable methods and techniques for this purpose?
E. What is a suitable metric condition to meet both qualitative and quantitative usability results?
F. Are there usability standards that can be used to support usability measurement of VGs based applications?
G. Is it possible to validate VGs based applications usability in scientific research and/or specialized uses?
H. What are the variables (factors) needed for improving the usability of VGs based applications for scientific research and/or specialized uses?
I. What are the methods and techniques for measuring or identifying those variables?
J. In which way the use of a conceptual model could be useful for improving the usability of VGs based applications oriented to statistical data dissemination?
K. Which are the elements to be considered for developing a conceptual design of a VG based application?
L. Can such a model be developed using a non VG based statistical data dissemination application?

1.5. THESIS STRUCTURE

This thesis consists of six chapters. Throughout the different chapters of this research, answers to the research questions are presented as defined in the previous section.

Chapter I - Introduction

The first Chapter provides an overview of the research. It presents author's motivation, problem description and it supplies references to related studies. This chapter outlines the overall objective of the research and the research questions. Finally, it presents the structure of the thesis.

Chapter II - Theoretical Background

This chapter contains the results of the literature review and the theoretical background supporting the core of the thesis research topics.

The chapter is divided into two main sections: 1) First section is focused on virtual globes, their definition, description of their main functionalities, and an overview of their main applications. The concept of *mashup* is also introduced. 2) The second part of the chapter refers to usability issues, some usability definitions are given and the usability methods and techniques used during the research process are described.

Chapter III - Research Methodology

This chapter contains a detailed description of the methodology applied during the "fieldwork". The methodology is oriented to: 1) analysing the current usability of Virtual Globes based applications and 2) developing a conceptual design of an improved VG based application focused on statistical data dissemination.

Chapter IV - Research Results

The first part of the chapter is focused on analysing the results related to the state of the art of virtual globes, their functionalities and their main common applications.

The second part of the chapter presents interprets and discusses the results of the usability testing process. Subsequently outcomes of the tasks executions are reviewed, as well as the observations or spoken thoughts from the testers during the tests sessions, are summarised and analysed. Analysis of the responses to the questionnaires and the reaction adjectives preferred by test subjects is discussed in the last part of the chapter.

Last section of the chapter contains the results of the non functional requirement analysis using the guided interviews method.

Chapter V - Conceptual Design of a Virtual Globe based Application for Statistical Data Dissemination

This chapter contains the description of the conceptual design for and improved VG based application. A description of the design elements is explained in detail.

Chapter VI – Conclusions and Recommendations

Finally, the thesis research overall conclusions and recommendations are presented in this chapter, as well as some ideas about some future work.

CHAPTER II

THEORETICAL BACKGROUND

This chapter contains the results of the literature review and the theoretical background supporting the core of the thesis research topics.

The chapter is divided into two main sections:

1) First section is focused on virtual globes and virtual globes based applications, their definition, description of their main functionalities, and an overview of their main applications. The concept of *mashup* is also introduced.
2) The second part of the chapter refers to usability issues, some usability definitions are given and the usability techniques used during the research process are described.

2.1. VIRTUAL GLOBES

A virtual globe can be described as a 3D software model representing the surface of the planet earth. Usually a virtual globe gives de user the possibility to freely move around the surface of the earth in a virtual environment using different tools. Compared to a conventional globe, virtual globes have the additional capability of representing many different views on the surface of the earth. These views may be of geographical features, man-made features such as roads and buildings, or abstract representations of demographic quantities such as population[4].

Virtual globes have proven widely popular since the moment they were available trough Internet in 2005 when both Google and Microsoft introduced free, online virtual globe software. It seems that such public interest gives a wide variety of opportunities, challenges, and questions for geographers and ordinary users around the world, probably because their main characteristics: they use satellite and aerial imagery draped over interactive, three-dimensional software representations of the earth; users can easily move and view locations-of-interest through search queries and user interface controls. They have also available additional and useful data such as political boundaries, roads, etc that can be added over the images. Many of the most used virtual globes (VG) have Application Program Interfaces (API) and eXtensible Mark-up Language (XML)-based data specifications allowing developers and advanced users to create new functions, data and new applications based on them[5].

For Blower *et al.* (2007) Virtual Globes have been designed such to let the general public use them in a very easy and intuitive way[6]. These authors tried to discover the possibilities of using VG on professional and scientific environments pointing out two principal capabilities of the VGs that can be fully exploited in professional environments:

- Support for simple file formats for data exchange.
- The capability of displaying multiple datasets simultaneously.

Riedl (2007) cited by Aurambout *et al.* (2008), pointed pout that the special features of VGs give them several advantages over other more traditional interfaces for data mapping as:

[4] Nation Master Website <http://www.statemaster.com/encyclopedia/Virtual-globe> Retrieved on February, 2010.
[5] Geography 2.0: Virtual Globes Blog <http://geography2.blogspot.com/2005/09/virtual-globes-session-at-aag2006.html.> Retrieved on February 2010.
[6] Power Point Document <http://www.nesc.ac.uk/talks/ahm2007/792.ppt.> Retrieved on February 2010.

- The earth imagery (satellite and aerial) displayed on a globe structure is free of distortion
- Data displayed in VGs can be viewed at any scale and from any angle.
- VGs provide a large degree of interactivity, allowing the user to move to different locations and visualize different types of spatial data.

Aurambout *et al* (2008), state that those special features convert VGs into important tools to be used for publishing spatial information to a broader research community and general public. This can be evident by the diversity and multitude of VGs based applications currently available through the Web. There is not a formal definition of VGs based applications. For the purposes of this research, the definition that will be used is as follows: ***a VG based application can be defined as an application or system designed and built specifically for use with Virtual Globes***.

Shepard and Cizek, 2008 point out that scientists and professionals belonging to different disciplines are starting to use VGs especially in the fields of 3D modelling for visual communication purposes. Communicating science in this way has important advantages, such as,

- Scientific findings can be seen and understood by more people compared with the commonly used dissemination mechanisms
- Enhancing the awareness of certain important scientific events
- Increased impact on target communities
- Enhanced collaboration with other expert users
- Increased publicity and recognition, and
- Improved fundraising possibilities for research
- Accessibility to huge amounts of data and information (previously private)
- Possibilities of online feedback and dialogue

Even currently there are more than 40 internet based VGs available trough the Web (Table 2.1 shows the list and their URLs. A detailed list containing a brief description of their main characteristics, main features and applications based on them is presented in Appendix A), the most used and popular are Google Earth and Google Maps. Both have almost the same features. The main difference is that while Google Earth (GE) contains a downloadable application that to be installed on the computer, Google Maps is available through a window of a Web browser. GE also provides more fast, powerful and interactive tools to the user, allowing also possibilities of measuring distances, draw lines and shapes and overlay users' own data[7]. Recently, on October the 28th, Google Maps launched the first application for mobile navigation in real time and for free, it is called Google Maps Navigation (Beta) and can be used on Android 2.0 devices[8].

Table 2.1. Virtual Globes currently available in the Web

N°	Virtual Globe Name	URL
1	CitySurf Globe	http://www.citysurf.com.tr/en/index.asp
2	Nintendo Wii Weather Channel	http://www.engadget.com/2006/12/19/wii-weather-channel-finally-launches/
3	Microsoft Virtual Earth	http://www.microsoft.com/virtualearth/
4	Dapple Earth Explorer	http://dapple.geosoft.com/
5	Wayfinder Earth	http://www.wayfinderearth.com/?id=3983⟨=nl-BE
6	3D Weather Globe & Atlas by Software MacKiev	http://www.mackiev.com/3d_globe.html
7	ESRI ArcGIS Explorer	http://www.esri.com/software/arcgis/explorer/index.html
8	Erdas Imagine Virtual GIS	http://gi.leica-geosystems.com/documents/pdf/IMAGINEVirtualGISProductDEscription.

[7] Softpedia Website <http://news.softpedia.com/news/Google-Earth-vs-Google-Maps-65440.shtml.> Retrieved on January, 2010.
[8] Official Google Blog < http://googleblog.blogspot.com/2009/10/announcing-google-maps-navigation-for.html.> Retrieved on January 2010.

		pdf
9	Google Earth	http://earth.google.com/
10	Global-i	http://infoview.infomagnet.com/index.html
11	EarthSLOT	http://www.earthslot.org/index.php.*
12	ESRI ArcGlobe	http://www.esri.com/news/arcnews/winter0304articles/3danalyst9.html
13	Eingana (is not a web available, comes on CD and one need to buy it!)	http://www.amazon.co.uk/Eingana-First-Live-Atlas-3D/dp/B00006TLTO
14	NASA World Wind	http://worldwind.arc.nasa.gov/
15	Celestia	http://www.shatters.net/celestia/
16	SINTEF Virtual Globe (too old, 2003)	http://www.virtual-globe.info/
17	GeoFusion	http://www.geofusion.com/index.html
18	SRI Terravision (2002). Too old	http://www.ai.sri.com/tvgeo/
19	Earthbrowser	http://www.earthbrowser.com/
20	Microsoft MapPoint (is not a VG)	http://www.microsoft.com/mappoint/en-us/default.aspx
21	Planet 9's VirtualEarth	http://www.planet9.com/products.html
22	Mark Pesce's WebEarth	http://www.webearth.org/
23	Blue Marble's Talking Globe CD	http://svs.gsfc.nasa.gov/index.html
24	Hipparchus	http://balder.prohosting.com/stouch/HIPPARCHUS.html
25	GeoVirtual GeoShow3D	http://www.geovirtual.com/
26	Viewtec TerrainView	http://www.viewtec.net/index.php?page=terrainview-globe
27	Virtual Terrain Project	http://www.vterrain.org/
28	Earthsim	http://www.earthsim.tv/
29	GRIFINOR	https://www.grifinor.net:8443/cms/daisy/www/2.html
30	Talent Cruiser	http://www.cruiser.gr/product.html
31	WW2D	http://ww2d.softonic.com/
32	Genesis MP	http://www.diamondvisionics.com/
33	PYXIS DGGS	http://www.pyxisinnovation.com/
34	Dapple	http://dapple.geosoft.com/
35	CitySurf Globe	http://www.citysurf.com.tr/en/index.asp
36	Geoweb3d	http://www.geoweb3d.com
37	OSSIM, OsgPlanet	http://www.ossim.org
38	Fledermaus	http://www.ivs3d.com/products/fledermaus/fledermaus_pro.html
39	Geodyssey Limited, Hipparchus	http://www.geodyssey.com
40	SkylineGlobe	http://www.skylinesoft.com/SkylineGlobe/corporate/home/index.aspx
41	Virtual Earth 3-D	http://www.microsoft.com
42	Multimap	http://www.multimap.com/maps/?qs=london&countryCode=GB

* The server is temporarily offline

In general almost all VGs allow the user to perform the following actions:

1) Availability of high-resolution and up-to-dated images
2) Searching of places functionalities.
3) 2D and 3D visualization of the earth surface
4) User friendly interface and tools
5) Easy sharing of geospatial data over the Net.
6) Overlaying of different types of thematic data
7) Increasing the development of applications through API's.

With these new advances nowadays Google Earth and Google Maps are the most popular and widespread used, as mentioned before. (Blower, *et al*. 2007*;* Beeckman & de Jonge, 2008).

2.2. GOOGLE EARTH

Nowadays, the most known and commonly used VG is Google Earth, a virtual globe, map and geographic information program originally called Earth Viewer; created by Keyhole, Inc, and know owned by Google since 2004. Its main feature is the interface showing the Earth surface as a map and by the superimposition of images obtained from satellite imagery, aerial photography and GIS 3D globe. There are two many types of licenses in order to be able to use it: Google Earth, a free version with limited functionality and Google Earth Pro ($400 per year), intended for

commercial use[9].

Hunter *et al*. (2007), remark some Google Earth key elements that increase its usability and popularity, all of them related to the three main aspects of usability: efficiency, effectiveness and satisfaction. In terms of efficiency, they highlight its free cost, speed of access and convenience (which means that it can be accessed trough the Web, at any time and anywhere). Another very important key element is the data integration capability, allowing the user to easily include additional vector data and image layers.

Regarding its effectiveness, the most important aspects of GE, according Hunter *et al* (2007) are its popularity, the easy of use, its content expressed via high-resolution images, the added value through the possibilities to extend its capabilities by *mashups*, and finally its novelty.

Concerning the satisfaction elements, the key issue is its visual appearance and the functions that support it, like: zooming, terrain modelling, tilting of the terrain for flyovers, and selectable mapping layers (Hunter *et al*, 2007).

2.3. APPLICATIONS

There are many semantics conflicts at the moment of defining what an application is. After reviewing some available literature the following definitions were found:

1. According to The American Heritage® Science Dictionary; an application is "*a computer program with an interface, enabling people to use the computer as a tool to accomplish a specific task. Word processing, spreadsheet, and communications software are all examples of applications*"[10].

2. In the Webster's Online Dictionary[11] application in computer science is "*A computer application (or sometimes app for short) is a computer program, or collection of programs, designed to provide some functionality to the end user* ".

3. For the UNCCD Project Management, an application is: "*any tool that functions and is operated by means of a computer, with the purpose of supporting or improving the software user's work. In other words, it is the subclass of computer software that employs the capabilities of a computer directly and thoroughly to a task that the user wishes to perform. This should be contrasted with system software (infrastructure) or middleware (computer services/ processes integrators), which is involved in integrating a computer's various capabilities, but typically does not directly apply them in the performance of tasks that benefit the user. In this context the term application refers to both the application software and its implementation*"[12].

Typical examples of software applications are word processors, spreadsheets, media players and database applications

2.4. APPLICATION PROGRAMMING INTERFACE (API)

An application-programming interface (API) can be defined as a "*set of routines, data structures, object classes and/or protocols provided by libraries and/or operating system services in order to support the building of applications*"[13] .

[9] Google Earth Website <http://download-earth.org/.> Retrieved on February, 2010.
[10] The Free Dictionary Website <http://www.thefreedictionary.com/application.> Retrieved on February 2010.
[11] Webster's Online Dictionary <http://www.websters-online-dictionary.org/.> Retrieved on January 2010.
[12] UNCCD Project Management Website <http://www.unccd.ch/computer-applications.> Retrieved on January 2010.
[13] Shamasis Bhattacharya Personal Website: <http:// www.shamasis.net/2009/.../why-to-design-a-good-api/>. Retrieved on January,

An API of any program allows and defines the proper way that a developer may request a service from that program. Trough an API it is possible to connect different software in a standardized way[14].

An API is typically defined in terms of the programming language used to build an application and to connect and create new applications from two or more existing ones. Some other examples of API's are: Facebook API (Facebook), Mac OS X, Java APIs, DirectX for Microsoft Windows, jus to mention some of them.

Google Earth API allows users to embed a 3D digital globe on their own web pages. The GE API enables the user for drawing markers and lines, add own information and load KML files for creating diverse 3D map applications[15]. The Google Earth API is a free service, available for any website that is free to consumers.

2.5. MASHUPS (Web application hybrid)

A *mashup* can be defined as a "*Web application that combines data or functionality from two or more sources into a single integrated application. The term mashup implies easy, fast integration, frequently done by access to open APIs and data sources to produce results that were not the original reason for producing the raw source data*"[16].

Brown, 2006, makes a differentiation between the two common techniques used to increasing the functionality in Google Maps applications: overlays and mash-ups. In an overlay "*information is placed on top of a "hot" map, which is an interactive and controllable map of a particular area*" while in a *mashup* a variety of information is "*combined*" creating a completely new application.

A similar *mashup* definition is given by Cartwright (2009), when he states that Web 2.0 allows users to produce *mashups* by combining already available maps and satellite imagery which are "mashed" together through their APIs.

In the last few years a growing interest for combining different types of applications had arose. As the quality, quantity, and diversity of information grow, users desires, are focused to access to any digital content source, handles any content type, and applies any software service to this content; they simply "…*want tools that are utterly simple and allow them to blog everything that they can think, in any format, from any tool, from anywhere…"* (Yee, 2008). Mashups are starting to concrete this desire. Yee (2008), states that there are different ways for combining data from different sources. Data can be handled in the following form:

1. Data is extracted from a source web site.
2. This data is translated into a form meaningful to the destination web site.
3. The repackaged data is sent to the destination site.

Some important questions must be answered in order to create a *mashup*. Answers to questions like: What is being combined? Why are these elements being combined? Where is the remixing or recombination happening? How are they being combined, in terms of the interface and behind the scenes in the technical machinery? How can the *mashup* be extended? will lead us to create diverse types of *mashup*s.

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[14] Computerworld Website <http://www.computerworld.com/s/article/43487/Application_Programming_Interface.> Retrieved on January, 2010.
[15] Google Earth Website <http://code.google.com/intl/en/apis/earth/.> Retrieved on February, 2010.
[16] TOPHOSTS Website <http://www.tophosts.com/articles/008723.html.> Retrieved on February, 2010.

Mashups can be classified in different ways. The most common ones are consumer oriented, for the general public. As example of this type of *mashups* are those which use Google Maps or Google Earth combined with other and diverse types of web data sources, generating valuable interactive cartographic maps.

A commonly used example is the *HousingMaps Website*[17]; this is a *mashup* or a composite web application that uses data from *graiglist.org* [18] with Google Maps data. This type of applications can be created because of the support of the Google Maps API.

There are also several examples of data *mashups* that combine media and information from multiple sources into one single representation; such is the case of the Havaria Information Services' AlertMap[19]. This *mashup* combines data from over 200 sources related to severe weather conditions, biohazard threats, and seismic information, and displays them on a map of the world.

According to Alertmap, *mashups* can be classified also as:

- Presentation centred *mashups*, used to present something: e.g. a Google map based *mashup* combining some disease spread over the world with poverty figures.
- Data centred *mashups*, which just combine two or more data sources to get more useful information without the need of showing or presenting it[20].

On the other hand, Lew (2009)[21] classifies *mashups* in three types:

- Consumer *mashups* – where data elements from various sources are "hidden" behind a simple unified graphic interface.
- Data *mashups* – a mixture of similar data types from different resources (i.e. Yahoo pipes that combines multiple RSS feeds into a single feed);
- Enterprise *mashups* – the integration of data from internal and external sources (i.e.: JackBe®[22], a company that delivers mashup software to a wide variety of organizations).

The idea of using Digital Earth for integrating multiple source data was revealed in Gore's book in 1992. (Goodchild, 2008). Gore[23] defined Digital Earth as "*a multi-resolution, three-dimensional representation of the planet, into which we can embed vast quantities of geo-referenced information*", including the mechanisms for data integration and display of multisource information. Nowadays GE is just starting to implement that concept.

Google Earth implements many aspects of Gore's vision; but still there are some other ones that need to be improved or developed, like:

- Develop a voice recognition capabilities for information request purposes
- Improve overlay capabilities not only for map layer, but also for newsreel footage, oral history, newspapers and other primary sources.
- Data need to be generated and maintained by thousands of different organizations using their own databases and servers, being connected and using high-speed networks. For doing this a new generation of Internet technology is needed.

[17] Housingmaps Website <http://www.housingmaps.com/.> Retrieved on February, 2010.
[18] Craiglist Website <http://www.craigslist.org/about/sites.> Retrieved on January, 2010.
[19] Hungarian National Association of Radio Distress-Signalling and Infocommunications (RSOE) Website< http://hisz.rsoe.hu/alertmap/>. Retreived on February, 2010.
[20] Mashupshub Website <http://www.mashupshub.com/web-application-hybrid/types/.> Retrieved on December, 2009.
[21] Slideshare Website <http://www.slideshare.net/alew/web20-mapping-by-alanlew?src=related_normal&rel=1316782.> Retrieved on November, 2009.
[22] JackBe Website <http://www.jackbe.com/.> Retrieved on January 2010.
[23] "The Digital Earth" Gore's Speech < http://www.isde5.org/al_gore_speech.htm>. Retrieved on February, 2010.

- Improved interoperability between diverse type and sources of geographical information is needed. Some advances are already available through the Open GIS Consortium, but still more development is needed.
- Metadata is a "must". Even currently there are some huge advances on the use of metadata standards, its use is currently not a "requirement" when using and sharing data over VGs.
- Some technological progress is still pending for actions like: automatic interpretation of imagery and fusion of data from multiple sources.

A systematic inventory of current VGs based *applications* was carried out to identify what are the common fields currently taking advantage of the capabilities and functionalities of the VGs, which are the preferred ones. Due to the fact that thousands of diverse VGs based applications were found during the Web searching, it was decided to analyze only those ones developed as mashups.

The ProgramableWeb[24] presents up-to-date information about mashups development. Using that information it was realized that the majority of the applications based on VGs are oriented to mapping purposes. The ProgrammableWeb maintains the statistics about the available mashups since September 2005. They categorize the mashups by fields of application types as follows:

Table 2.2. Types and Number of Mashups (August, 2009)

#	Mashup Type	Number of Mashups
1	Mapping	(1967)
2	Photo	(571)
3	Shopping	(515)
4	Search	(459)
5	Video	(452)
6	Travel	(368)
7	Social	(301)
8	Music	(271)
9	News	(262)
10	Messaging	(239)
11	Sports	(205)
12	Real estate	(201)
13	Mobile	(186)
14	Widgets	(178)
15	Visualization	(142)
16	Uk	(139)
17	Bookmarks	(126)
18	Reference	(122)
19	Events	(118)
20	Auction	(112)

Source: ProgrammableWeb.

As can be seen, to date there are 1967 mashups for mapping purposes (see Table 2.2), which represent 36% of the currently available (See Figure 2.1). From that 1967; 1602 use Google Earth as virtual globe base, 119 are based on Yahoo Maps and only 14 use Google Maps.

[24] Programableweb Website <http://www.programmableweb.com.> Retrieved on December, 2009.

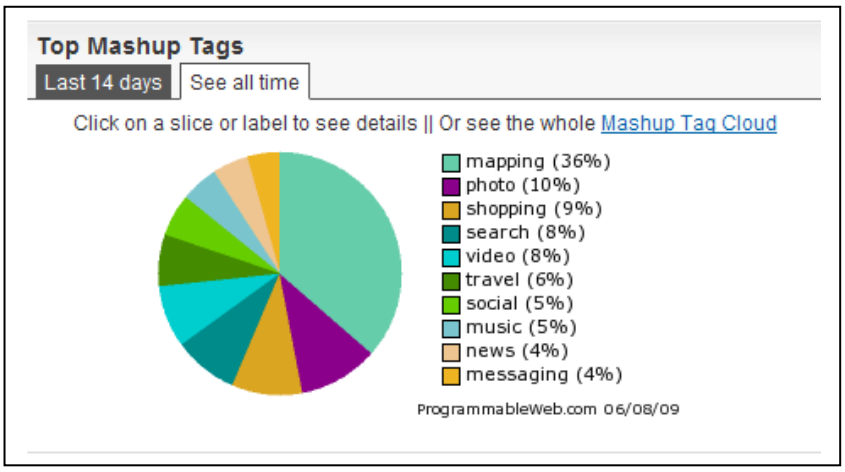


Figure 2.1. Types of mashups expressed in percentage
Source: ProgrammableWeb (*ibid*)

2.5.1. EXAMPLES OF MASHUPS USING VIRTUAL GLOBES

In this section, examples of existing VGs based applications created with mashups are presented and discussed. The objective is to identify positive and negative usability issues concerning data visualization and representation, that later will be taken into account when conceptually designing an improved VG based application for statistical data dissemination.

2.5.1.1. Flex, Yahoo Maps, and RSS Feeds Mashup[25]

This is a mashup example of Yahoo maps where GeoRSS or RSS feeds directly a map, as well as displaying traffic or weather data. A regular RSS feed without location data is converted to geoRSS using a service from GeoNames which searches items in a Feed for locating data.

Figure 2.2. Flex, Yahoo!Maps and RSS Feeds Mashup Interface

[25] Flex, Yahoo!Maps and RSS Feeds Mashup Website <http://www.andrew.cmu.edu/user/astyler/project/> Retrieved on January, 2010.

Traffic and weather data can be obtained for any location. When a requested zip code is entered; traffic and weather data are displayed. The traffic data information is provided by Yahoo! Maps, while the weather data is grabbed from a geoRSS feed (Figures 2.2 and 2.3).

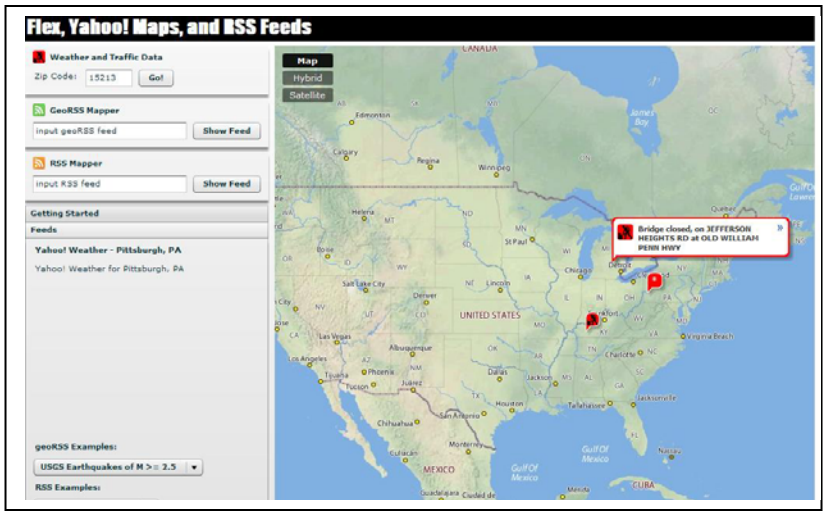


Figure 2.3. Flex, Yahoo!Maps and RSS Feeds Mashup Interface showing requested information

This is a nice mashup example; but its main drawback is that the user needs to introduce a zip code in order to get the information about traffic and weather. The application does not offer any possibility to move directly to a specific place using the mouse tool. Thus, if the user does not know ZIP codes, he / she will be no able to obtain any information. Another usability problem is the missing information regarding the date and time of the data available. This must be definitely included in applications like this.

2.5.1.2. SDI Colombia[26]

This example belongs to the official Spatial Data Infrastructure of Colombia. Colombian's SDI is a massive initiative at national level supported by around 20 governmental institutions, research institutes, Ministries, etc. They have a very complete up-to-date database and a well organized website with a user-friendly interface, where it is easy to visualize the maps and geoservices contained on the Website.

This application is not a VG based application. The Website contains a window for displaying geographic data, which was developed with XML and uses a WMS (see Figure 2.4). The geographic visor allows the user to have certain interactive capabilities. One can zoom in/out, pan, activate and deactivate available layers and print. It is also possible to add WMS data layers from other external sources.

The main drawbacks of this application reside on the cartographic aspects (i.e. colours, line types and symbol points used for representing information in the form of maps). It is not easy to distinguish the different categories on the map. When adding different layers, if you add a polygon layer (i.e. municipalities) and a lines layer (i.e. contour lines) you are not able to see the lines because they appear under the polygons.

The application is also very slow. It takes too much time to reload the data every time you change something on the interface, for example when zooming or adding/removing layers. The application also provides the possibility to add Landsat mosaic images. This is the main aspect that needs to be urgently improved. This situation can be easily overcome if combining its content

[26] Colombian SDI Website <http://www.icde.org.co/web/guest/visor_geografico> Retrieved on February, 2010.

and functionalities with a VG based application trough a mashup. Any VG can surely improve its functionality.

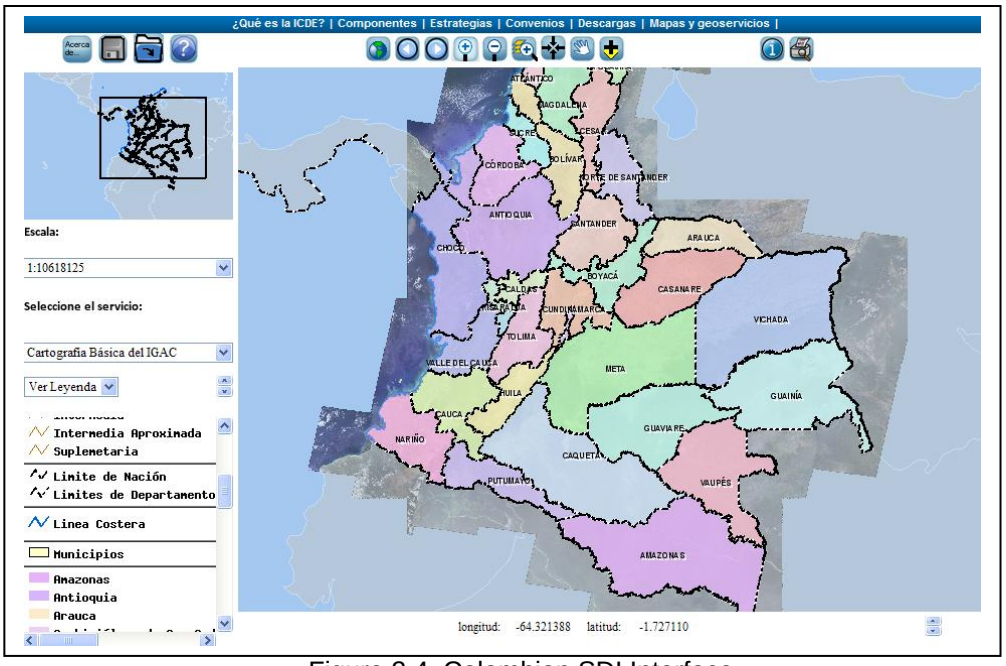


Figure 2.4. Colombian SDI Interface

2.5.1.3. 360 Cities[27]

This is an amazing GE based application (see Figure 2.5), representing the future's example of Virtual Globes and their applications. 360Cities offers high quality panoramas from different places around the world. Virtual Reality photographers maintain its platform. This application is focused on touristic uses, but can be, in the future, adjusted to be used for many other fields of applications. The company is registered in The Netherlands with offices in Prague.
With this application you can navigate cities like you were there, you can zoom in/out, turn, and go down or up (see Figure 2.6). There is no need for travelling anymore!

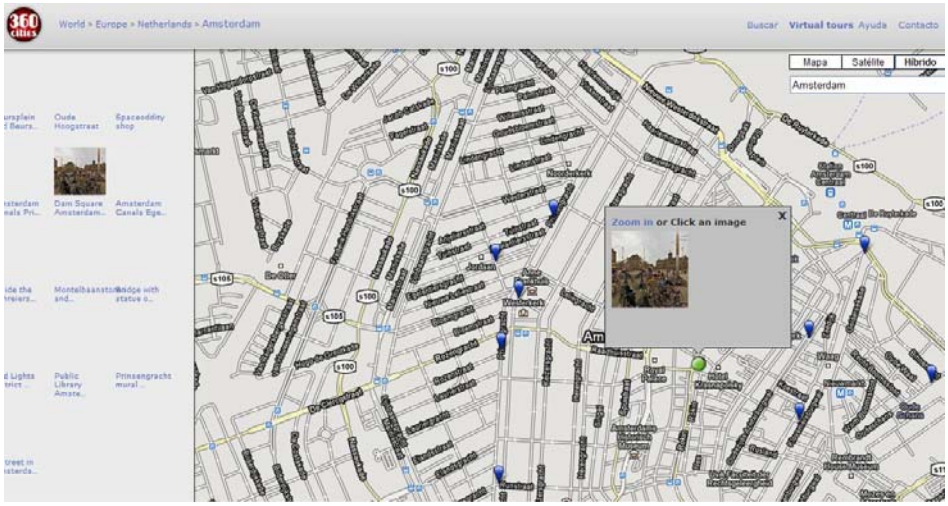


Figure 2.5. 360 Cities application – Main map window

[27] 360 Cities Website <http://www.360cities.net> Retrieved on February, 2010.

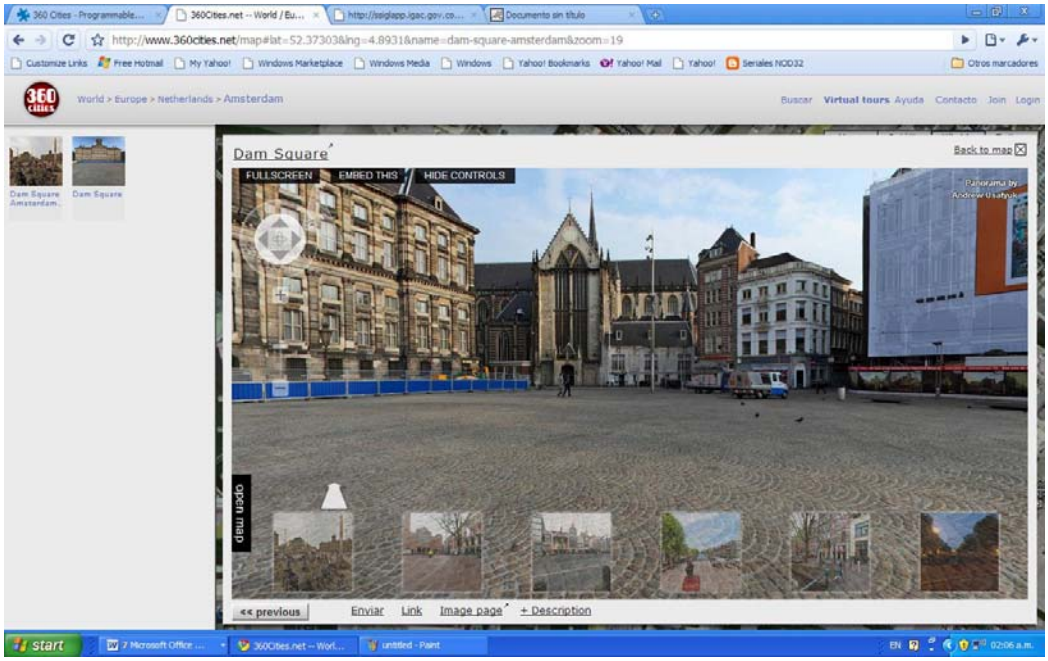


Figure 2.6. 360 Cities application – Amsterdam - Dam Square

2.6. STATISTICAL DATA DISSEMINATION

Nowadays, almost every country in the world has a National Statistical Office in charge of collecting, maintaining up to date and disseminating statistical data to the public (van Elzakker et al, 2003). In Bolivia, the Instituto Nacional de Estadística, INE[28], a governmental institution, does the work.

There are different ways for disseminating statistical data. Because of the "globalization" and the development of the World Wide Web (WWW), a start has been made with sharing and distributing statistical data through the Web. According with van Elzakker *et al* (2003) the dissemination through the WWW has two main advantages: accessibility and actuality. The first one refers to the possibility of accessing data anytime and from anywhere using the Internet. The latter is related to making data available immediately after their collection. Another advantage important to mention, are the low costs of dissemination. Disseminating information trough the WWW is cheaper than distributing it in the traditional way: using printed maps.

Statistical data is used worldwide for an enormous diversity of purposes. Usually tables, charts and thematic maps are presented in a static form. Sometimes there are also available some interactivity functions, enabling the user to manage and adjust the display according to his/her needs.

van Elzakker et al (2003), state that in almost every country in the world there is a National Office collecting statistical data and sharing through different ways. In general the common users of those type of data are "government officials, scientists, planners, teachers, students or, for instance, private companies looking for markets".

Web maps can be used for disseminating statistical data. Disseminating census data through the Web enables users to "individually prepare the desired output data on-line" (van Elzakker et al, 2003). In the following section two examples of VGs based applications for statistical data dissemination are presented.

[28] INE Website <http://www.ine.gov.bo/.>Retrieved on January, 2010.

2.6.1. EXAMPLES OF VGs BASED APPLICATIONS FOR STATISTICAL DATA DISSEMINATION

2.6.1.1. GCensus - free online GIS using Google Earth[29]

GCensus is a VG based application that allows the user to display statistical data over Google Earth. The main page (see Figure 2.7) lets the user select the type of information he wants and then select the place and then the type of data he needs. The application only gives the user limited possibilities for selecting the number of classes and the colour representation of the legend, causing that the maps displayed over the GE interface would cartographically well designed.

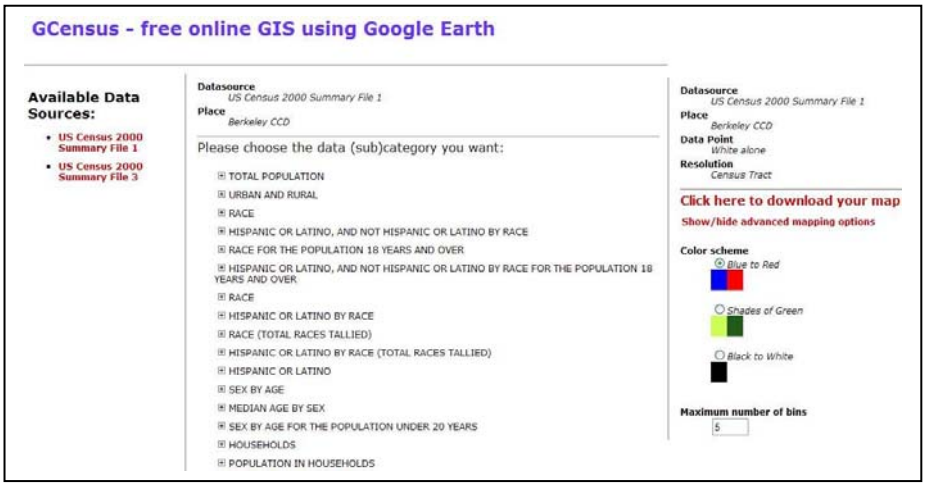


Figure 2.7. Gcensus' interactive window for selecting statistical data to be visualized

The positive aspect of this application is ease of access and visualization of census data, in addition to the additional functionalities and tools offered by Google Earth.

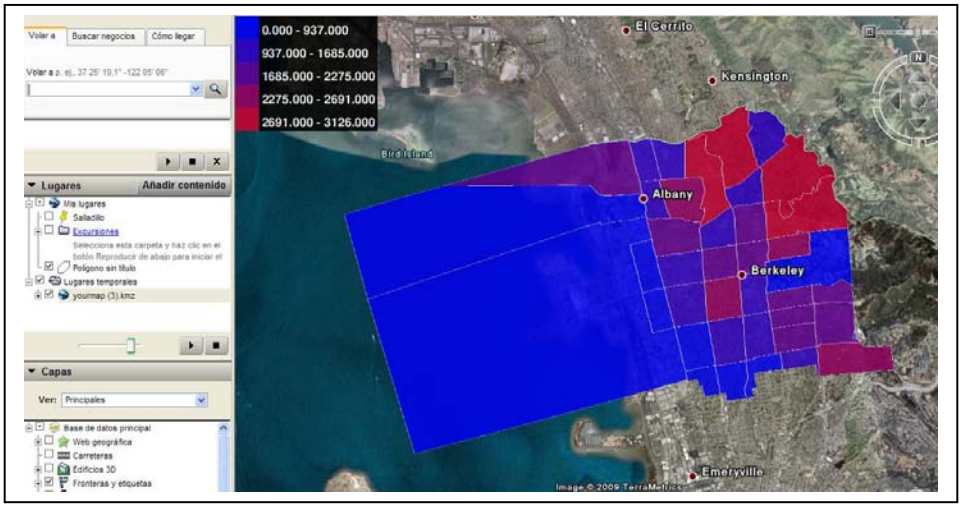


Figure 2.8. Gcensus' statistical data visualized over Google Earth Interface

The weakness of this application is that once the desired data are selected, it is not possible to visualize it directly. The application generates a KML file which is automatically downloaded to

[29] Gcensus Website <http://gecensus.stanford.edu/gcensus/index.html.> Retrieved on February, 2010.

the user's computer. The user then needs to open the KML in order to view the selected data in the GE environment (see Figure 2.8). If the user wants to get more data, he must perform the complete process once again.

2.6.1.2. Website Neighbourhood Statistics in Google Earth[30]

Statistics Netherland in Your Neighbourhood is a website developed and maintained by Statistics Netherlands (see Figure 2.9), it is supported and developed using Google Earth for displaying statistical information at Neighbourhood level. The layer for Google Earth contains twenty variables for 11 thousand neighbourhoods and their detailed borders, divided into 450 chunks (municipalities).

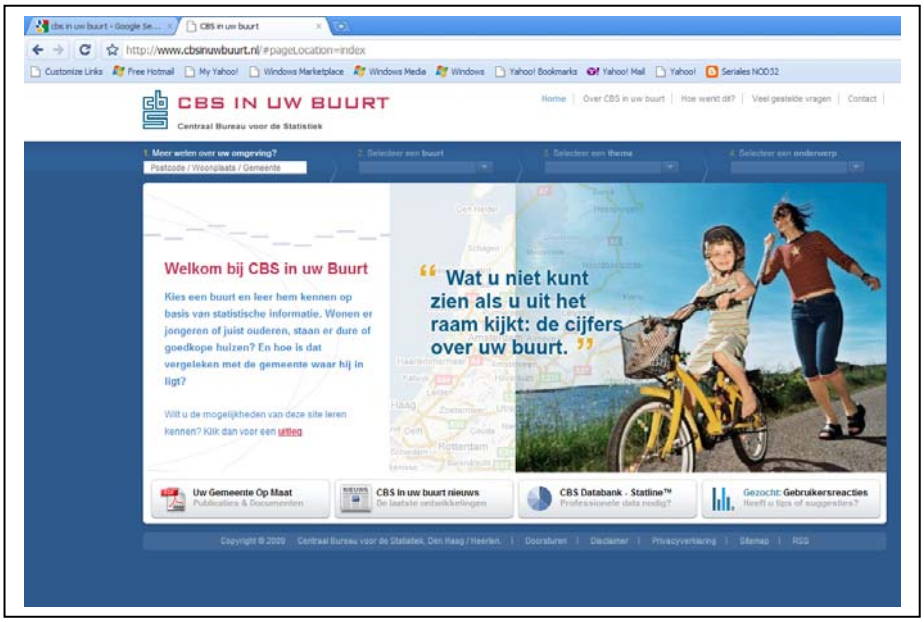


Figure 2.9. Neighbourhood Statistics in Google Earth Website

In order to view the statistical information, a KML file needs to be downloaded in the user's computer and then open the Google Earth program for displaying the information. The main drawback of the application is the way statistic information is displayed over GE. When zooming at neighbourhood level the Statistics Netherlands (CBS) icon appears in each neighbourhood, when doing a click over the symbol, statistic information is displayed as a window containing the information in form of text (see Figure 2.10) unfortunately the data are not yet visualized through thematic map displays, and that is something that needs further improvement.

[30] Statistics Netherlands in your Neighbourhood Website <http://www.cbsinuwbuurt.nl/#pageLocation=index>. Retrieved on February, 2010.

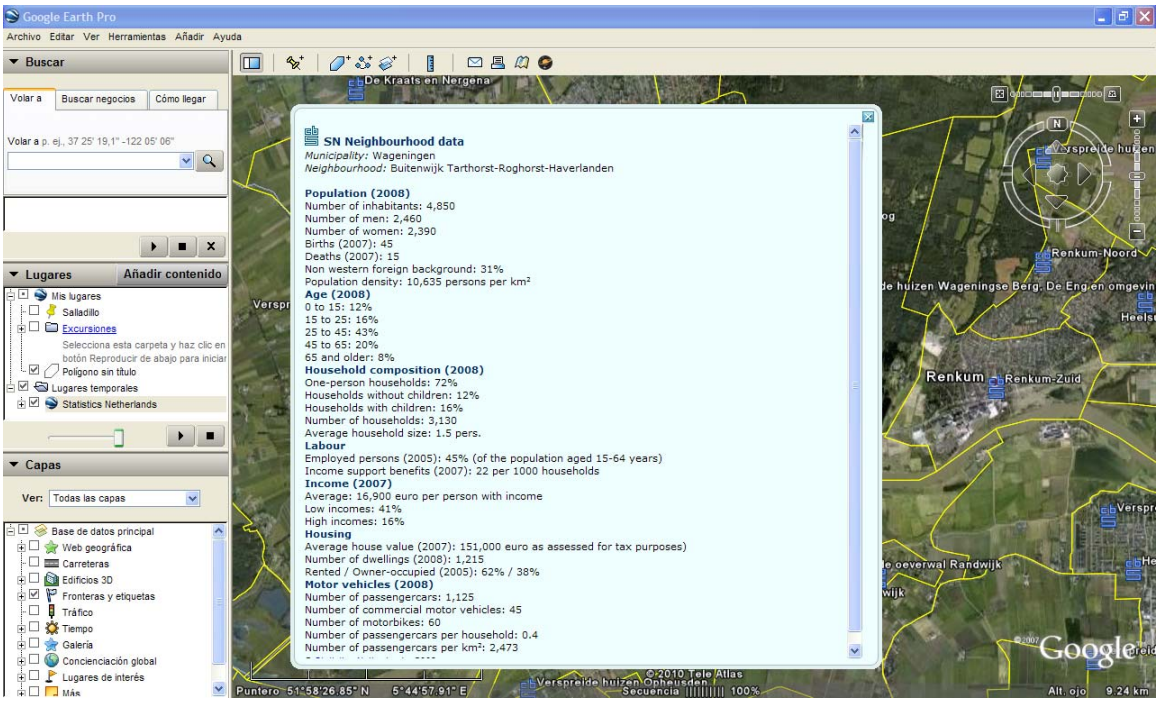


Figure 2.10. Displayed information on Neighbourhood Statistics in Google Earth

2.7. USABILITY

Usability is a term related to the "user-friendly" concept denoting the ease with which a particular tool is used for a specific purpose. Usability can also refer to measuring usability methods and the study of the principles behind an object's perceived efficiency or elegance.[31]

Usability also means “making products and systems easier to use”, and making them closely matched to user’s needs and requirements. In this sense, the international standard ISO 9241-11 provides guidance on usability, defined as:

> “*The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*” (ISO 9241-11).

The term “usability” refers to:

- Effectiveness: “*the accuracy and completeness with which users achieve specified goals*” meaning that if users can complete tasks and/or achieve goals with the product, i.e. do they do what they want to do with it?
- Efficiency: “*the resources expended in relation to the accuracy and completeness with which users achieve goals*”. How much effort do users require to accomplish it? (Often measured in time)
- Satisfaction: “*the freedom from discomfort, and positive attitudes towards the user of the product*”. What do users think about the product’s ease of use?)[32].

[31] Usernomics Website <http://www.usernomics.com/usability-consulting.html.> Retrieved on January, 2010
[32] UsabilityNet <http://www.usabilitynet.org/management/b_what.htm.> Retrieved on December, 2009

There are many definitions for the term "usability", but in general all of them refer to the same concept: the ease to use "for people who use it", ("it" can be software, hardware, system, etc). For the Usability Professional's Association (UPA)[33], usability is a *"quality or characteristic of a product. It is whether a product is efficient, effective and satisfying for those who use it".*

Usability also takes into account the type of users and the degree of knowledge they must have to handle a system. The important aspects to analyse usability and users are: who is using the product? Are they highly trained and experienced users, or novices? What are their goals? What are the users trying to do with the product? Does it support what they want to do with it? The usage situation or the context of use is also very important to consider; and also where and how is the product being used?, etc.

Sometimes usability is confused with functionality. Just to make a distinction between both definitions: functionality is purely concerned with the functions and features of the product. It does not consider and has no bearing on whether users are able to use them or not. Increased functionality does not mean improved usability[34].

The ISO/IEC 9126: Software engineering—Product quality (International Organisation for Standardisation, 2001) defines usability as "*the capability of the software product to be understood, learned, used and attractive to the user, when used under specified conditions"* considering the following software characteristics:

- *Understandability*: the capability of the software product to enable the user to understand whether the software is suitable or not, and how it can be used for particular tasks and conditions of use.
- *Learneability*: software capability to enable the user to learn its application.
- *Operability*: software capability to enable the user to operate and control it."

Some other definitions of usability can be found in the pertaining literature. All of them are just variations to the definition given in the ISO. Some definitions add more terms in order to complete the usability concept. Terms like "memorability" or "error frequency and severity" can be frequently found (Hunter *et al,* 2003).

2.8. TESTING USABILITY

Usability testing is used to evaluate a specific product by testing it with representative users.

According to the "usability.gov", an official U.S. Government Web site managed by the U.S. Department of Health & Human Services, the main goal of testing usability is "*to identify any usability problems, collect quantitative data on participants' performance (e.g., time on task, error rates), and determine participant's satisfaction with the product"*[35].

There are different well-known and widely used methods for testing and measuring usability, according to the "usabilitynet.org"[36]. When selecting a method to use, there is a need to consider the type of product to be tested, the availability of representative users, and the availability of the time and financing resources.

From representative user selection's point of view, the evaluation method can be user based or expert based. User based testing provides information related to the task at hand – when the software supports the users in their work. Expert based surveys are used to identify lack of

[33] Usability Professionals' Association Website <http://www.upassoc.org/usability_resources/about_usability/index.html.> Retrieved on January, 2010.
[34] Usability Net <http://www.usabilitynet.org/management/b_what.htm.> Retrieved on: January, 2010.
[35] Usability.gov Website <http://www.usability.gov/methods/test_refine/learnusa/index.html.> Retrieved on: December, 2009.
[36] Usability Net <http://www.usabilitynet.org/tools/test&measure.htm.> Retrieved on: January, 2010.

conformity to standards, interface design guidelines and expert comments based on experience.

Figure 2.11 and Table 2.3 summarize the different existing methods for testing the usability, their objectives, their main characteristics and their expected outputs.

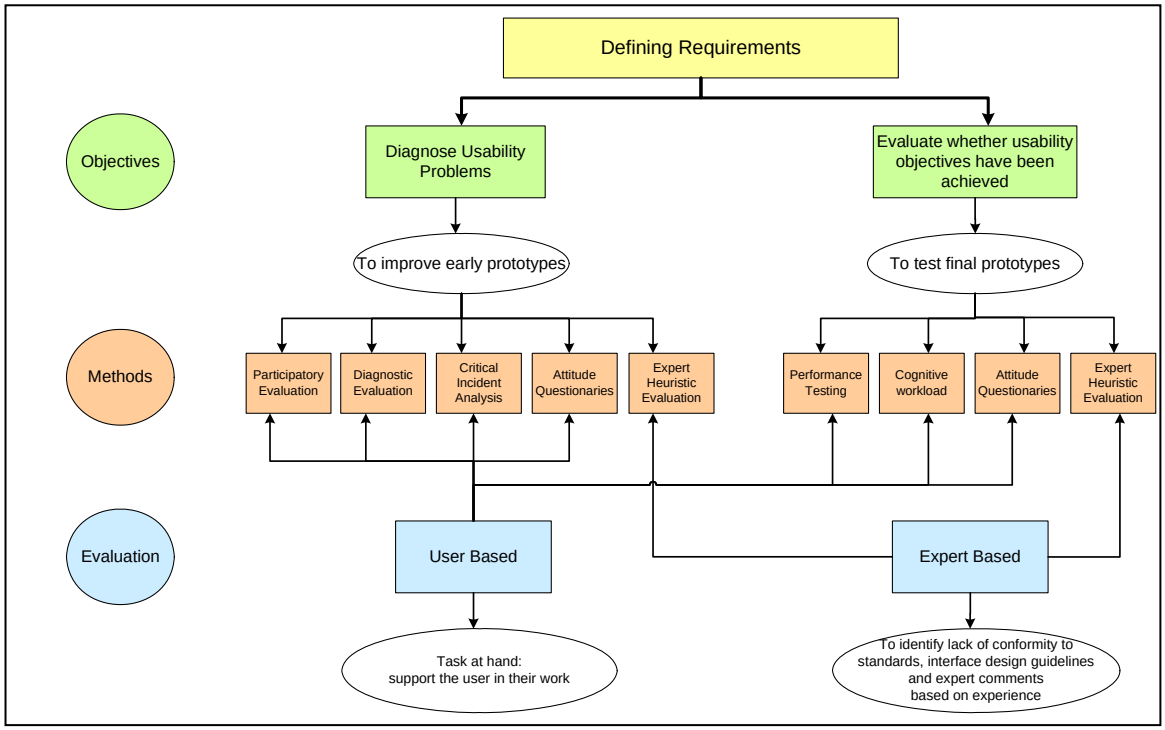


Figure 2.11. Usability Testing Methods
Source: based on usabilitynet.org *(ibid)*

Table 2.3. Some Commonly Used Usability Testing Methods

Testing Method	Evaluation	Description	Benefits	Methodology	Output
Participatory Evaluation	User based	Evaluation of prototype to identify usability problems, the user is probed to explain their expectations and problems	Potential usability problems can be detected at an early stage before development is complete. A deeper understanding of the users' expectations and impressions of the system.	Select the most important tasks and user group(s) to be tested Select users who are representative of the user group(s). 3-5 users Produce task scenarios and input data and write instructions for the user (tell the user what to achieve, not how to do it)	A list of usability problems, categorised by importance, and an overview of the types of problems encountered. Meeting with the designers to discuss whether and how each problem can be fixed.
Diagnostic Evaluation	User based	Evaluation of a working system, where the primary objective is to identify usability problems.	Major usability problems are identified. An understanding is gained of why the user has difficulties with the system. Approximate measures can be obtained for the users' effectiveness, efficiency and satisfaction.	Select the most important tasks and user group(s) to be tested Select users who are representative of the user group(s). 3-5 users are sufficient to identify the main issues. 8 or more users of each type are required for reliable measures. Produce task scenarios and input data and write instructions for the user (tell the user what to achieve, not how to do it). If usability measures are required, observe the user without making any comments. If measures are not required, prompt the user to explain their interpretation of the contents of each screen and their reason for making choices.	A list of usability problems, categorised by importance, and an overview of the types of problems encountered. Meeting with the project manager and developer to discuss whether and how each problem can be fixed. If measures have been taken, summarise the results of the satisfaction questionnaire, task time and effectiveness (accuracy and completeness) measures.
Critical Incident Analysis	User based	Users are asked to identify specific incidents which they experienced personally and which had an important effect on the final outcome. The emphasis is on incidents rather than vague opinions	The CIT is an open-ended retrospective method of finding out what users feels are the critical features of the software being evaluated. It is more flexible than a questionnaire or survey	CIT analysis uses a method known as Content Analysis in order to summarise the experiences of many users or many experiences of the same user.	Categorised the incidents and produce a relative importance weighting for each - some incidents will happen frequently and some less frequently. Collection of enough critical incidents which enable to make statements such as "x percent of the users found feature y in context z was helpful/ unhelpful."
Attitude questionnaires (subjective assessment)	User based	Subjective assessment tells the evaluator how the users feel about the software being tested. This is distinct from how efficiently or effectively they perform with the software.	In a discretionary use scenario, user satisfaction is most probably the largest single key factor, which will influence the users' decision whether or not to continue with the software (other key factors may include price,	Uses a standardised opinion questionnaire to avoid criticisms of subjectivity. This method gives the evaluator information about how the users feel about using the software being evaluated. This should be distinguished from: 1) how well they perform	Complementary data from efficiency and effectiveness measures. A list of satisfying and unsatisfying software features, which is especially useful if testing, is

			technology, and brand loyalty). In a mandatory use scenario, poor satisfaction leads to absenteeism, fast staff turnover, and unrelated complaints from the workforce.	with the software (effectiveness) and 2) how efficiently they work with the software (efficiency)	taking place during development. The readable body of the report include: summary statistics & diagnostic data on the software features, which in your opinion influenced the subjective assessment. The full scored data in an appendix is included
Performance testing	User based	Is a rigorous usability evaluation of a working system under realistic conditions to identify usability problems and to compare measures such as success rate, task time and user satisfaction with requirements.	Major usability problems are identified that may not be revealed by less formal testing, including problems related to the specific skills and expectations of the users. Measures can be obtained for the users' effectiveness, efficiency and satisfaction.	Select the most important tasks and user groups to be tested Select users who are representative of each user group. 3-5 users are sufficient to identify problems. 8 or more users of each type are required for reliable measures. Produce a task scenario and input data and write instructions for the user. Plan sessions allowing time for giving instructions, running the test, answering a questionnaire, and a post-test interview.	A list of usability problems, categorized by importance An overview of the types of problems encountered. If measures have been taken, Summary with the results of the satisfaction questionnaire, task time and effectiveness (accuracy and completeness) measures.
Cognitive Workload	User based	Relates to the mental effort required to perform tasks. It is a useful diagnostic of situations where users have to expend excessive mental effort to achieve acceptable performance, and is particularly important in safety-critical applications.	A task demanding too little mental effort may result in a lowered efficiency because it leads to boredom and lack of vigilance, which directly lowers effectiveness. Excessive cognitive workload may also result in lowered effectiveness, if it causes information to be missed and results in errors. This is a particularly important issue in situations where safety is critical, e.g. air traffic control and process control. Measures of cognitive workload can be used to predict these types of problems.		Cognitive workload is closely related to comfort: even if a system is apparently acceptable for use, it may be low in comfort if it demands too little or too much mental effort.
Heuristic/expert evaluation	Expert based	A form of usability inspection where usability specialists judge whether each element of a user interface follows a list of established usability heuristics. **Expert evaluation** is similar, but does not use specific heuristics.		Two to three analysts evaluate the system with reference to established guidelines or principles, noting down their observations and often ranking them in order of severity. The analysts are usually experts in human factors or HCI, but others, less experienced have also been shown to report valid problems.	

Source of information: *usabilitynet.org*.[37]

[37] Usability Net <http://www.usabilitynet.org/tools/test&measure.htm.> Retrieved on: January, 2010.

2.9. USABILITY TESTING METHODS/TECHNIQUES

Travis, D. 2009[38], states that in general usability tests only take into account the participant's reaction to a user interface. For the author this aspect only reflects one part of the usability analysis, the satisfaction. Travis mentions the need for considering, when testing usability, also effectiveness (can people complete their tasks?) and efficiency (how long do people take?, in order to get the complete usability picture.

The International Standard, ISO 9241-11 considers those three dimensions of the usability, but generally people only take into account one of them. Frøkjær *et al*, 2000; mentions that the three measures of usability — effectiveness, efficiency and satisfaction — are independent and the usability analysis needs to measure all three to get a rounded measure of usability.

Among the various available techniques for testing the usability the researcher has chosen expert based ones for the thesis research considering the available time for testing and the accessibility to the testers.

The techniques were selected because they allow closer and quick contact with testers, providing fast, reasonable and reliable information and possibilities of getting further information related with the test.

Following sections describe those that where used during the thesis research.

2.9.1. PERFORMANCE TESTS

Performance tests are designed for measuring the ability of users when navigating a webpage or application, in order to complete specific tasks[39]. Usually the process consists of three parts:

1. The user is introduced to the application. After some time of inspection of it, user is requested to give his first impressions of the application.
2. Second parts are based on the completeness when carrying out specific tasks. By analysing the process the user applies to perform the tasks, it is possible too to measure and to identify the strong and weak aspects of the application.
3. The final part consists of getting the user's opinion about the application.

2.9.2. THINKING ALOUD METHOD

Jaspers (2008), states that from the user's perspective "*the user interface is the only visible and, hence, most important part of the computer system; thus it receives high priority in designing computer systems*".

The thinking aloud method requires participants that must talk aloud while solving a problem or performing a task (Ericsson & Simon, 1993. Cited by Jaspers, 2008). During the process a test person is requested to perform a task on a computer, and while doing this he/she must think aloud. Both the computer screen and the user talking aloud are recorded using a video camera. After finishing the testing session, the recording is analysed in order to identify and to analyze the usability aspects/problems.

Jaspers pointed out that when using this method the selection of the test subjects is crucial. Participants must be representative persons of that end-user who will use the system in the

[38] Userfocus Website <http://www.userfocus.co.uk/articles/satisfaction.html.> Retrieved on January, 2010.
[39] PDF Document available at: http://labs.nypl.org/wp-content/uploads/2007/09/usabilityfindings.pdf. Retrieved on February, 2010.

future. Another aspect that is also essential for the success when applying this method, is the tasks for testing purposes, according to Jaspers, they must be realistic and representative for daily life situations. According to van Elzakker (2004), this has been used to improve user interfaces of computer software, and to test the effectiveness of websites.

According to Jaspers (2008), the main advantages of the method are:

1. Requires little expertise and provides detailed insights related to user behaviours when interacting with computers.
2. It provides quicker responses compared with other methods.
3. The promptness of the response it provides compared with other techniques.

And the main disadvantages are:

1. The information obtained is subjective, that is why the selection of the test participants is crucial.
2. The results are strongly dependent on the recording method.
3. Analyzing the verbal protocols can be very time-consuming and requires that studies are well planned in order to avoid wasting time

2.9.3. QUESTIONNAIRES

The use of questionnaires is frequent when measuring user satisfaction, but this is not the only tool to measure this aspect[40]. Nowadays there are commonly used questionnaires created for their use when measuring the most important dimensions of usability, and across diverse domains like software, hardware, services, and user support materials. Examples of mostly used or well-known questionnaires are presented in Table 2.4.

Table 2.4. Well Known Questionnaires

Acronym	Instrument	Reference	Institution	Example
QUIS	Questionnaire for User Interface Satisfaction	Chin et al, 1988[41]	Maryland	27 questions
PUEU	Perceived Usefulness and Ease of Use	Davis, 1989	IBM	12 questions
NAU	Nielsen's Attributes of Usability	Nielsen, 1993[42]	Bellcore	5 attributes
NHE	Nielsen's Heuristic Evaluation	Nielsen, 1993[43]	Bellcore	10 heuristics
CSUQ	Computer System Usability Questionnaire	Lewis, 1995[44]	IBM	19 questions
ASQ	After Scenario Questionnaire	Lewis, 1995[45]	IBM	3 questions
PHUE	Practical Heuristics for Usability Evaluation	Perlman, 1997[46]	OSU	13 heuristics
PUTQ	Purdue Usability Testing Questionnaire	Lin et al, 1997[47]	Purdue	100 questions
USE	USE Questionnaire	Lund, 2001[48]	Sapient	30 questions
SUMI	Software Usability Measurement Inventory	Kirakowski[49]	University College Cork	50 statements
MUMMS	Measurement of Usability of Multi-Media[50] Systems		HFRG	50 Items
WAMMI	Website Analysis and Measurement Inventory	Kirakowski & Claridge[51]	WAMMI	20 Statements

Source: *usabilityhome.com*, 2009[52]

[40] Userfocus Website <http://www.userfocus.co.uk/articles/satisfaction.html.> Retrieved on February, 2010.
[41] QUIS Website <http://lap.umd.edu/quis/>. Retrieved on February, 2010.
[42] NAU Website <http://hcibib.org/perlman/question.cgi?form=NAU>. Retrieved on February, 2010.
[43] NHE Website <http://hcibib.org/perlman/question.cgi?form=NHE>.Retrieved on February, 2010.
[44] CSUQ Website <http://oldwww.acm.org/perlman/question.cgi>. Retrieved on February, 2010.
[45] ASQ Website <http://hcibib.org/perlman/question.cgi?form=ASQ>. Retrieved on February, 2010.
[46] PHUE Website <http://hcibib.org/perlman/question.cgi?form=PHUE>. Retrieved on February, 2010.
[47] PUTQ Website http://oldwww.acm.org/perlman/question.cgi?form=PUTQ.Retrieved on February, 2010.
[48] USE Website <http://usesurvey.com/>.Retrieved on February, 2010.
[49] SUMI Website <http://sumi.ucc.ie/>.Retrieved on February, 2010.
[50] MUMMS <http://www.ucc.ie/hfrg/questionnaires/mumms/index.html>.Retrieved on February, 2010.
[51] WAMMI Website <http://www.wammi.com/>.Retrieved on February, 2010.
[52] Usabilityhome Website <http://www.usabilityhome.com/FramedLi.htm?http://www.acm.org/~perlman/question.html.> Retrieved on February, 2010.

Kirakowski (2000), defines a questionnaire as: *a method for the elicitation, and recording, and collecting of information*. The author states that questionnaires are tools that can help to obtain information from the user allowing starting a process of discovery in the user's mind. The answers given by the user can be stored in different forms (hard copies, recordings, etc) in order to be used and analyzed as needed.

Kirakowski highlights some important advantages of using questionnaires when performing usability research.

- Reliable questionnaires give trustworthy feedback from the user's point of view.
- Measures obtained from a questionnaire are independent of the system, users or tasks to which the questionnaire was applied.
- They are usually quick, the costs of use them are very low and you can obtain lot of data and information from them.

Same author also mentions some disadvantages:

- A questionnaire reflects the user reaction to a given situation. The way he perceives the situation can be subjective. Some questions can be sometimes not reliably answered.
- In general, questionnaires are used in order to get information for many different situations, so, detailed information about specific issues can be missed. The questionnaire design is the key issue in order to get the information needed.

Finally, Kirakowski (2000) recommends that when someone decides to carry out the overall usability of a piece of software, the process must consider also performance, mental effort, and effectiveness data. And also, in order to be able to find answers for the "why" questions, talking and observing the user is required.

2.9.4. REACTION ADJECTIVES

The original method was presented in 2002, in an article of a Microsoft Conference Proceedings (Benedek and Miner, 2002). The method was part of the so-called Desirability Toolkit. The method uses a series of 118 "product reaction cards", containing words like "Consistent", "Sophisticated" and "Useful". After the completion of a usability test, participants are asked to select the five cards that most closely matched their personal reactions to the system they had just used.

Travis 2009[53] developed a modified version of the method. Instead of cards, he used a paper checklist of adjectives. The participant, after completing the task session, is asked to select the number of adjectives that better reflects his feeling about the application he was able to test. After doing this, from the chosen words, he must select the five most representative words that will be used for a post-guided interview. This is a good method for a qualitative approach.

2.9.5. GUIDED INTERVIEWS

An interview is a qualitative method that allows identifying effectiveness and satisfaction aspects of the usability analysis. This method is commonly used to obtain detailed information as well or information that can only be obtained from the interactive process between the interviewer and the user[54]. There are two possibilities to conduct an interview: unstructured and structured. The first one, does not use a well-defined agenda, and does not include specific aspects of the system. The main objective is to gather as much information as possible concerning the user's

[53] Userfocus Website <http://www.userfocus.co.uk/articles/satisfaction.html.> Retrieved on January, 2010.
[54] Usabilityhome Website <http://www.usabilityhome.com/FramedLi.htm?Interview.htm.> Retrieved on February, 2010.

experience. This type of interview is like a conversation. The structured interview, on the other hand, uses a specific and predefined agenda with specific questions to guide and direct the interview. It is like an interrogation.

Individual interviews "*do not involve watching a user work*" while testing[55], they only can give information about the user's attitudes, beliefs, desires and experiences, so, individual interviews are also used to supplement online surveys.

Main advantages when performing Individual interviews compared to focus groups[56] is that you have more time to discuss topics in detail and thus you can give the interviewee your full attention and adjust the interviewing style (*op.cit*).

2.9.5.1. NON-FUNCTIONAL OR QUALITY REQUIREMENT ANALYSIS USING GUIDED INTERVIEWS

Eide (2005) states that in software technology a non-functional requirement is a requirement that is used to evaluate the operation of a system rather than specific behaviours, contrasted with functional requirements used to define specific behaviours or functions. In general, functional requirements define what a system is supposed to do whereas non-functional requirements define how the system is supposed to be. Non-functional requirements are also known as "quality" requirements.

According to Glinz (2007), 'non-functional requirements' have been used for more than 20 years, and there is not still a formal or standard definition of them. On the other hand, there is a unanimous agreement about their importance.

Quality requirements are referred to wanted qualities of the product; they are not directly related to product's functionality. Malan and Bredemeyer (2001), define "Qualities as properties or characteristics of the system that its stakeholders care about and hence will affect their degree of satisfaction with the system". Eide, 2005 mentioned that this type of requirements are usually difficult to capture or identify, mainly because users (in interviews of discussion groups) express what they do in function but not what quality they are expecting, thus quality is usually implicit.

Another name for quality requirement analysis is qualimetry, a relatively newly applied field of knowledge (Eide, op cit) dealing with the need of quantifying relationships between complex criteria needed for analysing improvement processes consisting in continuous and not-continuous changes (Bluvband, 1995).

Several taxonomies exists for classifying quality requirements, they differ from each other mainly on the type of quality factors, their complexity and detail. Some well known are listed below:

- McCall & Matsumoto quality factors
- ISO9126
- IEEE Std 830
- VOLERE Taxonomy (Robertson & Robertson)
- Firesmith Taxonomy[57]

As revealed above, defining quality factors can be complex and time consuming. Malan and

[55] The Usability.gov is an official U.S. Government Web site managed by the U.S. Department of Health & Human Services <http://www.usability.gov/methods/analyze_current/learn/individual.html.> Retrieved on January, 2010.
[56] Focus groups: "a informal technique that can help you assess user needs and feelings both before interface design and long after implementation. In a focus group, you bring together from six to nine users to discuss issues and concerns about the features of a user interface. The group typically lasts about two hours and is run by a moderator who maintains the group's focus". Nielsen, 1997.
[57] Engineering Security Requirements. PDF Document. Available at: http://www.jot.fm/issues/issue_2003_01/column6/. Retrieved on January, 2010.

Bredemeyer (2001), advised to prioritize non-functional requirements to ensure that, the most important aspects of the system will be fulfilled. They recommend collecting user goals, extracting quality requirements, and prioritizing them.

2.10. MEASURING USABILITY

According to Hornbaek (2006), usability cannot be directly measured. Usability aspects can be measured but there it is needed to identify if such measure is a valid indicator of usability. The author points out that this difficulty had been well described in the literature, as the question about "*which measures of usability to select is consequently central in many approaches*". The author found is "easily" to measure the three aspects of usability (efficiency, effectiveness and satisfaction) separately.

Similarly Frøkjær *et al* (2000), suggest that effectiveness, efficiency, and satisfaction should be considered independent aspects of usability that need to be measured separately and independently but all the results must be included in the final usability testing result.

Hornbaek (2006) investigated and summarized current practices in measuring usability. He analyzed the usability measures in180 studies published in core HCI journals and proceedings. Table 2.5 synthesizes the current practices for measuring the usability.

Table 2.5. Current practices for measuring effectiveness, efficiency and satisfaction

USABILITY ASPECT	MEASURE	DESCRIPTION
Measures of efficiency	Time	Measures of how long users take to complete tasks with the interface.
	Input rate	Measured in a number of studies, typically in the form of text entry speed (words per minute, corrected words per minute) or throughput.
	Mental effort	Concerns the mental resources users spend on interaction.
	Usage patterns	Include measures of how the interface used number of mouse clicks needed to complete video browsing tasks or for example the number of objects visited in a virtual space
	Communication effort	Measures of the resources users expend in communication typically employed in studies of groupware, i.e.: number of turns in conversation.
	Learning measures	Use changes in efficiency as an indicator of learning, for example in the time used for completing tasks.
	Time controlled	Refers to studies where users are given a fixed amount of time to complete their tasks.
Measures of effectiveness	Binary task completion	Measures of whether users complete tasks or not. Includes measures of the number of correct tasks, the number of tasks where users failed to finish within a set time
	Accuracy measures	Quantify the number of errors users make either during the process of completing tasks or in the solution to the tasks.
	Recall	Measures of how much information users can recall after having used the interface. Typically, the information recalled is parts of the content of the interface.
	Completeness	Measures of the extent to which tasks are solved. Such measures are orthogonal to accuracy measures as they capture effectiveness in situations where it does not

		make sense to say that users made errors in completing tasks, but only that users reached solutions of different completeness.
	Quality of outcome	A more extensive attempt to measure the outcome of tasks.
Measures of satisfaction	Standard questionnaires	Use standard questionnaires for measuring satisfaction or build directly upon previous work for questions on overall user satisfaction.
	Preference	Measures capture which interface users prefer to use.
	Ease-of-use	Measures of general satisfaction with the interface, intended to measure the same construct as the standard questionnaires.
	Specific attitudes	Include measures aimed at capturing specific attitudes toward or perceptions of the interface; like liking, fun, and annoyance. A whole range of measures is concerned with users' attitudes and perceptions of phenomena other than of the interface itself.
	Content of the interface	Such questions could be about the quality of the information; the interest subjects took in the information, or the organization of the information.
	Perception of outcomes	Refers to users' rating of their perception of the outcomes of the interaction. This is measured as answers to questions on users' confidence in the solution to tasks, as users' perception of comprehension, as users' perception of learning, or as users' assessment of their own performance.
	Perception of interaction	Refers to users' rating of their perception of the process of interaction. This most often regards users' perception of task complexity and of task completion times.
	Other measures	Include measures of beauty, how cluttered subjects find a display, and a measure of users' embarrassment.

Source: Hornbaek (2006)

Hunter *et al,* 2003 identified some characteristics that determine the success or failure of spatial data applications. They suggested that those are "*fundamental elements that need to be present in information for it to be considered sufficiently usable for scientific or professional purposes*". They found 40 elements of usability (Table 2.6) needed to be considered when analysing spatial information

Table 2.6. Fundamental Elements for Usability Measures

FUNDAMENTAL ELEMENTS		
Adding of value	Integrity	Quality
Authoritativeness	Interestingness	Reliability
Benefits	International Standards	Searchability
Best practice	Legally defensible.	Security
Certification	Logical consistency	Shelf-life
Completeness	Low Cost	Speed of access
Content	Metadata	Temporal accuracy
Convenience	Novelty	Trust
Data accuracy	Officially sanctioned	Type of application
Data integration	Popularity	Type of decision

Ease of use	Presentation	Unexpectedness
Exclusiveness	Product purpose	User skill levels
Guarantee	Producer/Provider reputation	Validity
		Visual appearance (tools)

2.11. CHAPTER CONCLUSIONS

More than forty virtual globes are readily available after a thoroughly search of the Web; most of them providing 3D imagery access, relief data, and navigation and searching functionalities. Issues like import and export of both vector and raster data still require considerable improvement.

Virtual globe based application definitions were not found in the literature, so the researcher has proposed the following one: "… an application or system designed and built specifically for use with Virtual Globes" that fits the scope of the present work.

Currently Google Earth is the most popular and widely used virtual globe in a wide variety of applications starting from recreational purposes and ending in sophisticated, professional and specialized uses. Google Earth is the most commonly used and popular virtual globe in mapping mashups. Mashups are web application hybrids allowing multiple combinations of different sources of information, but still difficult to be implemented in a general way as they demand significant coding skills from the user in order to render desiderable outcomes.

Most of the mashups currently found on the Web, are mainly used for mapping purposes, for their possibilities of enhancing the potential of VGs for the presentation and visualisation of spatial data. Some examples are successful results of their use in well known applications as those presented in this Chapter.

As a result of globalizations and the fast development of the WWW, most countries in the world are currently sharing and disseminating their statistical data and information for multiple purposes. Virtual globes are potentially useful tools for improving the visualization of data and helping to make them available to all kinds of users.

Usability is a relatively old concept used for measuring how "user-friendly" is a computer application. Currently usability is being used for making products and systems easier to use and to identify user needs. ISO 9241-11 defines it in a modern and standard way.

Usability consists in three basic aspects that can be measured separately: effectiveness, efficiency and satisfaction. Each aspect possesses specific measuring methods and techniques. A wide variety of derived combinations of methods and techniques have been developed for measuring usability for different purposes.

Promising and outstanding methods and techniques for measuring the usability of VGs based applications are: Performance testing, Thinking Aloud Method, Questionnaires, Reaction Adjectives and Guided Interviews. Qualimetry is a technique used for measuring abstract properties as those related to the quality of use of VGs based applications and they fit the objectives of the research.

The theoretical background just described is the backbone of the research methodology proposed in Chapter III.

CHAPTER III

RESEARCH METHODOLOGY

3.1. INTRODUCTION

This chapter contains a detailed description of the methodology applied during the research process.

According to the overall research objective (see section 1.3), the aimed thesis research outputs are the following:

1. Results of the analysis of the current usability of Virtual Globe based applications
2. Conceptual design of an improved Virtual Globe based application focused on statistical data dissemination.

The research methodology was set up and organized focused on achieving both outputs. This chapter presents the methods and the steps carried out in order to tests the current usability of VGs based applications. Figure 3.1. shows the schema of the followed methodology.

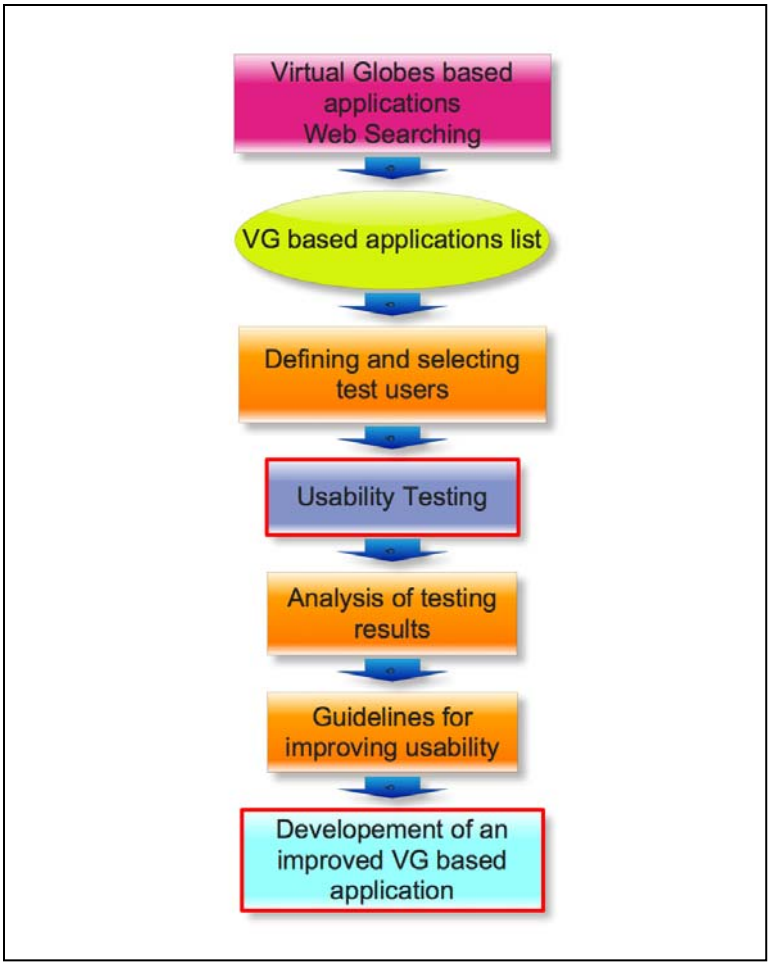


Figure 3.1. Research Methodology Schema

As it is shown in Figure 3.1. the research began with a Web searching of VGs based applications, so a VG based application list was constructed in order to select the ones to be tested empirically. The next step of the process consisted in defining, selecting and contacting the people for the usability testing process. Once they accepted to act as testers testing process was carried out, and the analysis of the obtained results was performed. Writing the guidelines for improving the VGs based applications followed the testing results. The last part of the research methodology is focused on designing with those results a conceptual model of an improved application based on VG.

3.2. SELECTION OF VIRTUAL GLOBE BASED APPLICATIONS TO BE TESTED

In order to identify representative VGs based applications to be tested a web scrolling was carried out. After scrolling the Web hundreds of VGs based applications, created and developed for different types of users and for a diverse and wide range of purposes was found.

Some representative VGs based applications were needed in order to perform a representative usability testing procedure. In order to be oriented to professional or scientific use and considering the rapid growth and development of new information technologies, a VG based application to be tested needs to have the following characteristics considered as very important ones by most serious professional users:

1. A truthful and recognized institution responsible of the maintenance of the application
2. Truthful and trustable sources of information and databases
3. A well structured, complete, working, and finished application
4. A continuously up-to-date application
5. World-widely used.

After a very careful pre-selection process, two VGs based applications where found to accomplish all the above listed requirements: the OBIS Seamap and the Earth Knowledge VGs based applications. Both are described in the following section.

3.2.1. OBIS SEAMAP APPLICATION

The Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP) Application[58] is a spatially referenced, temporally interactive online database aggregating marine mammal, seabird and sea turtle data from across the globe. It is one of the projects of the Census of Marine Life[59]. The observation data held by OBIS-SEAMAP are collected from various data providers worldwide. Data can be displayed using a Google Maps and Google Earth interface. Figure 3.2 shows the home page of the application.

[58]OBIS SEAMAP Website <http://seamap.env.duke.edu/datasets.> Retrieved on January, 2010.
[59] Census of Marine Life <http://www.coml.org/.> Retrieved on February, 2010

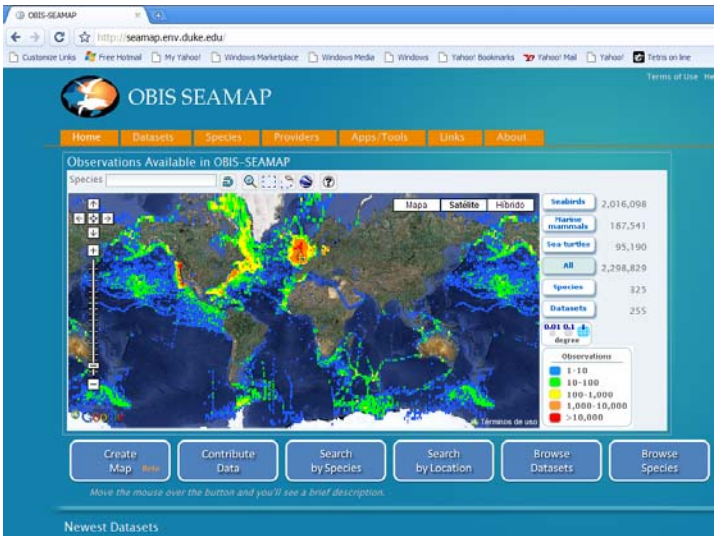


Figure 3.2. Testing Application 1 - OBIS SEAMAP

3.2.2. EARTH KNOWLEDGE APPLICATION

Earth Knowledge[60] is a Google Map based application containing updated information about the Earth. They provide a bridge from the scientific community to all those who care about the Earth – business and community leaders, students and educators, the media, and others. Earth Knowledge is actively involved in facilitating day-to-day conversations among communities, policy makers and scientists to help maintain the delicate balance between consumption and preservation of the earth's resources. The aim is to provide information to facilitate the decision making process

The Earth Knowledge is maintained and fed by a network of different data, information, and knowledge providers. They integrate and access some of the Earth's most interesting and pressing environmental issues. Their network members include science, content, knowledge and technology providers.

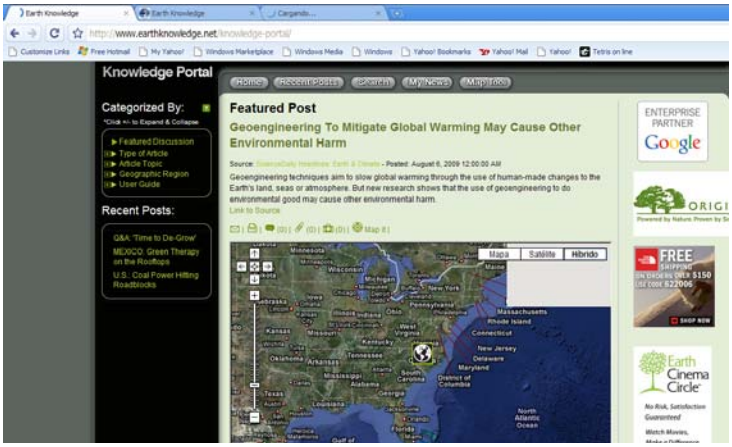


Figure 3.3. Testing Application 2 - Earth Knowledge

[60] EarthKnowledge Website <http://www.earthknowledge.net/home/.> Retrieved on February, 2010.

3.3. USABILITY ELEMENTS TO BE EVALUATED

The principal objective of the thesis research was to assess the current usability of VGs based applications for suggesting the improvement of their capabilities and to increase its potential use. It is assumed that currently VGs based applications are not used at their full capacity because there is always "something not working properly"; so the principal aim of this part of the thesis research was focused on discovering what is "wrong" with them. After discovering the "wrong aspects" (but also the "good ones"), an improved application is conceptually defined and used based on the results of this section.

In order to discover the "wrong aspects" in the representative VGs based applications, some elements were required for testing purposes.

As described in Section 2.10, Hunter *et al,* (2003) identified 40 elements of usability needed to be considered to determine the success or failure of spatial data applications. After a very deep analysis 23 elements out of those 40 fundamental elements, were selected as they were considered to be the most useful to evaluate the usability of the selected applications. Following they were grouped according the usability aspects they are related to, Table 3.1 shows the selected elements used for the present usability testing.

Table 3.1. Selected elements for testing the usability of VGs based applications

Efficiency	Effectiveness	Satisfaction
Best practice	Adding of value	Authoritativeness
Convenience	Benefits	Producer/Provider reputation
Cost	Content	Quality
Data integration	Ease of use	Metadata
Searchability	Novelty	Visual appearance (tools)
Speed of access	Popularity	Trust and reliability
Completeness	Product purpose	Validity
	Type of decision	Integrity

After the identification of the elements to be tested the next step was to define the way of measuring them, selecting the variables or metrics and the technique to use. As it was previously described in section 2.10 about the difficulties in measuring usability, it was decided to use the suggestions of the mentioned author (Hornbaek, 2006) and to measure the three aspects of usability. Table 3.2 shows the metrics considered and the techniques used.

Table 3.2. Metrics and Techniques for measuring the usability aspects

Usability Aspects	Metrics	Techniques
Efficiency	Time	Performance tests
	Input rate	Not measured
	Mental effort	Performance tests
	Usage patterns	Performance tests
	Communication effort	Thinking Aloud
	Learning measures	Not measured
	Time controlled	Not measured
Effectiveness	Binary task completion	Performance tests
	Accuracy measures	Performance tests
	Recall	Performance tests
	Completeness	Performance tests
	Quality of outcome	Not measured
Satisfaction	Visual appearance (tools)	Questionnaires

	Preference	Not measured
	Ease-of-use	Questionnaires
	Specific attitudes	Reaction Adjectives
	Content of the interface	Reaction Adjectives
	Perception of outcomes	Thinking Aloud/Questionnaires
	Perception of interaction	Thinking Aloud/Questionnaires

As it is shown in Table 3.2 in order to test the current usability of the selected VGs based applications a combination of four different methods was used. The fifth method (guided interviews) was used specifically for analysing applications focused on statistical data dissemination. In the following section, a detailed description of the way the usability testing process was carried out is presented.

3.4. PARTICIPANTS OF THE TESTING PROCESS

Jackob Nielsen in his alert box from March 19th, 2000[61] mentioned that the best results on usability testing come from testing no more than 5 users and running as many small tests as you can afford. Nielsen states that "*after the fifth user, you are wasting your time by observing the same findings repeatedly but not learning much new*"

The author also mentioned that "*as you add more and more users, you learn less and less because you will keep seeing the same things again and again. There is no real need to keep observing the same thing multiple times, and you will be very motivated to go back to the drawing board and redesign the site to eliminate the usability problems*".

Once the applications to be tested were selected, it was necessary to define what kind of users would be selected to perform the tests, i.e. how many *testers* were required and their knowledge about the testing topics.

After defining the type of usability testing techniques to be applied it was decided that 5 to 8 *testers* would be needed (based on the Nielsen's experiences) and that they necessarily should be professionals working with and having an experience in cartography or related geographic fields. Regarding their academic/professional background it was decided that formally educated cartographers or other professionals working and using cartography as input in their daily work would fit the task for the sake of technical language and consistence of the answers.

After a careful national searching, six professionals where kindly invited to participate in the usability testing process. Their professional background and work experience are summarized in Table 3.3.

Table 3.3. Participants of the usability testing process

#	Profession	Academic Degree	Current Work	Cartography Experience
1	BSc in Biology	BSc	FAN (Friends of Nature Foundation)	She does not create maps, but she uses maps for decision making processes
2	BSc in Agronomy	Professional Master in Natural Resources Management	She works for Government Office at regional level	She has a vast experience as GIS technician
3	BSc in Biology	Master of Science in Cartography	FAN (Friends of Nature Foundation)	He works for the GIS Department at FAN.
4	Cartographer	MSc in Natural Resources Management	GIS Coordination in a development project in Canada	Head of GIS Department
5	BSc in Economy	MSc in Economy applied to Natural Resources	Coordinator of the Land Use Plan Department for	He uses maps for decision-making on Land Use Plans in

[61] Jakob Nielsen's Alertbox <http://www.useit.com/alertbox/20000319.html.> Retrieved on January, 2010.

		Management	the Government at regional level.	Bolivia.
6	Civil Engineer	B.Sc in Engineering	Currently he works as a private consultant for geological projects and geological surveys	He is thesis coordinator for the Civil career at the University in topics related to GIS and Remote Sensing used for civil projects

3.5. USABILITY TESTING SETUP

After selecting the VGs based applications to be tested, and defining the elements to be tested, the metrics and the techniques, the testing phase setup was carried out.

The testing process occurred between the 16th and 19th of July 2009. A conference room, a laptop and a camera recorder were prepared for the testing process. Previously, the required material was typed and printed out. This material consisted of the performance tests instructions, the questionnaires and the reaction adjectives list. Five *testers* participated in the testing process, separately, one by one.

Before starting the testing process each tester received a detailed spoken explanation about the objective of the testing process, a brief description of the applications they needed to test and an explanation of the techniques to be used during the testing process. The thinking aloud technique was carefully explained and it was asked whether the person would have some troubles in performing such requirements.

Another aspect that was explained carefully to the *testers* was that their abilities while performing the tasks were not evaluated. They were told that it was not important whether they failed or not, or if they take too much time to solve some issue, because the main goal was to evaluate the application (good and bad things about it) and not the user performance. This aspect was remarked explicitly to ensure that *testers* do not think that I was testing them. It was explained that they were helping the researcher to find out the positive and negative aspects of the applications and the value of their help in the process was stressed.

Before starting with their assignment, *testers* were given some time to explore the application (one at a time) in order to become a little bit familiar with it. The testing process was not fixed in time, *testers* were free to use the time they required and desired.

During the testing process the researcher was recording the process, observing, listening and taking notes, from time to time she had to answer specific questions asked by the *testers*.

3.6. USABILITY TESTING PROCESS

The usability testing methodology for this research was focused on qualitative usability issues. After a careful review of literature on the topic, it was realized that applying only one of the various testing techniques, would not allow accomplishing the research requirements. As it is described in Table 3.2, three outstanding aspects of usability: efficiency, effectiveness and satisfaction were selected to be measured by different techniques. The methodology used consisted of a combination of four qualitative usability techniques: performance tests, thinking aloud, questionnaires, and reaction cards.[62]: The fifth technique: Guided interviews, is described later on Section 3.6.3 as it was used exclusively for the conceptual model design.

The usability testing began with an oral explanation to the *testers* of the objectives of the usability testing while introducing them with a brief background of the VGs based applications to be tested.

[62] Their theoretical background is already described in section 2.3

Printed material containing the explanation of the testing process they need to carry out was handed out to the participants in advance. The process was divided in two parts:

Part 1 – The performance tests (by tasks execution) and thinking aloud

Part 2 – Applying questionnaires and reaction adjectives:

3.6.1. USABILITY TESTING – PERFORMANCE TEST AND THINKING ALOUD

The objective of this part of the work was to evaluate the current usability of the two selected VGs based applications. The testing sessions were carried out working with one participant per session..

Previously, specific tasks were prepared for each of the applications and handed out as a printed material to the participants (see Appendix B). *Testers* were requested to use the thinking aloud method while performing the tasks. Every session was recorded using a video camera and both the user and the computer screen as well were recorded simultaneously in order to get the most complete information of the testing process (Figure 3.4 shows one of the testers while performing the usability testing using the Thinking Aloud method). The tasks lists are presented in the following sections.

Figure 3.4. Tester using the Thinking Aloud method while performing the assigned tasks.

3.6.1.1. TASKS FOR TESTING APPLICATION 1 – OBIS SEAMAP

Test persons were requested to open the URL: http://seamap.env.duke.edu/datasets and to perform the assigned tasks.

1. Identify the number of sea turtles near to Cabo Verde from 2004 – 2006.
2. Add an Environmental layer related to chlorophyll content.
3. Do you understand what the meaning of SST and SSH are?
4. Can you get any information about the time series option?
5. Can you know how many species of sea birds, marine mammals and sea turtles are available on the entire database?
6. How many providers of information are there?
7. Can you get information about the status of protection of the seabirds?

3.6.1.2. TASKS FOR TESTING APPLICATION 2 - EARTH KNOWLEDGE

Test persons were requested to open the URL: http://www.earthknowledge.net/home/ and to perform the assigned tasks.

1. What type of information can you expect to find in the page?
2. Find the "Map Tool" tab.
3. If you want to view the users of the page around the world, by country for example; do you understand the colour representation used?
4. When you select a topic of interest, what kind of information about it do you get?
5. Is this information useful for you? If yes, in which sense?
6. Are you able to understand the meaning of the used symbols?
7. Please find information about the Amazon Basin in South America.

3.6.2. USABILITY TESTING – QUESTIONNAIRES AND REACTION ADJECTIVES

After finishing the task execution of each of the VGs based applications, participants were requested to fill out a questionnaire.

In accordance with the literature review there are diverse opinions on the way of using questionnaires. Some people prefer to use already available and well-known questionnaires while other people prefer to use their own questionnaires. For this thesis research work commonly used existing questionnaires with modifications oriented to the research questions were used.

Two well know questionnaires were used as a base for the survey: the Computer System Usability Questionnaire - CSUQ[63]; and the Usefulness, Satisfaction, and Ease of Use Questionnaire – USE[64]. In order to avoid the "acquiescence bias"[65] and for *qualimetric* purposes[66] some statements were changed from the positive to the negative form, for example: the statement "*I am satisfied with it*" was changed to "*I am not satisfied with it*". In that way it was possible to equilibrate the positive and negative statements. Questions from both questionnaires were merged in a unique one and it is presented in Appendix C.

Once questionnaires were filled out, a list of 105 words (adjectives) was presented to the testers, who selected the adjectives that best summarized their feelings while performing the tasks. A separate list was required for each of the tested VGs based applications. From the chosen words, *testers* were asked to select five adjectives or words that better describe their feeling towards the tested application. See section 2.3 for an explanation of the Reaction Adjectives technique.

After selecting five of the most significant words, a discussion about their meaning and their feelings was carried out in order to find out what kind of motivation guided the selection of each word. This process was also video-recorded and later on analyzed. The adjectives list is presented in Appendix C.

3.6.3. NON-FUNCTIONAL REQUIREMENT ANALYSIS – GUIDED INTERVIEWS

The last part of the usability analysis was focused on answering the last three research questions related to finding out what is needed for improving VGs based applications towards its implementation using an application for statistical data dissemination. A non-functional requirement analysis using guided interviews was carried out.

[63] Computer System Usability Questionnaire Website <http://hcibib.org/perlman/question.cgi?form=CSUQ.> Retrieved on February, 2010.
[64] USE Questionnaire Resource Page <http://usesurvey.com/.> Retrieved on February, 2010.
[65] The fact that people are more likely to agree with a statement than disagree with it (Cronbach, 1946, cited by Travis).
[66] Qualimetry is a relatively new field of knowledge dealing with the need of quantifying relationships between complex criteria needed for analysing improvement processes consisting in continuous and not-continuous changes

In order to get specific information related to statistical data dissemination was decided to select and analyse three VGs based applications for statistical data dissemination. Guided interviews were used to analyse the current usability of applications for statistical data dissemination (the two applications previously described on Sections 3.2.1 and 3.2.1 were used to test the current usability for VGs based applications in general, while the following three were selected for analysing and to identify usability issues in applications oriented specifically to statistical data dissemination). The process was carried out based on pre-elaborated questions/tasks used as starting point of the guided interviews. Questions were oriented to the statistical data dissemination field, specifically on the manner in which statistical information is represented from a cartographical point of view.

The following sections present the reviewed, analysed and discussed applications. Testers were the same that performed the testing process for the two previous applications (see Section 3.4). Sessions were also video recorded. For each of the applications specific questions were designed in order to follow the same procedure and analysis among all the testers.

3.6.3.1. LONDON PROFILER[67]

London Profiler is an application developed and maintained by the NCeSS (National Centre for e-Social Science)[68], CASA (UCL Centre For Advanced Spatial Analysis)[69]; Spatial Literacy[70] and UCL (University College London)[71].

London Profiler is a web site that makes available datasets at neighbourhood level from the city of London, using a visualisation interface provided by Google Maps API (See Figure 3.5).
"*London Profiler allows users to visualise themes at different scales, to search by postcode or zoom at borough level, to change the layer's transparency and to add KML layers".*

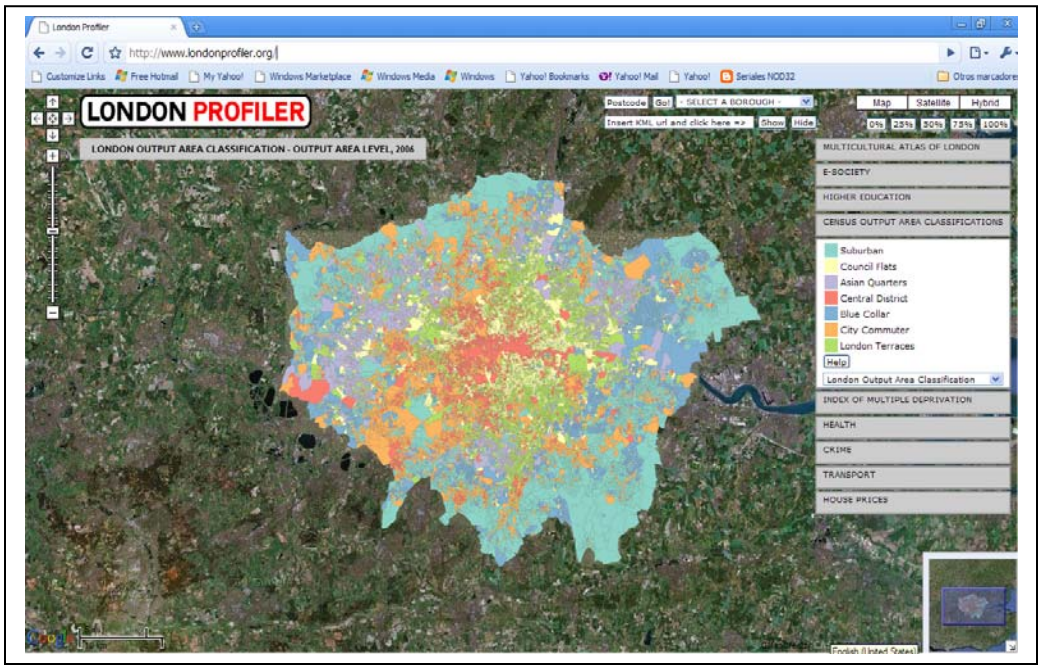


Figure 3.5. London Profiler Interface

[67] London Profiler Application <http://www.londonprofiler.org/>. Retrieved on January, 2010.
[68] NCeSS Website <http://www.ncess.ac.uk/> Retrieved on February, 2010.
[69] CASA Website <http://www.casa.ucl.ac.uk/> Retrieved on February, 2010.
[70] Spatial Literacy Website <http://www.spatial-literacy.org/> Retrieved on February, 2010.
[71] UCL Website <http://www.ucl.ac.uk/> Retrieved on February, 2010.

3.6.3.1.1. PRE-ELABORATED QUESTIONS FOR GUIDED INTERVIEWS - LONDON PROFILER APPLICATION

1. Display the census output area classifications. Do you understand the meaning of the display options? Do you understand what the polygons are?
2. Select the option “output area classification groups UK”.
3. Analyze the displayed map. Do you understand the classes that are shown?
4. Are you able to identify the different classes on the map? Can you get an idea about the surface area of a certain class or the percentage of the class compared with the other classes?
5. Go to the option “Index of Multiple Deprivation”. Select the “Income parameter”. Do you understand the meaning of the colour scheme names? Values?
6. Display the data for 2004 and then for 2007. Can you see the differences between the two maps?
7. What do you consider is needed in order to get more useful information from the previous maps?
8. Analyze the different ways of representing the “transport data”. Do you understand those types of representations?
9. Analyze the “house prices” option. Can you select some postcode district? Does the page give you the opportunity to solve the problem? Try pressing the Help button. Are you able to find the postcodes information on the rendered page?

3.6.3.2. THEMATIC MAPPING WEBSITE[72]

The Thematic Mapping Website (see Figure 3.6) contains information about how geobrowsers can be used for thematic mapping. The author of the website states that “*Thematic mapping has a long history in cartography, but the new geobrowsers tend to have a stronger focus on detailed satellite imagery and general-reference maps than on more abstract data sources*”. The site allows interchange of ideas of how geobrowsers and open standards can be used for thematic mapping purposes.

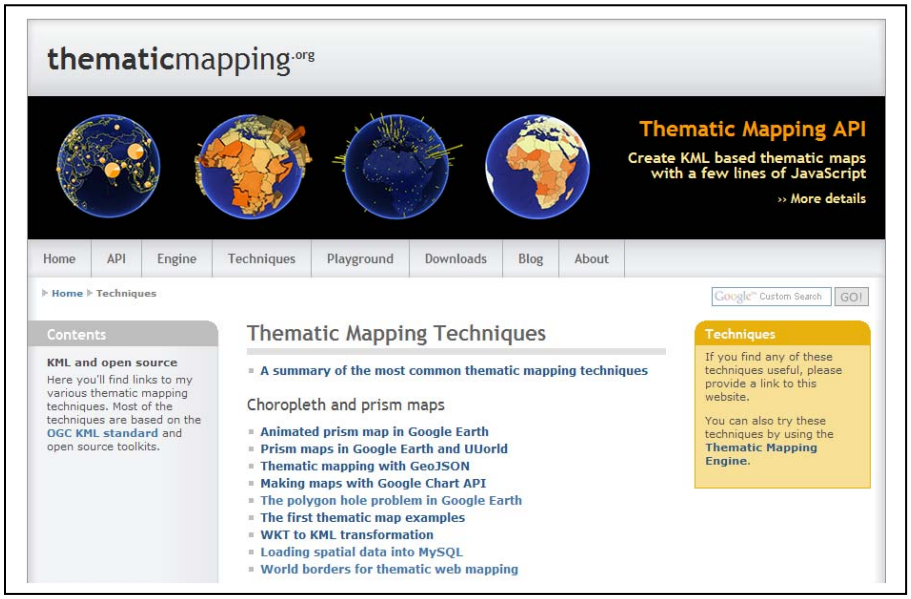


Figure 3.6. Thematic Mapping Website’s Interface

[72] ThematicMapping Website <http://thematicmapping.org/techniques/.> Retrieved on January, 2010.

3.6.3.2.1. PRE-ELABORATED QUESTIONS FOR GUIDED INTERVIEWS - THEMATIC MAPPING WEBSITE

The testers were asked to analyse the information provided for the following three URLs and to answer the questions. Questions were designed in order to get information about the usability of the data representation and to find out drawbacks related to thematic mapping aspects.

- http://blog.thematicmapping.org/2008/04/making-proportional-symbols-in-kml.html.
    - Analyze the usability and usefulness of this type of maps.
    - What is missing?
    - What else should they have?
    - How useful is this type of data representation?
    - Would you use that type of information and data in your work?
- http://blog.thematicmapping.org/2008/06/proportional-symbols-in-three.html.
    - Give your impression about the legend.
- http://blog.thematicmapping.org/2008/04/using-google-charts-with-kml.html.
    - Analyze the different ways of presenting information.
    - Which one do you think is better, more understandable and useful?
    - Which is the best for you?
    - Why?

3.6.3..3. BOLIVIAN NATIONAL STATISTICAL OFFICE (INE) WEBSITE[73]

The Bolivian National Statistical Office (INE) (see Figure 3.7) contains the statistical data of the country. It is a relatively well organized, structured and maintained Website, depending on the Bolivian Government. Even though this is a non-VG based application, due its importance both for the country and for their characteristics regarding the way statistical data is presented; it was selected for the conceptual design. The Website is described in detail later on Chapter V.

Figure 3.7. INE Website's Interface

[73] INE Website <http://www.ine.gov.bo/.> Retrieved on January, 2010.

The following aspects were reviewed and discussed with the testers: http://www.ine.gov.bo/

- Search information about the Census 2001. Select “Population” as example.
- Analyze the existing maps on the page.
- Analyze the representation of the information and the used cartographic style.
- Please mention the positive and the negative aspects of the available maps (like representation type, information content, interactivity, etc.)
- How do you think they should be?
- Is it possible to improve it?
- Is it needed to improve it?
- What is missing?
- What is needed?
- Would you like to see the same type of information running over a Google Earth interface?
- Do you think this would give more usefulness?
- Do you think this is needed?
- In which cases would you use it?

3.7. CHAPTER CONCLUSIONS

The first part of the chapter describes the selection process of the VGs based applications to be tested in order to identify “what” is going to be tested and “why”, so the criteria elements for the selection are also highlighted.

Once the VGs based applications to be tested were selected, the elements to be tested were identified. Those elements correspond to the three aspects of usability: effectiveness, efficiency and satisfaction. The second part of the chapter was focused on describing what elements were required for testing and how they were tested.

The last part of the chapter is focused on the usability testing process as such; the *testers* and the applied techniques selected for the testing process are described briefly.

Chapter IV presents the results obtained after applying the methodology just discussed.

CHAPTER IV

RESULTS

4.1. INTRODUCTION

This chapter is organized in two parts. The first part (Part 1), presents, interprets and discusses the results of the usability testing process of two VGs based applications. The outcomes of the task executions are reviewed, and the observations or spoken thoughts from the participants during the tests sessions are summarized and analyzed. Analysis of the responses to the questionnaires and the reaction adjectives preferred by tests users is also discussed.

The last part of the chapter (Part 2) presents the results of the non-functional requirement analysis – using guided interviews for three VGs based applications for statistical data dissemination.

4.2. USABILITY TESTING RESULTS (PART 1)

This section contains the results obtained from the usability testing process of the selected VGs based applications using: performance testing, questionnaires, thinking aloud and reaction adjectives methods.

4.2.1. RESULTS OF TESTING THE OBIS SEAMAP APPLICATION

4.2.1.1. PERFORMANCE TEST

Results of the assigned tasks using the performance testing are presented in tables which are organized as follows:

- ***Tester***: identifies the test person
- ***Time Min. (minutes)*:** the time needed for the tester to perform the task
- ***Accomplishment***: indicates whether the tester was able to complete the task correctly
- ***Confidence about the results***: refers to the tester's confidence on the obtained results
- ***Use of external sources***: indicates whether the tester required an external source of information for completing the task
- ***Use of Help***: indicates whether the tester used available Help tools in order to complete the assigned tasks

The following tasks were assigned to the testers:

Task 1: Identify the number of sea turtles near to Cabo Verde from 2004 – 2006.

Tester	Time Min.	Accomplishment	Confidence about the results	Use of external sources	Use of Help
1	16	NO	NO	YES	NO
2	7	NO	NO	NO	NO
3	5	YES	YES	NO	NO
4	2	YES	YES	NO	NO
5	11	YES	YES	NO	YES
6	4	YES	NO	NO	NO

Testers' thoughts/observations: Literally, the following expressions were recorded:

- "Difficulties in finding the requested information".
- "Use of external sources in order to clarify doubts generated when reviewing the page".
- "Difficulties when using mapping tools, for selecting a specific area, tools do not work as they should work" (for example for drawing a square it is expected that you can start drawing it from one corner and drag the area you want, in this application you need to click the first corner, release the mouse button and then click the opposite corner in order to get the desired square).
- "Difficulties when using the 'map tools' ". "Users are not very used to work with those not very common tools".
- Tests persons are not very used to use the HELP menu. (researcher observation)

Task 2: Add an Environmental layer related to chlorophyll content.

Tester	Time Min.	Accomplishment	Confidence about the result	Use of external sources	Use of Help
1	2	YES	NO	NO	NO
2	1	YES	YES	NO	NO
3	4	YES	NO	NO	YES
4	1	YES	YES	NO	NO
5	6	YES	NO	YES	YES
6	1	YES	YES	NO	NO

Testers' thoughts/observations: Literally, the following expressions were recorded:

- "Difficulties when using mapping tools, like adding layers or creating areas of interest".
- "The application does not offer maps interactivity possibilities".
- "When adding an information layer, the redraw or the overlay must be quick, sometimes it takes too long until the layer to be displayed on the screen, making the user to desist and to go one step backward".
- "When a request takes too much time, there is no signal that the system is working. Some other pages use to show some symbol (like a sand clock) which indicates the system is still processing something and the user needs to wait for a while, some systems even show the percentage of the completed request. In this application, that tool is not available and sometimes refreshing or redrawing the page takes too long and the user may think that it is not working anymore".
- "When the new layer is displayed on the screen, it comes without a legend or scale which indicates the meaning of the colours shown on the map. There is no information available concerning the values assigned to the colours. And when values are available, information about the units of the value are missing; the user is able to see just a number, but there is no information about what that number represents. In the application, the values of chlorophyll are unknown; it is not possible to see if they are measured values, and if so, daily, yearly, etc."

Task 3: Do you understand what the meaning of SST and SSH are?

Tester	Time Min.	Accomplishment	Confidence about the result	Use of external sources	Use of Help
1	2	YES	NO	NO	NO
2	4	YES	NO	NO	YES
3	1	YES	NO	YES	YES
4	1	YES	YES	NO	NO
5	1	YES	YES	NO	NO
6	1	YES	YES	NO	NO

Testers' thoughts/observations: Literally, the following expressions were recorded:

- "Some information is dependant on a specific field of knowledge. The use of abbreviations must be carefully managed in order to not restrict the use of the application to non-specialists."
- "The legend is not very informative. It is not possible to be sure what the values are about."
- "There are some wrong values of the legend related to the information presented on the maps."

Task 4: Can you get any information about the time series option?

Tester	Time Min.	Accomplishment	Confidence about the result	Use of external sources	Use of Help
1	2	YES	NO	NO	NO
2	3.5	YES	YES	YES (question to me)	NO
3	7	YES	YES	NO	NO
4	1	YES	YES	NO	NO
5	5	YES	NO	NO	NO
6	1	YES	YES	NO	NO

Testers' thoughts/observations: Literally, the following expressions were recorded:

- "Time series must be presented or represented in a different way, more visible, more understandable."
- "I do not understand the time series representation. Time series are there but I have doubts about where they correspond to which map, to which data."

Task 5: Can you know how many species of sea birds, marine mammals and sea turtles are available in the entire database?

Tester	Time Min.	Accomplishment	Confidence about the result	Use of external sources	Use of Help
1	5	NO	NO	NO	NO
2	4.5	YES	YES	NO	NO
3	9	YES	YES	NO	YES
4	2	YES	YES	NO	NO
5	8	NO	NO	NO	YES
6	6	YES	YES	NO	NO

Testers' thoughts/observations: Literally, the following expressions were recorded:

- "The accessibility to the database is limited, it is not fluent, and it is not very logic."
- "There is the need for some more easy access to the database or querying."
- "There is the need to present general numbers more clearly, like a table or chart, allowing the possibilities to find it quickly."
- "It is too difficult to find the requested data. Such type of information is really important, must be easy to find it, but it is not."

Task 6: How many providers of information are?

Tester	Time Min.	Accomplishment	Confidence about the result	Use of external sources	Use of Help
1	1	YES	YES	NO	NO
2	1	YES	YES	NO	NO
3	1	YES	YES	NO	NO
4	1	YES	YES	NO	NO
5	1	YES	YES	NO	NO
6	1	YES	YES	NO	NO

(No comments!)

Task 7: Can you get information about the status of protection of the seabirds?

Tester	Time Min.	Accomplishment	Confidence about the result	Use of external sources	Use of Help
1	2	NO	NO	NO	NO
2	2	YES	YES	NO	NO
3	4	YES	YES	NO	NO
4	1	YES	YES	NO	NO
5	6	YES	NO	NO	NO
6	2	YES	YES	NO	NO

Testers' thoughts/observations: Literally, the following expressions were recorded:

- "Improving the querying capacities for accessing the database is needed."

4.2.1.2. QUESTIONNAIRES RESPONSES – OBIS SEAMAP APPLICATION

Table 4.1 contains the test person's responses to the questionnaires. The ID allows the identification of the questions in figures 4.1, 4.2, 4.3, and 4.4 shown below; T1 until T6 identify the testers. Values assigned to each question refer to the following scale: 1="strongly disagree", 4="neither disagree nor agree", 7="strongly agree"; and NA="it does not apply".

Table 4.1. Questionnaire Responses - OBIS SEAMAP Application

		TESTER					
QUESTIONS	ID	T1	T2	T3	T4	T5	T6
Would like to be used for frequent and occasional users	**Q1**	3	5	2	7	6	2
I am not satisfied with it	**Q2**	6	1	7	1	1	5
It is simple to use	**Q3**	3	6	1	3	5	3
It is wonderful	**Q4**	4	6	1	6	5	5
It is not useful	**Q5**	2	1	4	1	2	2
I find to many inconsistencies while using it	**Q6**	6	1	NA	3	2	7
It is boring to use it	**Q7**	4	1	7	1	1	4
It makes everything I expect and I need to do	**Q8**	2	6	1	7	5	3
It requires to much steps to accomplish what I want to do with it	**Q9**	6	2	7	2	1	6
It is user friendly	**Q10**	2	6	1	NA	6	1
I don't like the user interface	**Q11**	7	2	4	1	2	7
It would help me be more effective	**Q12**	2	7	1	NA	6	3
It would help me in some work activities	**Q13**	6	7	4	6	6	7
I do not need it	**Q14**	4	1	1	1	2	3
I can use it successfully every time	**Q15**	3	7	7	7	6	4
It is not flexible	**Q16**	4	1	7	2	1	5
I learned to use it quickly	**Q17**	3	5	1	6	5	3
It helps me to do things quickly	**Q18**	6	7	1	7	6	5
I can not recover from mistakes quickly and easily	**Q19**	6	NA	4	1	6	6
It would help me be more effective	**Q20**	4	7	1	1	7	5
Organization of the screen is not clear	**Q21**	6	1	7	7	2	6
Use it requires to much effort	**Q22**	5	2	7	NA	1	6

I can use it without written instructions	**Q23**	3	7	1	7	7	2
It does not meet my needs	**Q24**	4	2	7	7	1	5
The interface is grateful	**Q25**	3	7	4	7	6	2
It works the way I want it to work	**Q26**	2	7	2	7	7	3
It helps me to perform my work in an efficient way	**Q27**	2	7	7	7	7	2
It would not save me time when I use it	**Q28**	6	1	7	NA	2	6
I easily remember how to use it	**Q29**	2	7	1	1	6	1
I quickly could become skilful with it	**Q30**	2	7	1	1	7	2
It is not pleasant to use	**Q31**	5	1	2	7	1	6
It is complicated to use it	**Q32**	6	1	7	1	2	6
I would recommend it to a friend	**Q33**	4	7	4	7	6	3
It would not help me be more productive	**Q34**	6	1	1	7	6	7
In general, the application satisfied me	**Q35**	2	6	1	7	7	2
It is easy to learn to use it.	**Q36**	2	7	1	7		1
Help information (online help, screen messages, etc.) is not useful/clear	**Q37**	6	NA	7	1	4	7

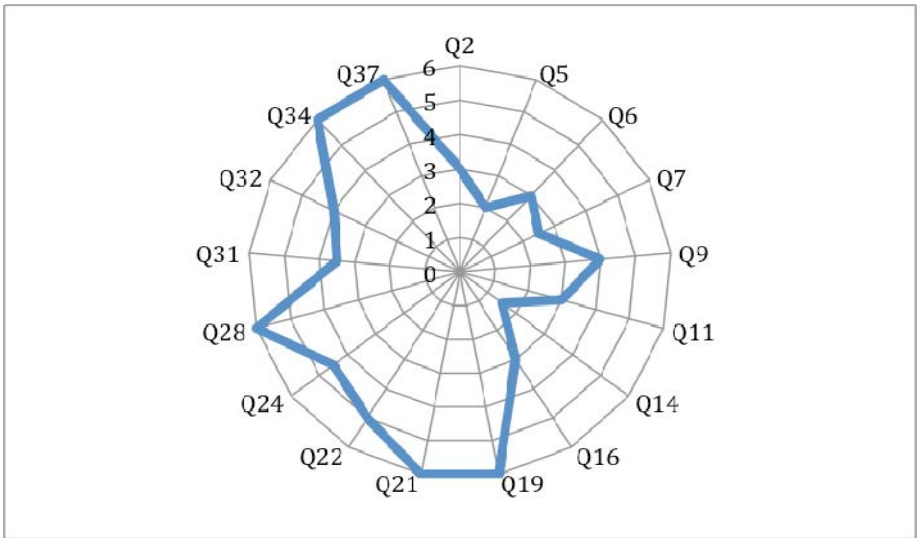


Figure 4.1. Median behaviour obtained from the negative statements. OBIS SEAMAP Application

Figure 4.1 above shows the represented median of the negative statements. Notice that questions number 19, 21, 28, 34 and 37 were assigned high values (6) of agreement. It means that, in general, testers agree with the following statements:

- (Q 19) I can not recover from mistakes quickly and easily
- (Q 21) Organization of the screen is not clear
- (Q 28) It would not save me time when I use it
- (Q 34) It would not help me be more productive
- (Q 37) Help information (online help, screen messages, etc.) is not useful/clear

On the other hand, questions number 14, 5, 6 and 7 were assigned with agreement values between 1 and 3, which means that most of the testers do not agree with the following statements:

- (Q14) I do not need it
- (Q5) It is not useful
- (Q6) I find too many inconsistencies while using it
- (Q7) It is boring to use it

Translating it into positive statements, it could be assumed that, in general, testers consider they could need the application; the application is useful, it does not present inconsistencies while using it and is not boring to use.

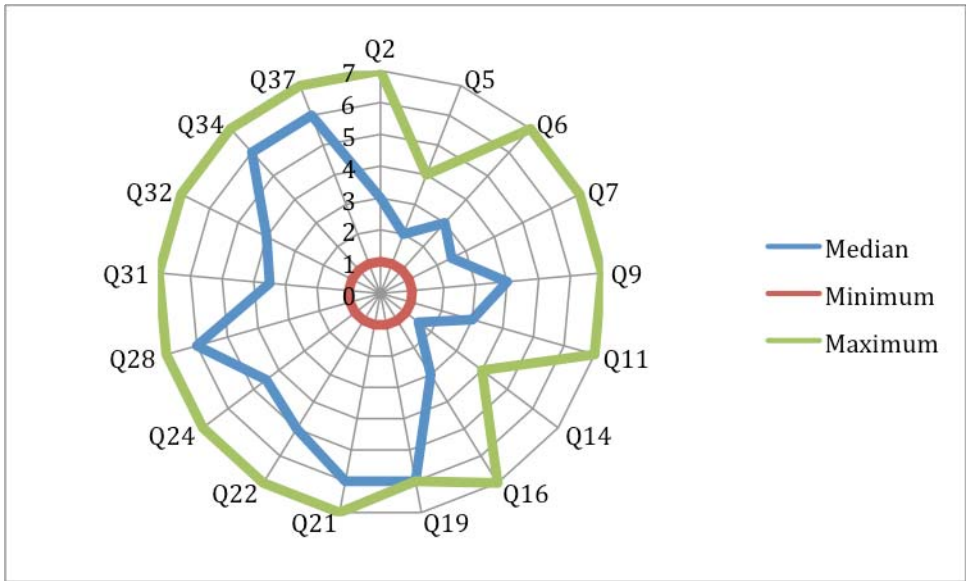


Figure 4.2. Max, Min and Median behaviour obtained from the negative statements - OBIS SEAMAP Application

Qualimeric data show that the median of the tester unanimously agree with questions: q19, q21, q28, q34 and q37 are main negative aspects of the tested application. As figure 4.2 shows there is a large difference between extreme opinions: Minimum qualimeric values receiving a uniform mark of 1 –completely low- for all testers and Maximum with a rather top qualification for 15 out of 18 questions.

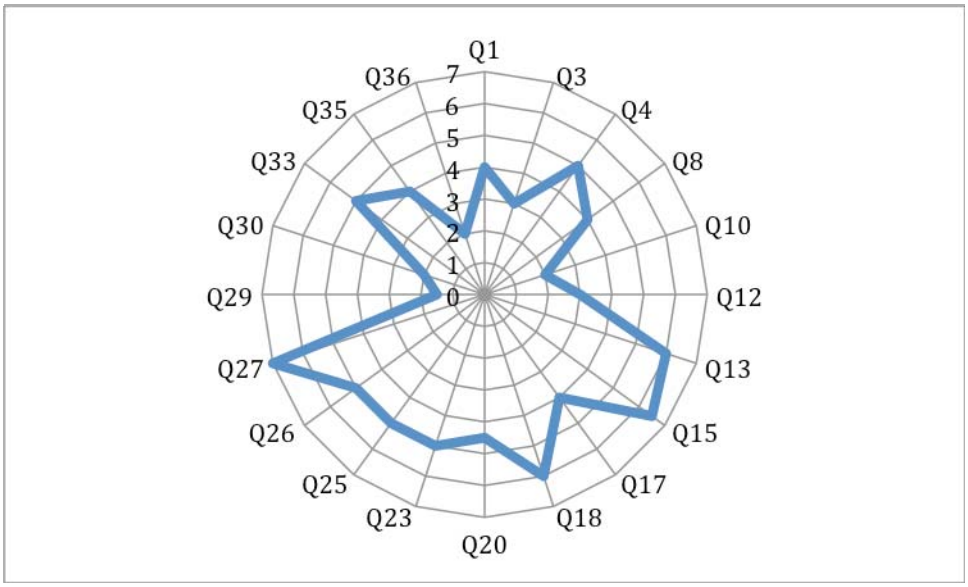


Figure 4.3. Median behaviour obtained from the positive statements - OBIS SEAMAP Application

After analysing the answers given to the positive statements (Figure 4.3.), it is found that questions 27, 18, 15, 13, 4 and 33 where assigned with values of agreements (between 7 and 5) which means that most of the testers agree with the following statements:

- (Q27) It helps me to perform my work in an efficient way
- (Q18) It helps me to do things quickly
- (Q15) I can use it successfully every time
- (Q13) It would help me in some work activities
- (Q4) It is wonderful
- (Q33) I would recommend it to a friend

In the other way round, the statements where test persons do not agree, were assigned with agreement values between 1 and 2 corresponding to questions 29, 36 and 10. It means that, in general, participants do not agree with the following statements:

- (Q29) I easily remember how to use it
- (Q36) It is easy to learn to use it.
- (Q10) It is user-friendly

This can be understood as tests persons think that it is not easy to remember how to use the application, it is not easy learn to use it and it is not user-friendly.

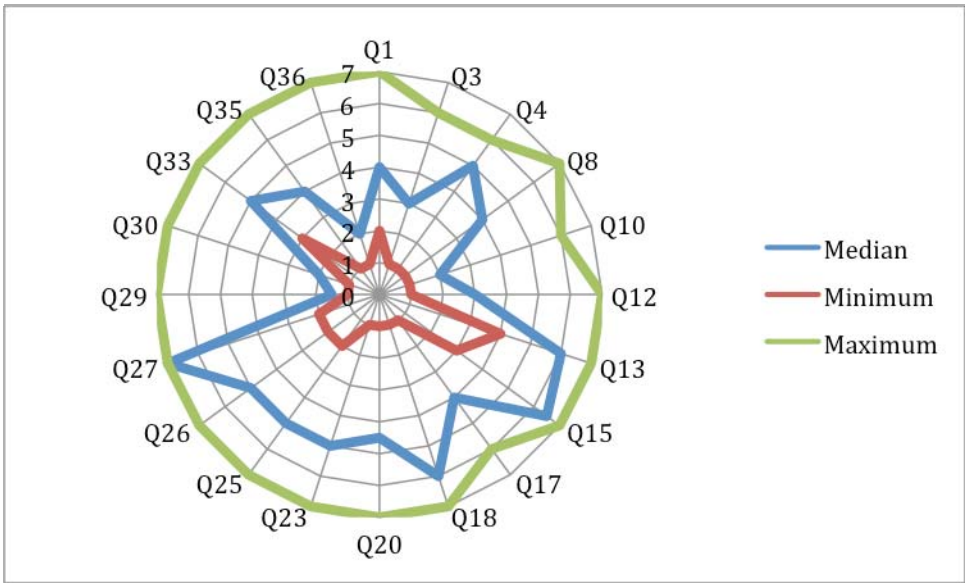


Figure 4.4. Max, Min and Median behaviour obtained from the positive statements - OBIS SEAMAP Application

Qualimetry statistics of the positive statements show quite different results as compared to negative statements, with a rather different median answers. Regarding the minimum, an important variability of answers is noticed, where q13, q15 and q33 show that testers are not completely unhappy with those factors. Similarly as it was observed with positive statements, top value qualifications were also given to positive statements in q1, q8, q12, q13, q15 and q18 through q36.

4.2.1.3. REACTION ADJECTIVES RESULTS – OBIS SEAMAP APPLICATION

Table 4.2 contains the selected words (adjectives) containing the testers' feelings regarding the tested application (OBIS SEAMAP).

Table 4.2. Selected Reaction Adjectives – OBIS SEAMAP Application

Adjectives	Tester					
	1	2	3	4	5	6
Irritant	X					
Sophisticated	X				X	
Time-consuming	X		X			X
Inconsistent	X					
Approachable	X					X
Saturated	X					
Complex	X		X	X	X	
Professional	X	X	X		X	
Confusing	X		X			X
Distractive	X	X	X			
Too technical	X		X		X	
Rigid	X					
Intimidating	X					
Slow	X		X		X	X
Comprehensive		X				
Obscure		X				
Simplistic		X				

Innovative		X		X	X	
Flexible		X				
Credible		X		X		X
Exiting		X		X		
Attractive		X				X
Efficient		X		X	X	
Controllable		X				
Satisfies		X			X	
New		X			X	X
Usable		X				X
Funny		X				
Friendly		X				X
Quick		X				
Trustworthy		X			X	
Direct		X				
Motivating		X				
Interesting		X			X	
High Quality		X				
Impressive		X				
Convenient		X				X
Clean		X				
Creative		X				X
Simple		X				
Organized				X		
Actual		X				X
Useful		X		X		
Advanced			X			
Difficult			X		X	
Unattractive			X			
Non-standard			X			

From the provided adjectives (105), 41 were selected as those that better represents the tested application. From those 41, the 78% (32 adjectives) were positive ones. From this results can be concluded that the OBIS SEAMAP application was considered in general as a good application.

The commonly adjectives selected for at least three testers were:

- Time-consuming
- Complex
- Professional
- Confusing
- Distractive
- Too technical
- Slow
- Innovative
- Credible
- Efficient
- New

4.2.1.4. PREFERRED REACTION ADJECTIVES – OBIS SEAMAP APPLICATION

As mentioned before (see section 2.3 for an explanation of the Reaction Adjectives Method) from the previously chosen words (adjectives), testers were asked to select five adjectives or words that better describe their feeling towards the tested application. Table 4.3 shows the selected most significant words selected by testers that better describes the tested application.

Table 4.3. Preferred Reaction Adjectives - OBIS SEAMAP Application

Adjectives	Tester					
	1	2	3	4	5	6
Positive Adjectives						
Take advantage	X					
Professional					X	
Innovative		X				
Flexible		X				
Interesting					X	
Usable		X				X
Useful		X		X		
Exiting				X		
Organized				X		
New					X	
Efficient				X		
Creative						X
Attractive			X			X
Credible		X		X		X
Negative Adjectives						
Complex	X		X		X	
Confusing	X					
Time-consuming	X					
Distractive			X			
Saturated	X					
Slow						X
Difficult			X		X	
Non-Standard			X			

Meaning explanation of the selected most significant words is given following:

TESTER 1:

1. ***Time consuming***: "Certain options take too much time when activating and deactivating. In general, time processing for most of the activation options takes too long and there is not any signal indicating that the program is still processing or if it is over. Is too slow".
2. ***Take advantage***: "In spite of application have many management failures; it has valuable information, important, serious and relevant databases. The fact the interface is not so good does not mean that the application's content is not valuable".
3. ***Saturated***: "The application has too many windows with too much text on them. This is a distractive factor that makes to loose attention".
4. ***Complex***: "It is not easy to find which one is looking for. Navigating the menus is complex".
5. ***Confusing***: "Like a summary of all the above, while not being intuitive, being distractive makes the user to be confused."

TESTER 2:

1. ***Innovative***: "Application is a very new and interesting manner of presenting valuable information."
2. ***Flexible***: "This application can be easily adapted to diverse user needs."
3. ***Credible***: "It is credible because the information providers, which seem to be serious, and responsible, thus the information is trustful".
4. ***Usable***: "This type of applications could be used at everyday work, to obtain up-to-date information quickly."
5. ***Useful***: "It is very useful for my work."

TESTER 3:

1. ***Attractive***: "In relation to visual aspects of the page. Maps always attract the attention of the people."
2. ***Distractive***: "There is too much information making not easy to concentrate/focus on something. In the end the user gets boring."
3. ***Non Standard***: "Because is not for a common or ordinary user. It depends on need and type of job, it is too specific and too technical."
4. ***Complex:*** "Similar to the previous one, because it is focused on specialized people in those areas of knowledge."
5. ***Difficult:*** "It is not easy to use."

TESTER 4:

1. ***Useful***: "It provides important information to be used for professionals, students, researchers, teachers, as well as general audience interested in such topics."
2. ***Exiting***: "This is an application, which makes you feel good while using it; mainly because of it's contents, links and maps."
3. ***Organized***: "The information is well organized. User cannot get lost when navigating through it."
4. ***Efficient***: "User can make an efficient use of the application to get usable information."
5. ***Credible***: "Information providers seem to be trustful. Databases are reliable and credible."

TESTER 5:

1. ***Complex:*** "There is too much information and databases are too big. The way it is organized makes not easy to find what someone is looking for."
2. ***Professional:*** "It was created and it is maintained by professionals and experts, thus it can also be used in the professional field."
3. ***Interesting:*** "It is a very particular manner to combine multisource information and make it available to worldwide users."
4. ***Difficult:*** "It is not easy to start using it, one needs some time to be confident while using it."
5. ***New:*** "Similar to the interesting comment. It is a very new manner to share and disseminate valuable information to a broad public."

TESTER 6:

1. ***Slow***: "It takes too much time for processing any request."
2. ***Credible***: "Site databases providers are credible and reliable."
3. ***Usable***: "It contains an enormous database that can be usable worldwide in projects related to the application topic."
4. ***Creative***: "It refers to the way the information is compiled and presented. It is a very interesting and new manner of summarizing information."
5. ***Attractive***: "The interface is attractive; the content is also reliable and complete; thus making the site attractive."

4.2.2. ANALYSIS OF RESULTS OF TESTING THE OBIS SEAMAP APPLICATION

4.2.2.1. ANALYSIS OF THE RESULTS OF PERFORMANCE TESTING – OBIS SEAMAP APPLICATION

Obtained results are summarized in Table 4.4. In general testers spent no more than 40 minutes performing the assigned tasks. It was observed that independently on the obtained result, testers did not spend too much time on accomplishing tasks.

Table 4.4. Overall Performance Test Results – OBIS SEAMAP Application

Tester	Overall Time Min.	Percentage of Accomplishment	Percentage of Confidence about the result	Use of external sources	Use of Help
1	30	57	14	14	0
2	15	86	71	14	14
3	31	100	71	14	43
4	9	100	100	0	0
5	38	86	43	14	43
6	16	100	86	0	0

After analysing the recorded test sessions, testers leaved the tasks after no more than 10 minutes trying to solve the assigned task, independently whether they accomplished it or not. This can be clearly observed by the percentage of accomplishment; only half of the testers accomplished the totality of the assigned tasks (an exception is Tester 4, maybe because she is a cartographer with huge experience when dealing with these types of applications). Similarly, the majority of the participants did not show to be completely confident about their achieved results.

Regarding the use of help resources, it seems that participants are not used to look for help in other sources of information. This was particularly evident when analysing the video recordings; in general, test persons prefer searching and exploring the site, than try finding information from external sources or via the application's Help option.

4.2.2.2. QUESTIONNAIRES RESULTS ANALYSIS – OBIS SEAMAP APPLICATION

As it was mentioned in section 3.2 regarding the metrics and techniques for measuring the usability aspects (see Table 3.2.), questionnaires were designed and used for measuring satisfaction aspects related to visual appearance (tools), ease-of-use, perception of outcomes and perception of interaction; the last two supported also by the thinking aloud technique. Summarizing these results it can be concluded that Application 1 (OBIS SEAMAP) needs to be improved in the following satisfaction aspects (Table 4.5):

Table 4.5. Usability Elements Requiring Improvement - OBIS SEAMAP Application

Needs of Improvement	Satisfaction Metric
I can not recover from mistakes quickly and easily	Perception of interaction
Organization of the screen is not clear	Visual appearance (tools)
It would not save me time when I use it	Ease-of-use
It would not help me be more productive	Perception of outcomes
Help information (online help, screen messages, etc.) is not useful/clear	Ease-of-use
It is not easy remember how to use it	Perception of interaction
It is not easy to learn to use it.	Ease-of-use
It is not user friendly	Visual appearance (tools)

4.2.2.3. REACTION ADJECTIVES RESULT ANALYSIS

Analysing the testers' preferences, it is possible to affirm that in general the satisfaction feeling towards the tested application (OBIS SEAMAP), was more positive than negative. This becomes evident while reviewing the selected adjectives.

An interesting observation appears when comparing positive towards negative adjectives. Positive adjectives points out to the application's content, while negative adjectives are focused on interface and interaction aspects.

4.2.3. RESULTS OF TESTING THE EARTH KNOWLEDGE APPLICATION

4.2.3.1. PERFORMANCE TEST – EARTH KNOWLEDGE APPLICATION

1. What type of information can you expect to find in the page?

Tester	Time Min.	Accomplishment	Confidence about the result	Use of other sources	Use of Help
1	1	YES	NOT SURE	NO	NO
2	3	YES	YES	NO	NO
3	8	YES	YES	NO	NO
4	4	YES	YES	NO	NO
5	6	YES	YES	NO	NO
6	3	YES	YES	NO	NO

Testers' thoughts/observations:

- "Based just on the title of the webpage and for some very identifiable things it seems it is an informative site for environmental aspects or issues related to the earth."
- "The application contains too much text on the interface."
- "It seems that the site is about conservation, climate issues."
- "A very good feature of the webpage is that news about any topic is connected to a place in the map. In this way it is easy to identify and visualize "where" something happened."
- "Web content about climate, water, environmental matters."
- "Information related to Earth Sciences."

2. Find the "Map Tool" tab.

Tester	Time Min.	Accomplishment	Confidence about the result	Use of other sources	Use of Help
1	3	YES	YES	NO	YES
2	1	YES	YES	NO	NO
3	2	YES	YES	NO	YES
4	1	YES	YES	NO	NO
5	4	YES	YES	NO	YES
6	2	YES	YES	NO	NO

Testers' thoughts/observations:

- "It is difficult to find "Map Tool" tab."
- "An explicit icon is expected."
- "A very positive aspect is the possibility for searching words or topics inside the site. This option is presented by a specific tool, for searching in the site."
- "Once found it, was realized that the tool was previously there but with a different name."
- "Displaying takes too much time."

3. If you want to view the users of the page around the world, by country for example; do you understand the colour representation used?

Tester	Time Min.	Accomplishment	Confidence about the result	Use of other sources	Use of Help
1	8	NO	NO	NO	YES
2	6	NO	NO	NO	NO
3	12	NO	NO	NO	YES
4	4	NO	NO	NO	YES
5	11	YES	YES	NO	NO
6	9	YES	YES	NO	NO

Testers' thoughts/observations:

- "Usually this information is available in the front page, home page."
- "Map tool seems not having more functions than the standard available on Google Maps tools, not more."
- "The map cannot be displayed."
- "Map tools should have a map list, to facilitate the user in the process of searching or adding information."
- "Too many clicks are required in order to find what the user is looking for. The user at this point, becomes disappointed and starts missing the interest in continuing searching and probably would go backwards."
- "After seven minutes of searching it was realized that the possibilities to adding layers is there, but there is not an explicit layer showing the number of users."
- "Do I need to find a list of countries or users? How to find this?"
- "May be doing a click on the map and then enter. Something happens with the map?"
- "The word "users" refers to users of the forest or web page users?"

4. When you select a topic of interest what kind of information about it do you get? Is this information useful for you? If yes, in which sense?

Tester	Time Min.	Accomplishment	Confidence about the result	Use of other sources	Use of Help
1	3	YES	NO	NO	NO
2	2	YES	YES	NO	NO
3	5	YES	YES	NO	NO
4	9	YES	YES	NO	NO
5	5	YES	YES	NO	NO
6	3	YES	YES	NO	NO

Testers' thoughts/observations:

- "News and articles."
- "Expecting to see the information related to the selected topic only."
- "This is global or general information to be used globally. For continental or country level information is vague, too general."
- "The map is too small."
- "The map as shown here is not useful."
- "It is useful to get just the complete and general overview about current situation at global level."
- "Used symbols are very useful and representative."
- "There are no data providers available for Bolivia."
- "This web page is really practical because latest news about places is connected and one can be well informed by using the webpage."
- "I get the location of the topic of interest."
- "The information may or not be useful depending on the type of information and the needs one has."
- "One can get general information about any topic of interest, and one can use it for research."

5. Are you able to understand the meaning of the used symbols?

Participant	Time Min.	Accomplishment	Confidence about the result	Use of other sources	Use of Help
1	2	YES	NO	NO	NO
2	1	YES	YES	NO	NO
3	3	YES	YES	NO	NO
4	1	YES	YES	NO	NO
5	2	YES	YES	NO	NO
6	1	YES	YES	NO	NO

Testers' thoughts/observations:

- "There are symbols on the map that are not represented on the legend."
- "The legend shows four big topics but on the map appear symbols not presented on the legend."
- "One can easily understand the used symbols."

6. Please find information about the Amazon Basin in South America.

Tester	Time Min.	Accomplishment	Confidence about the result	Use of other sources	Use of Help
1	1	NO	NO	NO	NO
2	3	YES	YES	NO	NO
3	10	YES	YES	NO	NO
4	6	YES	NO	NO	NO
5	7	NO	NO	NO	YES
6	4	YES	YES	NO	NO

Testers' thoughts/observations:

- "Searching the web page by key word. Only got articles and news about the place."
- "Words are not indexed to the region on the map."
- "There is information but is not appearing on the map. It is not connected."
- "They should be next to the articles or news some icon showing the availability of maps or graphs and a link to connect them to the map."
- "Amazing, my institution could be a very good provider of data, we have a huge amount of data from Bolivia, and there must be the way to connect this web page with my institution web page in order to make visible our information in this type of pages."

4.2.3.2. QUESTIONNAIRES RESPONSES – THE EARTH KNOWLEDGE APPLICATION

Table 4.6 contains the test person's responses to the questionnaire. The ID allows the identification of the questions in figures 4.5, 4.6, 4.7 and 4.8 shown below; T1 until T6 identify the testers. Values assigned to each question refer to the following scale: 1="strongly disagree", 4="neither disagree nor agree", 7="strongly agree"; and NA="it does not apply".

Table 4.6. Questionnaires Responses – EARTH KNOWLEDGE Application

		TESTER					
QUESTIONS	ID	P1	P2	P3	P4	P5	P6
Would like to be used for frequent and occasional users	Q1	6	7	7	4	6	5
I am not satisfied with it	Q2	4	1	1	4	2	3
It is simple to use	Q3	5	6	7	4	6	6
It is wonderful	Q4	4	7	6	3	6	4
It is not useful	Q5	3	1	1	4	1	2
I find to many inconsistencies while using it	Q6	3	1	2	7	2	4
It is boring to use it	Q7	6	1	2	3	1	2

It makes everything I expect and I need to do	Q8	3	6	6	NA	7	5
It requires to much steps to accomplish what I want to do with it	Q9	4	2	1	NA	2	3
It is user friendly	Q10	4	6	1	4	6	6
I don't like the user interface	Q11	6	1	4	6	2	5
It would help me be more effective	Q12	5	6	6	4	5	4
It would help me in some work activities	Q13	4	7	7	4	6	5
I do not need it	Q14	6	2	1	4	2	6
I can use it successfully every time	Q15	3	6	6	NA	5	2
It is not flexible	Q16	3	2	1	6	1	4
I learned to use it quickly	Q17	6	7	6	6	6	7
It helps me to do things quickly	Q18	4	7	7	4	6	5
I can not recover from mistakes quickly and easily	Q19	3	NA	4	NA	4	NA
It would help me be more effective	Q20	4	7	5	4	6	4
Organization of the screen is not clear	Q21	3	1	3	2	2	2
Use it requires to much effort	Q22	5	1	1	4	1	3
I can use it without written instructions	Q23	5	6	7	6	7	7
It does not meet my needs	Q24	4	2	1	4	2	5
The interface is grateful	Q25	3	6	4	6	5	4
It works the way I want it to work	Q26	3	7	6	NA	6	4
It helps me to perform my work in an efficient way	Q27	3	7	6	NA	7	1
It would not save me time when I use it	Q28	5	2	1	4	2	6
I easily remember how to use it	Q29	3	7	7	4	6	6
I quickly could become skilful with it	Q30	2	7	7	4	6	7
It is not pleasant to use	Q31	5	1	1	4	2	4
It is complicated to use it	Q32	4	1	1	4	1	2
I would recommend it to a friend	Q33	3	7	7	6	6	3
It would not help me be more productive	Q34	5	2	2	4	2	4
In general, the application satisfied me	Q35	3	7	7	5	7	5
It is easy to learn to use it.	Q36	4	7	7	6	6	6
Help information (online help, screen messages, etc.) is not useful/clear	Q37	5	1	3	1	2	2

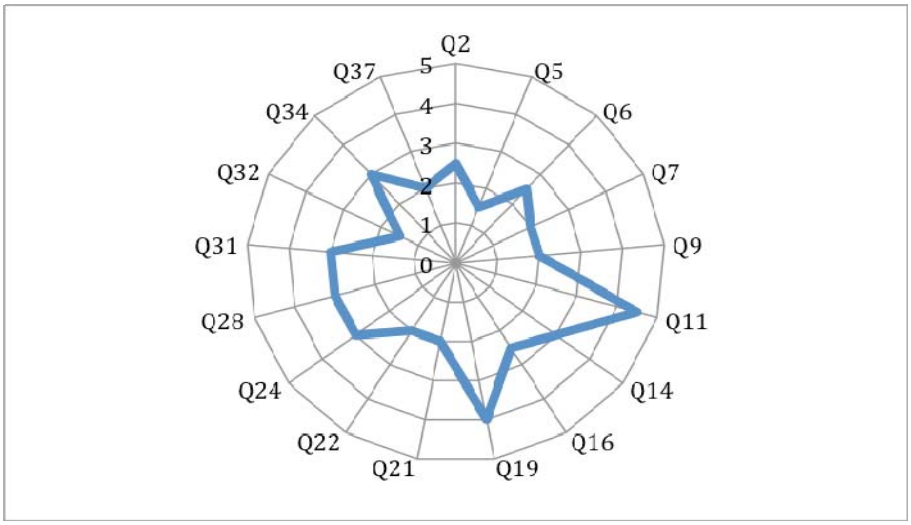


Figure 4.5. Median behaviour obtained from the negative statements. Application 2

In Figure 4.5 above the median of the negative statements is represented. Questions number 11 and 19 were assigned with values of agreement between 4 and 5. It means that testers, in general, do not see significant problems when using the application and their feelings are not as strong as with the first application (see Figure 4.1). Most negative aspects of the application are:

- (Q 11) I don't like the user interface
- (Q19) I cannot recover from mistakes quickly and easily

On the other hand, questions number 32, 5, 37, 22, 21, 9 and 7 were assigned with agreement values between 1 and 2, which means that most of the participants do not agree with the following statements:

- (Q32) It is complicated to use it
- (Q5) It is not useful
- (Q37) Help information (online help, screen messages, etc.) is not useful/clear
- (Q22) Use it requires too much effort
- (Q21) Organization of the screen is not clear
- (Q9) It requires too many steps to accomplish what I want to do with it
- (Q7) It is boring to use it

Translating into positive statements, it could be assumed that, in general, participants consider that the application is not complicated to use, that it is useful and the help information is helpful, that to use the application does not imply too much effort, that the organization of the screen is clear, that it does not require too many steps to accomplish what the user wants to do with it; and that it is not boring to use it.

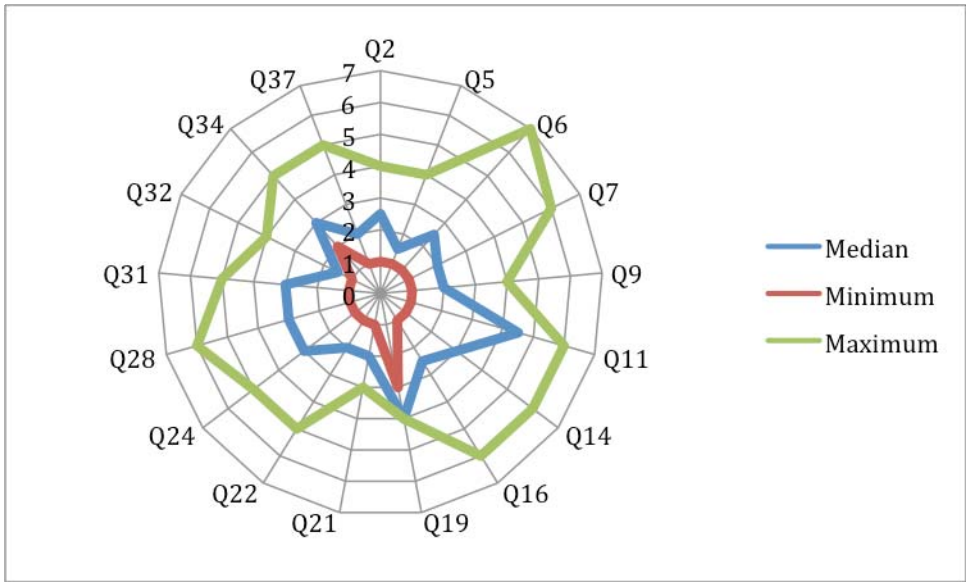


Figure 4.6. Max, Min and Median behaviour obtained from the negative statements - Application 2

Statistics of qualimery for Application 2 are quite interesting, as maximum and minimum values of the results somehow show that the testers paid more diverse reactions to Q1 through Q36. As a result of the tests, Q11, Q19 and Q34 are special characteristics while testing VGs usability on this application.

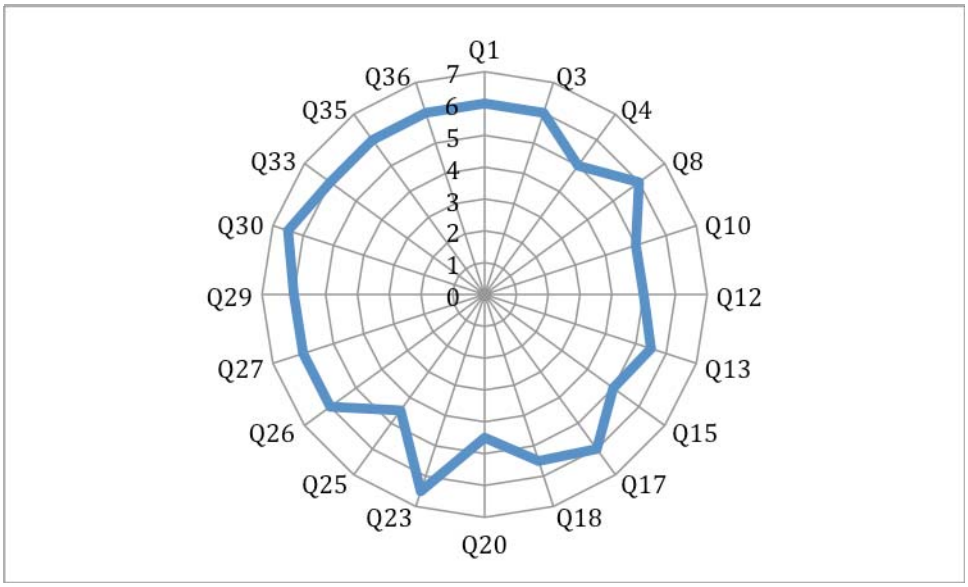


Figure 4.7. Median behaviour obtained from the positive statements – EARTH KNOWLEDGE Application

When analysing the answers given to the positive statements (Figure 4.7.), a major uniformity is found in the testers' responses as compared to those to Application 1 (OBIS SEAMAP) (see Figure 4.3). Almost all positive statements were assigned with high values of agreement (between 6 and 5). Only the statements 25 and 20 received the lowest agreement value (between 4 and 5). Those statements are:

- (Q25) The interface is grateful
- (Q20) It would help me be more effective

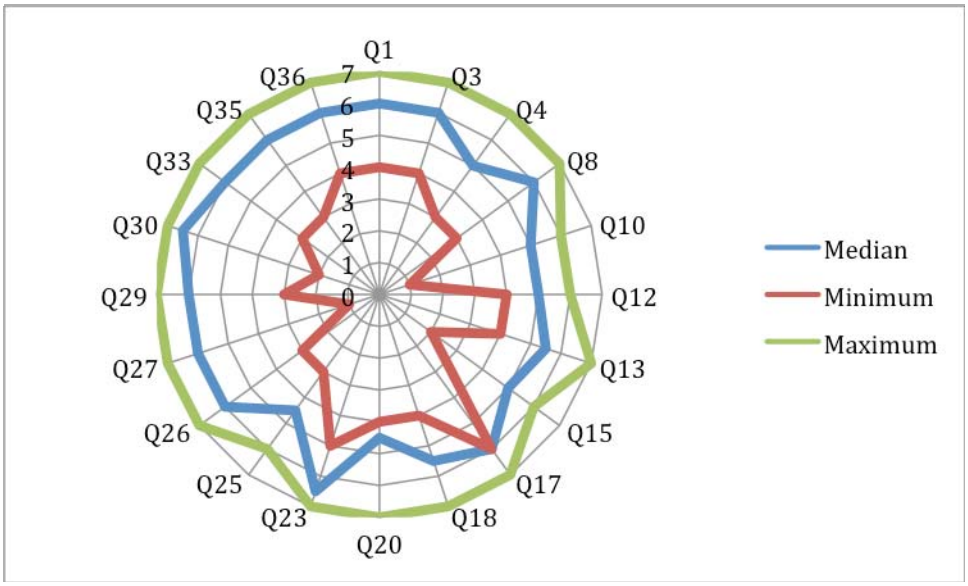


Figure 4.8. Max, Min and Median behaviour obtained from the negative statements - EARTH KNOWLEDGE Application

In figure 4.8. minimum values appear to control the test: Q4, Q12, Q13, Q17, Q23, Q27 and Q10 constitute important indicators to be taken into account while dealing with negative statements,

while the Median and Maximum statistics of the answers follow quite a similar pattern.

4.2.3.3. REACTION ADJECTIVES RESULTS

Table 4.7 contains the selected words (adjectives) containing the testers' feelings regarding the tested application (EARTH KNOWLEDGE).

Table 4.7. Selected Reaction Adjectives – EARTH KNOWLEDGE Application

Adjectives	Testers					
	1	2	3	4	5	6
Relevant	X	X				X
Take advantage	X	X	X	X		
Saturated	X				X	X
Boring	X					
Not processed	X					
Distractive	X					
Vague	X					
Desiderable		X				
Innovator		X		X	X	X
Understandable		X	X		X	X
Distracting		X				
Sophisticated		X				
Organized		X	X		X	
Engaging		X				
Advanced		X				X
Significative		X				
Fast		X				
Trustworthy		X		X	X	
Easy to use		X	X	X		
Flexible		X			X	
Simple		X				X
Exiting		X				
Attractive		X	X		X	
Time-saving		X			X	
Efficient		X				
Controllable		X				
Satisfying		X	X			
New		X	X	X		X
Funny		X				
Cluttered				X		
Usable		X	X	X	X	
Friendly		X			X	
Direct		X				X
Professional		X	X	X		
Interesting		X	X		X	
High Quality		X				
Accessible		X	X			
Convenient		X		X	X	
Creative		X				
Expected		X			X	
Useful		X	X	X	X	X
Credible			X			

From the provided adjectives (105), 42 were selected as those that better represents the tested application. From those 42, the 83% (35 adjectives) were positive ones. From this results can be

concluded that the EARTH KNOWLEDGE application was considered by testers as a good application.

The commonly adjectives selected for at least three testers were:

- Relevant
- Take advantage
- Saturated
- Innovator
- Understandable
- Organised
- Trustworthy
- Easy to use
- Attractive
- New
- Usable
- Professional
- Interesting
- Convenient
- Useful

4.2.3.4. PREFERRED REACTION ADJECTIVES – EARTH KNOWLEDGE Application

As mentioned before (see section 2.3 for an explanation of the Reaction Adjectives Method); from the previously chosen words (adjectives), testers were asked to select five adjectives or words that better describe their feeling towards the tested application. Table 4.8 shows the selected most significant words better describing the tested application.

Table 4.8. Preferred Reaction Adjectives – EARTH KNOWLEDGE Application

Adjectives	Testers					
	1	2	3	4	5	6
Positive Adjectives						
Take advantage				X		
Understandable			X		X	
Organized			X			
Advanced		X				X
Flexible		X				
Satisfying			X			
Usable		X		X		
Direct		X				
Interesting			X			
Expected		X			X	
Useful	X		X	X	X	X
Professional				X		
Trustworthy					X	
Relevant						X
Innovator						X
Negative adjectives						
Saturated	X				X	X
Not processed	X					
Distractive	X					
Vague	X					
Cluttered				X		

Meaning explanation of the selected words is given following:

TESTER 1:

1. ***Useful***: "Data are from trustful sources. It has much value."
2. ***Saturated***: "Too much text, too many titles of articles. Same menu needs to have less text."
3. ***Not processed***: "Some intermediate step is required in order to filter, or to simplify the accessibility to the data, some indexing for connecting the information to the map. Is too automated."
4. ***Distractive***: "Too much text, same colours and tones, is not possible to concentrate in one aspect. Too many things to pay attention to, distracting the attention, missing the focus."
5. ***Vague***: "It takes some time to understand the message of the site. The orientation of the site is not very clear. Why somebody should need that amount and type of information. Too much information and not pretty sure for what."

TESTER 2:

1. ***Advanced***: "It is advanced because shows me too many things that I had no idea they existed. It fulfils my expectation. I found things I was not looking for."
2. ***Flexible***: "It can be adapted to a wide variety of necessities, I can use it in many ways for many things."
3. ***Usable***: "Almost same as flexible, can be used for many things."
4. ***Direct***: "The access to information is straightforward; you can enter and find immediately what you are looking for."
5. ***Expected***: "I was waiting for something like this, because there are many necessities I have on my job and a tool like this can help me a lot."

TESTER 3:

1. ***Understandable***: "The application content and the structure are easy to understand. It is easy to move around the site and find information."
2. ***Organized***: "As mentioned above, it is well organized and structured."
3. ***Satisfying***: "The available information is valuable, can be used in different ways and also the way it is presented on the map is appealing."
4. ***Interesting***: "The way that site presents the information is interesting, not many sites present information in that way."
5. ***Useful***: "As mentioned previously the content of the site is valuable and useful because one can have up-to-date information from worldwide just accessing the site."

TESTER 4:

1. ***Cluttered***: In general contains too much information in only one page."
2. ***Usable***: "It includes information about datasets, includes metadata, which is fundamental when working with this type of datasets."
3. ***Take advantage***: "This is an application that can be very useful, mainly because the content of the information."
4. ***Professional:*** "It can be used in professional works. Information is valuable and reliable."
5. ***Useful:*** "It is practical, can be used for scientific and educational communities as well as for general public."

TESTER 5:

1. ***Understandable***: "It is easy to understand the content of the information."
2. ***Expected***: "Sites like this are expected because they summarize worldwide information in one place."

3. ***Useful***: "As it was mentioned above, worldwide information contained in one website is time saving and allows the user to get a complete overview about what is happening worldwide."
4. ***Trustworthy***: "Datasets and information are reliable and trustful. User can feel confident about the content."
5. ***Saturated***: "The interface contains too much text, which causes the user to be confused and sometimes distracted too."

TESTER 6:

1. ***Advanced***: "It seems that it is not a very simple application. It is connected with some many sources of information."
2. ***Useful***: "Can be used at work."
3. ***Relevant***: "The content is very important because we can be updated with the latest news about any place in the world concerning environmental issues."
4. ***Innovator***: "It is the first time I see a Website like this."
5. ***Saturated***: "It contains too many things on the window interface. It looks crowded."

As observed in application 1, positive adjectives are related to the application's content and negative adjectives point out interface weaknesses.

4.2.4. ANALYSIS OF RESULTS OF TESTING THE EARTH KNOWLEDGE APPLICATION

4.2.4.1. ANALYSIS OF THE RESULTS OF PERFORMANCE TESTING – EARTH KNOWLEDGE APPLICATION

Similarly as with the obtained results when testing application 1 (OBIS SEAMAP); while testing the Earth of Knowledge application, it was observed that testers spent no more than 40 minutes performing the assigned tasks (Table 4.9). It was observed that independently of the obtained result, test users did not spend too much time on accomplishing tasks.

Table 4.9. Overall Performance Test Results – EARTH KNOWLEDGE Application

Tester	Overall Time Min.	Percentage of Accomplishment	Percentage of Confidence about the result	Use of external sources	Use of Help
1	18	67	17	0	33
2	16	83	83	0	0
3	40	83	83	0	33
4	25	83	67	0	17
5	35	83	83	0	33
6	22	100	100	0	0

Concerning the percentage of tasks accomplishment, in this case, the majority of the testers were unable to perform correctly the total of the assigned tasks (excepting Tester 6 who performed at 100% maybe because he has strong computing skills on web-based applications due to the fact he uses both on his daily work). Similarly, the majority of the participants were not confident about their achieved results.

Regarding the use of Help resources, while testing The Earth of Knowledge application, testers did no require to search for help on external sources. The general tendency of the testers was to use the Help option provided by the application.

4.2.4.2. ANALYSIS OF QUESTIONNAIRES RESULTS – EARTH KNOWLEDGE APPLICATION

This application has only two aspects related to Satisfaction aspects that need further improvement. The first one belongs to the visual appearance metrics (I don't like the user interface) and the second one belongs to the perception of interaction (I cannot recover from mistakes quickly and easily) as shown in Table 4.10.

Table 4.10. Usability Elements Requiring Improvement - EARTH KNOWLEDGE Application

Needs of Improvement	Satisfaction Metric
I don't like the user interface	Visual appearance (tools)
I can not recover from mistakes quickly and easily	Perception of interaction

4.2.4.3. ANALYSIS OF REACTION ADJECTIVES RESULTS – EARTH KNOWLEDGE APPLICATION

Analysing the tester's preferences, it is possible to affirm that in general the satisfaction feeling towards the tested application was positive rather than negative. This becomes evident while reviewing the preferred selected adjectives. The majority of the testers agree on finding this application useful. The main drawback of this application is that the interface is too saturated.

4.2.5. RESULTS OF NON FUNCTIONAL REQUIREMENT ANALYSIS – GUIDED INTERVIEWS (PART 2)

The following sections present the results from testing the VGs based applications for statistical data dissemination.

4.2.5.1. LONDON PROFILER – TESTERS' RESPONSES[74]

Question 1: Display the census output area classifications. Do you understand the meaning of the display options?. Do you understand what the polygons are?. The application does no give any explanation about the map content. This question was intended for trying to discover it and was oriented to identify those types of common drawbacks on VGs based applications.

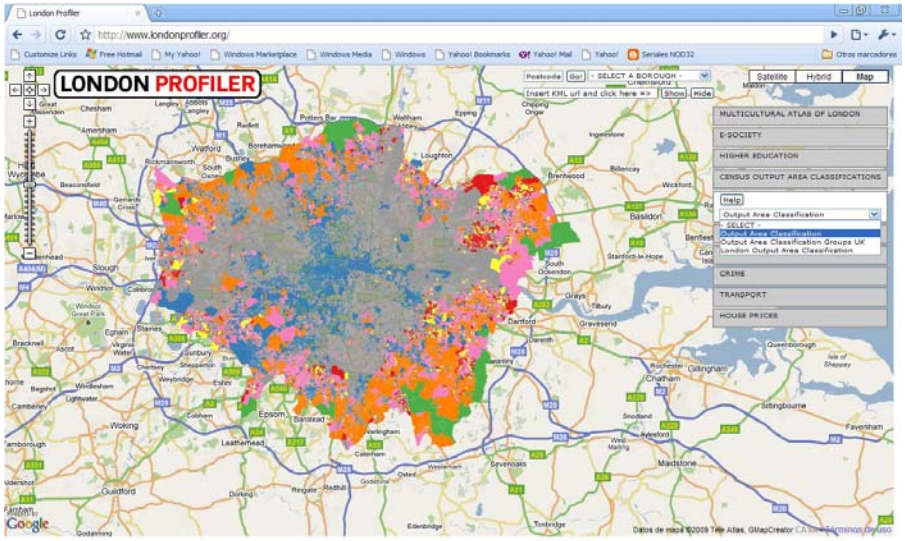


Figure 4.9. London Profiler - Census output area classification

[74] London Profiler Application <http://www.londonprofiler.org/.> Retrieved on January, 2010

Testers' Answers:

- They do not understand what the meaning of "output area classifications" is (see Figure 4.9).
- They do not know what the polygons are about.
- When displaying the polygons and when analyzing the legend of the map, it seems the information belongs to a map showing the income classified by socioeconomic classes.
- Some testers knew already some of the terms presented in the legend, but there are other terms that are unknown for them.
- The legend contains too technical terms which are not useful for ordinary users.

Question 2. Select the option "output area classification groups UK"

Testers' Answers:

- In this case testers were not able to interpret or understand the legend mainly because the presence of legend's codes.
- There are too many similar colours in the legend which cannot be distinguished in the map.
- Tests persons agree that the codes must be appearing on the map when the mouse is passing over the map, in order to identify them easily.

Question 3. Analyze the displayed map. Do you understand the shown classes?

Testers' Answers:

- There are too many colours.
- There is no idea about the meaning of the codes.
- It is possible to differentiate only very contrasting colours, but there are a lot that are very similar and it is difficult to know which one belongs to the legend.
- Would be very useful, if when moving the mouse over the map the values of the polygons are displayed. In that way one can be sure about the meaning of the colours.
- Participants are not familiar with the classification system.
- Can it be understood from the legend that under each census output area there is sub-classification.

Question 4. Are you able to identify the different classes on the map? Can you get an idea about the surface area of a certain class or the percentage of the class compared with the other classes?.

Testers' Answers:

- They can be classified by income classes for census units.
- Some possibilities for analysing the data must be available.

Question 5. Go to the option "Index of Multiple Deprivation". Select the "Income parameter". Do you understand the meaning of the colour scheme names? Values? (see Figure 4.10)

Testers' Answers:

- The legend says something more than the previous one.
- It seems that the map is showing the different areas according to the income types
- It is possible to identify where poor people live.
- The page is too slow; it takes too much time to reload it.

- The warmer the colour, the most deprived the areas.
- Values using deciles, distribution representing 1/10 of the population
-

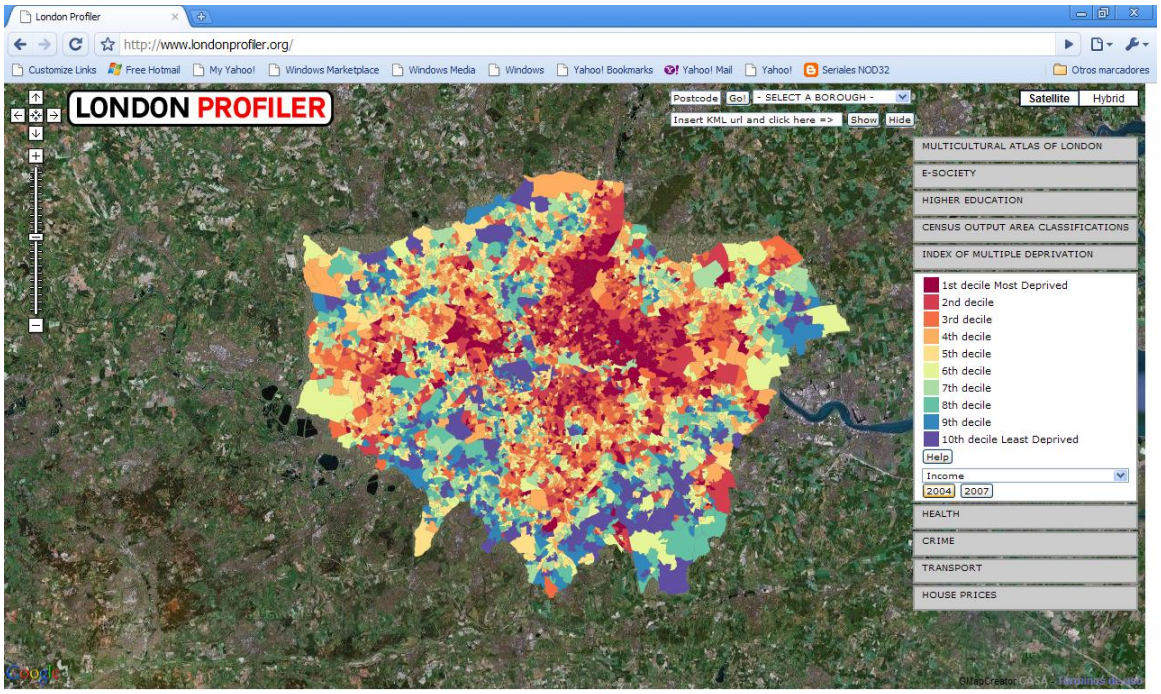


Figure 4.10. London Profiler - Index of Multiple Deprivation: Income parameter (2004)

Question 6. Display the data for 2004 and then for 2007. Can you see the differences between the two maps?.

Testers' Answers:

- Colours on the legend and the map are difficult to differentiate.
- There is no information available related to the mapping units. There is no manner to associate them to the colours.
- There is no possibility to identify differences between two years. It is not possible to compare both years.
- Would be nice to have the possibilities to see both maps next each other, or accelerating the display, can be in a PDF format.
- The ideal will be the possibilities to show the changes in a different colour as a third map.

Question 7. What do you consider is needed in order to get more useful information from the previous maps?

Testers' Answers:

- Users would like to see the difference by colours, not using values.
- Overlaying the two maps can be a good option.
- One layer can be transparent or semitransparent with possibilities for graduating the transparency.
- Will be good to have an identifying tool with pop-up information about the total population in that area.

Question 8. Analyze the different ways of representing the "transport data". Do you understand those types of representations? (see Figure 4.11). The application does no give any explanation

about the meaning of “DATA PTAL”. This type of “too-technical” language was commonly found on several VGs based applications, and this question (Question 8) was oriented to identify those types of drawbacks.

Testers’ Answers:

- Users understand the way of representing this information because they already knew about this, but it does not mean that the way it is presented is completely understandable for everybody.
- Users have no idea about what PTAL maps are about.
- Participants are not able to understand what the map is representing. It can be noise, traffic congestion, etc.
- In general, users are not familiar with transportation planning, apparently the map shows a classification of the transportation types. seems that is a way to classify transportation access.
- It is clear that it is divided in zones and it will be more useful if the meaning of each range would be shown somehow.

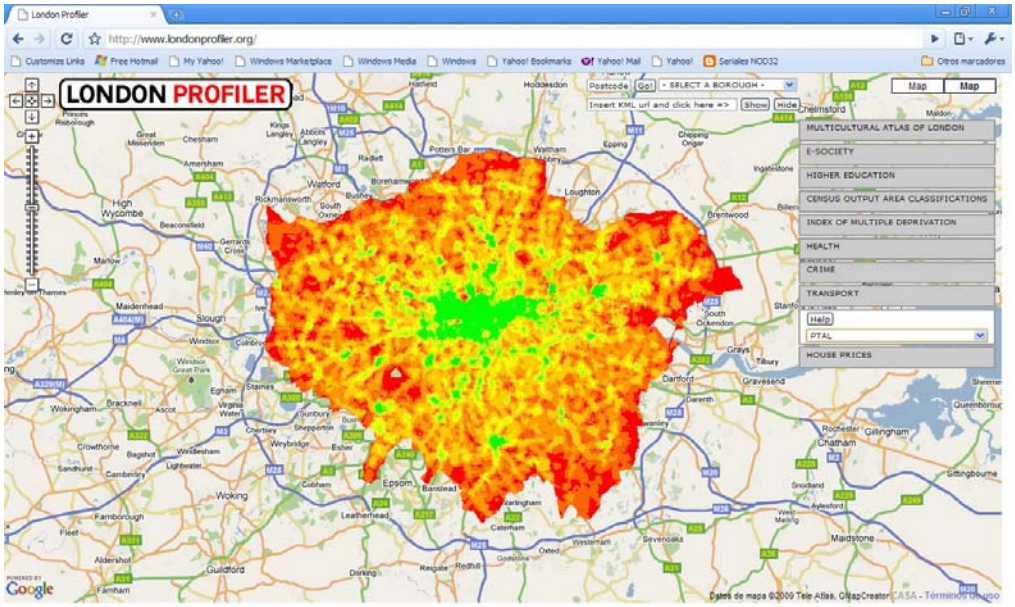


Figure 4.11. London Profiler – Transport Data - PTAL

Question 9. Analyze the “house prices” option. Can you select some postcode district? Does the page give you the opportunity to solve the problem? Try pressing the Help button. Are you able to find the postcodes information on the rendered page? (see Figure 4.12).

Testers’ Answers:

- Postcodes are needed.
- Going to help for postcodes searching derives to other link and the page is not very useful, is too general.
- It does not provide a list with postcodes. You have to spend some time looking for London postcodes.
- A map is needed with more accessible codes. Once the code is found, the resulting point map is very useful and well presented.
- It is important to read the links provided in the help window in order to get familiar with the application.

- Users can also find the postal code trough the royal mail website; however this service is not provided during Sundays and bank holidays.

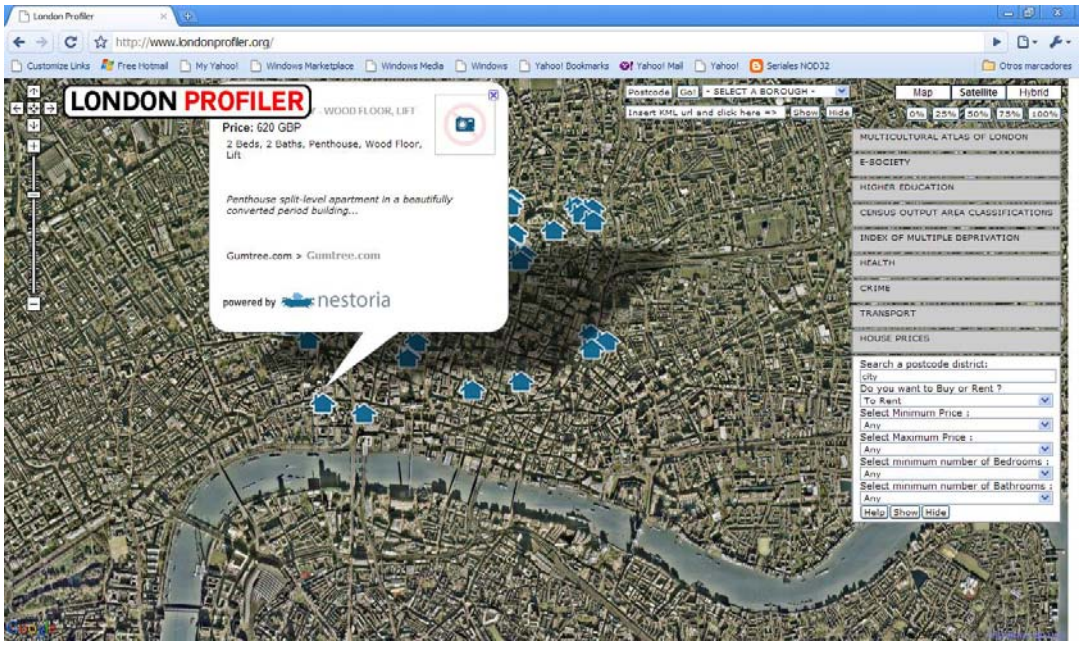


Figure 4.12. London Profiler – House Prices

4.2.5.2. THEMATIC MAPPING WEBSITE – TESTERS' RESPONSES

QUESTION 1. Access the following URL (see Figure 4.13) and answer the following questions: http://blog.thematicmapping.org/2008/04/making-proportional-symbols-in-kml.html.

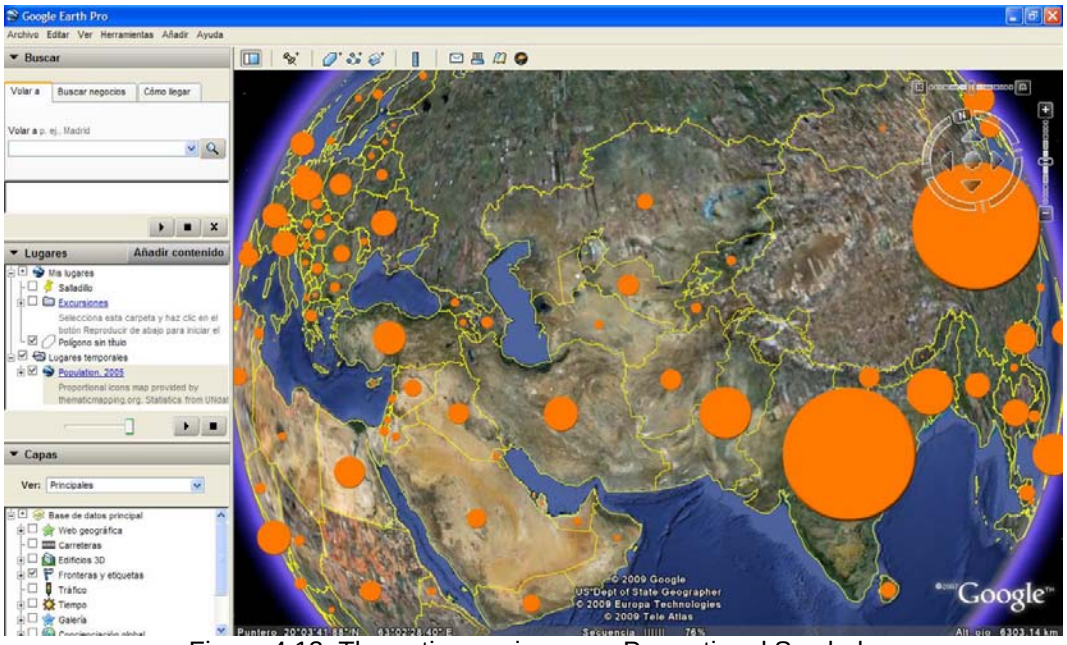


Figure 4.13. Thematicmapping.com. Proportional Symbols

- Analyze the usability and usefulness of this type of maps.
- What is missing?

- What else should they have?
- How useful is?
- Would you use them in your work?

Testers' Answers:

- Representation of population: the representation of circles on 2D for representing the size population.
- A legend is needed, may be some more 3D in bars.
- Legend is imprescindible in order to have the idea about the values. Also some colours associated with the range values of the legend are needed.
- The legend is missing
- Used symbols give an idea about the country's population
- This type of applications can be useful for education purposes.

- **QUESTION 2**. Access the following URL (see Figure 4.14) and give your impression about the legend: http://blog.thematicmapping.org/2008/06/proportional-symbols-in-three.html.

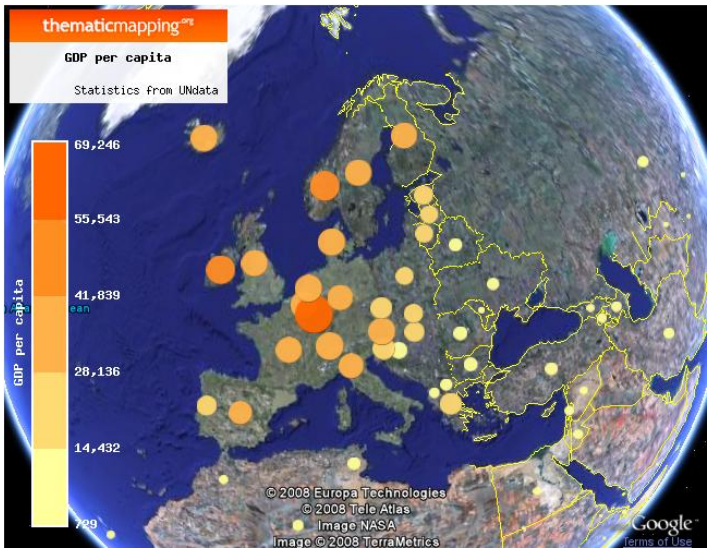


Figure 4.14. Thematicmapping.com. Proportional Symbols with Legend

Testers' Answers:

- The 3D representation is better for visual aspects. The legend uses colours what is very useful. There is a better idea about the values and grouped by ranges, by colours.
- This map has a legend facilitating the data interpretation.

QUESTION 3. Access the following URL (see Figure 4.15) and answer the following questions: http://blog.thematicmapping.org/2008/04/using-google-charts-with-kml.html.

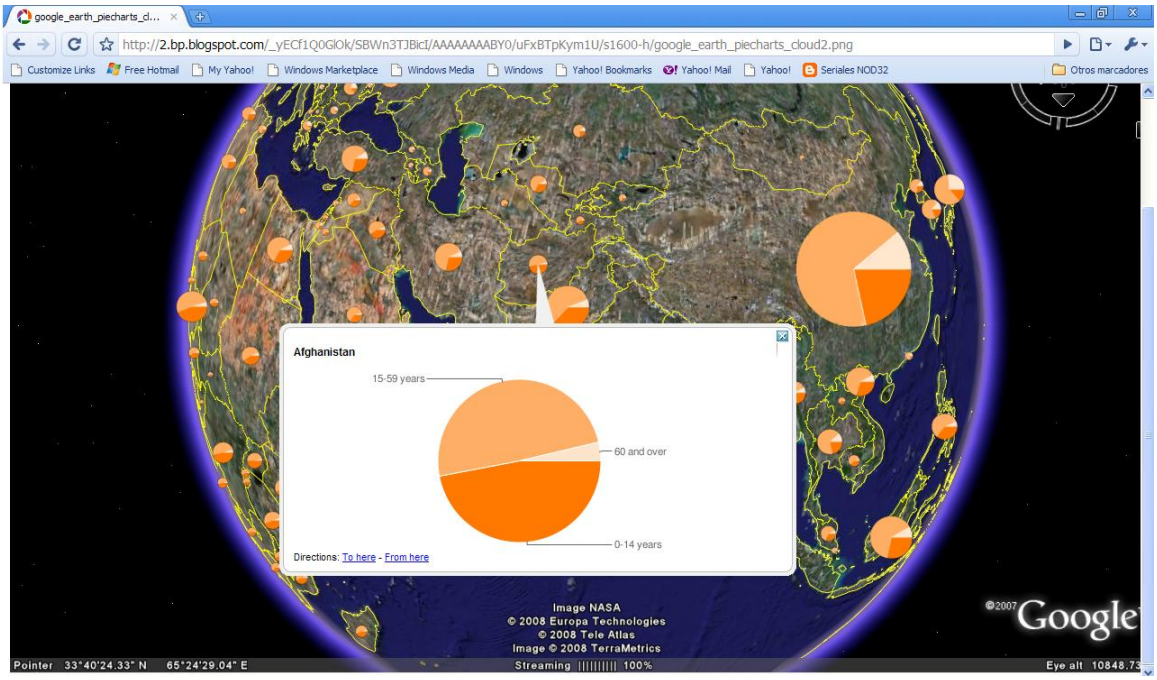


Figure 4.15. Thematicmapping.com. Pie Charts

- Analyze the different ways of presenting information.
- Which one do you think is better, more understandable and useful?
- Which is the best for you?
- Why?

Testers' Answers:

- Pie charts: legend is missing, but some values are still missing.
- It is not possible to understand what is compared there.
- Usefulness depends on the type of data participants will use it with.
- It is important to consider the type of audience or the final users, and analyse the type of data use type.
- The usability depends on the purpose of the data, the final use to be given to them.
- For a very preliminary idea about the situation of certain information, this graphic representation is very useful, giving immediately the idea about the data. If I require a more deep and rigorous and serious analysis of the data that type of information is not very useful because it does not have the precision required.
- This type of representation is more visual, for some public presentation of very general information. More used for informative purposes, than for real and serious analysis.
- Some users prefer to see the representation as colour gradient and not with graduated symbol points. When using representations as symbol pie, values on the slices are required.

4.2.5.3. INE WEBSITE – QUESTIONS RESPONSES

Access the following URL: http://www.ine.gov.bo/geoclip/launchmap.php and answer the following questions (see Figure 4.16):

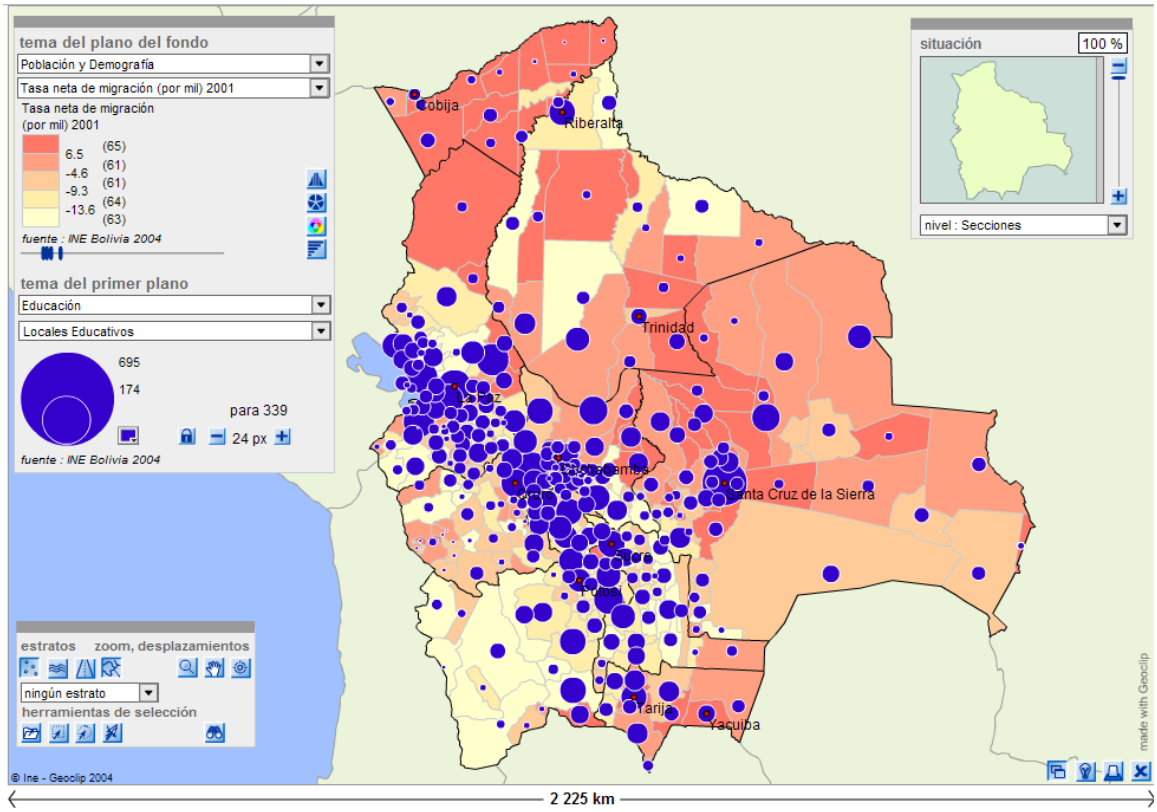


Figure 4.16. Displayed map in INE Website

- Search information about the Census 2001. Select “Population” as example.
- Analyze the existing maps on the page.
- Analyze the representation of the information and the used cartographic style.
- Please mention the positive and the negative aspects of the available maps (like representation type, information content, interactivity, etc.).
- How do you think they should be?
- Is it possible to improve it?
- Is it needed to improve them?
- What is missing?
- What is needed?
- Would you like to see the same type of information running over a Google Earth interface?
- Do you think this would give more usefulness?
- Do you think this is needed?
- In which cases would you use it?

Testers’ Answers:

- This type of data representation is very attractive, but it not substitutes the information contained on a table. Would be useful to have available both the map and the table.

- These types of representations are very useful for students, for people that want to know or see basic and very superficial and quick information. For more deep and serious analysis this type of information is not very useful, not needed.
- GE offers possibilities to see the details of the terrain, like roads, buildings, etc, but INE does not have that level of detailed information, so is not very necessary.
- In general, test persons agree that the possibility of combining GE and INE data into a single interface, is very interesting only for visualization purposes, but not for deeper analysis, because of the used scale.
- In general, participants prefer to use tables and graphics; in that way they can easily and faster export the data needed.
- INE web page in general is very interactive.
- It contains supportive information.
- It is easy to use.
- The interface is pretty good.
- In general terms this website offers very useful tools for user interactivity.
- The way the information is presented currently is useful. Users do not see the necessity to improve it and are less combining it with GE.
- GE only would be used for illustrative purposes and not for analysis.

4.3. FEATURES OR CHARACTERISTICS TO BE IMPROVED IN VGs BASED APPLICATIONS

The results allowing identifying the features or characteristics which need to be improved in VGs based applications. Some of these features need to be improved in all VGs based applications. On the other hand some other features needing improving are specifically related to applications oriented to statistical data dissemination. Both groups of features are listed in the following sections:

4.3.1. FEATURES OR CHARACTERISTICS TO BE IMPROVED IN ALL VGs BASED APPLICATIONS

The research results revealed the principal aspects that need improvement on VGs based applications, in the short time; those are specially and mainly related to their user interfaces and to their functionality.

The following aspects were identified as those needing improvements:

1. To support various data formats, vector and raster data.
2. To improve the capabilities for spatial analysis, and simulation. To add tools for performing analytic procedures, like modelling and simulation of processes (i.e. land use changes, flooding risks, urban growth, migration, etc). This could be useful for supporting the decision making process. Improving the display of dynamic processes, it is also needed to meet this objective.
3. To give the users the possibility of avoiding the use of traditional GIS' for processing their data. This means, to give possibilities to the user to create the tools he/she needs, just by "clicking" a specific button.
4. The development of more user-friendly tools (in order to eliminate any type of "code writing" by the user). It means, to eliminate the current required advanced computer programming skills for performing advanced spatial analyses.
5. To improve the symbology for displaying imported data, allowing the user to maintain the quality of their maps (symbology, colours, legend features, etc).
6. Include the possibilities for topological overlay allowing to perform typical GIS analysis, like logical or arithmetic operations for layer combinations
7. Include functionalities for analyzing a specific "object" at different times (currency). The user would be able to perform monitoring analyses of any kind of events.

8. In order to assure the quality of the data and information, implement the use of metadata as a requirement, when performing import/export operations.
9. Some important advances have already been made on Virtual Reality (see e.g. 360Cities.net in Section 2.5.1.3). Make available this type of visualization for every place around the world. In addition, allow the interaction of this type of representations with the already mentioned analysis tools. This can be really a huge difference when compared with the current use of VGs that c certainly would be fully exploited in professional and scientific fields. A person can interact better in an environment that looks natural for him/her.
10. Improve interactivity processes. Letting users to be on full control over their data and the way they want to use them surely would be a crucial advance. Even that currently some interactivity is available in many VGs applications, users still cannot easily add their own data on them.
11. To increase the possibilities for combination of information. A single interface must provide opportunities for linking with other sources of information. The data combination process needs to be improved. Advances on integration process with any database and scripting language like ASP, ASP.NET, PHP, JSP, ColdFusion etc. using a single clickeable tool. This means to improve the interoperability across the various information technology platforms.
12. Improve the uniformity in the spatial resolution of the images, because currently not all the places over the earth surface count with high-quality image resolution.

4.3.2. FEATURES OR CHARACTERISTICS TO BE TAKEN INTO ACCOUNT IN THE CONCEPTUAL DESIGN

The reviewed examples of existing VGs based applications for statistical data dissemination and the results from the testing process carried out during the research; revealed the following usability aspects needing improvement, which must be taken into account when developing the conceptual design of an improved application.
The following aspects need to be improved:

1. The colour representation of the maps, avoiding the use of too similar ones for facilitating visualization aspects.
2. Terms used on the legend must reflect the exact meaning of the information, in such a way that can be understood even by users not familiar with the topic.
3. It was observed that when legend presents data expressed in values, usually the units of the classes are missing.
4. Would be helpful to let the legend appear over the map when the mouse is passing over it, through pop-ups, in that way map classes can be easily distinguished.
5. Some pages take too much time for displaying the selected map, causing the user to loose the interest on the information
6. Some applications present thematic maps over GE interface, but usually the legend is not available on the display. The research revealed that even maps are very appealing for the user a descriptive map legend is required.
7. Testers prefer the use of symbols in 3D, because they support the visualization of the information
8. Regarding the usability of displaying thematic maps over a VG interface, testers agree that it depends on the purpose of the use. This type of representation is more visual, oriented to public presentation or for getting very general information. More used for informative purposes, than for real and formal analysis.
9. Testers indicate that even map representations are appealing; they would still require the raw data contained in tables in order to extract information for deeper analysis. They consider the use of maps just for a general overview of the information and not for thoughtful analysis.

10. Regarding the INE Website and the way of thematic information is presented and displayed; testers agree that INE interface is very interactive, it is easy to use it, and contains supportive information, however testers still prefer the use of tables and graphics. Testers agree that accessing that type of information facilitates its use.
11. In general, testers agree that the possibility of combining GE and INE data into a single interface would be very interesting for visualization purposes, but not too much useful for thoughtful analyses, because of the scale of the available INE's data. Testers do not see any other advantage of combining both applications; probably because they are not aware of the potential functionalities the VGs offer.

4.4. CHAPTER CONCLUSIONS

Current usability for two virtual globes based applications: OBIS SEAMAP and EARTH KNOWLEDGE, was evaluated to identify usability drawbacks. Three usability aspects were tested: efficiency, effectiveness and satisfaction:

In relation to the performance testing, the analysis of the recorded test sessions showed that, after some time, testers get bored abandoning the task independently whether it was accomplished or not. Only half of the testers accomplished the totality of the assigned tasks. Similarly, the majority of the testers did not feel to be completely confident about their achievements. This result suggests that VGs based applications should be improved trying to make them more intuitive and straightforward to use.

Regarding the second usability method, the use questionnaires, results showed that major usability problems are related with three satisfaction aspects: Perception of interaction, Visual appearance (tools) and Ease-of-use. It can be concluded that this three aspects should be carefully managed while improving VGs based applications. Responses to questionnaires pointed out that both tested applications need maturity on interface aspects rather than in their application's content. User interactions, visual appearance and ease of use, appear to be usability factors demanding considerable development. This conclusion is supported by the results reach with the reaction adjectives technique, which revealed that the applications' contents do not show usability problems, compared with the interface and user interaction aspects.

The thinking aloud technique demonstrate to be very useful for supporting the performance testing, questionnaires and the adjective reaction cards results facilitating the analysis of the information. Recorded sessions allowed analysing detailed aspects of the testers' behaviour, their emotions and difficulties while performing the assigned tasks; thus helping the researcher to identify areas of improvement.

Qualimetry has proved to be very useful for applying statistics to qualitative data. It can be worked out with simple spreadsheets rendering explicit and very simple to communicate graphic results.

Currently VGs users are not fully aware and do not use the potential capabilities of the VGs tools mainly because: 1) VGs are still not easy to use for advanced analysis forcing the user to gain certain level of expertise in programming languages, leaving these tools still reserved for a reduced group of users, because the required skills are beyond the knowledge of the everyday VG user; 2) VGs users are not fully aware of all the potential these tools have. They do not consider usable statistical information running over a VG interface; they are used to work just with tables and graphics and then export that information to their traditional GIS. It seems there is some fear for changing the way they are used to work. This can be easily understood because until now VGs are more oriented to visualization purposes than to data analysis. VGs still do not support easily and fast traditional GIS capabilities and this aspect needs for sure to be improved in the short time.

Testing results revealed the usability aspects requiring further development for VGs applications in general and also for those applications oriented specifically to statistical data dissemination purposes. These findings become the guidelines when designing the conceptualisation of an improved VG application for statistical data dissemination, fully described presented in the following chapter.

CHAPTER V

CONCEPTUAL DESIGN OF AN IMPROVED VIRTUAL GLOBE BASED APPLICATION FOR STATISTICAL DATA DISSEMINATION

5.1. INTRODUCTION

Until now the thesis research was focused on analysing current usability of VGs based applications in order to discover what their main drawbacks are, and how to deal with them.

In Chapter IV the main aspects of current usability problems are described and highlighted. Those usability problems are the base for formulating and for developing a conceptual design of an improved VG based application for statistical data dissemination in Bolivia.

This Chapter present an overview of the current state of the Bolivia National Statistical Office (INE), as being it selected as the application to be improved and to be used for the conceptual design of an improved VG based application.

The last part of the Chapter outlines the conceptualised improved VG based application, their components and the way they should be inter-related.

5.2. OVERVIEW OF THE INE WEBSITE

This aim of the thesis research was to highlight the real possibilities of finding innovative formal applications for VGs as useful tools, to be used in professional and academic scientific work, especially where availability and software costs become a limiting factor (i.e. in developing countries like Bolivia. The Bolivian National Statistical Office (INE) Website was selected as a representative application to be improved by adding VGs functionalities, because it shows outstanding features in thematic mapping, but it is lacking of the advantages of VGs usability qualities. On the other hand, being a Bolivian National reference widely used for getting statistical information, its improvement in aspects related to statistical data dissemination would facilitate and give a support a wide variety of professional and scientific future endeavours.

The current INE Website (http://www.ine.gov.bo/) interface is shown in Figure 5.1. The upper left part of the page contains the displayable menus of both National as well as International statistical data (remarked with a green box in Figure 5.1). The statistical data is organized in tables, which can be exported to Excel. The lower left, marked as yellow box, presents links to related or interesting sites.

The centre of the page is designed to show up-to-date statistical indicators, which are shown as percentage by monthly or yearly depending on the indicator type (they can vary according the type of indicator). The user can select the indicator type he is interested in. The lower centre section contains up-to-dated relevant and latest news or announcements about courses, publications and presentations concerning INE issues.

The right part of the INE's main page contains the Feeds, invitations, other indicators, bulletins and the available downloadable documentation.

Figure 5.1. INE Website-Main page

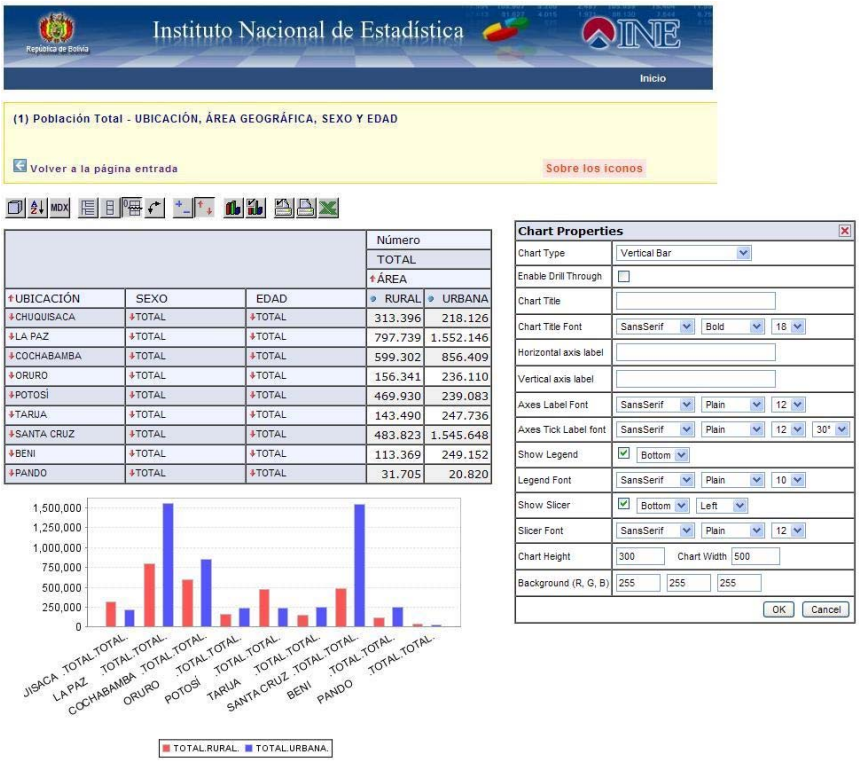
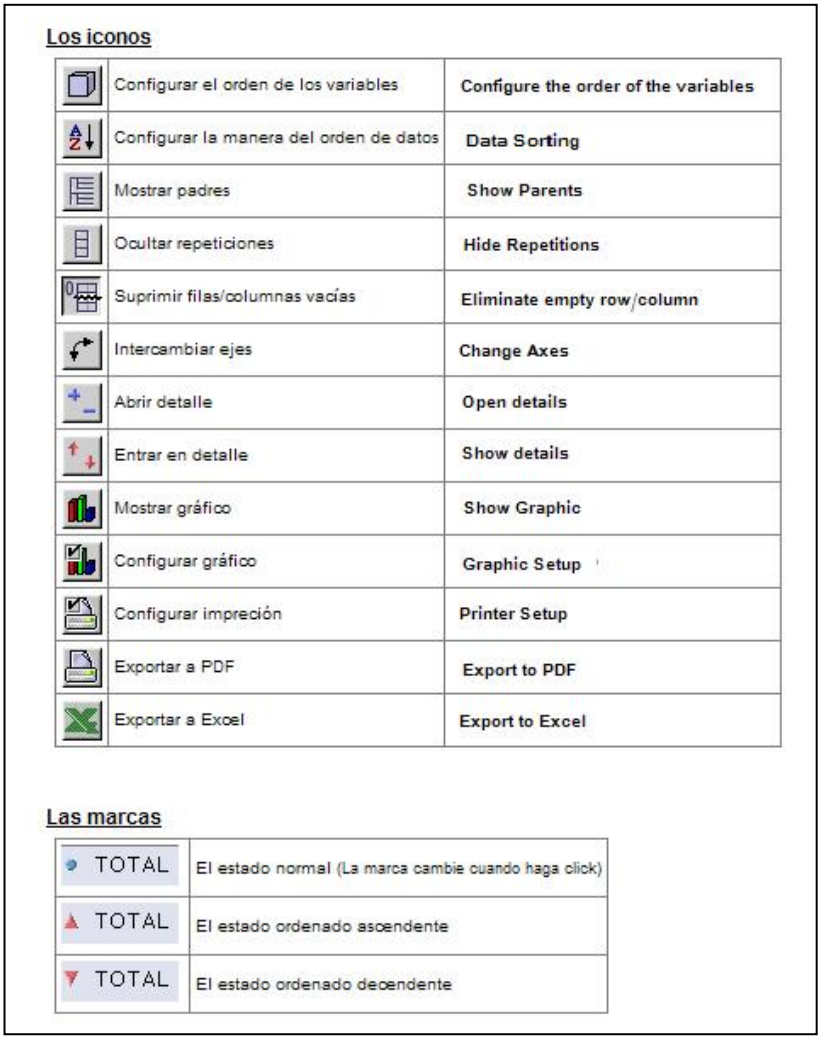


Figure 5.2. INE's Interactive Tools

Relevant information for this thesis research is contained in the page's upper tabs: Database (Banco de Datos inside the pink oval) and Cartographic Information (Informacion Cartografica, marked with the red oval in Figure 5.1).

The Database contains information about the last Census carried out in Bolivia in 2001. The information is also available in tables. Some interactive tools allowing users to manage and view data as graphics are also available (See Figure 5.2). An aspect that is important to observe here is that the page was developed in Spanish; however, the window for setting up the graphics, appears in English. Software used to create and manage cartographic information is originally in English and the developers of the site did not pay attention to this aspect and did not translate the affected parts to Spanish. An aspect like the just mentioned surely needs further corrections. Translation of the interactive tools meanings are depicted in Figure 5.3.



Los iconos

Configurar el orden de los variables	**Configure the order of the variables**
Configurar la manera del orden de datos	**Data Sorting**
Mostrar padres	**Show Parents**
Ocultar repeticiones	**Hide Repetitions**
Suprimir filas/columnas vacías	**Eliminate empty row/column**
Intercambiar ejes	**Change Axes**
Abrir detalle	**Open details**
Entrar en detalle	**Show details**
Mostrar gráfico	**Show Graphic**
Configurar gráfico	**Graphic Setup**
Configurar impreción	**Printer Setup**
Exportar a PDF	**Export to PDF**
Exportar a Excel	**Export to Excel**

Las marcas

TOTAL	El estado normal (La marca cambie cuando haga click)
TOTAL	El estado ordenado ascendente
TOTAL	El estado ordenado decendente

Figure 5.3. INE's Interactive Tools Meanings

The Cartographic Information tab contains the statistical data, which is represented using interactive maps (Figure 5.4). Interactive maps were created using Geoclip[75] an interactive cartography tool for the Internet.

[75] Geoclip Website <http://www.geoclip.fr/an/p11_webmapping.php>. Retrieved on December, 2009.

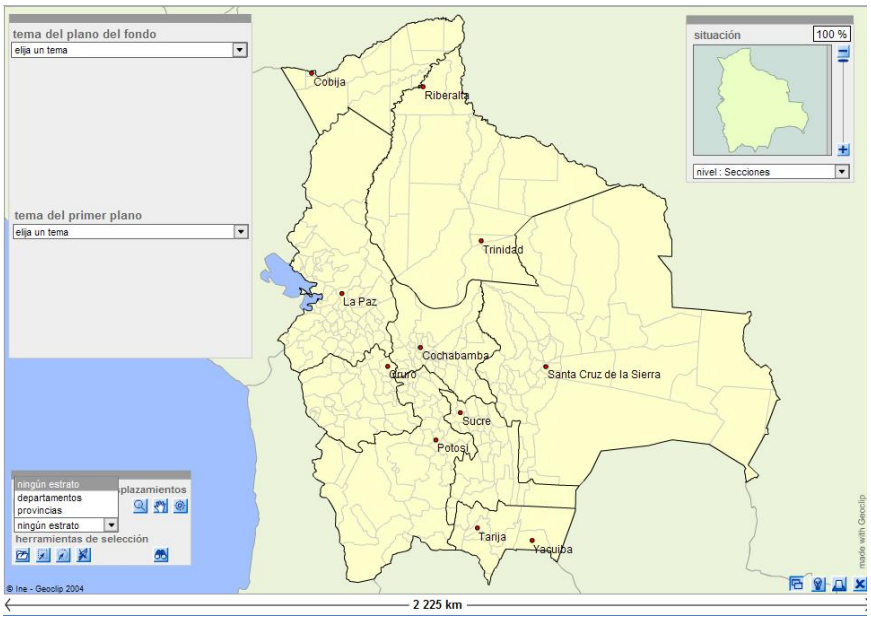


Figure 5.4. INE's Cartographic Interface

The graduation of the point symbols in the map representation (see Figures 5.5 and 5.6) is not understandable. The user is allowed to change the size of the circles, but there is no relation with the meaning of the numbers appearing next to the circles in the legend. Graduated points can be changed both in colours as well as in the filling. Only boundaries can be displayed depending on the users' needs.

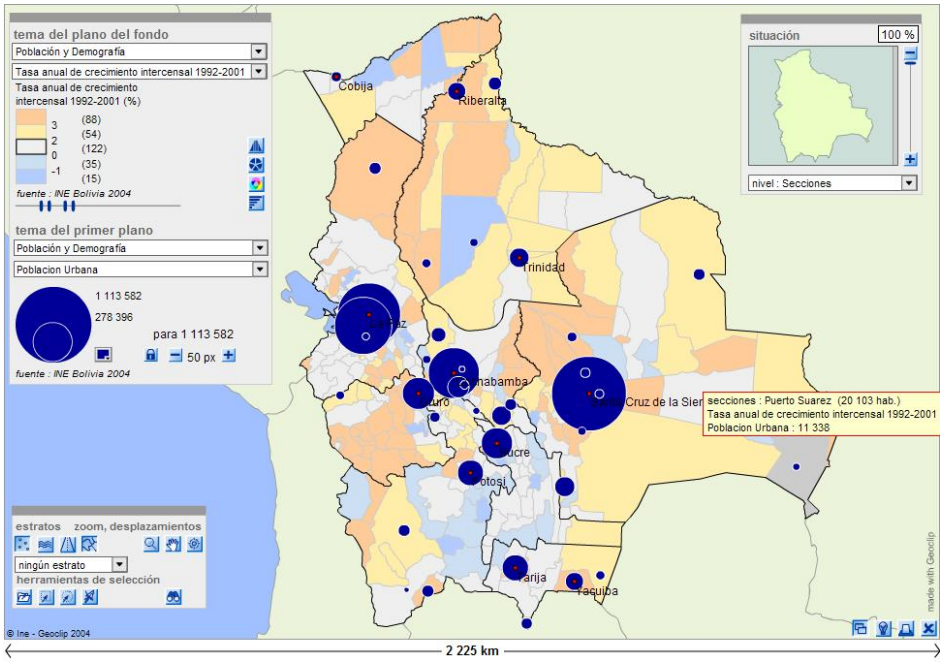


Figure 5.5. Graduated Point's Representation – Option 1

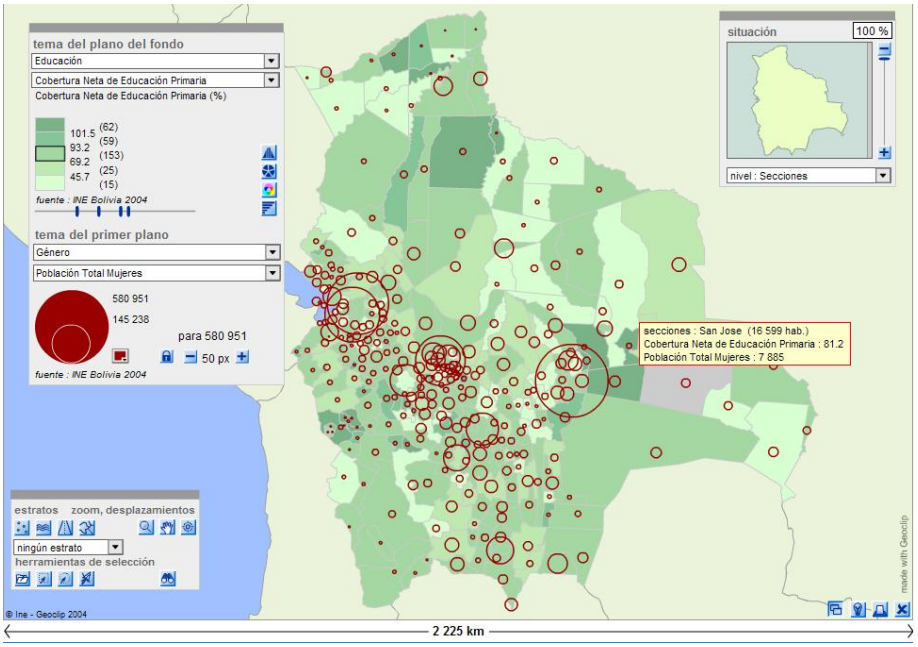


Figure 5.6. Graduated Point's Representation – Option 2

Choropleth maps are widely used in INE's website. Interactive tools are also available in order to manage the display options. As shown in Figure 5.7, the user is able to define and change the representation colours, and also manage and vary the range of the classes.

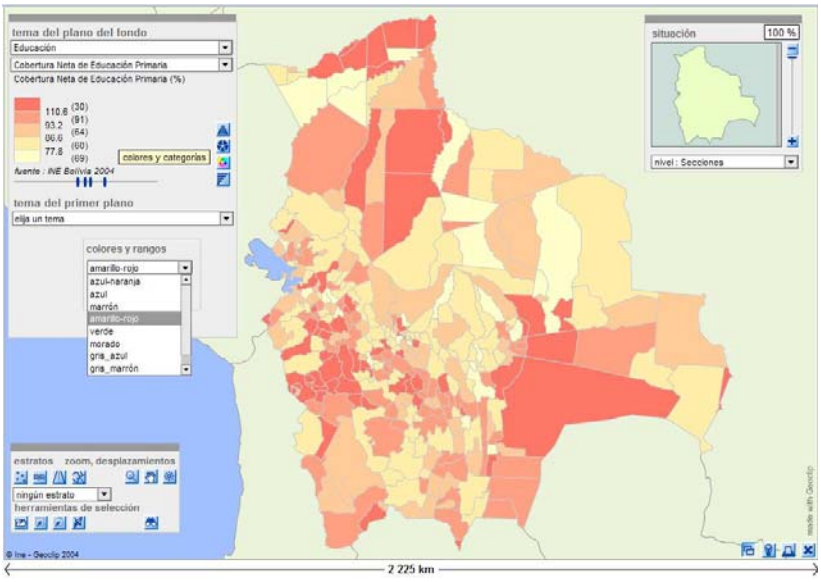


Figure 5.7. INE's Choropleth Representations

A characteristic that is really positive to mention of INE's interactive maps, is that while moving the mouse over the map, a pop-up window showing the map information is displayed. By using such tool, the user can be sure about the meaning of the objects he/she is visualizing (Figure 5.8.).

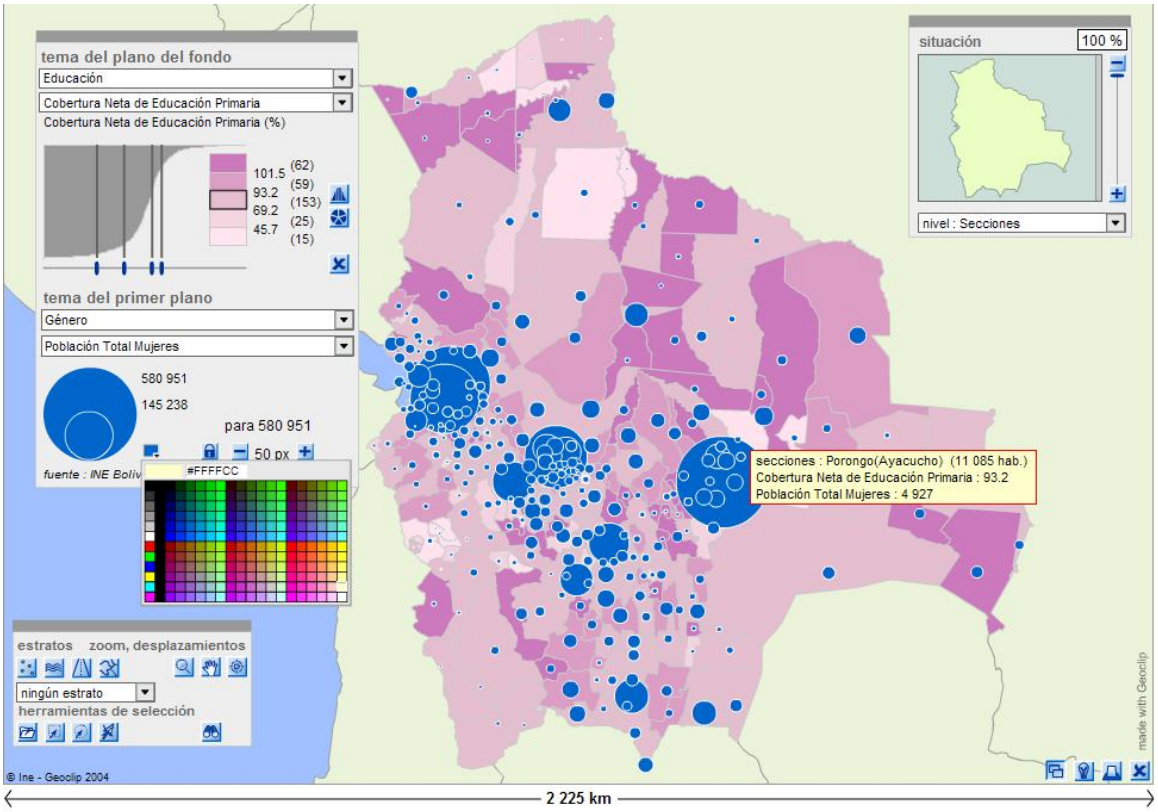


Figure 5.8. INE's Interactive Tools and Pop-up Window

5.3. OVERVIEW OF THE PROPOSED IMPROVED APPLICATION

The conceptual design that is proposed for improving the statistical data dissemination in Bolivia consists of a mashup integrating the INE Website content and Google Earth functionalities (INE+GE Mashup). Figure 5.9 shows the application components and the way it is structured.

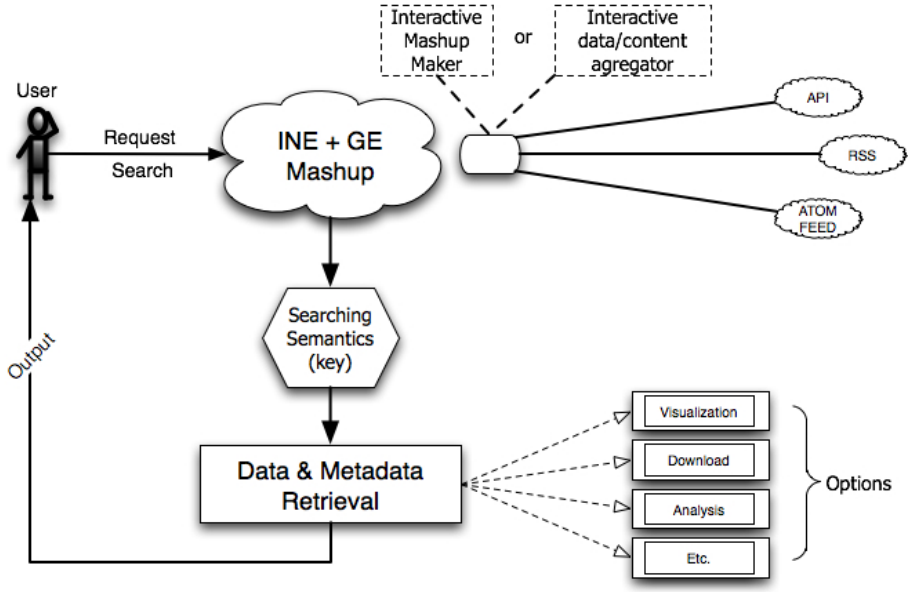


Figure 5.9. Application Components and Structure

The proposed application will function as explained in the following sections.

The INE+GE Mashup will be accessible through the INE Website. When a user requests some statistical data contained in the INE site, the request will be rendered to a searching engine in order to get the data. All statistical data that can be represented on a map interface will be assigned with a "Semantic Key", required for the searching engine to find and retrieve the data. Once the requested data is found, it can be retrieved through the user interface. The retrieved data will always contain metadata.

The user will have several interaction options with the retrieved data.

- Visualization: user will be able to define how to see the data: as tables, charts, graphics, or/and maps. He/she will be allowed to select and change colours, magnitudes, ranges, legends, etc.
- Analysis: user will be able to perform predefined analysis
- Adding personal data: like shapes, tabular data, etc
- Create new data: as vectors, tables, graphics, etc
- Download
- Printing

The INE+GE Mashup are going to be an extensible application. The user will be able to append content from other sources just using the "Interactive Mashup Maker", a button for selecting and adding content from other Websites. This process would not need any programming from the user side. By clicking the "Interactive Mashup Maker" button, the user will be able to select from the Web, all the available websites that can be included in the mashup. This will be done using website APIs, or Web feeds from news resources, geotagged images (like PlaceOpedia[76] a site where you can connect Wikipedia articles with places), photographs, Podcasts and RSS feeds. Figure 5.10 illustrates how integration occurs.

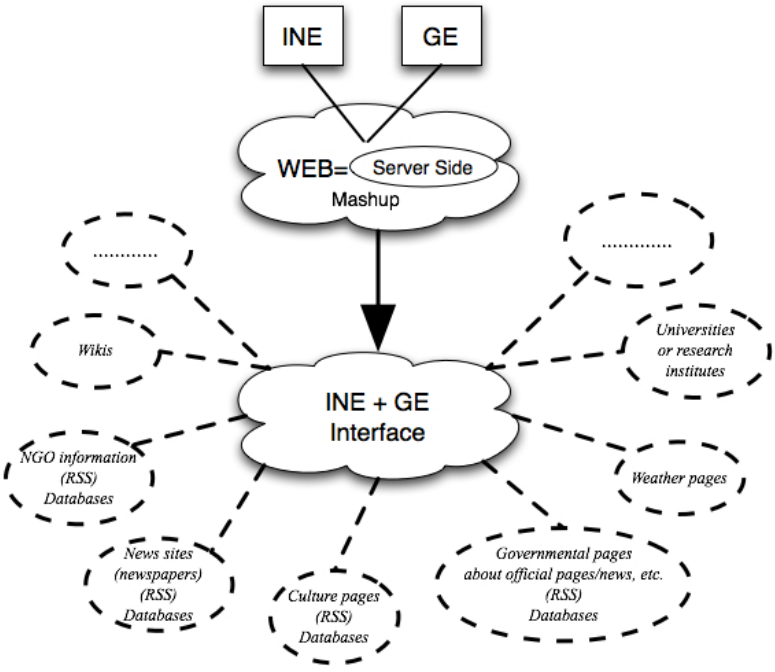


Figure 5.10 Content Integration

[76] PlaceOpedia Website <http://www.placeopedia.com/>. Retrieved on February, 2010.

The improved application is going to work with all types of Internet web browsers. It has no interoperability problems and can be supported by any operative system.

Data sharing will be two directional, from the client side to the server side and vice versa. The application will support export/import functions for a wide variety of formats allowing to easily exchanging tables, graphics and maps objects (i.e. shapes, images). When using server side, the output file will be saved on the server. In this way information from different sources and providers is going to be easily overlaid and visualized simultaneously. As a consequence, the capabilities for performing analyses will be increased (see Figure 5.11).

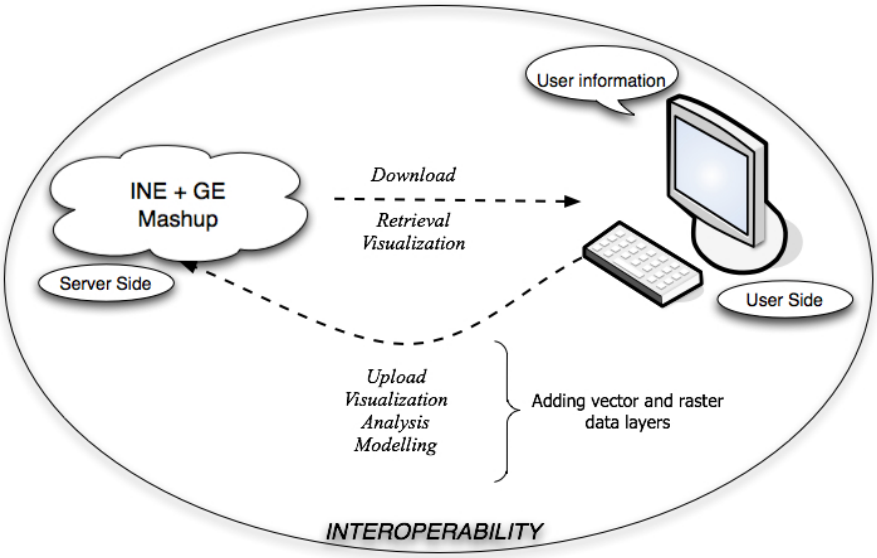


Figure 5.11. Bi-directional Integration

5.3.1. INTERFACE CHARACTERISTICS

The improved application will be accessed trough the existing "Informacion Cartografica" (cartographic information) tab provided on the INE Website. The cartographic interface will offer the possibility for advanced customization as user requirement. The displayed window is going to directly render the application's cartographic interface for finding and retrieving statistical data, avoiding the need of downloading any type of file to user's computer (see Figure 5.12). Usually KML files are downloaded on user's computer in order to visualize the requested information, as described on Section 2.6.1; just for mentioning two examples. Both characteristics are the major differences and improvement in the proposed application, when comparing it with existing similar VGs applications. (i.e.: GCensus and Netherlands Statistics in Your Neighbourhood described in section 2.6.1).

The obtained results from the usability analysis revealed important aspects needing improvement, as explained in section 4.3.2. Seven out of nine are referred to cartographic improvements (i.e. colours, legend, symbols used in the maps). Based on those results the proposed improved application will have the following menus and tool bars available in its cartographic interface, in this was the cartographic representation would be on the user's hands:

- Existing Google Earth menus and tools
- Existing menus and tools already available on INE (improved as described in the previous section)
- "Mashup Maker" button for adding content as user requirement
- Database querying tools
- Metadata information

- Import/export menus
- Drawing and editing toolbars
- Predefined analysis toolbars

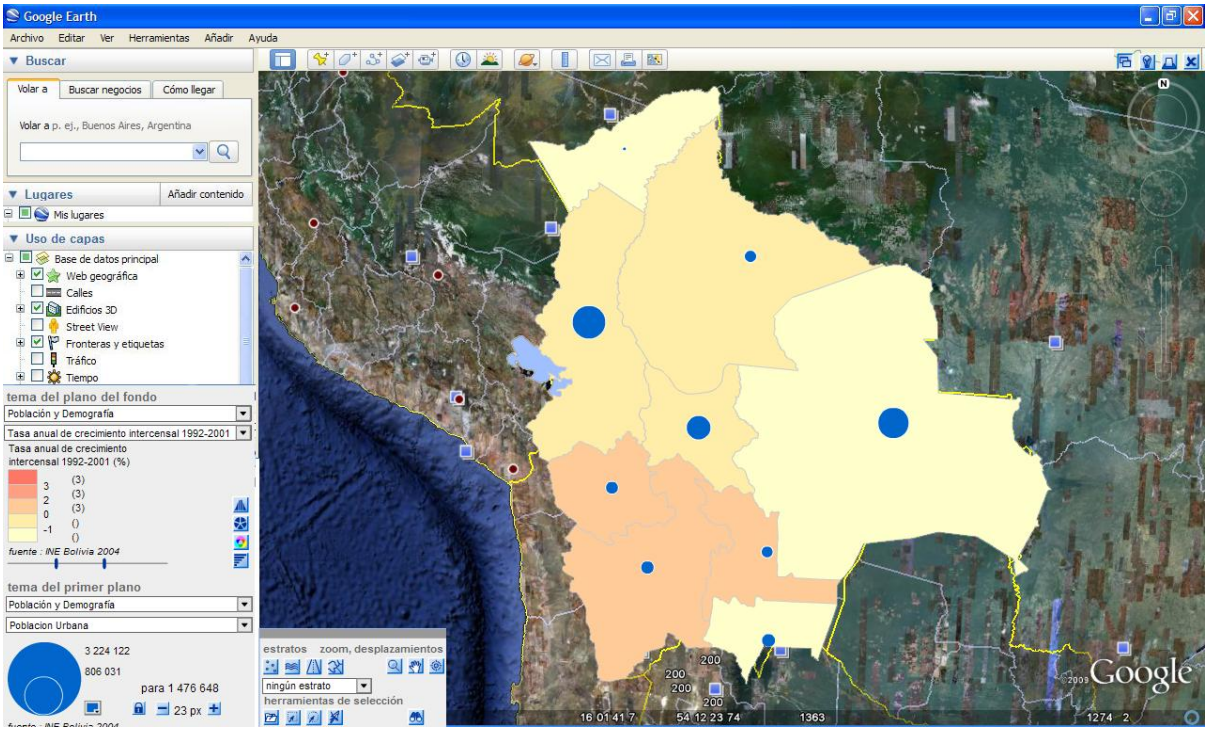


Figure 5.12. Improved Application's Interface

In the same way, when selecting the specific statistical data to be displayed, the user will be able to visualize the requested data in the following formats:

- Legend: channel contents thematically grouped in categories and sub-categories. Supporting colouring by data range, with the option to show/hide the legend.
- Tables
- Graphics
- Charts
- Tools for supporting different animation styles

5.4. CHAPTER CONCLUSIONS

A conceptual design of an application based on VGs has been proposed for improving the INE Website. The proposed application has important differences compared with existent applications elsewhere in the world, improving thematic mapping aspects in Web statistical data dissemination and visualisation.

Current INE Website is already a user-friendly and "usable" application from the point of view of thematic mapping aspects. The adding value of combining it with a virtual globe application lies in the fact that their functionalities will be increased by the already available ones given by the VG. In this way, the potential use of the INE Website will be increased as well, presenting new and huge opportunities for its use in professional and scientific fields currently lacking of such type of tools and applications, especially in developing countries, like Bolivia, where usually the availability and software costs become a limiting factor.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

The thesis research was focused and oriented to achieve the main objective of the thesis research: to assess the current usability of VGs based applications, suggesting their potential improvement and use, followed by the development of a conceptual design of a VG based application focused on national statistical data dissemination.

To reach this objective, four main areas were investigated in an attempt to answer the established thesis research questions: 1) identifying the types of uses currently utilizing virtual globes based applications; 2) establishing the basic usability elements, metrics (qualimetrics) and techniques for measuring and validating the current usability of the VGs based applications used in scientific research and/or practical applications; 3) determining the conceptual variables (factors) needed for improving the usability of VGs based applications, as main tools for scientific research and/or practical applications; and 4) identifying the elements to be considered for developing a conceptual design of an improved VG based application for statistical data dissemination with an improved usability.

After completing the thesis research the following general conclusions emerged:

1. More than forty virtual globes are currently available on the Web. Current virtual globes based applications are mainly oriented to mapping purposes and Google Earth is the most commonly used and popular virtual globe application for mapping mashups nowadays. Most of them are used for leisure;. and only a few are used for professional or scientific purposes in spite of the available Web variety of VGs based applications.

2. A first definition of "Virtual Globe based application" has been introduced: "…*an application or system designed and built specifically for use with Virtual Globes*".

3. Current usability was evaluated for two virtual globes based applications using the appropriate testers who were selected taking into account their formal education and experience in the geographic field.

4. Three aspects of usability were tested: efficiency, effectiveness and satisfaction using specific metrics and techniques: a) Performance tests were used for evaluating effectiveness and efficiency aspects; b) Questionnaires and "reaction adjectives" techniques were used for measuring satisfaction aspects; c) "Thinking aloud" technique was used for complementing and supporting the analysis of the results obtained with the mentioned techniques.

5. A non-functional requirement analysis: qualimetry, using guided interviews, was carried out to identify specific usability elements required for the conceptual design of an improved VG based application for statistical data dissemination...

6. Results of the current usability evaluation revealed that main factors requiring further improvement are: user interactions; visual appearance and ease of use; all three belonging to the Satisfaction usability aspect.

7. Guided interviews allowed determining the elements needing improvement. Those elements were later used as the base for the conceptual design of the improved VG based application for statistical data dissemination.

8. Finally, the proposed conceptual design of an improved VG based application for statistical data dissemination was developed. Such proposed improved application consists of a mashup using the cartographic content of the Bolivian National Statistical Office (INE) Website and the Google Earth application. The main features of the proposed application can be summarized as:
    a) Improvement of the interactive statistical data representation options; as compared to the currently used ones.
    b) Improved import/export capabilities;
    c) Possibilities for adding content through a clickable mashup maker button eliminating programming processes;
    d) Possibilities for overlaying and creating vector data;
    e) The improved application does not present interoperability problems allowing its use on any operative system and with any Internet web browsers.

6.2. RECOMMENDATIONS

The following recommendations have been formulated based on the research performed:

- To improve the use of qualimetric methods and techniques for developing standards and reference values regarding usability of VGs based applications.

- To further develop the potentialities of mashups in order to create a wider range of applications covering mainly scientific and specialised professional interests.

- To create awareness of the potential uses of VGs based applications, by diffusing it to potential users in relevant media and activities, i.e.: scientific and professional meetings, journals and conferences

6.3. FUTURE WORK

Future work must be oriented to:

- Implement the model and fully test its usability employing user-based methods.

- Persuading scientists and specialised professional users of the advantages of VGs based applications for sharing and employing all the potentiality and usability of these tools.

- Further development of VGs tools following the advancing in information technologies (i.e. the jump from dos to windows applications)**.**

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APPENDICES

APPENDIX A

VIRTUAL GLOBES ON THE WEB

In this section, a summary of the current Virtual Globes available on the Web is presented. This Appendix provides a detailed description of the current virtual globes available trough the Web. It contains a brief description of their main characteristics, their main features, applications based on them and the URL where they can be found.

N°	Virtual Globe Name	Description	Key Features	Applications
1	CitySurf Globe	is a new generation geographical information system software Is a family of Geography 2.0 Geographical Information System software, developed by PiriReis Bilisim, known as a new model in mapping servers and interaction with the final user. Allows sharing data by 3D modelling of high-resolution satellite images, digital elevation model of the land surface and the digital urban data such as building, road, plot.	**Ease of Use:** User-friendly interface allows even beginner level computer user to use the software easily. **Client Server Architecture:** With the client-server architecture easy sharing of large geospatial data to authority level over the network. **High Performance:** High-speed connection and display of the data stored in the server computer While minimizing hardware and network systems requirements with our highly-efficient streaming technology. **Analyses and Query:** Using the unique query and analysis features make it easy to learn information about geography and cities.	**3D City Information System:** Analyzing of the databases stored in local governments according to public needs in 3D platform. **Military and Defence Industry:** incorporates a suite of display and analysis tools tailored to meet the special needs of the defence and intelligence user. **Oil, Gas and Electric Industry:** provides products and services for planning and designing sites, infrastructure and pipelines networks for the Oil, Gas, Electric industry. **Real Estate Industry:** Real estate customers can directly benefit from the advanced visualization capabilities of the CitySurf technology when integrated with other complementary technologies such as still photos and panorama imaging. **Travel and Tourism:** With the CitySurf environment, travel services, property owners and local/city governments can create virtual cities including hotels, restaurants, features and points of interest. **3D Visualization for Civil Engineering:** can show the presentation process of a project and can assist in visualizing existing 3D models, overlaying your own drawings and GIS layers on the actual terrain.
2	Nintendo Wii Weather	It is more like and application	User can search for locations and see	

	Channel	used to show the weather. It does have a pretty fly Google Earth style globe rotate-and-drag.	the current and the tomorrow's weather.	
3	Microsoft Virtual Earth	The Microsoft Virtual Earth platform is an integrated set of services providing quality geospatial data, rich imagery, cutting-edge technology, and dependable performance that helps organizations visualize data and provide immersive end-user experiences. This platform, supported by the Virtual Earth Map Control and the Virtual Earth Web Services, offers new map detail, feature enhancements, and robust platform capabilities.	Virtual Earth Map Control: includes immersive imagery and enables rich mapping and enterprise-class application development, with an intuitive JavaScript programming model. Virtual Earth Web Services: offers static map images, direct map tile access, one-box search functionality, geocoding, reverse geocoding, and routing. MapPoint Web Service: is a programmable Web service hosted by Microsoft and used by enterprises and independent software developers to integrate location-based services into software applications and business processes.	**Photosynth:** Transform digital photos into a panoramic experience that displays the big picture, as well as its details. **Maps for Mobile Devices:** Develop mobile applications with imagery optimized for mobile devices. **Expanded Number of Rooftop Views:** VE offers 85 million unique addresses—more than 70% of all rooftops in the U.S. **Bird's Eye1 Views and Bird's Eye Hybrid:** Exclusive to Microsoft, these unique views of real-world locations provide insight into "what it's like there." **3D Imagery:** Create more realistic 3D views of buildings and landscapes. **Geocoding and Reverse Geocoding:** Get the most accurate locations through integration of multiple geocoders and to provide the most relevant and accurate results. **International Geocoding** **Localized Maps and Directions** **Extended International Parsing** **Near-matching:** find locations using alternate and similar spellings. **Virtual Earth Web Services:** Developers can use the API, which offers static map images, direct map tile access, one-box search functionality, geocoding, reverse geocoding, and routing. **Pushpin Clustering** **Traffic Reports:** Help your users avoid traffic jams by using traffic reports that overlay the Virtual Earth map with color-coded traffic flow visuals above the roads. **GeoRSS Feeds:** Import shapes, pushpins, and polylines, with GeoRSS feeds. **Weather Integration:** With 3D view, get near real-time weather and cloud formation data.
4	Dapple Earth Explorer	Dapple is a global data explorer designed to provide an open and optimal environment for visualizing, presenting and sharing massive quantities of geoscientific data on desktop computers. Dapple lets you browse, discover and display graphically rich data from global and corporate spatial servers – Geosoft DAP servers, NASA servers, USGS servers, and the many, many WMS servers	Search the Web for spatial data. Search internal DAP servers and known Web servers for spatial data. View geoscience data, satellite imagery, remote sensing data, geology maps, geophysical data, and many other earth data sets of interest to geoscientists. Save an earth view and share your view with colleagues. Add new Geosoft DAP, WMS and ArcIMS servers of interest. View GeoTIFF files. View KML files (2.0.3 beta).	

		currently available. The Dapple project is an open-source activity sponsored by Geosoft and derived from the NASA World Wind open source project. Dapple represents the effort to make this powerful technology accessible and useful to professional earth scientists.		
5	Wayfinder Earth	Wayfinder is a leading supplier of innovative location and navigation services for mobile phones. User-friendliness, the core attribute of all Wayfinder's applications and services, makes it easy for consumers to take advantage of cutting edge innovation for both business and leisure use. Wayfinder Earth™ presents you with a 3D globe representing the planet earth, visible on the display of your mobile phone	Wayfinder offers a range of products in its portfolio, the one's portfolio of location applications includes the flagship product, Wayfinder Navigator. All of Wayfinders applications are available in 19 languages and have a user base that now excees 3,5 million global users. In early 2009, Wayfinder was acquired by Vodafone and is now a part of Vodafone Internet Services.	You are able to spin the globe manually, selecting an area or city, and zoom in for a closer look. The maps of Europe and North America are detailed and you can easily zoom to street level, making any tourist map obsolete. Additionally includes more than three million Points of Interest (POIs), such as restaurants, train stations, bars, museums, gas stations or hospitals represented as icons on the maps of Europe and North America. By clicking on an icon is possible get instant interactive information such as addresses, opening hours, phone numbers and more.
6	3D Weather Globe & Atlas by Software MacKiev			An astronaut's-eye-view of the Earth Mountains, rivers, lakes, and deserts Real-time weather and cloud cover 7-day forecast including wind and humidity Day/night line changing with the seasons Accurate latitude/longitude markings All countries in the same time zone Hurricanes, tropical storms, rain patterns Famous routes (eg. Magellan's voyage) Distances between any of 40,000+ cities
7	ESRI ArcGIS Explorer	is a free downloadable application that offers an easy way to access online GIS content and capabilities. With ArcGIS Explorer, you can connect to a variety of free, ready-to-use datasets hosted by ESRI. Combine these with your own local data or other 2D and 3D Web services to create custom maps and perform spatial analysis.	Fuse your local data with data and services from ArcGIS Server, ArcIMS, and Open Geospatial Consortium WMS to create custom maps. Perform GIS analysis (e.g., visibility, modelling, proximity search). Use custom tasks to manage, edit, and analyze your data. Share your maps and results with others.	Access 2D and 3D mapping services from ArcGIS Server, ArcIMS, and Open Geospatial Consortium (OGC) WMS Add local data such as geodatabases, shapefiles, KML/KMZ, GPX, and raster formats (JPEG 2000, GeoTIFF, MrSID). See a demo of adding GPX data to ArcGIS Explorer. Connect to free ESRI-hosted ArcGIS Online (satellite imagery for the entire world, worldwide streets, terrain, boundaries and labels, political maps, and physiography). Answer geographic questions and share the answers with others. Perform GIS analysis (such as visibility, direction finding, and proximity search). Add custom tasks to manage, edit, and analyze your data.

				Author tasks using ArcGIS Desktop and serve them to ArcGIS Explorer via ArcGIS Server. Connect to GeoRSS feeds. See a demo. E-mail your projects directly from the application. See a demo. Customize your map display (symbology, pop up windows, layer transparency, sun shading, clouds, graticules). Use the free downloadable SDK to extend default tasks or create new ones. Connect to the online Resource Centre for a one-stop place to access online help, blogs, and samples, as well as free tasks, layers, and results.
8	Erdas Imagine Virtual GIS	Is a powerful yet easy-to-use visual analysis tool that offers GIS functions and capabilities in a 3D environment. Beyond simple 3D renderings and basic fly-throughs, it allows you to create accurate 3D interpretations of your projects for interactive presentations.	Real-time fly-throughs of geographic data in a 3D environment Drape vector GIS data (point, line, polygon) across landscapes Display vector and annotation polylines and polygons as 3D objects Place true 3D objects into scenes Mouse operated 3D angular pan, zoom and flight control Generate, edit and display flight lines Advanced, tabular flight path editor Full X, Y and Z splining of flight paths Variable pitch, azimuth, roll and speed "Billboarded" text and symbols that rotate to always face the observer Optional terrain following mode Geographically link 2D and 3D viewers Create, manage and optimize large data sets with the Virtual World editor Real-time lighting effects Stereo display capabilities Print 3D views using Map Composer Wire frame and reduced resolution solids display options Viewpoint control tool with terrain profiles Save and recover viewpoints with the Positions Editor Generate intervisibility and threat analysis domes from single or multiple observation points, from various heights and with desired viewing angles Animate multiple features in the 3D scene Create movies for screen and output	

9	Google Earth			
10	Global-i	Global-i is a 3-dimensional interactive globe that displays information about the world in your browser. The Earth can be rotated and inspected and displays can be changed to see information in the most appropriate form. Global-i has been described as "A Global Marketer's Dream" but it is not just for marketers or economists. It is for anyone who wants to learn about the world and what makes it go round. By viewing this information in context, the world makes more sense..		At present the emphasis is on economic data and there is plenty of other information too - health, infrastructure, energy, military.....and more - from present day back to 1960 and we are adding to this list all the time
11	EarthSLOT	Its mission is to advance earth science and earth science education through the use of Virtual Globes to help scientists, resource managers, educators, and the public better understand our planet and the earth science that goes on here.		They developed two applications for Google Earth.
12	ESRI ArcGlobe	Enables users to manage and visualize, from a local or global perspective, extremely large sets of three-dimensional geographic data. These capabilities are available as part of ArcGIS 3D Analyst 9 in a new desktop application called ArcGlobe. ArcGlobe provides the capability to seamlessly interact with any geographic information as data layers on a three-dimensional globe.	As an extension to the ArcGIS Desktop products, ArcGIS 3D Analyst allows users to leverage the GIS analysis tools available in ArcView, ArcEditor, and ArcInfo to perform geoprocessing tasks in a 3D environment. Using standard interactive mapping tools, users can also pan, query, and analyze data at any scale, or they can zoom right into their local area and view very high-resolution spatial data, such as parcels or detailed aerial photographs, of their area of interest.	With ArcGIS 3D Analyst 9 and ArcGlobe, users can Use all types of geographic data including vector data (e.g., buildings, parcels, roads, power lines, water hydrants, and soils) and raster data (e.g., digital elevation models [DEM], satellite imagery, digital orthophoto quadrangles [DOQ], and aerial photography). Manage and navigate through extremely large databases (terabytes). Extrude two-dimensional representations to three dimensions. Create three-dimensional fly-through animations. Perform analyses such as overlay, viewshed, and buffer. Use GIS tools and functions in a 3D environment. Apply various data layer effects such as transparency, lighting, shading, and depth priority. View multiple perspectives simultaneously.
13	Eingana (is not a web available, comes on CD and u need to buy it!)	This ambitious and unusual title is a cross between an electronic atlas and a computer video game.		Satellite images of the whole planet with high resolution images 1 cm virtual accuracy everywhere Hydrographic network and sea floorsand climate phenomena

		It takes a while to install which is hardly surprising given the amount of 3-D content and satellite images it offers. You can then travel quickly through a virtual representation of planet earth, sweeping over high mountain ranges, visiting countries and cities, and seeing and hearing animated creatures. You can visit forests, tops of mountains or journey underwater. The best place to start is the demo, which automatically takes you on a quick tour taking in herds of elephants and giraffes as you sweep over breathtaking computer-generated landscapes. This title will be hugely entertaining for enthusiastic video gamers. Not only does it include virtual creatures alive today, but it also features mythical ones such as the Yeti, who you can find on the Himalayan glaciers. At the bottom of the screen various pieces of information are displayed, such as the height above ground and sea level according to where you are based on this virtual representation of the earth's surface. It is hard not to be impressed by the amount of work that has gone into generating these virtual models of the world. The long-term aim is for you to be able to build houses, create virtual representations of yourself and virtually inhabit these lands that have been created. --Justin Hunt		Time of day and season manipulation More than 100 species of animals (cattle, fish, birds, reptiles) More than 30 types of objects (Monuments, ships, Space Shuttles) More than 20 types of mythical objects or creatures … discover them A database of 40,000 place names
14	NASA World Wind	World Wind lets you zoom from satellite altitude into any place on Earth. Leveraging Landsat satellite imagery and Shuttle		3D engine Blue Marble Land Sat 7 SRTM

		Radar Topography Mission data, World Wind lets you experience Earth terrain in visually rich 3D, just as if you were really there.		Animated Earth MODIS GLOBE Country & State Borders Place Names Visual Tools Landmark set
15	Celestia	The free space simulation that lets you explore our universe in three dimensions.	Unlike most planetarium software, Celestia doesn't confine you to the surface of the Earth. You can travel throughout the solar system, to any of over 100,000 stars, or even beyond the galaxy. All movement in Celestia is seamless; the exponential zoom feature lets you explore space across a huge range of scales, from galaxy clusters down to spacecraft only a few meters across. A 'point-and-goto' interface makes it simple to navigate through the universe to the object you want to visit. Celestia is expandable. Celestia comes with a large catalog of stars, galaxies, planets, moons, asteroids, comets, and spacecraft. If that's not enough, you can download dozens of easy to install add-ons with more objects.	
16	SINTEF Virtual Globe	A 3D globe viewer with elevations, satellite and aerial images, maps and 3D features. This is a client-server application for displaying very large (=global scale) terrain models. The terrain database is stored on a server, and the client program only fetches the data required for generating an image on your screen with the wanted resolution. As you moves around the program loads and throws out data as needed.		Global land terrain with Landsat images Global land and ocean floor terrain Virtual Mars Globe with 3d features Placename search
17	GeoFusion	GeoFusion offers a complete set of products and services for application developers and end-users that cover all aspects of Digital Planet business	A fast and versatile rendering engine that can bring together multiple image and terrain datasets at runtime. Dynamic terrain tessellation on unique global grid.	Creating Digital Planet data. Streaming Digital Planet data over the Web. Authoring custom Digital Planet configurations. Viewing Digital Planet with: stand-alone viewers, web-based viewers, high-end stereo viewers, high-end viewers for large-

			High-quality image and terrain processing for fast, multi-resolution tile streaming from disk or over the Internet. Programming interface for all functions, including communications interfaces for XML, IPC and plug-in modules.	format and multi-panel displays using multiple graphics cards.
18	SRI Terravision (2002).	TerraVisionTM is an Open Source distributed, interactive terrain visualization system developed by SRI International. It allows users to navigate, in real time, through a 3-D graphical representation of a real landscape created from elevation data and aerial images of that landscape.		There are many terrain visualization tools on the market, but here are some of the features that make TerraVisionTM unique: New: Full Open Source hosted on SourceForge. TerraVisionTM can browse huge datasets, in the order of terabytes. All data can be distributed over multiple servers across the Web. 3-D VRML and GeoVRML models can be overlaid, e.g. buildings, wind vectors, etc. TerraVision can access OGC Web Map Servers (WMS) [More] Datasets of different size, resolution, source, and coordinate system are supported. New: TerraVision Server on Internet2. Available for free for Windows, Linux, and SGI platforms. New: Version 6.0 released
19	Earthbrowser	EarthBrowser is an innovative earth simulation that combines an easy to navigate 3 dimensional globe with real-time weather conditions and 7 day forecasts for thousands of locations worldwide. Live earthquakes, hurricanes, webcams, volcanoes and cloud animations are just some of data that is available in an instant. A great aid to teachers for visualizing earth and space with their students. A must have for anyone who loves to watch the weather	• Worldwide 7 day forecasts and animations from the NOAA • International Space Station, Hubble and other satellites • Earthquakes, volcanoes, hurricanes and wildfires • Street Maps courtesy of Open Street Map • Doppler radar, polar auroras, tectonic plates and ocean buoys • Hundreds of dynamic webcams all over the globe • Create your own locations and favourite views • View and create your own KML files • World time zones	
20	Microsoft MapPoint	MapPoint® 2009 gives you the power to visualize business data		Updated maps—New geographic and demographic data Data mapping—Use maps to visualize the meaning of your data

		and communicate insights with instant impact. Before you hit the road, plug in your stops and MapPoint plots the most efficient course with turn-by-turn driving directions. MapPoint 2009 with GPS Locator adds routing and directions to easily plan your trips and track your location in real-time.		Custom territories—Define your own delivery or sales areas Programming—Build custom solutions and Office add-ins Go mobile—Send addresses and phone numbers to your mobile device
21	Planet 9's VirtualEarth	Planet 9 Studios is focused on providing the highest quality and performance in 3D city data and software.		Our core software products include RayGun (client) and GeoFeeder (server). RayGun is robust navigation / friend finding / social networking platform that runs on cell phones, Personal navigation devices, in-car navigation systems and PC's. RayGun is a highly scalable multi-user geographic server that runs on Linux and Windows platforms. Planet 9 also provides custom versions and ports of RayGun to our customer's specifications. We supply over 100 "off the shelf" virtual city models to applications including games, movies and mobile devices. We offer a mobile bundle called "Virtual Cities 2008" with 100 North American cities and 20 EU cities. We also develop custom models of real world places. Virtual Earth is an Earth globe platform used as a "space to face" interface for a number of applications. Virtual Earth, first launched in 1995, is available in both web and mobile versions.
22	Mark Pesce's WebEarth	WebEarth builds a live VRML model of Earth as it is right now . Drawing from composite satellite photos created by John Walker, WebEarth employs a set of server-side scripts which build the model and maintain the current image database. To load the model, click on the words "Current Earth Image" in the left-hand frame.		
23	Blue Marble's Talking Globe CD	The mission of the Scientific Visualization Studio is to facilitate scientific inquiry and outreach within NASA programs through visualization. To that end, the SVS works closely with scientists in the creation of visualization products, systems, and		All the visualizations created by the SVS (currently totalling over 2,900) are accessible to you through this Web site. More recent animations are provided as MPEG-4s, MPEG-2s, and MPEG-1s. Some animations are available in high definition as well as NTSC format. Where possible, the original digital images used to make these animations have been made accessible. Lastly, high and low resolution stills, created from the visualizations, are included, with previews for selective downloading.

		processes in order to promote a greater understanding of Earth and Space Science research activities at Goddard Space Flight Centre and within the NASA research community.		
24	Hipparchus	a fully integrated software package for positional astronomy. HIPPARCHUS will run on any computer in the Macintosh family. We take great pride in the precision, adaptability, flexibility and ease of operation of HIPPARCHUS as an astronomical planning, observing, and research tool.	Among its many features HIPPARCHUS will allow you to produce star maps and charts in either Mercator or polar projection of any region of the sky, at varying scales, in color or Black-and-White. Stellar positions are rigorously processed to the equator and equinox of any date, with or without corrections for stellar proper motions. Targeted regions may be selected for display or tabulation either by absolute boundary coordinates, centring on a celestial target, or solar system target, or on the observer's zenith. Individual stars may be selected based upon position, brightness, proper motions, catalog numbers, spectral type, and/or stellar characteristics such as duplicity and variability. Zoom in or out on targeted regions by interactively choosing the area from the HIPPARCHUS star chart and horizon view windows, or by varying field radii in a polar projections. Any or all stars may be annotated with their HR (BS) catalog numbers, Bayer or Flamsted designations, V-magnitudes, spectral types and luminosity classes. Indications of stellar duplicity and variability, and constellations overlays may be applied. Non-stellar objects from the Messier catalog also may be displayed and annotated. The instantaneous positions, or orbital tracks , of any of the planets, Sun, Moon (drawn to scale, or designated by their symbols), minor planets, comets and artificial Earth-orbiting satellites may also be indicated on any star chart or horizon view when they fall within the selected area boundary for a specified date or range of	

			dates. Click on any stellar target in the HIPPARCHUS window to obtain detailed catalog and instantaneous topocentric, or field centred positional information about that object.	
25	GeoVirtual GeoShow3D	GeoShow3D is a powerful software technology that makes is possible to handle an unlimited amount of 3D geographic information on a regular pc in a way that can be compared with the professional flight simulators used with powerful computers. The result is a free and fluid movement on the part of the navigator over photographic quality scenery, undistinguishable from a video filmed from a helicopter. The natural navigation interface makes this user friendly technology very simple, even for non professional users, to manage.		Fully functional via the Internet Real-time integration of a GPS signal Multiuser 3D GIS Multiple coordinate and projection systems Raster and vector overlays Consultation and measurement tools Animated and static 3D elements Geoide
26	Viewtec TerrainView	TerrainView-Globe™ lets you display and analyze the whole earth in 3D. TerrainView-Globe can pre-process and then access, in real-time, any amounts of geo-specific data. These 3D data can be accessed locally or remotely via internet. Supported data includes images, textures, terrain, and 3D objects such as buildings and trees. All data can be layered and combined with a variety of overlay graphics, text, models of buildings, planes, etc., and used to produce still images, motion picture sequences, or interactive sessions on a PC. TerrainView-Globe supports the global reference system and offers space-to-street-level in superior rendering quality. High performance on low cost	A ground-breaking interactive 3D visualization technology for Defence Industry, Homeland Security, Oil & Gas Industry, Insurance Industry, Flight Simulation & Training, Television Broadcasting & MultiMedia, Travel & Tourism, Civil Engineering, Urban Planning, Architecture & Real Estate, Imagery & Geodata Industry.	Spherical Earth rendering Multi-resolution support for four basic data types: imagery, terrain, vector, and annotation Rendering and display of global and local scale imagery, elevation, and vector-based datasets Support of all common projections, raster and vector formats Use your local data with internet based data services from ViewTec or other data providers Supports any number of overlapping, high-resolution image or terrain data inserts Continuous level of detail while zooming Terrain morphing between different resolution levels Ultra-fast Level-Of-Detail calculation Demand paging of tiled data for four basic data types: imagery, terrain, vector, annotation Memory resources are efficiently recycled among the currently used memory pages Multiple globes can be coincident, concentric, or separated to provide various effects such as translucent overlays (used with clouds above the Earth), fade between datasets, geologic features, planets, etc. Scene scaling allows both global and street level features to be

		hardware platforms and fully interactive control of rendered objects and views are main features of this application.		rendered while retaining numeric precision Ability to add your own polygonal model for airborne, ground, and space-based objects Datasets are independent. Ability to attach or detach, and render an arbitrary number of datasets each with an arbitrary, potentially very large, amount of data Supports industry standard texture compression formats Lossless compression of datasets further reduces disk and bandwidth requirements
27	Virtual Terrain Project	The goal of VTP is to foster the creation of tools for easily constructing any part of the real world in interactive, 3D digital form. This goal will require a synergetic convergence of the fields of CAD, GIS, visual simulation, surveying and remote sensing. VTP gathers information and tracks progress in areas such as procedural scene construction, feature extraction, and rendering algorithms. VTP writes and supports a set of software tools, including an interactive runtime environment (VTP Enviro). The tools and their source code are freely shared to help accelerate the adoption and development of the necessary technologies.		
28	Earthsim	Earthsim's Earth is a stunning high-resolution 3D model that you can control. The Earth forms the hub of the Earthsim browser interface, and is the entrance to the Earthsim universe. The Solar System (see below) is a natural extension of the current Earthsim zoom in/out interface, and in the future a timeline will allow you to travel forward in time to see the effects of climate change and wind the clock back to enter the World of Dinosaurs (see bottom).		Higher resolution graphics Fly around the Solar System Visit Mars, Jupiter, Venus and more Realistic Atmospheres Accurate Orbits Accurate Star Positions Regular content updates All Features of the of the Earthsim Online Screensaver, plus Access to the Constantly Growing Catalogue of Documentaries Information Overlays Regular Content updates

		If you subscribe to Earthsim TV, you can listen to narrated documentaries providing fascinating information about the many natural wonders of the planet, and superimpose overlays on to the surface to discover new facts about the features you can see. Earthsim's Earth will never stop growing: we will continue to add new documentaries and information overlays, such as real-time views of the clouds over the planet and the tectonic plates, to enhance your learning entertainment experience.		
29	GRIFINOR	GRIFINOR is an open source development initiative for 3D virtual globe platform, written in Java. It allows publishing a georeferenced 3-D model, which we call a model map, on the Internet and render the scene using OpenGL. You can explore the model map itself but also associate parts of the model map with data stored in your databases, your analytical functions or resources available on the Web. Like the content on the Web, the model map in GRIFINOR can be build by independent contributors collaboratively in a decentralized manner (everybody can have their own server with the content contributing to the whole). Users can navigate through the model map over the network in a 3-D scene, and interact with it in an application-specific way.		
30	Talent Cruiser	Cruiser is a Java-based platform for creating feature and experience rich geo-information		Seamless map navigation (pan-around, zoom in / zoom out) • Seamless fly-overs over three-dimensional terrain models

		applications for Geo-Portals, On-line communities, Location-based directory services and advertising, Tourism, Real Estate, Fleet Management & Tracking, Navigation, LBSs, Media, Education, Local administration, Safety and Risk Management, Environmental management, and more.		• Combined display of vector, raster and altitude data • Dynamic display of scale, coordinates, angle of sight and viewing height • Support for any map projection system • Direct display of associated descriptive information (brief, detailed) • Direct access to web sites associated with geographic features (map elements) • Selective display of the geographic features of the map, via a dynamic legend • Free-format or structured search based on geographic and descriptive criteria • Creation of geographic objects (points, lines, polygons) • Attaching documents of any type to the geographic objects • Creation and saving of map views and place-marks • Export and sharing objects and place-marks among users • Combined on-line / off-line use • Measurement of distances and areas • Printing of selected map areas • Routing instructions and spatial guidance • Import/export from/to GPS devices • Management of channels and application options • Support for user interface “skins” • On-line help provided for all functions and controls • Multi-lingual user interface, where language can be changed on the fly • Linking and activation of functions from within web pages, using special HTML tags • Data entry from popular GIS formats (e.g. ESRI shapefiles) • Editing of vector data

				• Creation of animated navigation movies (e.g. fly-overs along paths) • Management of descriptive data in tabular form • Report creation and printing
31	WW2D	WW2D es un proyecto multiplataforma que surge como alternativa de código libre a programas del tipo NASA World Wind o Google Earth. Es decir, todo un explorador con el que recorrer nuestro planeta y viajar hasta cualquier rincón del mundo, todo ello desde la comodidad de nuestro hogar.	El programa hace uso de imágenes de satélite, mapas topográficos y otros datos de varias fuentes de información, mostrando además detalles como fronteras, nombres de países y demás a voluntad del usuario. Cuenta también con un sistema de búsqueda, la posibilidad de marcar determinados lugares como favoritos. Además, al ser GNU, su código está disponible para todo aquel que quiera mejorarlo y crear extensiones para el programa, tarea a la que se han lanzado ya diversos miembros de la comunidad de usuarios de WW2D (ver Extras).	Soporte para la Luna y Marte Indicador de descarga Exportar como imagen Errores corregidos y más
32	Genesis MP	Genesis is the original COTS 3-D visual simulation and visualization technologies that reduces and eliminates significant time, cost, and effort from the traditional database development process. Genesis enables run-time "Dynamic Construction" of high-quality 3D Terrain Scenes directly from scatter GIS source data. Data changes and updates are visualized instantly instead of requiring time-consuming off-line optimization processes and custom formatting with expensive and challenging to operate terrain generation tools. The user controls how the scene renders with user friendly tools, while the Genesis technology takes care of the performance, by automatically optimizing the		GenesisAPI: Embedded 3D or Custom Image Generator GenesisIG: Multiple Channel 60Hz Image Generator GenesisMP: Multiple Purpose Viewer

		scene paging, caching, and rendering characteristics of your source data based on your screen resolution and platform performance. So add data, teach the tool the attributes of your data, and fly instantly through advanced 3D Scenes.		
33	**PYXIS DGGS**	PYXIS Philosophy When humanity emerges with the capacity to change the Earth, we must rapidly assess the consequences and respond. At PYXIS, we believe that this call to action begins when we each have the unfettered power to survey and witness the Earth's complexity, its beauty, its condition and its vulnerability. PYXIS technology supports evidence based decisions by rapidly connecting data, information and knowledge flow through the common ground we stand on. PYXIS is a momentous advancement in Earth reference that will bring it all together,…anything, everywhere, on-demand, now. Find out more about us by contacting: getyourglobe@pyxisinnovation.com	Spatial data value is locked up, unable to be released due to the inability to do massive on-the-fly geospatial integration. Historic approaches to geospatial information integration cannot meet this growing expectation for general on-demand net-centric access to the rich and diverse knowledge that is held worldwide. PYXIS provides a necessary solution to have a Geospatial-Web – a digital Earth where anyone can complete the geospatial search "What is here?". The key is the PYXIS innovation: a Digital Earth Reference Model encompassing principals of a digital model: A discrete uniform partitioning (a tessellation or tiling of cells over the Earth surface); A unique linear non floating point index for each discrete cell that encompasses within the index both a parent child hierarchical relationship and a coordinate system that converges to the set of all real numbers; A set of mathematical relationships built on the index: algebra, geometry, Boolean operations, image processing, etc; and A strategy for quantizing values, preferable integers, to each discrete cell.	WorldView: a desktop peer-to-peer application to use, analyze, and share spatial data. Find out [more...] SDK: a software development kit that will bring the power of a global grid into your software or data product. Find out [more...] PyxNet: a peer to peer network infrastructure for the GeoWeb that allows you to share your work and manage your data licenses the way you want. Find out [more...]
34	Dapple	Dapple is a global data explorer designed to provide an open and optimal environment for		Search the Web for spatial data. Search internal DAP servers and known Web servers for spatial data.

		visualizing, presenting and sharing massive quantities of geoscientific data on desktop computers. Dapple lets you browse, discover and display graphically rich data from global and corporate spatial servers – Geosoft DAP servers, NASA servers, USGS servers, and the many, many WMS servers currently available. The Dapple project is an open-source activity sponsored by Geosoft and derived from the NASA World Wind open source project. Dapple represents our effort to make this powerful technology accessible and useful to professional earth scientists.		View geoscience data, satellite imagery, remote sensing data, geology maps, geophysical data, and many other earth data sets of interest to geoscientists. Save an earth view and share your view with colleagues. Add new Geosoft DAP, WMS and ArcIMS servers of interest. View GeoTIFF files. View KML files (2.0.3 beta).
35	CitySurf Globe	Citysurf is a family of neogeography concept software, developed by PiriReis. Citysurf is a new model for serving maps and interacting with the end user and has been created to model and serve raster data at high speed and low bandwidth. Databases such as high resolution satellite images and aerial images are combined with digital terrain models and vector-based geographical information. Citysurf data are distributed across local networks or the internet. Each end user can manage and analyse geographical data through the Citysurf Globe interface.	Fast adaptation and transfer secured data due to special data storage structure. • With OGC Compatiable 3D Server (WMS) excellent quality and fast 2d map rendering. • First professional 3D GIS Api include ActiveX (COM Automation) object. • Dynamic spatial data editing on 3d Client monitor, data stored in Oracle SDO or PostGIS • Serving continuous and instant service to many users thanks to expansion ability and load sharing features. • Perfect adaptation to different authorization needs of your company/organization with flexible authorization models for different user groups (LDAP and Active Directory support)	3D City Information System: Analyzing of the databases stored in local governments according to public needs in 3D platform with CitySurf. Military and Defence Industry: CitySurf incorporates a suite of display and analysis tools tailored to meet the special needs of the defence and intelligence user. Oil, Gas and Electric Industry: CitySurf provides products and services for planning and designing sites, infrastructure and pipelines networks for the Oil ,Gas , Electric industry. Real Estate Industry: Real estate customers can directly benefit from the advanced visualization capabilities of the CitySurf technology when integrated with other complementary technologies such as still photos and panorama imaging. Travel and Tourism: With the CitySurf environment, travel services, property owners and local/city governments can create virtual cities including hotels, restaurants, features and points of interest. 3D Visualization for Civil Engineering: CitySurf can show the presentation process of a project and can assist in visualizing existing 3D models, overlaying your own drawings and GIS layers on the actual terrain.
36	Geoweb3d	product integrates our		Geoweb3d Desktop

		revolutionary new 3D technology with both ESRI's ArcGIS Engine and an embedded web browser. Core integration with ArcGIS ensures GIS interoperability across projects, geodatabases, services, and broader enterprise solutions. The browser engine provides for seamless collaboration, interoperability, discovery, scalability, and delivery of geospatial data via the web. These capabilities all now exist within one easy to use application, enhancing visualization for the Geoweb and for Web GIS. Geoweb3d mashes 3D, ArcGIS, and the Web into one easy-to-use product.		Geoweb3d Desktop is our flagship product, enabling you to create stunning 3D scenes directly from source GIS data. With this product you will be able to load large datasets from a wide variety of file formats and represent them in a multitude of ways. Available representations include thematic overlays, 3D models, and light points that will illuminate surrounding terrain and objects. Geoweb3d is built for high content and high performance. Load high-resolution imagery and terrain. Visualize an entire city's worth of buildings, streetlights, fire hydrants, etc. within minutes, and navigate your creation interactively! You can then group your layers, and instantly turn them on and off in order to look at your data in many different ways, or analyze multiple scenarios. ArcGIS users can directly access their maps and geodatabases. An embedded geoenabled browser lets you move seamlessly between your 3D space and the geoweb. You can see your current location in a variety of web mapping sites, discover data, and access other location-based information. Geoweb3d SDK Geoweb3d SDK lets you embed our unique 3D engine into your own application. It can be integrated into any OpenGL application, or it can be used as a stand-alone visualization component. Geoweb3d SDK can be interfaced using C++, or via an easy-to-use ActiveX component that can easily be embedded into any application, or even in a web page. The versioned API ensures backwards and forwards compatibility. Geoweb3d Viewer For customers that need to share their 3D visualization with remote users that do not have a Geoweb3d license, we provide a free web-embeddable viewer. This viewer is part of the Desktop and SDK product offering and can be distributed at no extra charge. It has all the visualization capabilities of the 3D engine, without the ability to modify the contents of the scene.
37	OSSIM, OsgPlanet	OSSIM is a high performance software system for remote sensing, image processing , geographical information systems and photogrammetry. It is an open source software project maintained at www.ossim.org and has been under active	Designed as a series of high performance software libraries it is written in C++ employing the latest techniques in object oriented software design. A number of command line utilities, GUI tools and applications, and integrated systems have been implemented with the baseline. Many of	Parallel processing capabilities with mpi libraries • Rigorous sensor modelling • Universal Sensor Models (RPCs) • Wide range of Map Projections and Datums supported • Non-destructive, parameter based image chains • Native file access • Precision Terrain correction and orthorectification • Advanced Mosaicing, compositing, and fusions

		development since 1996.	those tools and applications are included with the software releases.	• Elevation support • Vector and shapelib support • Projection and resolution independent • Equation editors • Histogram matching and tonal balancing
38	Fledermaus	Fledermaus Professional is a powerful 3D data visualization system that uses the same core technologies as Fledermaus Standard, plus adds a sophisticated Area Based Editing module, cable and route planning, and real-time tracking of objects. Fledermaus Professional is used in a variety of applications such as swath bathymetry editing and quality control, marine construction, military applications, and coastal zone mapping. Featuring the same intuitive data display as Fledermaus Standard, Fledermaus Professional is capable of visualizing large volumes of data of numerous types in a single 3D scene with the powerful ShiftScapeTM rendering engine. Data display can be controlled with the Bat, an intuitive 6 degree of freedom input device. A wide variety of industry standard formats are supported for direct import of data to the 3D scene, and Fledermaus also allows data from remotely operated vehicles, ships or other entities, to be visualized in real-time. Due to its flexible object oriented software design, Fledermaus can be easily tailored to support many additional visualization modules. If you would like more information on Fledermaus, the full	Contains all of the functionality of the Fledermaus Standard visualization package. Adds a powerful Area Based Editing module for processing data from a wide variety of multibeam, single beam, Lidar, or other data formats. Support for CUBE based statistical based processing with support for uncertainty surfaces, error modelling, and multiple hypothesis editing, QC, and analysis. Track the position of remotely operated vehicles, AUVs, or other vehicles and visualize the object in real-time in a 3D scene. Plan routes for pipelines or cables with the Routeplanner application. Perform sophisticated statistically analysis of multibeam surveys to ensure data quality control.	View some applications of Fledermaus in the industry and in research: Geological Surveys Hydrographic Survey QC Offshore Industry Academic Research Environmental Applications Military Applications Large Immersive Visualization Centers Marine Construction Coastal Zone Mapping Google Earth View some of the technologies available in Fledermaus: The Bat GIS/3D GIS Capability Surface Analysis Imagery Analysis Multibeam-QC Data Real-time Monitoring Data Sharing Movie Animations

		documentation is available online. A free viewer for Fledermaus files named iView3D is also available.		
39	Geodyssey Limited, Hipparchus	is an "open" function library that provides C/C++ and other application developers with the tools to deal with the "where" of things. And, for the first time, recognizes the ellipsoidal shape of the Earth. Hipparchus is the component that provides seamless, lightning-fast access to your geographic databases, "in-the-blink-of-an-eye" rendering of geographical scenes, and (possibly more importantly), an incredibly fast, yet very precise, geospatial calculus. Co-existing with your chosen graphical user interface (GUI) and database management system (DBMS), Hipparchus communicates with your application via C/C++ memory structures.	Hipparchus provides full geographic functionality without forcing a packaged approach. New or existing applications can now deal with the geography of things without requiring the use of the monolithic solution.	
40	SkylineGlobe	Skyline provides software tools for enabling 3D geo-spatial applications. With support for real-time fusion and streaming of massive data sets, open standards and a full API, you can use the SkylineGlobe tools to easily add interactive 3D capability to your application.	Fly through SkylineGlobe to view our highly detailed 3D USA. View street and traffic cameras, weather and other live content. Take your friends or customers on interactive guided tours. Add 3D and animated models like buildings and vehicles to bring your world to life. Develop tools and customize SkylineGlobe using the robust, open API.	For the military, intelligence services and law enforcement we aid in disseminating 3D geographic information for mission planning and rehearsal, asset tracking (vehicle, personnel and equipment) and training & simulation. For the civil engineer or architect, state and local governments, we provide the capability to see the impact of development, visualize new projects and conduct wide-scale planning. For utilities we offer a platform that can support the core operations with location services, the ability to visualize resources above ground, below ground or underwater, in a rich variety of devices and capabilities. In telecommunications, our capabilities assist in deploying next generation services, and provide a platform for deploying location based services. For the web designer and consumer markets we offer a way of increasing sales effectiveness by creating longer visits and providing localized information.
41	Virtual Earth 3-D			
42	Multimap			We've made quite a few changes to the Multimap site! Here are some of the key features we hope you find particularly interesting and useful:

				Basic maps site: The 'Basic maps' site carries the appearance of the new 'interactive maps' site and also includes many new features previously only available on the 'interactive maps' site. The 'basic maps' site has static maps which are non-draggable and you will also be able to use it without having to enable JavaScript. Birds Eye: Birds Eye or 'oblique' imagery, gives a unique perspective by taking images at a 45-degree angle and from four different directions. The imagery is captured by low-flying aircraft and is constantly being expanded and updated. Find A Business: This service allows you to quickly find local businesses and services, get directions to them using our route planner and share what you find with friends and family. Improved travel directions: We now offer you walking directions as well as driving directions; the ability to route between points of interest, as well as between addresses; and directions for even more countries. We also give separate maps for the start and end points as well as for your full journey. Search the web: The 'Search the web' tab will take you away from the Multimap site and onto the 'Bing' homepage powered by Microsoft. And much, much more! We're very excited about all the new features and functions we've added to our award-winning Multimap site. We hope you agree that they make the site even more user-friendly and an even better tool to help you navigate your world.

Source: Alan Glennon at http://geography2.blogspot.com/2005/11/listing-of-virtual-globes.html

APPENDIX B

USABILITY ANALYSIS OF VIRTUAL GLOBES BASED APPLICATIONS

USABILITY TESTING – PART 1

TASK 1:
Open the follow URL: http://seamap.env.duke.edu/datasets

8. Identify the number of sea turtles near to Cabo verde from 2004 – 2006.
9. Add an Environmental layer related to chlorophyll content.
10. Do you understand what the meaning of SST and SSH are?
11. Can you get any information about the time series option?
12. Can you know how many species of sea birds, marine mammals and sea turtles are available on the entire database?
13. How many providers of information are?
14. Can you get information about the status of protection of the seabirds?

Please complete the provided questionnaire.

TASK 2:
Open the following URL: http://www.earthknowledge.net/home/

8. What type of information can you expect to find in the page?
9. Find the "Map Tool" tab.
10. If you want to view the users of the page around the world, by country for example; do you understand the color representation used?
11. When you select a topic of interest what kind of information about it do you get?
12. Is this information useful for you?, if yes, in which sense?
13. Are you able to understand the meaning of the used symbols?
14. Please find information about the Amazon Basin in South America.

Please complete the provided questionnaire.

USABILITY TESTING - PART 2

Please fill out the provided questionnaires, one for each task.

USABILITY TESTING - PART 3

In this section some WebPages will be analyzed contained information related to statistical data dissemination and specifically the way this information is represented in a cartographical point of view.

1. http://www.londonprofiler.org/

    - Display the census output area classifications. Do you understand de meaning of the display options?. Do you understand what the polygons are?
    - Select output area classification groups UK
    - Analyze the map. Do you understand the shown classes?
    - Are you able to identify the different classes on the map?
    - Can you have an idea about the area of a certain class or the percentage of the class compared with the other classes?
    - Index of Multiple Deprivation. Select the Income parameter
    - Do you understand the meaning of the color scheme names? Values?
    - Display data for 2004 and then for 2007. Can you see the differences?
    - What do you consider is needed in order to get more useful information from these maps?
    - Analyze the different ways of representing transport data. Do you understand those representations?
    - Analyze the house prices option. Can you select some post code district? Does the page give you the opportunity to solve this problem? Try pressing the Help button. Are you able to find the postcodes information?

2. http://thematicmapping.org/techniques/
    - http://blog.thematicmapping.org/2008/04/making-proportional-symbols-in-kml.html. Analyze the usability and usefulness of this type of maps. What is missing? What else should they have?. How useful is? Would you use them in your work?.
    - http://blog.thematicmapping.org/2008/06/proportional-symbols-in-three.html. Give your impression about the legend.
    - http://blog.thematicmapping.org/2008/04/using-google-charts-with-kml.html. Analyze the different ways of presenting information. Which done do you think is better, more understandable and useful?. Which is the best for you?. Why?.

3. http://www.ine.gov.bo/

    - Search information about the Census 2001. Select Population as example.
    - Analyze the existent maps on the page. Analyze the representation of the information and the cartographic style.
    - Please mention the positive and the negative aspects of the available maps. (Like representation type, information content, interactivity, etc.)
    - How do you think they should be? It is possible to improve it?. It is needed to improve them?. What is missing?. What is needed?
    - Would you like to see the same type of information running over a Google Earth interface?. Do you think this would give more usefulness? Do you think this is needed?. In which cases would you use it?

APPENDIX C

QUESTIONNAIRES

Instructions: **Participant #**

Based on your experience on similar applications, please rate your agreement with the following statements about how you feel in general when using, the application _____. Just circle or X out the level of agreement that applies (where 1 means strongly disagree, 4 means neither disagree nor agree, and 7 means strongly agree; and NA means it doesn't apply).

Would like to be used for frequent and occasional users	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
I am not satisfied with it	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It is simple to use	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It is wonderful	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It is not useful	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
I find to many inconsistencies while using it	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It is boring to use it	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It makes everything I expect and I need to do	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It requires to much steps to accomplish what I want to do with it	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It is user friendly	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
I don't like the user interface	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It would help me be more effective	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It would help me in some work activities	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
I do not need it	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
I can use it successfully every time	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree

It is not flexible	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
I learned to use it quickly	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It helps me to do things quickly	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
I can not recover from mistakes quickly and easily	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It would help me be more effective	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
Organization of the screen is not clear	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
Use it requires to much effort	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
I can use it without written instructions	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It does not meet my needs	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
The interface is grateful	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It works the way I want it to work	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It helps me to perform my work in an efficient way	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It would not save me time when I use it	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
I easily remember how to use it	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
I quickly could become skilful with it	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It is not pleasant to use	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It is complicated to use it	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
I would recommend it to a friend	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It would not help me be more productive	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
In general, the application satisfied me	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
It is easy to learn to use it.	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree
Help information (online help, screen messages, etc.) is not useful/clear	Strongly disagree	1	2	3	4	5	6	7	NA	Strongly agree

APPENDIX D

REACTION ADJECTIVES LIST

Step 1: Read over the following list of words. Considering the product you have just used, tick those words that best describe your experience with it. You can choose as many words as you wish.

Randomise word list

Accessible	Effortless	Ordinary
Advanced	Empowering	Organised
Ambiguous	Energetic	Overwhelming
Annoying	Engaging	Patronising
Appealing	Entertaining	Poor quality
Approachable	Exciting	Powerful
Attractive	Expected	Predictable
Awkward	Familiar	Professional
Boring	Fast	Relevant
Bright	Faulty	Reliable
Business-like	Flexible	Responsive
Busy	Fresh	Rigid
Clean	Friendly	Satisfying
Clear	Frustrating	Secure
Cluttered	Fun	Simple
Compelling	Hard to Use	Simplistic
Complex	High quality	Slow
Comprehensive	Illogical	Sophisticated
Confusing	Impressive	Stable
Consistent	Inadequate	Stimulating
Contradictory	Incomprehensible	Straightforward
Controllable	Inconsistent	Stressful
Convenient	Ineffective	System-oriented
Counter-intuitive	Innovative	Time-consuming
Creative	Insecure	Time-saving
Credible	Intimidating	Too technical
Cutting edge	Intuitive	Trustworthy

Dated	Irrelevant	Unattractive
Desirable	Meaningful	Unconventional
Difficult	Misleading	Understandable
Distracting	Motivating	Unpredictable
Dull	New	Unrefined
Easy to use	Non-standard	Usable
Effective	Obscure	Useful
Efficient	Old	Vague

Step 2: Now look at the words you have ticked. Circle five of these words that you think are most descriptive of the product.