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Master's thesis

Research on Geovisualization Methods and Technology for The WikiGlobe System

Study Programme: Geodesy and Cartography

Field of Study: Geoinformatics

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Abstract

The main goal of the thesis is to conduct a research on geovisualization methods and technology of the WikiGlobe system, a project developed at Beihang University by a team of GIS software-specialized students under the guidance of Prof. Weng Jingnong from the College of Software. WikiGlobe project can be seen as "Wikipedia on Digital Globe" and its purpose is to merge 3D virtual globe with different kinds of information, such as text, audio recordings or video. It has its own SDK, which is based on NASA World Wind Java SDK, a technology for displaying 3D virtual globe. The research is maintained by developing *Great Places WikiGlobe*, an application incorporating 100 Great Places of History according to the book *Great Places of History: Civilization's 100 Most Important Sites: An Illustrated Journey*, published by TIME. About every site, data is collected and then displayed in a user-friendly and logical way with an extensive use of geovisualization methods. Even though the main part of the thesis is connected to the application, its workflow and methodology, a sufficient interest is also given to a research on the literature describing the terms Digital Earth and Virtual Globe as both of the terms are very closely related to each other. A very precise description of NASA World Wind Java SDK as a technology being extensively used in application's development is convened as well.

Key words : NASA World Wind Java SDK, Virtual Globe, Digital Earth

Abstrakt

Hlavným cieľom tejto diplomovej práce je výskum geovisualizačných metód a technológie systému WikiGlobe, projektu realizovanom na Beihang univerzite tímom študentov špecializovaných na vývoj GIS softvéru pod vedením profesora Weng Jingnong. WikiGlobe projekt môže byť popísaný ako „Wikipédia na Digitálnom Glóbe“ a jeho hlavným cieľom je dosiahnuť zlúčenie technológie zobrazujúcej 3D virtuálny glóbus s rozdielnymi druhmi informácií, ako je text, zvuková nahrávka alebo video. Disponuje svojím vlastným SDK, založeným na NASA World Wind Java SDK, technológii ktorá umožňuje zobraziť 3D virtuálny glóbus. Výskum je realizovaný prostredníctvom vývoja aplikácie s názvom *Great Places WikiGlobe*, ktorá má za úlohu implementovať 100 najdôležitejších miest histórie vzhľadom ku knihe *Great Places of History: Civilization's 100 Most Important Sites: An Illustrated Journey*, vydanou nakladateľstvom TIME. O každej pamiatke sú zozbierané potrebné data a zobrazené v aplikácii užívateľsky príjemne a logicky. Práca sa, okrem popisu metódologie a postupu pri vytváraní aplikácie, zaoberá taktiež rešeršé literatúry ohľadom pojmov Digitálna Zem a Virtuálny Glóbus nakoľko sú si navzájom veľmi blízko prepojené. Veľmi podrobne je taktiež popísaná NASA World Wind Java SDK, technológia nezbytná pri tvorbe aplikácie.

Kľúčové slová: NASA World Wind Java SDK, Virtuálny Glóbus, Digitálna Zem

Declaration of authorship

Hereby I declare that I have completed the Master thesis called *Research on Geovisualization Methods and Technology for The WikiGlobe System* by myself. Literature used and all other references are mentioned in the Bibliography.

In Prague, May 17th, 2013 ....

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Finally, I would like to thank my family, without whom this thesis would never be a reality, for their financial and psychological support during my whole studies at either CTU Prague or Beihang University.

Contents

Introduction

Today's world is the world of the information. A new wave of technological innovation is allowing us to capture, store, process and display an unprecedented amount of information about our planet and a wide variety of environmental and cultural phenomena [7]. The most of this information refers to a specific place on the Earth, i.e. it is georeferenced. We call this data geospatial data and the information derived from it geospatial information.

The amount of geodata that large spatial databases have to deal every day with is incredibly huge. *Examples are the terabytes of georeferenced data generated daily by Earth Observation Satellites, census databases and large databases of climate and environmental data* [12]. The question that arises from managing such flood of geospatial information is how to manage and take an advantage of this data, how to turn them into an understandable information. Satellite systems, such as Landsat, is capable of taking the digital images of the whole planet every two weeks, which gives us a great number of such images for 20 years of its working. Viewing these images one by one would be ineffective and not helpful in terms of finding any valuable information or spatial pattern in this data.

The solution for this issue was firstly presented by former U.S. vice-president Al Gore during his speech in 1998 in California. He spoke about the project called Digital Earth, which described as a *" ... multi-resolution, three-dimensional representation of the planet, into which we can embed vast quantities of georeferenced data"* [7]. He saw the way of depicting geographic information on the globe as a very revolutionary attempt of displaying geodata that will be understandable at the same time.

Al Gore's innovating idea turned into creation of many different projects. One such example is Google^{TM} Earth, one of the phenomena of these days, being widely used by millions of people at their home. In 2004, a group of engineers in NASA[1] came up with the project called NASA World Wind. They created a so-called virtual globe, a 3D model representing the Earth. Since NASA has more planetary information than any other organization in the world, the software's population was increasing rapidly. Different geovisualization technologies, that time revolutionary, were implemented. For example, the user could zoom from a space altitude onto the whole Earth covered by the satellite imagery, or, in contrary, zoom into a particular place on the Earth and look on its features. He could plan a journey from New York to Beijing by exploring the route and measuring the length between the cities. All of that could be done within a short time and for free, what in a real world would cost much money.

The goal of this Master thesis is to give a deeper look into geovisualization techniques that NASA World Wind Java SDK is equipped with. This research is conducted via creating the WikiGlobe application called *Great Places WikiGlobe.* WikiGlobe is a project undertaken by a team of GIS-specialized students at Beihang University for many years with the basic idea of putting the 3D globe together with different kind of information, such as text, audio recordings or video. It disposes with its own SDK, which is based on above mentioned World Wind Java SDK. The application is incorporating 100 Great Places of History according to the book *Great Places of History: Civilization's 100 Most Important Sites: An Illustrated Journey* published by TIME Home Entertainment.

The remainder of the thesis is organised as follows: the chapter 2 serves as a theoretical background of the thesis, where sufficient interest is given to a research on the literature describing the terms Digital Earth and Virtual Globe as both of them are very closely related to each other. A very precise description of World Wind Java SDK as a technology being extensively used in application's development is convened as well. The chapter 3 describes the workflow of the application's development as well as methods and technology needed for it. In the chapter 4, the results are depicted. Chapter 5 offers the conclusion of the thesis together with the discussion, where future possible work is outlined.

[1]National Aeronautics and Space Administration

Chapter 1

Theoretical background

This chapter serves to clarify and get better understanding of the terms being continuously used in this thesis and so Digital Earth and Virtual Globe. The first section deals with the term Digital Earth, its evolving over time, the technology hidden behind it and an initiative in scientific, commercial and academic areas. The second section describes the term Virtual Globe and its connection to Digital Earth in terms of the development. It is also listing the most famous virtual globes today with pointing out Google Earth as the leader on the market within this technology. Last section serves as a deep introduction into NASA World Wind, one of the virtual globes being developed these days. Firstly, it explains the difference between two its applications: WorldWind.NET and World Wind Java SDK. Afterwards, the process of data retrieval is outlined, together with mentioning all the digital imagery this virtual globe disposes with.

1.1 Digital Earth

1.1.1 Definition

It was January 31, 1998 when an US vice-president Al Gore (Figure 1.1) mentioned the term Digital Earth for the first time in its relatively short history. This all happened during one of his speeches given at California Science Center in Los Angeles. Speaking to the crowd, he described Digital Earth as *" ... a multi-resolution, three-dimensional representation of the planet, into which we can embed vast quantities of geo-referenced data"* [7]. He tried to outline its potential use by giving the following example (a passage extracted from his speech):

"Imagine, for example, a young children going to a Digital Earth exhibit at a local museum. After donning a head-mounted display, she sees Earth as it appears from space. using a data glove, she zooms in, using higher and higher levels of resolution, to see continents, then regions, countries, cities, and finally individual horses, trees, and other natural and man-made objects. Having found an area of the plant she is interested in exploring, she takes the equivalent of a "magic carpet ride" through a 3-D visualization of the terrain. Of course, terrain is only one of the many kinds of data with which she can interact. Using systems' voice recognition capabilities, she is able to request information on land cover, distribution of plant and animal species, real-time weather, roads, political boundaries, and population" [20].

Figure 1.1: Former US vice-president Al Gore.

To fulfil this vision, according to [7] there was a need to merge following technologies: *Computational Science, Mass Storage, Satellite Imagery, Broadband Networks, Interoperability* and *Metadata*. Each of them would play an important role in creating a global, collaborative linking of systems. *Computational Science* is a technology that is all around us in every aspect of our life. Al Gore said that *" ... with high-speed computers as a new tool, we can simulate phenomena that are impossible to observe, and simultaneously better understand data from observations ... modelling and simulation will give us new insights into the data that we are collecting about our planet"* [7]. *Mass Storage* is another important element in the process of Digital Earth's development as it is obvious that creating Digital Earth would require storing billions of bytes of information. *Satellite Imagery* would fulfil its importance as a very rich source of data. Taken into account number of satellite images provided by for example Landsat satellite every day, it would give the whole technology another dimension. *Broadband Networks* would play their role in connecting all the servers storing data by thousands of different organizations. *Interoperability* could not be omitted as there would be a huge need for stating a protocol upon which all the geographic information produced would become compatible and readable by different application software. Finally, *Metadata*, also known as data about data, would be the last piece of imaginary puzzle. It would provide us with extremely useful information of let's say imagery, with its name, location, data format or resolution. Here we have to understand that technologies which seem to be for us a natural part of our life and science nowadays, have not been truly realized 15 years ago.

From the example with the young girl mentioned above, one could see Google Earth as being the perfect example of Digital Earth application. After all, the following extraction of Al Gore's speech includes Virtual Globe as a technology incorporated within Digital Earth:

"A Digital Earth could provide a mechanism for users to navigate and search for geospatial information-and for producers to publish it. The Digital Earth would be composed of both the user interface - a browsable, 3D version of the planet available at various levels of resolution, a rapidly growing universe of networked geospatial information, and the mechanisms for integrating and displaying information from multiple sources" [7].

In a scientific community, however, different authors offer different perspectives towards this issue while using different terminology as well. Majority of them call Google Earth Virtual Globe or geobrowser rather than Digital Earth. There is no clear "yes" or "no" answer on the question whether geobrowsers could be considered being Digital Earth. Grossner and Clarke [20] say that *"Google Earth is fun, and it is breakthrough technology with terrific potential, but it is simply not that (Digital Earth)"*. They argue Google Earth (or any other geobrowser being used nowadays) is just a part of Digital Earth system and *" ... a notable advance in virtual globe interfaces and geographic visualization that will inform any digital earth system going forward"*. Madden et al. [11] also call Google Earth

Virtual Globe rather than Digital Earth. Foresman [18] sees creation of geobrowsers as a transition point in Digital Earth community. He stresses an importance of its release and says ”*... Digital Earth vision can be expressed as reaching its first operational phase with the advent of multiple commercial and government web-based 3D geobrowsers.”* Guo et al. [16], on the other hand, consider Google Earth as an example of commercial Digital Earth systems. The same pays for Wang et al. [10] who see 3D geobrowsers as Digital Earth Science system.

As can be seen from the previous paragraph, opinions regarding whether Digital Earth and Virtual Globe (or geobrowser) should be considered as one system, differ. Looking back to the past and taking into account the words spoken by Al Gore, it looks like Virtual Globe cannot be truly considered being Digital Earth. Digital Earth, in a vision of former US vice-president, should be a system that *” ... will include not only high-resolution satellite imagery of the planet, digital and economic, social and demographic information. If we are successful, it will have broad societal and commercial benefits in areas such as education, decision-making for a sustainable future, land-use planning, agricultural and crisis management.”* [7]. As virtual globes do not meet all the mentioned requirements, then, in this work, Virtual Globe and Digital Earth are regarded as two different terms, however, and this has to be stressed, closely related to each other. Because of that reason, a first part of this chapter deals with the development of Digital Earth, since advent of geobrowsers can be regarded as an important step in order to realize the Gore’s vision.

1.1.2 Digital Earth Initiative

It has been 15 year since the term Digital Earth has been mentioned for the first time. During this time period, a lot of effort have been put in order to try to fulfil the vision outlined by former US vice-president. While at the beginning it has been mainly research community (USA, China) putting the idea of Digital Earth technology forward, later on, commercial sector has also given a valuable input into it by creating already mentioned geobrowsers.

The first country that took part in developing Digital Earth was USA. During the three years between 1998 and 2001, a US Government sponsored ”Digital Earth Initiative”, coordinated by the Interagency Digital Earth Working Group (IDEWG), and chaired by the National Aeronautics and Space Administration (NASA), sought to realize the Gore's vision to priorities outlined in the speech: *"In the first stage, we should focus on integrating the data from multiple sources that we already have"* [7]. The group itself has specialized on the following sectors defining the early concept for Digital Earth: visualization and exploration, education and outreach, science and applications, advanced display sites, data access and distribution and standards and architecture. Government patricipants of IDEWG included representatives from NOAA, USGS, USACE, EPA, USDF and NSF[1]. Major standard associations taking part in IDEWG were the Open Geospatial Consortium (OGC), the Global Spatial Data Infrastructure (GSDI) and the International Standards Organization (ISO).

The three-years working effort of IDEWG resulted into development of widely known and accepted Web Mapping Service (WMS) and Digital Earth Reference Model (DERM) in order to define standards and architecture guidelines of Digital Earth. The workshops organized by IDEWG became visited by more and more representatives from industry and academia. By march 2000, over dozens of Digital Earth 3D prototypes, called also Digital Earth Alpha version, were presented by different industries. Within two years, these prototypes were captivating international audiences in government, business, science, and mass media who began to purchase the early commercial geobrowsers (Figure 1.2, more about geobrowser in the section 1.2). Therefore we can call the advent of geobrowsers becoming a symbolic harbinger for the Digital Earth initiative.

After 2001, the banner raised for Digital Earth Initiative lowered down and the coordination of related activities was taken up by Geospatial Applications and Interoperability (GAI) working group, a part of the US Federal Geographic Data Committee (FGDC), formed in 1990 [20]. This working group remained active until 2004. During these three years, a couple of achievements were made, from which the biggest one was a development of Geospatial Interoperability Reference Model (GIRM). By 2008, Digital Earth initiatives in US Government were limited primarily to NASA's World Wind (more about it in section 1.3), Earth Observatory programs and NOAA's Science on a Sphere [18]. Besides governmental support of Digital Earth, there were also academia and industry taking part in its development, however, being not so active as could be expected. IDEWG documents

[1] National Oceanographic and Atmospheric Administration (NOAA); US Geological Survey (USGS); US Army Corps of Engineers (USACE); Environmental Protection Agency (EPA); US Department of Agriculture (USDA); National Science Foundation (NSF)

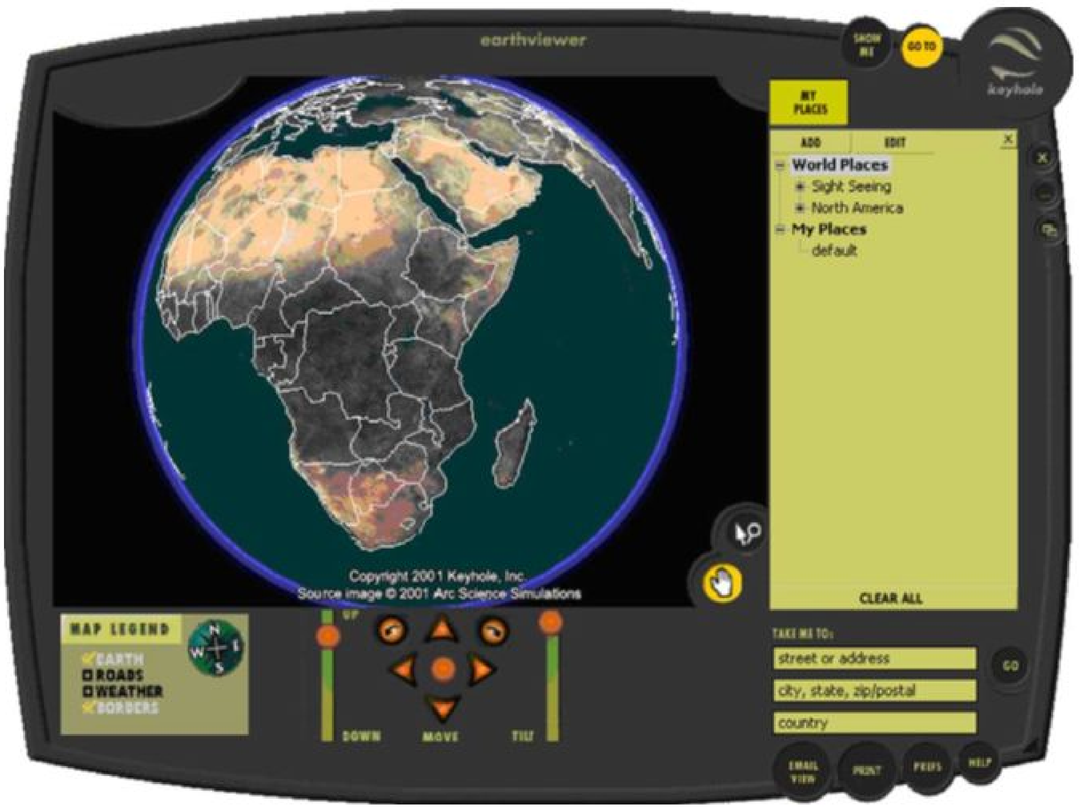


Figure 1.2: First international showing of Earthviewer® geobrowser in Nairobi, Kenya 2001.

mentioned only University of Maryland and GIS software developers, ESRI®, as only two representatives from either academia or industry involved in the process of development of Digital Earth in USA.

1.1.3 Academic platforms of Digital Earth

One academic organization, that has been playing an important role in the development of Digital Earth, is Chinese Academy of Sciences[2] (CAS), concretely its Institute for Remote Sensing Applications. CAS has led an international collaboration for Digital Earth concept and its activity was mirrored in sponsoring International Symposium on Digital Earth (ISDE), where the first ISDE was organised by CAS in Beijing in November 1999. CAS has also initiated a founding of International Society for Digital Earth (ISDE) together with the experts and scholars from more than 10 countries, such as China, Canada, USA, Japan, Russsia and Czech Republic [16].

[2] http://english.cas.cn/

Series of International Symposia on Digital Earth

As mentioned above, the first ISDE was convened in Beijing in November 1999. From that time on, every odd year the event was repeated with another country hosting it. Starting from 2006, because of increasing influence of Digital Earth, apart from ISDE, Digital Earth Summit (DES) was another event being organized. Unlike to ISDE, DES was convened every even year and was focusing more on special themes than on Digital Earth concept in general. The list of all ISDE/DES can be found in the Table 1.1.

ISDE/DES events			
Event	**Year**	**Location**	**Theme**
ISDE 1	1999	Beijing, China	Moving towards Digital Earth
ISDE 2	2001	New Brunswick, Canada	Beyond Information Infrastructure
ISDE 3	2003	Brno, Czech Republic	Information Resources for Global Sustainability
ISDE 4	2005	Tokyo, Japan	Digital Earth as a Global Commons
DES '06	2006	Auckland, New Zealand	Information Resources for Global Sustainability
ISDE 5	2007	Berkeley, USA	Bringing Digital Earth down to Earth
DES '08	2008	Potsdam, Germany	Geoinformatics: Tools for Global Change Research
ISDE 6	2009	Beijing, China	Digital Earth in Action
DES '10	2010	Nessebar, Bulgaria	Sharing Information, Building Knowledge
ISDE 7	2011	Perth, Western Australia	The Knowledge Generation
DES '12	2012	Wellington, New Zealand	

Table 1.1: Series of ISDE/DES events.

The 1st ISDE, taking place in Beijing, was attended by more than 500 scientists, engineers, educators, managers and industrial entrepreneurs from 20 countries. The three days event resulted in creating a document *Beijing Declaration on Digital Earth* [27] stating the motivation for creating Digital Earth, its future goals and importance in achieving global sustainable development. The advent of ISDE made a successful impact on chinese government that included Digital Earth technology into its 5-year plan [18]. The 2nd ISDE held in New Brunswick showed a strong support for Digital Earth vision as well as presented Canada as a highly-developed country in geographic information. The main goal of the 3rd ISDE in Brno was to prove the ability of Digital Earth to assist in global sustainable development. Tokyo, Japan was a host of the 4th ISDE that provided *" ... evidence of regional collaboration for Digital Earth ... in the activities, such as the Digital Asia Network"* [18]. The goal of the 5th ISDE in Berkeley was *" ... to demonstrate the* *pace of the world's leading countries in Digital Earth construction"* [10]. 10 years after the 1st ISDE was convened in Beijing, its 6th continuation took place again at the same place. And again, a document *Beijing Declaration on Digital Earth* [27] was presented and somehow highlighted the advance in Digital Earth development that has happened during previous 10 years. The 7th, and until now the last ISDE was convened in Perth and explored the role Digital Earth played in economic and social sustainable development, environmental protection, disaster mitigation, natural resource conservation and improvement of human being's living standard [26].

Apart from ISDE, a series of DES has been convened continuously every 2 years from 2006. The DES '06, which took place in Auckland, represented the most significant scientific gathering ever held in this part of the world [28]. It focused on the most important issue in last decade – long-term survival. The importance of Digital Earth as a technology to ensure the global sustainability was stressed. Two years later, DES '08 was held in Potsdam and its main goal was *" ... to discuss a role of digital earth science and technology, especially geoinformatics, in global change issues, which has significant meanings"* [29]. The DES '10 in bulgarian Nessebar focused on the role that Digital Earth played in the society and sustainable development at a local and regional level [29]. Last year, DES '12 was organized in Wellington with three main work streams: Digital environment, Resilient cities and Growing up digital [31].

International Society for Digital Earth

International Society for Digital Earth (ISDE)[3] is a *" ... non-political, non-governmental, and not-for-profit international organization initiated by the CAS with the collaboration of institutes and related scholars throughout the world. The ISDE secretariat is hosted by the Center for Earth Observation and Digital Earth, CAS. Prof. Lu Yongxiang serves as the founding president of the ISDE"* [16]. It was established in 2006 with the aim *" ... to promote international cooperation of Digital Earth vision and enable Digital Earth technologies to play key roles in, inter alia, economic and socially sustainable development, to promote information technology and to reduce the digital gap"* [14]. From 2006 on, both bi-annual symposia and summits were convened under the auspices of ISDE. It is worth it to mention that former US vice-president Al Gore, from who the vision of Digital Earth

[3]`http://digitalearth-isde.org/`

was predicted, acts as the Special Advisor of the Society.

Figure 1.3: A logo of ISDE.

International Journal of Digital Earth

One of the big achievements made by ISDE was a release of the electronic journal focusing on Digital Earth issues, International Journal of Digital Earth (IJDE). It was launched with a cooperation of Taylor & Francis Group in March 2008. IJDE is *" ... an international, peer-reviewed research journal and it is the first professional journal in the field of Digital Earth"* [16]. It serves as a response to the Digital Earth initiative and focuses on Digital Earth applications that can improve human conditions, protect the environment and support sustainable development. The International Editorial Board of IJDE includes 23 experts from 16 different countries. It is likely that IJDE is going to play an important role in a future research of Digital Earth.

1.2 Virtual Globe

1.2.1 Definition

Virtual Globe is a 3D software model or representation of Earth or another world [6]. It provides user with an ability to move around the globe, zoom in/out, view the globe from a different angle and position. As being mentioned for couple of times before, advent of the geobrowser can be regarded as the first milestone in the development of Digital Earth according to the vision of Al Gore.

Virtual Globe is a term closely related with the term (3D) geobrowser. Because of that, many authors do not distinguish between them, such as Grossner and Clarke [18], who

Figure 1.4: A cover of IJDE.

even put these two terms together and call Google Earth *"virtual globe geobrowser"* software. Foresman [18] uses only the term geobrowser, while Madden et al.[11] call it virtual globe. Guo et al.[16] regard Google Earth and other virtual globes being *"commercial Digital Earth systems."*

1.2.2 Development of virtual globes

In 2000, the United Nations Environment Programme (UNEP) applied Digital Earth architecture in order to design its data and information resources. The application UNEP.Net was based on GSDI/DERM architecture, that is, a network of databases creating a framework of linked servers, incorporating that time advanced GIS tools and its capabilities. However, there was clearly a need for a universal interface, that could be easily operated by non-scientists as well. *UNEP began actively testing prototypes for UNEP.Net geobrowser beginning in mid-2001 with a showcase for the African community displayed at the 5th African GIS Conference in Nairobi, Kenya in November 2001* [18]. Lot of prototypes were presented, among which the most promising were Keyhole's Earthviewer® (Figure 1.2) and the Goefusion's Geoplayer®. At the same time, NASA was hard at building its own virtual globe called NASA World Wind, being firstly released in 2004.

The demand for creating prototypes for 3D geobrowsers became such huge that a document called *Functional User Requirements for geobrowsers* was proposed in order to define the requirements that common user of geobrowser would have on this system. The proposal was sent to the ISDE Secretariat and organising committee for the 3^{rd} ISDE and together with CAS an agreement was made to host the first of the geobrowser meetings. *In December 2002, the 1^{st} International Digital Earth Workshop (IDEW) was hosted by the newly constituted ISDE secretariat to review the status of visualization and geobrowser technological advances* [18]. It was such a great success that a series of similar events focusing on 3D geobrowsers were convened. During the ISDE5, which was held in Nessebar in Bulgaria, a maturity of geobrowsers was so big that it started to find its use in different areas and applications for humanitarian, environmental protection and community empowerment were presented.

Despite a huge scientific effort given to the development of geobrowsers, the biggest breakthrough in its history was made in a commercial sector by the release of Google Earth presented by Google^{TM}. The advent of Google Earth as a free commercial product brought the idea of Digital Earth to the home of millions of users of the internet, what significantly increased the popularity of this system. Zooming from a birds-eye (or satellite's) 3D view of the planet to hovering helicopter-like over the site of a news event has become commonplace, thank to the unique technology developed by Keyhole®. *While Google Earth was not the first virtual globe geobrowser software, it has been easily the most successful with having more than 100 million product activations by June 2006* [20]. Later on, in November 2006, Microsoft® entered the market of virtual globes as well with Virtual Earth 3D® (Figure 1.5) application that was similar to Google Earth in terms of its functionality but was lacking the number of users. At the same time, ESRI came up with ArcGIS® Explorer (Figure 1.6), a client of its ArcGIS® Server. It differed from the other geobrowsers in a way that it was a "true" GIS application allowing users queries and analysis on the underlying data.

1.2.3 List of virtual globes

During last decade, many different virtual globes were produced. To keep it all organized, here is the list of most famous and used virtual globes today according to [6]:

- NASA World Wind;

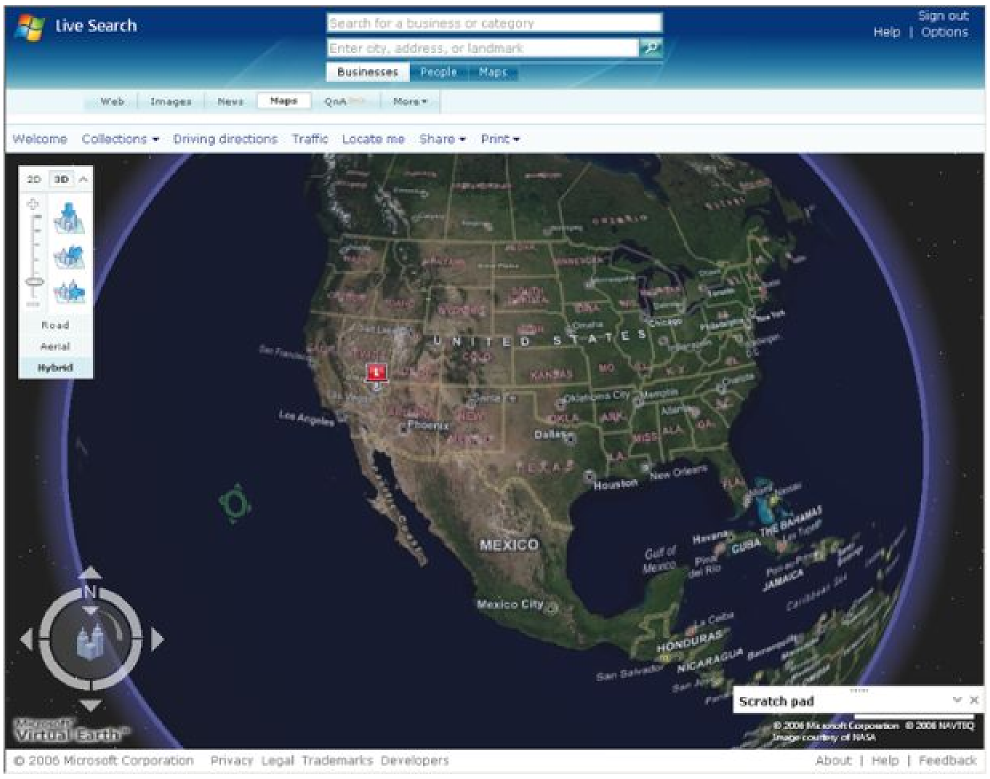


Figure 1.5: Microsoft Virtual 3D.

- CitySurf Globe;
- Bing$^{®}$ Maps 3D (previously Microsoft Virtual Earth 3D);
- Worldwide Telescope;
- Google Earth;
- Marble;
- OpenWebGlobe;
- Cesium;
- ArcGIS Explorer;
- EarthBrowser;
- Earth 3D;
- Bhuvan.

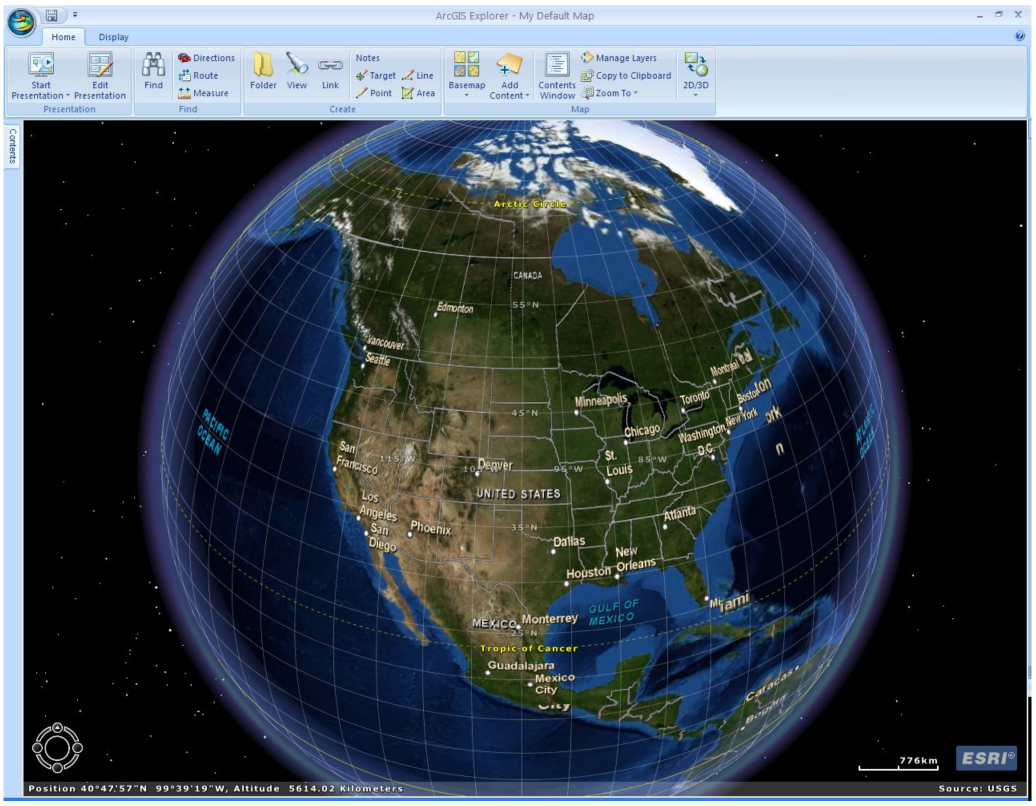


Figure 1.6: ArcGIS Explorer.

Every virtual globe will be briefly presented in the following part of the text. NASA World Wind will be deeply described in section 1.3.

Google Earth *Google Earth*[4] *is a virtual globe, map and geographical information program that was originally called EarthViewer 3D, and was created by Keyhole, Inc., a Central Intelligence Agency (CIA) funded company acquired by Google in 2004* (Figure 1.7) [6]. As has been already mentioned, Google Earth is the most famous virtual globe these days and the one that changed the direction in the development of Digital Earth. Currently, it is available under two licenses (previously three): a free version Google Earth and paid Google Earth Pro, which is intended for commercial use.

It is a cross-platform application available on personal computers running Windows 2000 and above, Mac OS X 10.3.9 and above and Linux kernel 2.6 or later. Google Earth can be used as a desktop application, mobile application as well as a browser plug-in. In addition to this, Google also added the imagery from Earth database into their web-

[4]`http://www.google.com/intl/cs/earth/index.html`

based mapping application, Google^{TM} Maps [6]. The user can view the Earth in 3D by using Digital Elevation Model (DEM) collected by USGS. Another interesting feature is its own developed language for managing geospatial data, Keyhole Markup Language (KML), allowing user to add his own data into the application. As of October 2011, this application has been downloaded for more than a billion times.

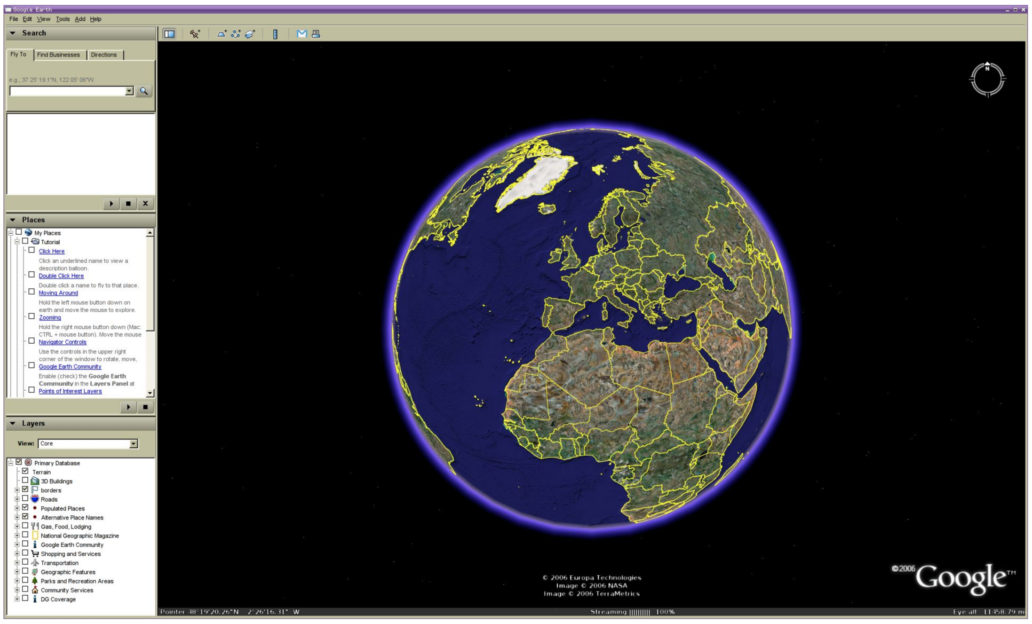


Figure 1.7: Google Earth.

CitySurf Globe CitySurf Globe[5] is developed by PiriReis Bilişim Teknolojileri and is known as a new model in mapping servers and interaction with the end user (Figure 1.8). It models raster data, such as satellite images under using high-speed digital terrain model and vector geographical information systems and accordingly serves that via internet or local nets. With its OpenGL-based viewer connecting to the server for streaming data is similar to Google Earth, Bing Maps or ArcGIS concept.

Bing Maps *Bing Maps*[6] *is a web mapping service provided as a part of Microsoft's Bing suite of search engines and powered by the Bing Maps for Enterprise framework* [6]. In order to view 3D maps (Figure 1.9), a user is required to install plug-in. An interface runs in Internet Explorer and Mozilla Firefox and uses NASA Blue Marble:Next Generation globe cover imagery. It lets users see the buildings in 3D with ability to rotate it, tilt

[5]`http://www.citysurf.com.tr/en/index.asp`
[6]`http://www.bing.com/maps/`

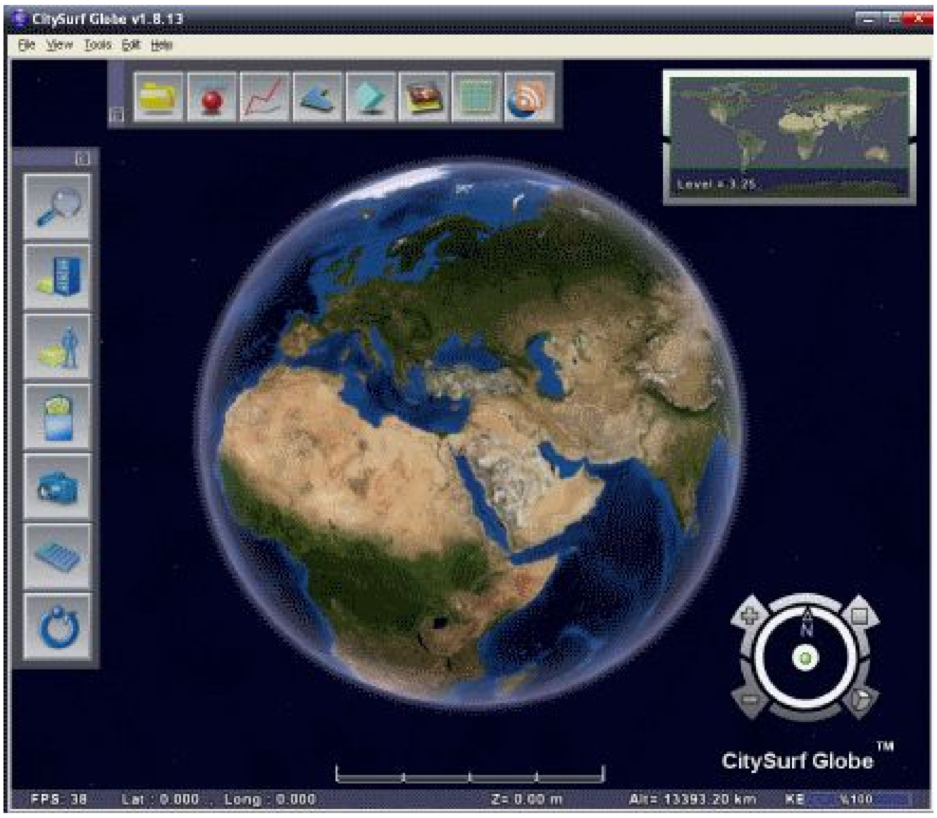

CitySurf Globe v1.8.13
File View Tools Edit Help
Level = 3.25
CitySurf Globe™
FPS: 38 Lat: 0.000 , Long: 0.000 Z= 0.00 m Alt= 13393.20 km KB %100

Figure 1.8: CitySurf Globe.

the angle of the globe, pan and zoom in/out. Besides controlling the 3D interface with a mouse or keyboard, it is possible to explore it using Xbox360 controller or another game controller in Windows 7, Windows Vista or Windows XP.

WorldWide Telescope *WorldWide Telescope*[7] *features an Earth mode with emphasis on data import/export, time-series support and a powerful Tour authoring environment* (Figure 1.10) [6]. Created by Microsoft, it displays astronomical sky, 3D Universe as well as earth science data. Images were taken by Hubble Telescope (which is not in operation anymore) and approximately ten earth-bound telescopes. The program runs on Microsoft Windows or a web client based on Silverlight[8].

Marble Marble[9] is an open-source software with data provided by OpenStreetMap as well as NASA Blue Marble:Next Generation imagery (Figure 1.11). It is a part of

[7]`http://www.worldwidetelescope.org/Home.aspx`
[8]Microsoft Silverlight is an application framework for running rich Internet applications, similar to Adobe Flash.
[9]`http://www.openwebglobe.org/`

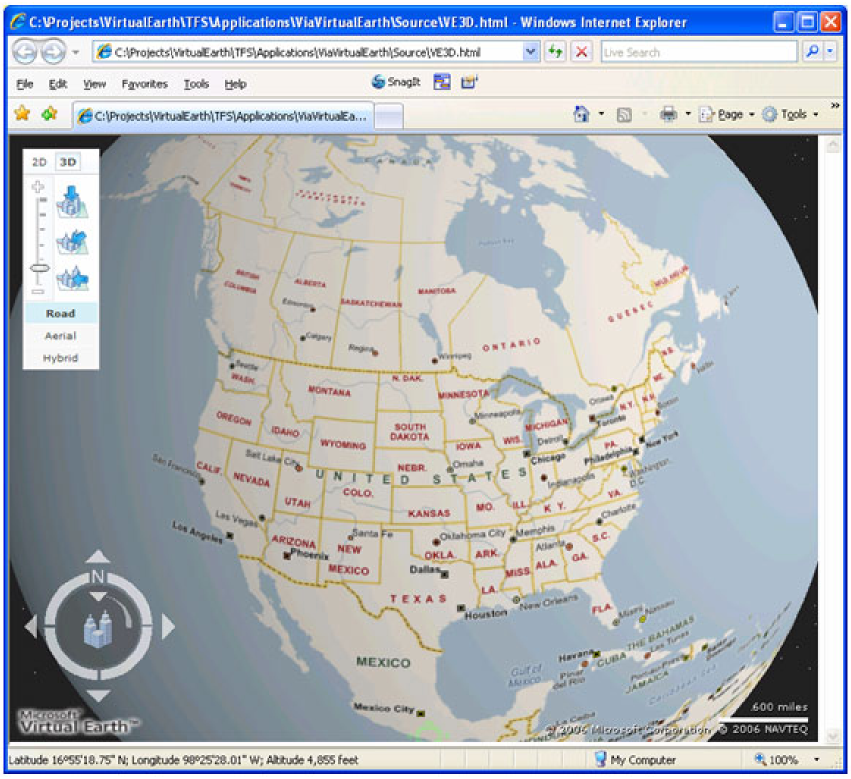

C:\Projects\VirtualEarth\TFS\Applications\ViaVirtualEarth\Source\VE3D.html - Windows Internet Explorer
File Edit View Favorites Tools Help
2D 3D
Road
Aerial
Hybrid
Microsoft Virtual Earth
600 miles
© 2006 Microsoft Corporation © 2006 NAVTEQ
Latitude 16°55'18.75" N; Longitude 98°25'28.01" W; Altitude 4,855 feet
My Computer
100%

Figure 1.9: Bing Maps 3D.

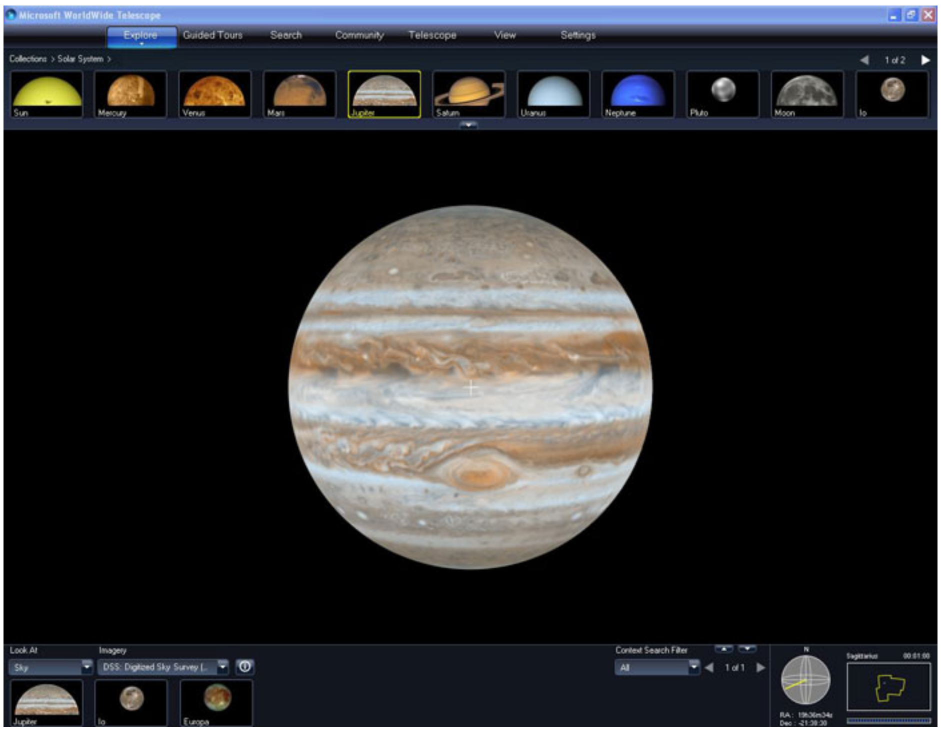


Figure 1.10: Worldwide Telescope.

KDE, a free software community producing cross-platform applications designed to run on GNU/Linux, FreeBSD, Solaris, Microsoft Windows and OS X operating systems. It allows the user to choose among the Earth, the Moon, Venus, Mars and other planets to explore. Besides its cross-platform availability, its components are intended to be easily integrated into other programs, what makes Marble very flexible. It disposes with a navigation mode that was developed as a part of Google Summer of Code 2010[10].

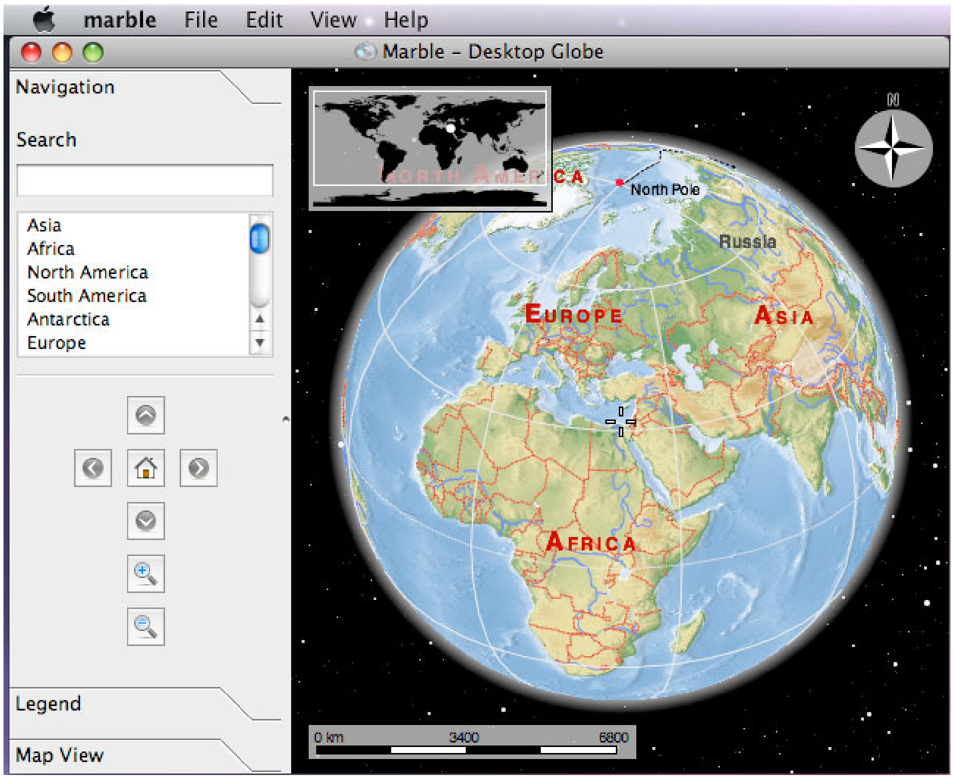


Figure 1.11: Marble.

OpenWebGlobe OpenWebGlobe[11] is a virtual globe SDK written in JavaScript[12] using WebGL[13] with the lead developer as the Institute of Geomatics Engineering at the University of Applied Sciences Nothwestern Switzerland (Figure 1.12) [6]. The most successful application using OpenWebGlobe is *Switzerland 3D*[14].

[10]Google Summer of Code is an annual program, where the students are being awarded by completing free and open-source software during the summer.
[11]`http://www.openwebglobe.org/`
[12]JavaScript is a prototype-based scripting language originally invented for an interaction of the user with the web browser.
[13]WebGL is a Javascript Application Programming Interface (API) for rendering 3D graphic without need of installing any plug-in.
[14]`http://swiss3d.openwebglobe.org/`

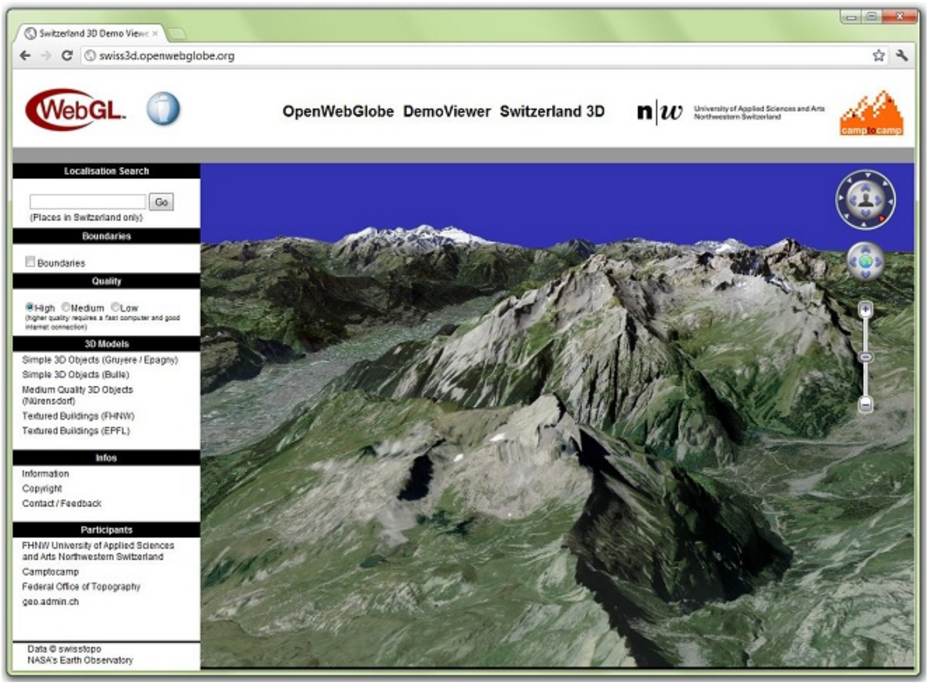

Switzerland 3D Demo Viewer
swiss3d.openwebglobe.org
WebGL
OpenWebGlobe DemoViewer Switzerland 3D
Localisation Search
Go
(Places in Switzerland only)
Boundaries
Boundaries
Quality
High Medium Low
3D Models
Simple 3D Objects (Gruyere / Epagny)
Simple 3D Objects (Bulle)
Medium Quality 3D Objects (Nürensdorf)
Textured Buildings (FHNW)
Textured Buildings (EPFL)
Infos
Information
Copyright
Contact / Feedback
Participants
FHNW University of Applied Sciences and Arts Northwestern Switzerland
Camptocamp
Federal Office of Topography
geo.admin.ch
Data © swisstopo
NASA's Earth Observatory

Figure 1.12: OpenWebGlobe.

Cesium Cesium[15] is an open-source software under the Apache License 2.0 using WebGL virtual globe and map engine (Figure 1.13). It is cross-platform, cross-browser and tuned for dynamic-data visualization [35].

ArcGIS Explorer ArcGIS Explorer[16] is a product of ESRI, a lightweight client for ArcGIS Server that supports WMS and many other GIS file formats (Figure 1.6). It is a free GIS viewer that gives you an easy way to explore, visualize and share GIS information. It adds an important value to GIS since it helps to bring your own data to a broad audience. With ArcGIS Explorer, you can access ArcGIS Online basemaps and layers; merge your local data with map services to create your own maps and share it online; add photos, videos, text and other information to your maps and perform spatial analysis on your data. The last mentioned feature makes ArcGIS Explorer unique and different from other virtual globes that are lacking this capability [34].

EarthBrowser EarthBrowser[17] is a virtual globe developed by Lunar software (Figure 1.14). It can be available either as online Adobe Flash application or installed locally as

[15]`http://cesium.agi.com/`
[16]`http://www.esri.com/software/arcgis/explorer`
[17]`http://www.earthbrowser.com/`

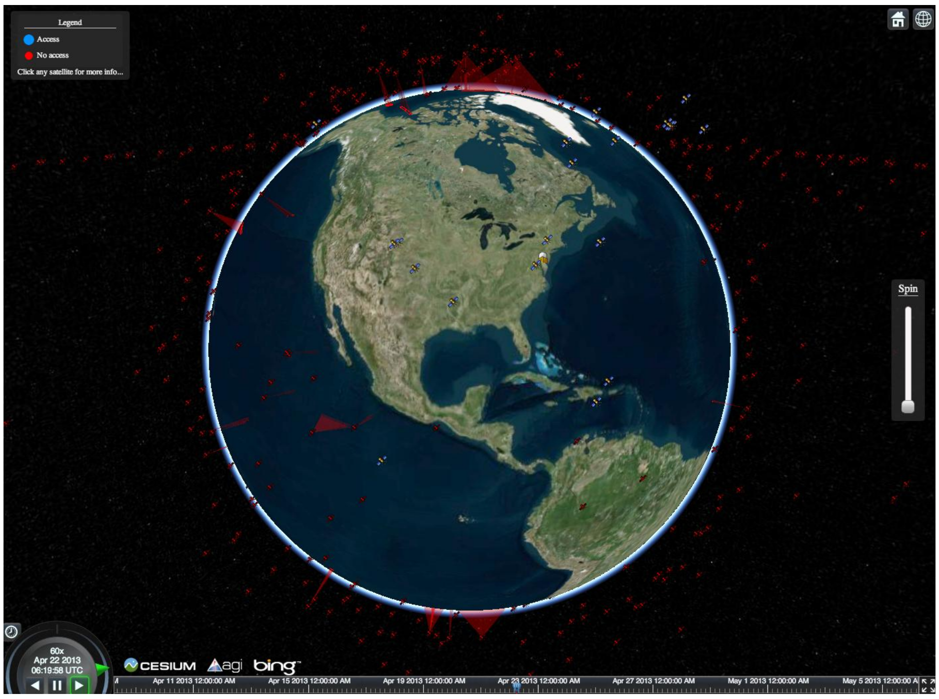


Figure 1.13: Cesium.

an AIR application [6]. Its main interest is in visualizing geophysical information such as real-time weather forecasts, earthquakes or volcano. Besides this, it is also compatible with KML files.

Earth3D *Earth3D*[18] *is an open-source software developed as a part of diploma thesis of Dominique Andre Gunia at Braunschweig University of Technology to display a virtual globe* (Figure 1.15) [6]. An interesting thing about this application is that it has been developed even before the release of Google Earth. It uses data from NASA, USGS, CIA[19] and the city of Osnabrück. A strong feature that this virtual globe disposes with is an ability of displaying meteorological phenomena in near-real time [6]. It exists both as a Java and C++ application [37].

Bhuvan *Bhuvan 3D*[20] *is a virtual globe tailored specifically to India* (Figure 1.16) [6]. It allows users to view 2D and 3D images together with an information about soil, wasteland and water resources on Indian subcontinent. It has numbers of other features, including weather information and administrative boundaries of all states and districts in India. It

[18]http://www.earth3d.org/
[19]Central Intelligence Agency
[20]http://bhuvan.nrsc.gov.in/bhuvan_links.php

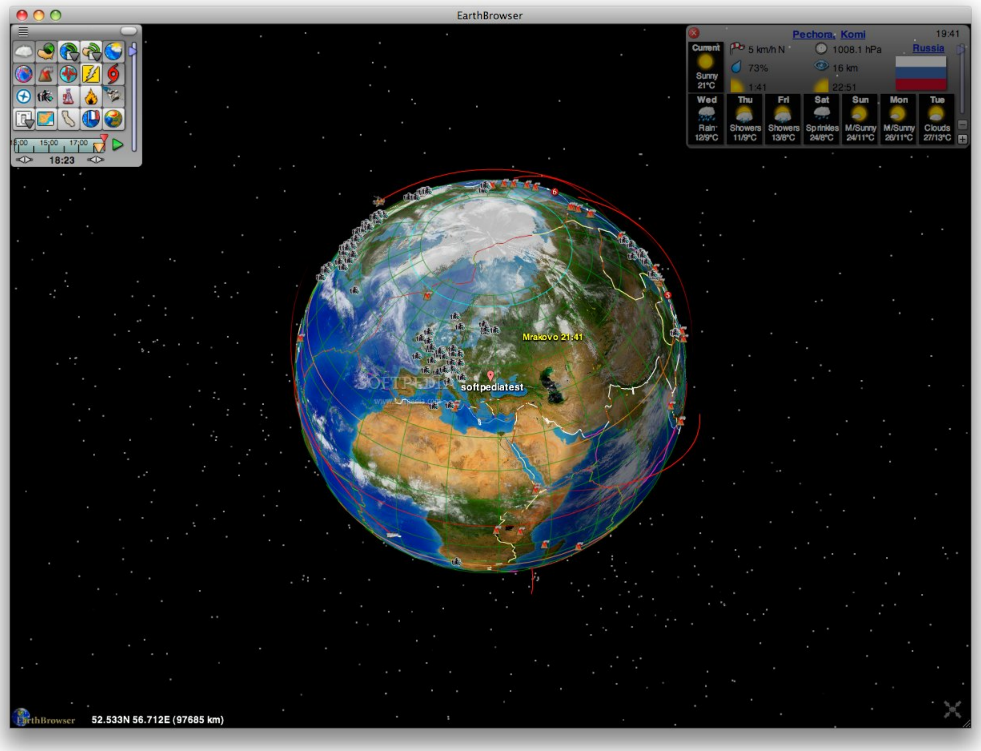


Figure 1.14: EarthBrowser.

is a free software and runs on Windows operating system.

1.3 NASA World Wind

1.3.1 Definition

Different definitions of NASA World Wind can be found from different sources. Bell et al. [13] say that *" ... NASA World Wind is a three-dimensional geographic information system developed by National Aeronautics & Space Administration(NASA), its partners, and the open-source*[21] *community. World Wind is both a system for highly interactive geographic data browsing utilizing the Internet, as well as a stand alone computer application."* Later, they are adding that World Wind *" ... provides graphical access to terabytes of imagery and elevation models for planets and other celestial objects including satellite and other data of the Earth, Moon, Mars, Venus, and Jupiter; ..."* Wikipedia [6] defines

[21]Open-source software (OSS) is a computer software with its source code made available and licensed with an open-source license in which the copyright holder provides the rights to study, change and distribute the software for free to anyone and for any purpose.

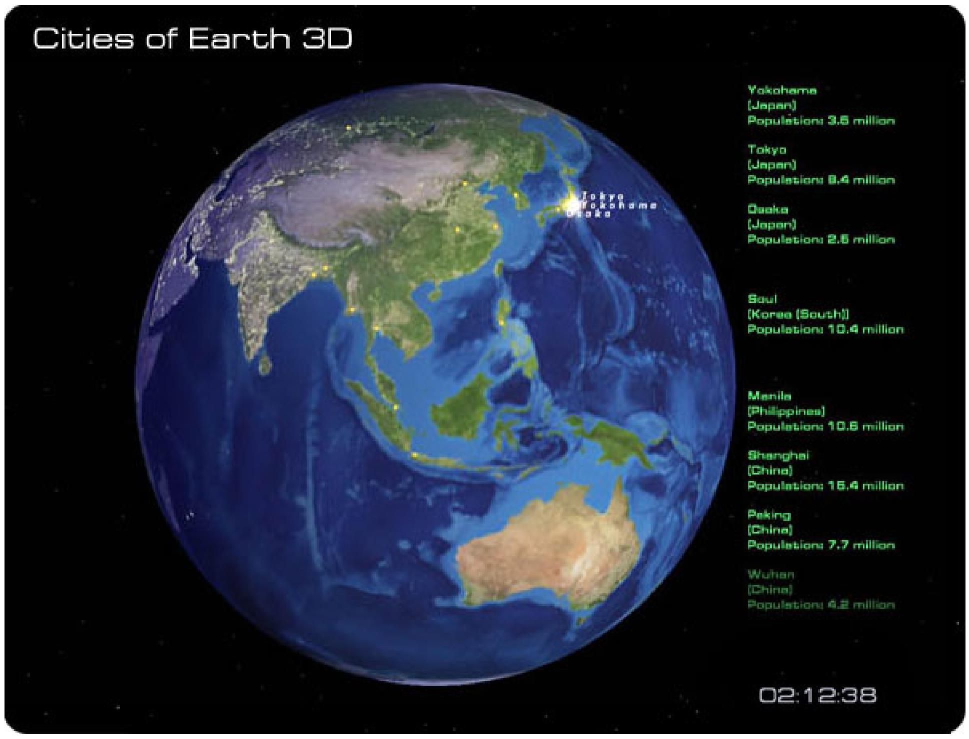


Figure 1.15: Earth3D.

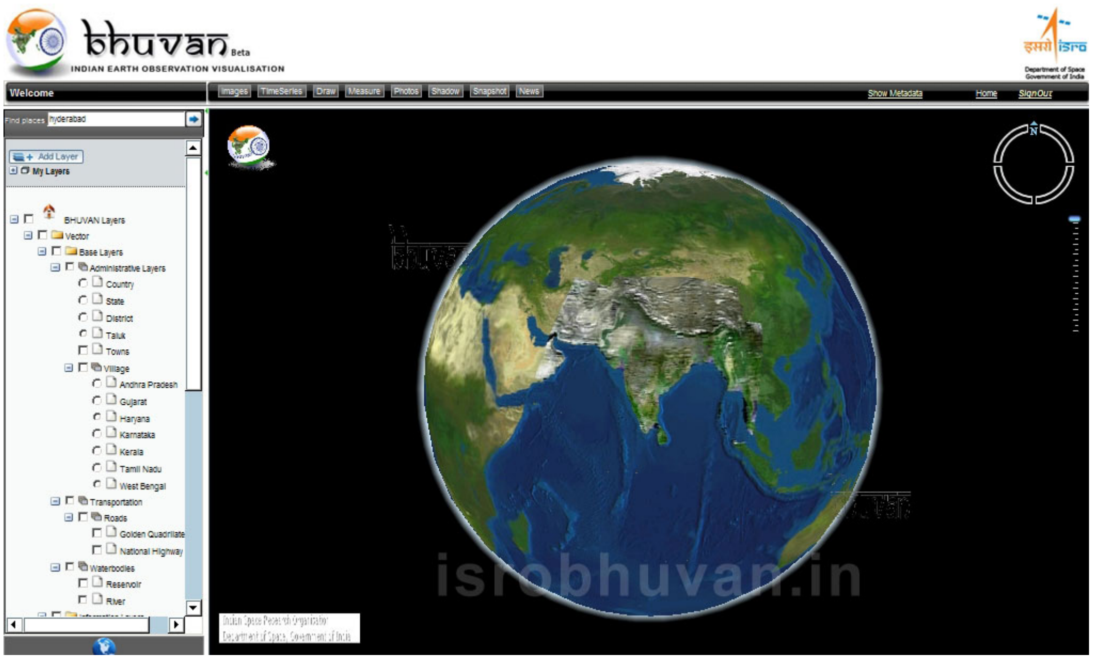


Figure 1.16: Bhuvan 3D.

NASA World Wind as *" ... an open-source (released under the NOSA*[22] *license) virtual*

[22]The NASA Open Source Agreement (NOSA) is an OSI-approved software license.

globe developed by NASA and the open source community for use on personal computers." Guo et al. [16] consider World Wind being a *"scientific digital earth system"* and *"... a scientific-oriented software, which provides an open framework of geographic information and allows users to further develop it in the future."* The most important thing about NASA World Wind is its unique potential to aggregate a huge number of public and private geographic data sets, providing access not only to NASA data but also to data from other government agencies, industries and the general public.

The history of NASA World Wind comes back to the year 2002, when the project began under the auspices of NASA Learning Technologies, a program to get "NASA content" into the classrooms [43]. Being lead by the project manager Patrick Hogan, NASA World Wind was released with its version 1.2 on August 6, 2004 and became one of the first NASA programs to be presented as open source [11][43]. An interesting thing is that World Wind existed approximately concurrently with Keyhole (that was developing Google Earth as it is known today), however, without knowing of each other until later. A popularity of the software was increasing rapidly and by September, 2004 over 60 000 copies of World Wind were distributed in one week [16]. NASA World Wind has been developed in two versions: WorldWind.NET and World Wind Java SDK.

WorldWind.NET

WorldWind.NET (Figure 1.17) is a NASA World Wind software that relies on .NET framework[23] and is restricted to Windows operating system. Besides displaying the Earth, there are also several other planets available: Moon, Mars, Venus, Jupiter etc. The application was developed in such a way that its operation would become instinctive for any possible user of the software, not looking on his technical background, who could naturally interact with the displayed planet by zooming in/out, rotating the globe and tilting the view.

WorldWind.NET provides the ability to browse maps and geospatial information using the WMS[24] servers, import ESRI Shapefiles and KML/KMZ files. Basically, the application is an extensive suite of plug-ins and add-ons. Here are listed possible types of add-ons

[23]The .NET Framework (pronounced dot net) is a software framework developed by Microsoft that runs primarily on Microsoft Windows.

[24]A Web Map Service (WMS) is a standard protocol for serving georeferenced map images over the Internet that are generated by a map server using data from a GIS database.

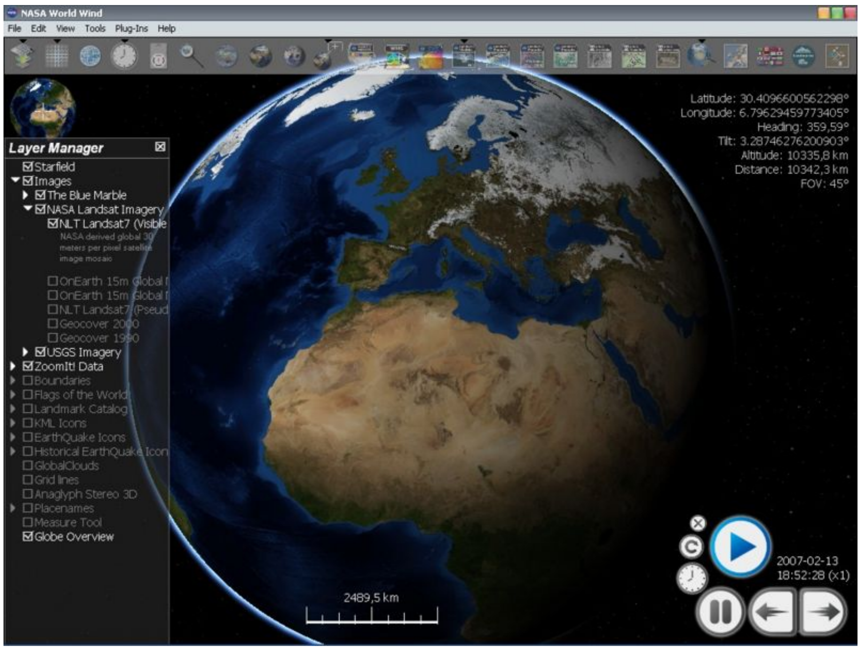


Figure 1.17: WorldWind.NET.

that can be imported into the application according to [6]:

- Point layer – XML file that displays placemarks as icons;
- Trail layer – paths (routes, boundaries);
- Line features – XML file with a list of points that are visualized as a line or wall;
- Polygon features – XML file with a list of points that are visualized as a filled polygon (flat or extruded);
- Model features – XML file used to load 3D textured meshes;
- Place names – specific points (such as cities, hills and buildings) that are assigned text labels;
- Image layer – high resolution imagery for various places in the world;
- Scripts – files that control camera movement.

World Wind Java

The latest .NET-based version, version 1.4, was released on February 14, 2007. After that, the team of developers in NASA, concentrated around Patrick Hogan, decided to change the concept of their project. Instead of one application, which could be enriched by users in form of new plug-ins or add-ons, they started to develop World Wind as a Java Software Development Kit and gave it name World Wind Java (often referred to World Wind SDK or NASA World Wind Java SDK) [43]. The main difference between .NET and SDK version is that while WorldWind.NET was a single application, World Wind Java SDK is, on the other hand, a set of development tools that can be used to create hundreds of different applications. Unlike to WorldWind.NET, World Wind Java is cross-platform, being able to be run on Windows, MAC OS X as well as on GNU/Linux. It has API-centric architecture, which puts World Wind itself in a role of plug-in. That means World Wind SDK can be used in a numerous number of applications, relying on different technologies. In one of the interviews, Mr. Hogan said that *" ... together, the NASA World Wind SDK client and WMS server provide the infrastructure for government, research, and business communities as well as education and public outreach, to both deliver and experience information, hopefully increasing our understanding"* [38].

World Wind Java disposes with the same features as were mentioned in the previous .NET version. However, it gives a developer much more flexibility to extend and adjust SDK in a way he finds it suitable. The first version 1.2 was released on July 19, 2011, while the last stable one 1.5 was presented on January 23, 2013 [8].

1.3.2 World Wind Data

NASA has more planetary information than any other entity on Earth [43]. Even though not all of those data are being used in World Wind, most of them do. They include animated data, satellite images, digital elevation models (DEM), country boundaries etc. The size of all currently available datasets is about 4.6 terabytes [6].

Data retrieval

Every World Wind application can be regarded as Geographic Information System (GIS), consisting of clients and heterogeneous networks of data (Figure no.1.18).

A client requests tiled imagery from a server using a NASA custom HTTP request protocol [13]. A simple request looks like this:

```
T=dataset&X=column&Y=row&L=level.
```

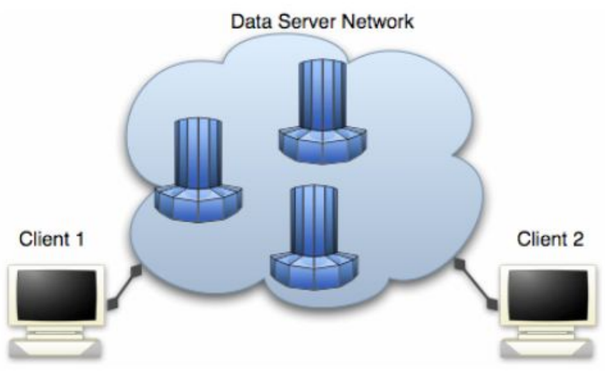


Figure 1.18: Client-server architecture.

To understand what attributes *column, row* and *level* parameters refer to, it is essential to get to know what tiled imagery is and how World Wind works with it.

In general, World Wind uses a multi-resolution layering technique [13]. The more user zooms in to the concrete location, the more detailed is this location shown progressively. This is done by storing multiple copies of the same map on the server. Taking a map of the Earth as an example, World Wind breaks down the image into 50 tiles, 36° x 36° segments (Figure 1.19). This is done at a level called Layer 0. Layer 1, then, breaks down the image into 18° x 18° segments, which results into 200 tiles of it. At Layer 2, the resolution of the image becomes 9° x 9° for 800 tiles. As can be seen, in every next layer, a number of tiles is 4 times higher than in the previous one, resulting in the segment 4 times smaller. When the user zooms in to a various location, World Wind requests the necessary data from the servers, downloading only the information that is required to display the view requested by the user [13]. Coming back to the the meaning of the parameters of the HTTP request, *level* refers to Layer in the concrete tiled imagery. After finding suitable Layer, *column* and *row* define a location of the particular segment in the image. Besides NASA HTTP request protocol, World Wind equally supports WMS protocol specification from the Open Geospatial Consortium (OGC) [13].

After requesting proper data at the specific resolution layer and view point, World Wind caches this data locally. Caching the data brings a lot of advantage to the client as well as the server. The response time when retrieving the data from the cache is on the order of 0.015 seconds, which is much shorter than overall processing time, that varies from a few to 20 seconds on a modern fast server [13].

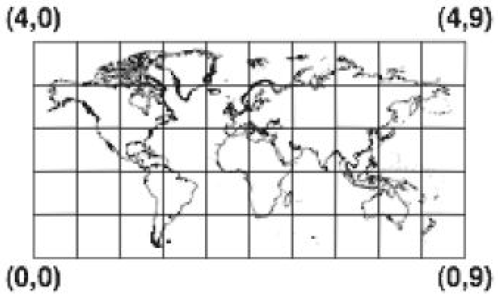


Figure 1.19: Tiled image of the Earth at Layer 0.

Digital Elevation Model (DEM)

For each globe (planet), there is a default DEM that is based the nominal radius of the globe and augmented with elevation data from available sources [13]. Figure 1.20 shows how the images are draped over the elevation model at a global scale and Figure 1.21 illustrates the same situation being done at a local scale.

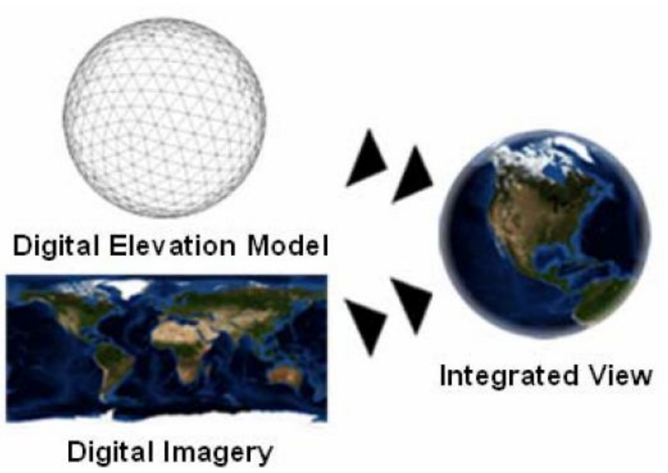


Figure 1.20: Texture mapping at a global scale.

In case of the Earth, World Wind uses DEM data collected by SRTM, NED and ASTER giving to the user final resolution of 30 m (1 arcsecond) for USA and 90 m (3 arcseconds) globally. Shuttle Radar Topography Mission (SRTM) is an international research effort to generate the most complete high-resolution digital topographic database of the Earth covering most of the land surface between 60° N to 54 ° S. It is a project spearheaded by U.S. National Geospatial-Intelligence agency (NGA) and NASA [6]. National Elevation

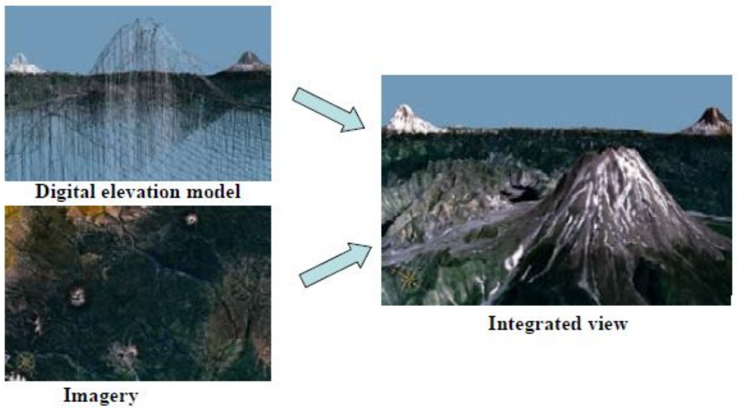


Figure 1.21: Texture mapping at a local scale.

Dataset (NED) merges the highest-resulution, best quality elevation data available for USA into a seamless format. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is a Japanese sensor which is one of five remote sensory devices on board the Terra satellite launched into the Earth orbit by NASA in 1999. It provides high-resolution images of the Earth in 14 bands of electromagnetic spectrum. In addition to DEM, bathymetry data with a resolution 2 arcminutes and better are involved in World Wind. For Moon, Lunar DEM is used as a product of various data sources and Lunar missions [13]. Obviously, the resolution is much lower than for DEM of the Earth. For Mars, the entire DEM is a result of MOLA experiment from Mars Global Surveyor (MGS) mission [13].

Digital Imagery

Following tables 1.2 and 1.3 list all available digital imagery datasets in World Wind for the Earth and other planets, respectively, according to [13][6]:

Blue Marble Next Generation Blue Marble Next Generation (BMNG) (Figure 1.22) serves as an "improved version" of previous Blue Marble imagery. Its predecessor was a composite of four months of MODIS[25] observations with a resolution of 1 kilometer per pixel. BMNG brings up all the attributes improved: it has higher resolution (500 m/pixel), disposes with better colors and consists of 3 different views (or layers) delivering a set of imagery for each month, making 36 new sets in total [6]. The three layers

[25]Moderate-resolution Imaging Spectroradiometer

Earth datasets		
Imagery	**Dataset**	**Resolution**
Blue Marble	Blue Marble Next Generation	500 m
Landsat 7	NLT Landsat Pseudo Color	30 m
	NLT Landsat Visible	30 m
	GeoCover 1990	30 m
	GeoCover 2000	15 m
	OnEarth Visible	15 m
	OnEarth Pseudo Color	15 m
	i-cubed	15 m
USGS	Digital Ortho	1 m
	Urban Area Ortho	0.25 m
	topographic maps	
ZoomIt!	LINZ	2.5 m
	GSWA	
	South Africa	0.5 - 10 m
	US imagery	0.15 - 1 m

Table 1.2: World Wind imagery for Earth.

composing BMNG are as follows: Blue Marble Base, Blue Marble Shaded (topographically shaded month-to-month record of the Earth) and Blue Marble Shaded + Bathymetry (Blue Marble Shaded with addition of the bathymetry data). In World Wind, the last layer is enabled by default and the month of the provided dataset is matched with the current month. All the imagery was acquired in 2004.

Landsat 7 imagery Landsat 7, launched on April 15, 1999, is the seventh satellite of the Landsat program [6]. The main goal is to provide a refreshed set of images, which are up-to-date and cloud-free. The program is managed by USGS. Following datasets are distributed within World Wind: i-cubed, NLT Landsat (Pseudo Color and Visible), GeoCover 1990 and 2000 and OnEarth (Pseudo Color and Visible). I-cubed dataset (Figure 1.23) is a result of sophisticated i3-color balancing algorithms, that optimally process raw Landsat data. NLT datasets were created by NASA Learning Technologies (NLT), an organization that was behind all World Wind project idea, with an intention to make

Extraterrestrial datasets	
Planet	**Dataset**
Mars	MOC 256(ASU)
	MOC 256 Colorized
	MOLA Color (ASU)
	Mars THEMIS (ASU)
	Mars THEMIS Color
Moon	Moon Base Image
	Clementine 40xx
	Clementine 30xx
	Shaded Elevation Map
Jupiter	Jupiter Base Map
Venus	Magellan Imaging Radar
	Shaded Relief

Table 1.3: World Wind extraterrestrial datasets.

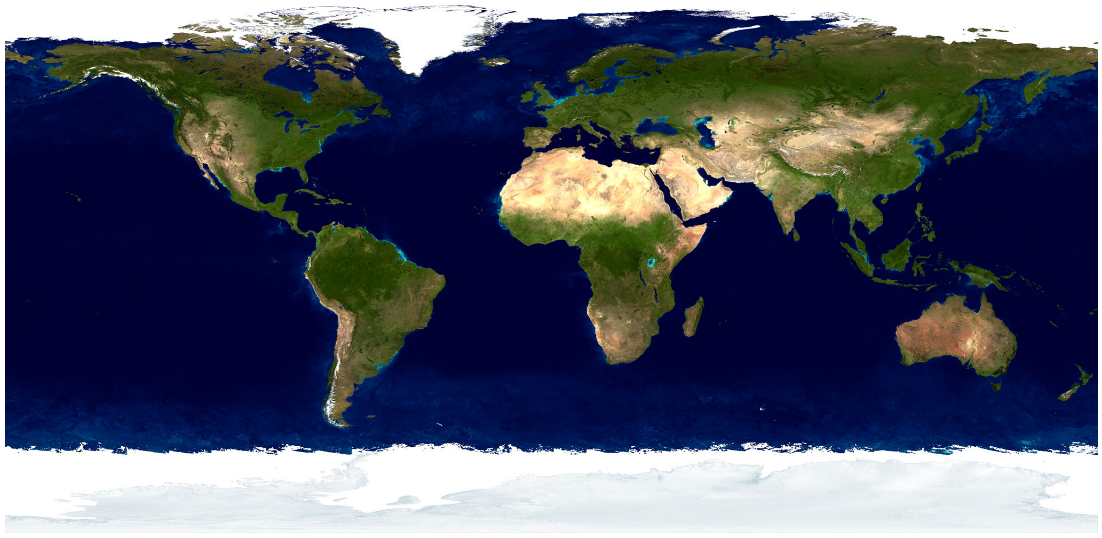


Figure 1.22: Blue Marble Next Generation imagery.

their own imagery (Figure 1.24). GeoCover, a positionally accurate orthorectified Landsat Thematic Mapper and Multispectral Scanner imagery covering the majority of the Earth's land mass, is a result of a contract between NASA and EarthSat (Earth Satellite Corporation). GeoCover 2000 (Figure 1.25) uses the same bands as its predecessor, GeoCover

1990, however, the resolution is twice higher - 15 metres. Finally, OnEarth:WMS Global Mosaic (Figure 1.26) is a project convened by NASA Jet Propulsion Laboratory. The images, being collected between 1999–2003, create a global image mosaic of the Earth, produced from more than 8200 individual Landsat 7 scenes [42].

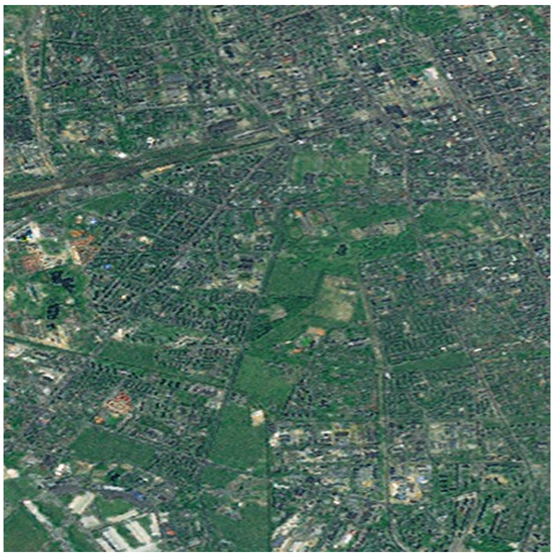


Figure 1.23: I-cubed at its highest resolution.

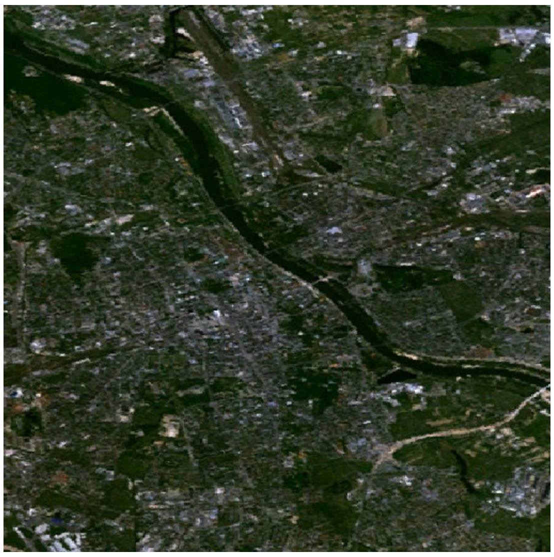


Figure 1.24: NLT Visible at its highest resolution.

ZoomIt! ZoomIt! is an add-on provided by NASA World Wind Central [42] that gives a user access to high-resolution imagery of areas not available before. Those areas include:

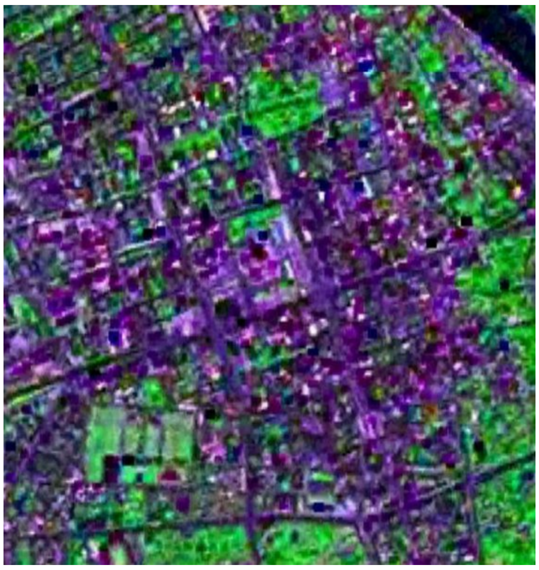


Figure 1.25: Geocover 2000 at its highest resolution.

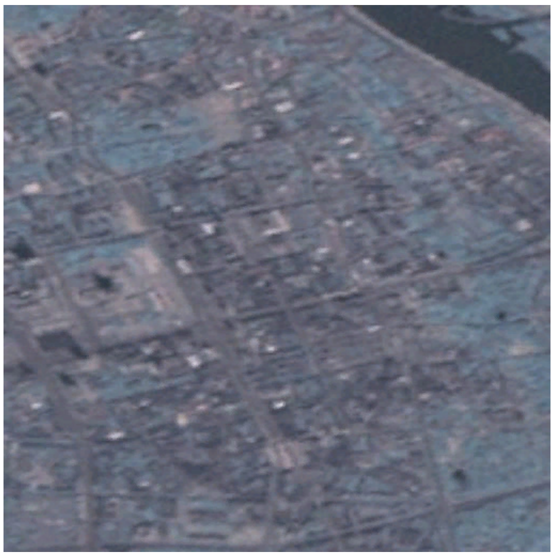


Figure 1.26: OnEarth Visible at its highest resolution.

New Zealand with its LINZ dataset, West Australia with GSWA dataset available and South Africa, with Robben Island and Johannesburg having a resolution of 0.5 m and 1 m, respectively. It also disposes with a high-resolution imagery of few cities in USA (Figure 1.27).

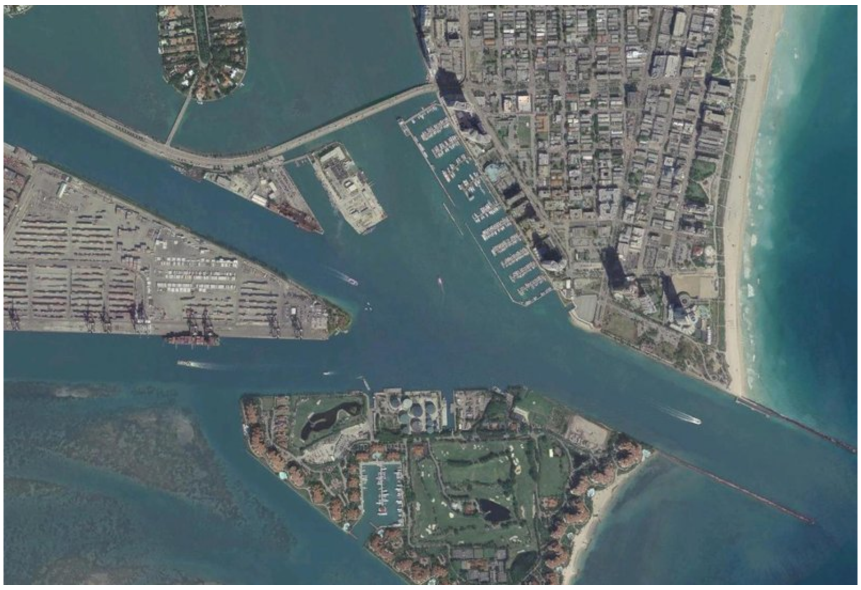


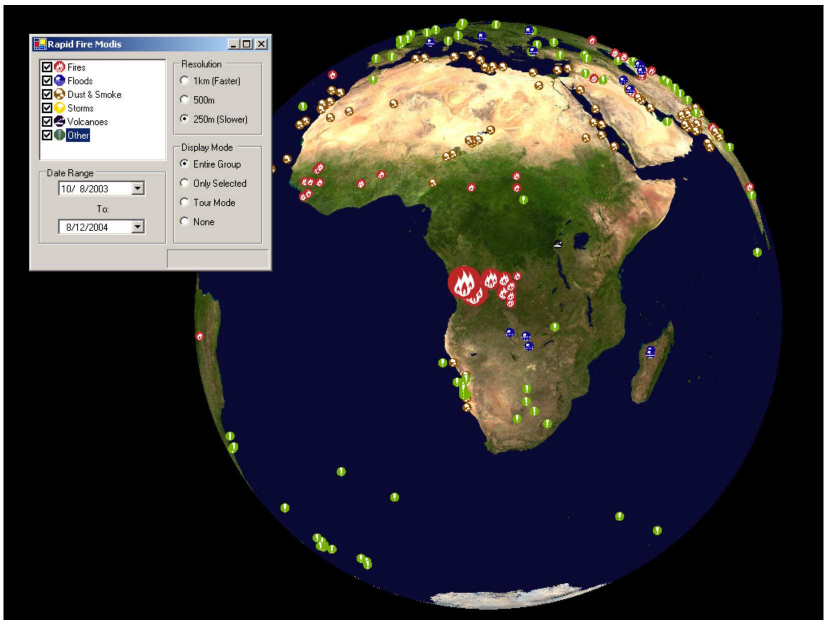
Figure 1.27: ZoomIt! image of Miami.

Animated data

Following animated data layers are available in World Wind: MODIS, GLOBE, NRL Real-Time Weather and NASA Scientific Visualization Studio data.

MODIS *The Moderate-resolution Imaging Spectroradiometer (MODIS) is a payload scientific instrument launched into Earth orbit by NASA in 1999 on board the Terra satellite, and in 2002 on board the Aqua satellite* [6]. It captures data in 36 bands and provides measurements of the dynamics of the changes on the Earth, including its cloud cover, radiation budget and processes occurring in the oceans, on land and in the lower atmosphere. Rapid Fire MODIS (Figure 1.28) is a feature in World Wind that produces an easily customized view of this information and marks then directly on the globe. When one of those markers is clicked, the full image of the event is automatically downloaded [40].

GLOBE The Global Learning and Observations to Benefit the Environment (GLOBE) Program is a program focused on the environment issues, primary- and secondary-school-based science and education program in more than 112 countries worldwide [39][42]. The main goal is to promote teaching and learning of science, enhance environmental literacy and promote scientific discovery. The program gives young students an unique opportunity to take part in real experiments in collaboration with scientists from numerous



✓ Fires
✓ Floods
✓ Dust & Smoke
✓ Storms
✓ Volcanoes
✓ Other

Resolution: 1km (Faster) / 500m / [✓ 250m (Slower)]

Display Mode: [✓ Entire Group] / Only Selected / Tour Mode / None

Date Range: 10/ 8/2003 To: 8/12/2004

Figure 1.28: Rapid Fire MODIS.

international agencies. It is housed by University Corporation for Atmospheric Research (UCAR) at Boulder, Colorado, USA and sponsored by National Oceanic and Atmospheric Administration (NOAA), NASA and the National Science Foundation through an inter-agency agreement first signed in 1998 [42]. GLOBE data can be viewed in World Wind through the WMS, where the user can specify from which date this data will be downloaded (Figure 1.29).

NRL Real-Time Weather *The United States Naval Research Laboratory (NRL) is the corporate research laboratory for the United States Navy and the United States Marine Corps and conducts a program of scientific research and development* [6]. Located in Monterrey, California, it provides real-time weather information from GEOS and POES satellites [13]. Data are being processed and modelled at NRL super computer facilities and the final real-time weather imagery with barometric weather information is available via World Wind (Figure 1.30).

NASA SVS The goal of NASA Scientific Visualization Studio (NASA SVS) Image Server is to make NASA Earth Science data and research results directly available to the students, educators, and general public through broadly useful applications [41]. The information that NASA SVS Image Server offers are samples of many different visualiza-

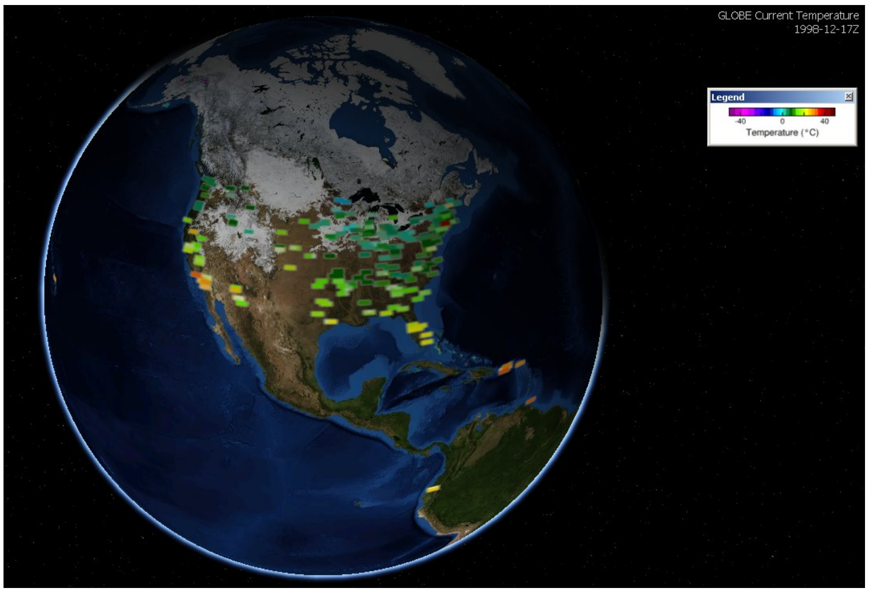


Figure 1.29: GLOBE data for air temperature.

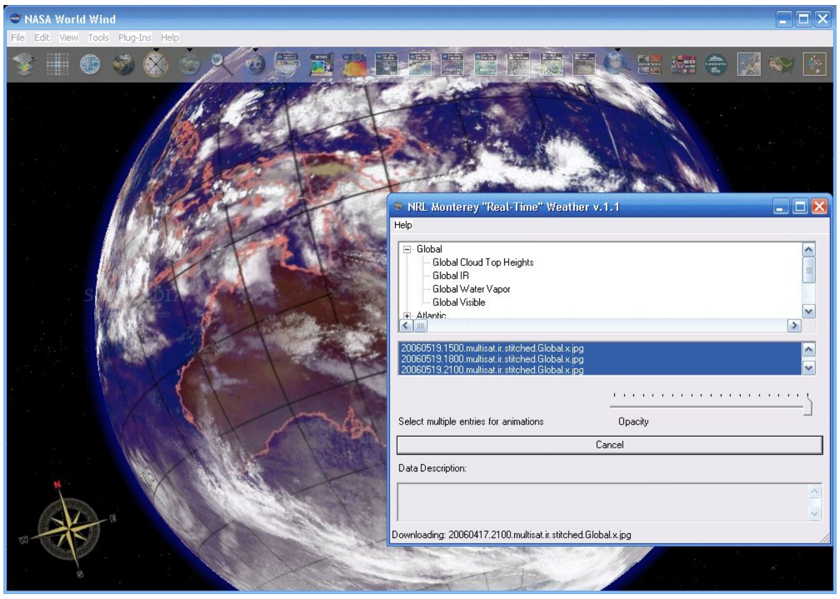

NASA World Wind
File Edit View Tools Plug-Ins Help
NRL Monterey "Real-Time" Weather v.1.1
Help
Global
Global Cloud Top Heights
Global IR
Global Water Vapor
Global Visible
Atlantic
20060519.1500.multisat.ir.stitched.Global.x.jpg
20060519.1800.multisat.ir.stitched.Global.x.jpg
20060519.2100.multisat.ir.stitched.Global.x.jpg
Select multiple entries for animations
Opacity
Cancel
Data Description:
Downloading: 20060417.2100.multisat.ir.stitched.Global.x.jpg

Figure 1.30: NRL Real-time weather data.

tions and animations provided by Goddard SVS. The main goal is to manage a server with a large amount of exciting, scientifically diverse product. For instance, Goddard Space Flight Center (GSFC) has produced a lot of visually intense animations that display various phenomena such as seasonal changes across the globe or hurricane dynamics. World Wind can take these animations and play them directly in the application [40].

Additional data

Except for the data mentioned above, World Wind offers by default the following 2 layers: Country & (USA) State Borders and Places Names.

Chapter 2

Methodology

This chapter serves as a comprehensive description of the workflow while creating the application *Great Places WikiGlobe* as well as an explanation of methods and technologies being used during the process. The first section describes the application's study area, concretely *100 Great Places of History* and offers some statistical relation between the data. The second section gives an insight into the methods and technology needed to create an application, and so Java programming language and RDBMS (Relational Database Management System), concretely MySQL. This section is not intended to be a deeply-comprehensive guide into the mentioned technologies, it just serves to outline them briefly. In the third section, the design of the database is shown, together with how the data were collected. The fourth section brings up an application design, where GUI (Graphical User Interface) is mentioned to be the right choice and is described appropriately. Last section comprises an implementation of the application, concretely setting up the development environment, implementation of GUI, World Wind Java technology into it and creating an information window.

2.1 Great Places WikiGlobe

2.1.1 Description

By increasing functionality of World Wind, many governmental, commercial or non-commercial organisations started to build their applications based on World Wind Java SDK. A fact that World Wind is open-source, gives a developer a lot of space to accommodate the SDK to its own needs. One of those projects that relies on World Wind

Java SDK is also WikiGlobe, a project undertaken at Beihang University (BU) under the guidance of Prof. Weng Jingnong from the College of Software. Its goal is to integrate an information that usually Wikipedia offers, and so text, pictures, audio recording or video into World Wind so that a user will have an opportunity to "browse Wikipedia on Digital Globe". The team of students specialized in the software applications of Geographic Information Systems have been working on the SDK based on World Wind Java SDK for couple of years. During that time, different topics connected to WikiGlobe project were completed, such as "WikiGlobe – Rise of Nations", which brings an information about all the countries of the world into the World Wind.

The aim of *Great Places WikiGlobe* is to create an application that will contain 100 important civilizations's sites according to the book *Great Places of History: Civilization's 100 Most Important Sites: An Illustrated Journey* [5], published by TIME (Figure 2.1), using geovisualization methods and technology that World Wind disposes with.

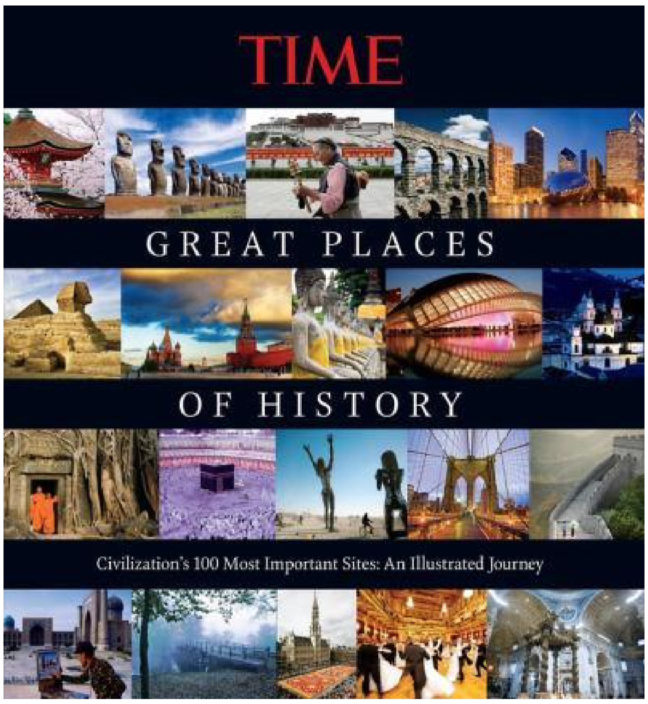

TIME
GREAT PLACES
OF HISTORY
Civilization's 100 Most Important Sites: An Illustrated Journey

Figure 2.1: TIME HOME ENTERTAINMENT. *Great Places of History: Civilization's 100 Most Important Sites: An Illustrated Journey.*

2.1.2 Study area

All the sites, included in the book *Great Places of History: Civilization's 100 Most Important Sites: An Illustrated Journey* [5], were about to be incorporated into the application *Great Places WikiGlobe.* The book divides them into the following categories according to their contribution and meaning in the history:

- Cultures,
- Religion,
- Society,
- Politics,
- Civilizations,
- Battles,
- Inquiry,
- Innovation,
- Arts.

All the places are listed in the appendix C. Every site is described in the book in one or two pages. The description of the place is not in a way that, for example Wikipedia gives us, mentioning all historical and important facts. On the contrary, each site is characterized such as an interesting story are picked up, from the point of view of TIME's editors, who personally visited all the places.

The sites are not distributed evenly within the continents or the countries. Table 2.1 depicts that the most places are located in Europe, which is more than twice more than Asia, followed by North America. On the other hand, the country with the highest number of the places is United States of America, with three European countries (England, Spain, Germany) and China right behind it (Table 2.2).

Sites by continent	
Continent	**Number of sites**
Africa	8
Antarctica	1
Asia	21
Australia	1
Europe	50
North America	15
South America	4

Table 2.1: Sites by continent.

Top countries by number of sites	
Country	**Number of sites**
United States of America	11
England	9
Germany	6
Spain	6
China	6
France	5
Greece	4
Italy	4
Russia	3
India	3
Austria	3

Table 2.2: Sites by continent.

Additional tables are included in the appendix C, depicting which countries and continents have their sites included between each category. One interesting point that can be observed is that Europe is the leading continent for every category except for *Religion* with Asia on the first place and *Battles*, where North America is taking the lead. Another finding is that United States of America being as a top country with the highest number of sites in the book, has no representative in four categories - *Cultures, Religion, Civilizations* and *Inquiry* while having as many as 5 sites in the category *Innovation* from the total of 16 sites. The only one site that belongs to Australia (*Australian Penal Sites*) is included in *Society* category. For Antarctica, the only representative in the book is *McMurdo station* belonging to *Inquiry* category.

Here is the list of all the countries with at least one site included in the book: Antarctica, Australia, Austria, Belgium, Bosnia and Herzegovina, Cambodia, Canada, Chile, China, Denmark, Ecuador, Egypt, England, Ethiopia, France, Germany, Ghana, Greece, Guatemala, India, Iran, Ireland, Israel, Italy, Japan, Mali, Morocco, Nepal, Norway, Pakistan, Panama, Peru, Poland, Russia, Saudi Arabia, Scotland, Spain, Syria, Tanzania, Thailand, Turkey, United Arab Emirates and United States of America.

2.2 Required methods

2.2.1 Java programming language

Definition

As has been already mentioned in this section, the application *Great Places WikiGlobe* is based on NASA World Wind SDK. This SDK is written in programming language Java. *Java programming language is a general-purpose, concurrent, class-based, object-oriented computer programming language that is specifically designed to have as few implementation dependencies as possible* [6]. It was "born" in 1995 in the laboratories of Sun® Microsystems. The name of the programming language can be also translated as "coffee" or "espresso" (the reason why there is a coffee mug displayed in the logo (Figure 2.2)), said to be consumed by language's creators in large quantities similarly as people drink coffee every day. Its founder, James Gosling, firstly wanted to give his newly developed programming language name Oak, pointing to the oak that has grown up in front of his house during the work on the language's development, later on, he came up with the name Green to finally decide for Java. Today, Java is one of the most popular programming languages with more than 10 million users, who use this language for developing applications such as applets[1], servlets[2], distributed systems[3] or applications for mobile or telecommunication devices.

[1]Java applet is a small application written in Java launched from a web page.
[2]Java servlet is a Java programming language class used to extend the capabilities of a server.
[3]A distributed system is a software system in which components located on a computer network communicate and coordinate their actions by passing messages.

Figure 2.2: Logo of Java programming language.

A current owner of Java platform is company Oracle®, after its acquiring of Sun Microsystems in 2010 [6]. Oracle implementation of Java is packaged in two different distributions: Java Runtime Environment (JRE) and Java Development Kit (JDK). For developers, it is intended to have JDK installed, for those who just want to run Java application(s), only JRE is needed.

There are five primary goals in the creation of Java language according to [6]:

1. It should be "simple, object-oriented and familiar."
2. It should be "robust and secure."
3. It should be "architecture-neutral and portable."
4. It should execute with "high performance."
5. It should be "interpreted, threaded and dynamic."

Java compoments

Java is composed of three basic components according to [2]:

1. Java programming language,
2. Java Virtual Machine (JVM),
3. Application Interface (API).

One characteristic feature of Java which makes it different from other programming languages, is its portability, meaning that computer program written in Java will run in a similar way on any operating-system platform. Java language code, unlike to other programming languages, such as C++, is not compiled directly to platform-specific machine code, but into its intermediate representation called Java bytecode. Firstly, a source code of the program represented by a text file with `*.java` suffix is compiled by a Java compiler into a language of JVM in a form of bytecode. Since this bytecode can be executed just on a virtual computer represented by JVM, it is not dependent on any specific hardware/-software requirements. Afterwards, the bytecode, producing a file with `*.class` suffix, is interpreted into the machine code of the running processor (Figure 2.3).

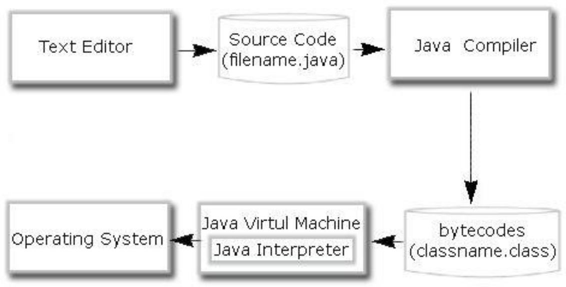


Figure 2.3: Java's portability.

Syntax

Syntax in Java is largely derived from C++ [6]. The simplest Java program is a famous Hello World program:

```java
class HelloWorld {
    public static void main(String[] args) {
        System.out.println("Hello World!"); // Display the string.
    }
}
```

Listing 2.1: HelloWorld.java.

The source file has to have the same name as the class does with `.java` suffix added, in this case `HelloWorld.java`. Firstly, the file is compiled into the bytecode, producing a file `HelloWorld.class`. Just after that, the program can be launched and a string `Hello World` will be displayed on the console. Looking back at the source code of the Hello

World program, line 1 defines the class name, which every class in Java has to start with. Everything written after that has to be a content of the class, defined by braces (closing brace is on line 5). On the line 2, a `main` method is called. It is a special type of method in Java, which Java launcher calls to pass control to the program [6]. It has to accept an array of `String` objects, which are often passed by means of a command line. The brace after the `main` method's definition on the line 3 indicates everything after that is the content of the method, enclosed by the brace on the line 4. In this case, it is just one line, saying to print a string "Hello World" and display on the console.

2.2.2 Relational Database Management System (RDBMS)

Except for Java, there is also needed the technology that will be able to store the data, able to operate with this data and make queries on them. There is a need of RDBMS (Relational Database Management System). RDBMS is a database management system of relational database.

Relational database

Relational database is a database that has a collection of tables of data items, all of which is formally described and organized according to the relational model [6]. The relation model is a result of a research conducted by IBM® (International Business Machines Corporation). It was firstly described by Dr.E.F.Codd in an article "A Relational Model of Data for Large Shared Data Banks" published in *Communications* of the ACM (Association for Computer Machinery) on June 1970 [4]. In the relational model, each *table schema* (or *relation*) is defined by *rows* (or *tuples*) and *columns* (or *attributes*). It has to be identified by a *primary key*, a column disposing with a set of values unique for each row in the database. It can also have a *foreign key*, that is pointing to a primary key of another table schema. Giving an example, table `students` (Table 2.3) contains the data about international students of Beihang university. It has 5 rows and 4 columns: `id, name, country` and `city`. As a primary key, an attribute `id` is chosen.

Relational Database Management System (RDBMS)

Relation Database Management Systems is, as has already been mentioned, a database management system based on the relational model described above. According to E.F.Codd,

Table students			
id	name	country	city
1	Wang	China	Beijing
2	Biman	Sri Lanka	Colombo
3	Peter	Slovakia	Kosice
4	Michela	Italy	Torino
5	Fredrik	Sweden	Stockholm

Table 2.3: Relational database table schema `students`.

every RDBMS has to fulfil Codd's 12 rules in order to be considered being RDBMS [4]. Basically, RDBMS is a software that serves as a tool to manage database, where table schemas are identified with their primary key and connected to each other according to their relation. To operate with the data within RMDBS, a special-purpose programming language, SQL (”S-Q-L” or as the word ”sequel”, Structured Query Language) was designed. It is based on relational algebra and consists of Data Definition Language (DDL) and Data Manipulation Language (DML). DDL is a language with syntax similar to programming language for defining data structures, especially database schemas. DML is a language used for inserting, deleting and updating data in the database. Looking back to the example of relational model table schema `students` (Table 2.3), to create this table, SQL code (Listing 2.2) has to be executed. Once the table is created, the data can be inserted into the table (Listing 2.3).

```
CREATE TABLE students (
    id            INTEGER       PRIMARY KEY,
    name          VARCHAR(50)   NULL,
    country       VARCHAR(50)   NULL,
    city          VARCHAR(50)   NULL
);
```

Listing 2.2: Creating a table `students`.

```
INSERT INTO students values (1, 'Wang', 'China', 'Beijing');
INSERT INTO students values (2, 'Biman', 'Sri Lanka', '
   Colombo');
```

```
INSERT INTO students values (3, 'Peter', 'Slovakia', 'Kosice'
   );
INSERT INTO students values (4, 'Alba', 'Bolivia', 'La Paz');
INSERT INTO students values (5, 'Fredrik', 'Sweden', '
   Stockholm');
```

Listing 2.3: Inserting the data into the table `students`.

MySQL According to the research made by company Gartner, the five leading commercial database vendors are Oracle, IBM, Microsoft, SAP® including Sybase® and Teradata® [6]. For the purpose of this application, it was MySQL RDBMS being used to work with the database. MySQL[4] is one of the three open source implementations of RDBMS by Oracle, together with PostgreSQL and SQLite and the world's most widely used open source RDBMS running as a server that provides multi-user access to a number of databases [6]. Its founder is Michael Widenius, who named by him developed RDBMS after his daughter, My. MySQL is usually the first choice from all RDBMS to use in web applications, including today's favorite World Wide Web products such as Facebook®, Wikipedia, Twitter, Flickr^{TM} or YouTube. It is a cross-platform RDBMS, running on different operating systems and written in C and C++. By default, MySQL as RDBMS comes with no GUI tools to manage the data contained in the database. The user can use command-line tools or so-called "front-ends", third-party proprietary and free graphical administration applications. Those tools give an advantage of a possibility to visually design the database, administer it and manage the data. One such application, MySQL Workbench, was officially developed by Oracle. Another one, phpMyAdmin, was used for the purpose of this work and is closely described in the section 2.5.1.

2.3 Database design

Before collecting the data, the database was designed in order to meet the requirements for the application. The database `wikiglobe` contained just one table named

[4]`http://www.mysql.com/`

greatplaces (Table 2.4), which included 100 rows representing *100 Great Places of History* [5]. An attribute id was chosen to be the primary key as it has a unique value for every site. The column name serves as a name of every site and is of type varchar, attributes longitude, latitude represent the coordinates of the site in decimal degrees. Columns country and continent are of type varchar and display a country and continent in which every site is located, respectively. Attribute type represents the category which every site belongs to and is of type varchar. Columns description_path, story_path, icon_path and picture_path are all absolute paths to the concrete files in the file system within the project. In case of description_path and story_path, those paths are addressing to the text files containing description and story about every place, respectively. In case of icon_path, the path is referring to the PNG[5] image representing concrete icon. The attribute picture_path is the absolute path to the folder in which pictures for a concrete site are stored. Finally, the attribute video_link is of type varchar and contains the URL link to the video about every site on YouTube[6].

greatplaces	
Attribute	*Type*
id	int
name	varchar
longitude	decimal
latitude	decimal
country	varchar
continent	varchar
type	varchar
description_path	varchar
story_path	varchar
icon_path	varchar
picture_path	varchar
video_link	varchar

Table 2.4: Table greatplaces.

[5]Portable Network Graphics
[6]http://www.youtube.com/

Data collection

The data were collected with a use of different sources. For attributes `name` and `story_path`, it was the book *Great Places of History* [5] that served as a source of data. For every site, the story written in the book was rewritten into the text file and the absolute path addressing this file was saved within `story_path` attribute. The values of attributes `longitude`, `latitude`, `country` and `continent` were extracted from Wikipedia [6]. Similarly for `description_path` containing the path referring to the text file, Wikipedia [6] was used as a source. Pictures stored in a separate folder for every site were retrieved from different websites over the internet, but mainly from [32], photo galleries produced by Alfred Molon. The videos were collected from YouTube.

A special interest was given to the design of the icons for every historical place. The process in their creating can be divided into three steps. Firstly, a search was made over the internet in order to find a suitable candidate for being an icon or a picture, whose part could be extracted and used to create the icon from it. In most cases, the latter option was present. After that, the picture was loaded into Photoshop® software, where it was modified in order to meet the final required design. Finally, the icon was saved as PNG image with a size of 32 x 32 pixels. Figure 2.4 shows how the original image was used to create the icon, in this case for the site *City of Arts and Sciences*.

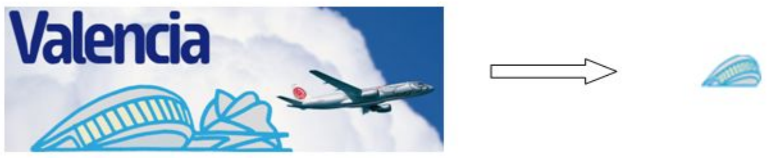


Figure 2.4: Creating an icon for the site *City of Arts and Sciences*.

2.4 Application design

2.4.1 Graphical User Interface

One of the main goals of the application *Great Places WikiGlobe* was to make it user-friendly, intuitive and able to be controlled by the user without a knowledge of any technology hidden behind it. Creating an interface between human and computer is a task being under research for many years. In the past, command-line interfaces (CLI) were in use. Operating this interface required typing commands on the keyboard, which logically meant one had to have a knowledge of the application's technology. Surely, once those commands were learned, an effective use of the application could be performed. However, this made a range of possible users very narrow. Graphical User Interface (GUI) is a solution how to make an application operable by different types of users, both experienced and non-experienced. GUI is a type of user interface that allows user to interact with electronic devices using images [6]. Besides computers, it is being used in hand-held services, such as MP3 players, portable media players or gaming devices.

GUI uses a combination of methods and technologies to provide a platform between the user and application. It offers a series of elements, that create a so-called visual language which allows user to interact with the software. The most common combination of such elements used today is called WIMP ("window, icon, menu, pointing device") paradigm, mainly between personal computers [6]. To implement those elements in one interface, a set of tools called widget toolkit[7] is used. There are different such toolkits based on different programming languages. In case of Java, the most used one today is a toolkit called Swing (more about Swing in the section 2.5.2).

The first WIMP component, *Window* is an area on the screen that serves to display an information within it and is independent from the other elements of GUI. There are different kinds of windows such as a container window, a browser window (used in web pages) or a text terminal window (used in CLI). Container window is the window invoked by clicking an icon and providing another set of icons than can be clicked. *Menu* provides a comprehensive set of the commands that can be executed by clicking the icon or by an input from the keyboard. Menu bar (Figure 2.5) is usually displayed horizontally across the top of the screen and is very often associated with a pull-down menu (Figure 2.6), that is shown every time the user clicks any of the menu bar elements. An *Icon* is a small picture representing some objects such as a program, file or web page. In GUI, icons can be grouped into a so-called toolbar (Figure 2.7), where each of them indicates the function that will be run once user clicks it. A *Pointing device* is an input interface that allows the user to input spatial data into application, by using different operations such

[7]Widget toolkit, or GUI library, or GUI toolkit is a set of widgets for use in designing applications with graphical user interfaces (GUIs).

as click or drag & drop. This is usually done by moving a cursor of the mouse across the screen of the GUI.

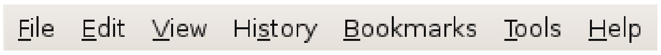


Figure 2.5: An example of menu bar.

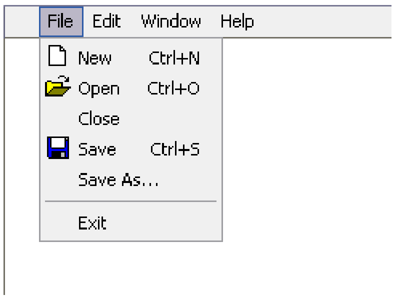


Figure 2.6: An example of pull-down menu.

Figure 2.7: An example of toolbar.

2.4.2 Design of GUI

A design of GUI of the application was made in such a way that the main part of it was taken by 3D globe. It was divided into 5 main parts (Figure 2.8):

1. menu bar and toolbar;
2. a window serving as a search engine for the places on the globe;
3. a window containing a list of layers;
4. a window containing a list of *Great Places of History* with an additional information to each of it;
5. a window containing 3D globe.

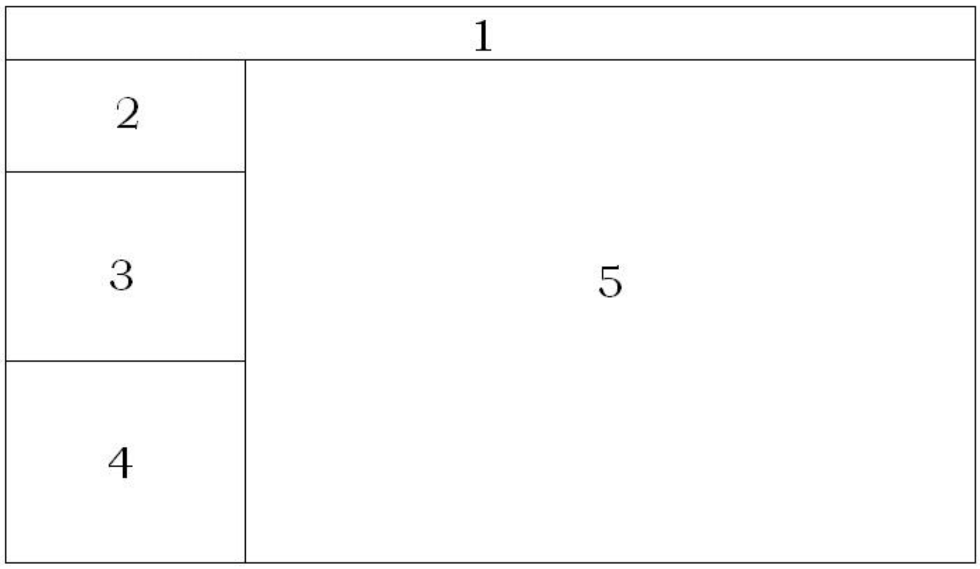


Figure 2.8: Design of GUI.

2.5 Implementation

2.5.1 Development environment

Once the database and application were designed, they were needed to be implemented. For that, an environment, in which the implementation would be undertaken, had to be chosen. To develop GUI application in Java, according to [33], there are basically two options how to make it:

1. by using a simple text editor;
2. by using IDE (Integrated Development Environment), a more sophisticated tool for creating applications in Java.

The opinions whether to use text editor or IDE differs, both concepts have their advantages and disadvantages. Writing the code within the text editor and then compiling it manually via command line is now used within smaller community of programmers. It becomes very useful when writing basic programs and learning how the whole programming works. Another advantage is that a developer does not have to learn how to operate a new software, what is needed in case of IDE. On the other hand, in the simple text editor, all the code has to be written by the developer. In order to create a sophisticated

GUI application, where the whole project consists of numbers of different classes included in many different packages, it is easier, time-saving and more clear to use IDE. IDEs are much more complex then text editors, they integrate tightly with the compiler or application server and usually dispose with SDK (Software Development Kit) as well as tools for debugging, version control and so forth [33]. According to [6], an IDE is *" ... a software application that provides comprehensive facilities to computer programmers for software development. An IDE normally consists of a source code editor, build automation tools and a debugger."* There are many of different IDEs used for developing applications in Java, from which the most used these days is Eclipse software [33].

Eclipse Helios

Eclipse is a multi-language software development environment comprising a base workspace and an extensible plug-in system for customizing the environment [6]. It is written mostly in Java and used to develop applications in Java as well. By using various plug-ins, other programming languages can be included, such as Python, C or C++. Eclipse SDK, which includes JDT (Java Development Tools), is a free open source software released under the term of the Eclipse Public License. It was firstly developed as a version 3.0 on June, 2004 and its last planned version (about to release on June 2014) is 4.4 with a project called Eclipse Luna. Eclipse Helios (Figure 2.9), which was used for the purpose of this work, was released on June 23, 2010 as the version 3.6 of this software.

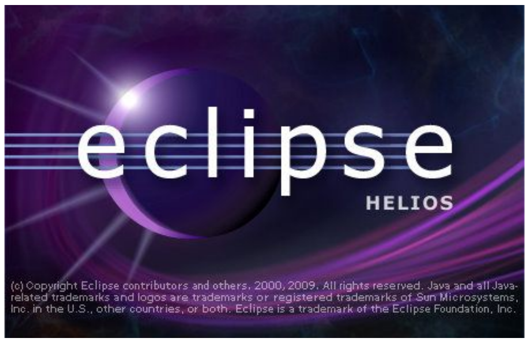


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Figure 2.9: A logo of Eclipse Helios.

phpMyAdmin client

Generally, to manage MySQL database, there are couple of third-party proprietary and free graphical administration tools, that are able to integrate with MySQL and enable users to work with data and database structure visually. For the purpose of this application, one such tool, phpMyAdmin (Figure 2.10) was chosen to work with the database `wikiglobe` defined in section 2.3. *PhpMyAdmin is a free and open source tool written in PHP*[8] *intended to handle the administration of MySQL with the use of web browser* [6]. It gives user a possibility to create, modify or delete database, tables, fields or rows as well as execute SQL statements.

Figure 2.10: A logo of phpMyAdmin.

At the beginning, the database named `wikiglobe` was created on localhost under `root` as a user. Afterwards, `*.xls` file, containing the only one table that database was consisting of (Table 2.4), was imported into this database and named as `greatplaces`. The whole process of creating the database was done then.

2.5.2 Implementation of GUI

To implement GUI, as has been already mentioned, there is a need of set of tools for creating GUI components and so widget toolkit. In Java, the first such toolkit was Abstract Windows Toolkit (AWT), followed by Swing, that is widely used in creating the majority of GUI applications in Java these days. In order to use this toolkit in the application, `swing` package has to be imported into the code: `import javax.swing.*`. Making the simplest GUI with Swing is very straight-forward and consists of following steps according to [3]:

1. making a frame by creating an instance of `JFrame` object: `JFrame frame = new JFrame();`

[8]PHP is a server-side scripting language designed for web development but also used as a general-purpose programming language.

2. making a widget (button, text field, ...): `JButton button = new JButton ("click me");`
3. adding the widget into the frame: `frame.getContentPane().add(button);`
4. displaying the frame (giving it size and making it visible): `frame.setSize(300,300); frame.setVisible()`.

Figure 2.11 depicts the class hierarchy of Swing components.

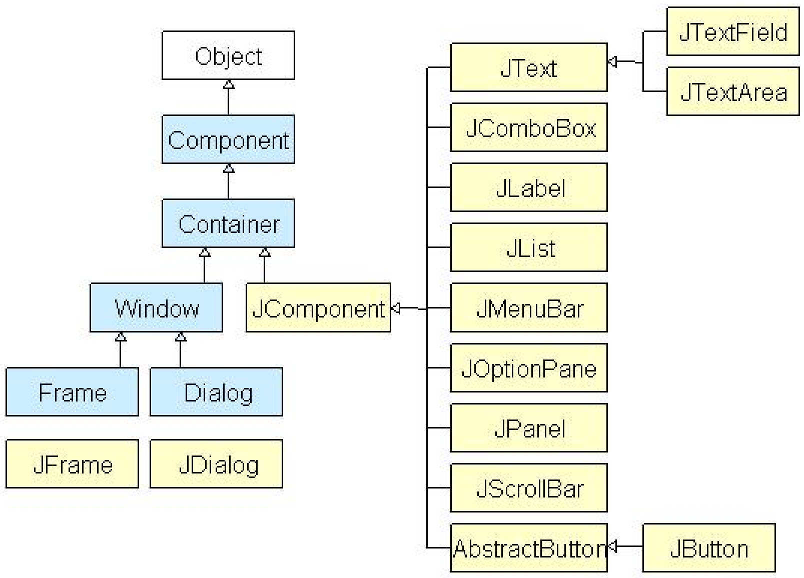


Figure 2.11: Swing class hierarchy.

In order to manage more sophisticated GUI, just simple `JFrame` window is not enough. Looking back to the application's design suggested, it is obvious that there will be a need of more than one window to be implemented within the main frame. Today, the most effective and popular way how to manage all these windows is making them *dockable*, i.e. to create windows that can exist either in a floating state or be attached to the main frame of the application [46]. Docking the component (or window) means that it can be dragged to a given location on the screen and then snapped into some unseen grid, not visible in a layout of the application. Hence, the component being dragged is docked into this layout at the location where it has been dropped. Dockable windows help to group the main application's frame into several fixed areas so that GUI does not look confusing and cluttered [45]. Docking framework is a set of tools responsible for providing a set of objects to manage these capabilities and its behaviour. There are several such frameworks available these days, such as Raven Docking, My Doggy, VL Docking, Docking Frames, JIDE Docking Framework and many others (according to [47]). From all of them, the most active one is Docking Frames, being also used for the purpose of this application.

Docking Frames

Docking Frames[9] is an open source Java Swing framework published under LGPL[10] 2.1, which allows a developer to use this framework in a way he likes [48]. As it has been already mentioned, the purpose of such framework is to write an application with floating panels that can be moved around by user. Here are some of the features listed according to [50]:

- pure Java/Swing;
- most components are replaceable and customizable;
- different "themes" allow to change look and feel during the runtime;
- client can associate buttons, checkboxes, drop-down menus and other components with the panels;
- toolbars;
- pop-up menus;
- behaviour of drag & drop can be modified;
- double clicks with the mouse are handled globally;
- panel's size can be locked while resizing its parent's window;
- color and fonts of tabs and titles can depend on the content.

[9] `http://dock.javaforge.com/index.html`
[10] Lesser GNU Public License

The project itself consists of two sub-projects: `Common` and `Core`, represented by libraries `docking-frames-core.jar` and `docking-frames-common.jar`, respectively. `Common` provides advanced functionalities that are built on top of `Core`, it is a wrapper around `Core` and requires `Core` to work [49]. On the client side, `Common` project is the one that should be used. In order to do so, both above mentioned libraries have to be included in the project.

Common project The most current version of Common project is 1.1.1., which consists of three layers: `common, facile` and `support`. For clients, the most used one is `common` layer [49]. The basic `Common` application consists of one main window represented by an instance of `JFrame` object, into which several other panels are incorporated, each of them for different purpose, grouping the GUI thematically. `Common` adds additional layer between main frame and panels in order to separate them and thus allows the user to use drag & drop mechanism within the panels (windows). For doing this, every panel has to be wrapped into a `CDockable`. Afterwards, the `CDockables` are put onto a set of `CStations` providing the mentioned layer between the main frame and panels inside it. Furthermore, a controller (of type `CControl`) has be to initiliazed in order to manage the look, position and behaviour of all the elements. Since `CDockable` is an interface, a developer should use one of two classes implementing this interface: `DefaultSingleCDockable` or `Default-MultiCDockable`. A basic difference between them is that `single-dockables` exist just once, while `multi-dockables` can be destroyed and created again by the framework any time.

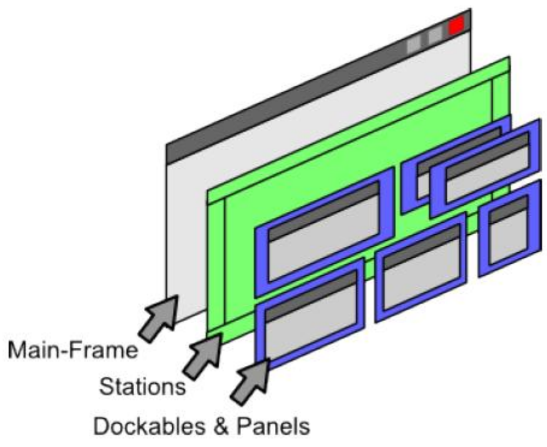


Figure 2.12: Basic components of `Common` library.

The application *Great Places WikiGlobe* used `Common` library to create its GUI. Before doing so, firstly a main frame together with a menu bar and toolbar were created in order to get a basic structure of GUI (Listing 2.4). All Swing components were implementing an interface `I18nComponent`, which was controlling an internationalization of the application.

```
...
  frame = new JMainFrame(GreatPlaces.class);

  menuBar = new JMenuBar();
  frame.setJMenuBar(menuBar);

  menuFile = new I18nJMenu(I18nKeyConstants.MENU_FILE);
  menuBar.add(menuFile);

  menuOpenFile = new I18nJMenuItem(I18nKeyConstants.MENU_FILE_IMPORTLAYER);
  menuOpenFile.setIcon(Icons.importlayer.getIcon());
  menuFile.add(menuOpenFile);
  menuFile.addSeparator();
...
```

Listing 2.4: Creating main frame and other Swing components.

According to the application's design, there were supposed to be four windows inside main `frame`. Eeach of them was wrapped into `CDockable` by creating a subclass of `DefaultSingleCDockable` called `I18nDefaultSingleCDockable`. This class was implementing `I18nComponent` interface similarly as `JComponents` described above. From `I18nDefaultSingleCDockable`, four different subclasses were extended, each of them defining a single window in GUI:

- `EarthViewDockable`, into which the 3D globe was implemented;
- `SearchViewDockable`, which provided a window for searching for the places on the globe;
- `LayerViewDockable`, providing a list of layers;
- `GreatPlacesInfoDockable`, providing a window for searching for a concrete place from *100 Great Places of History*.

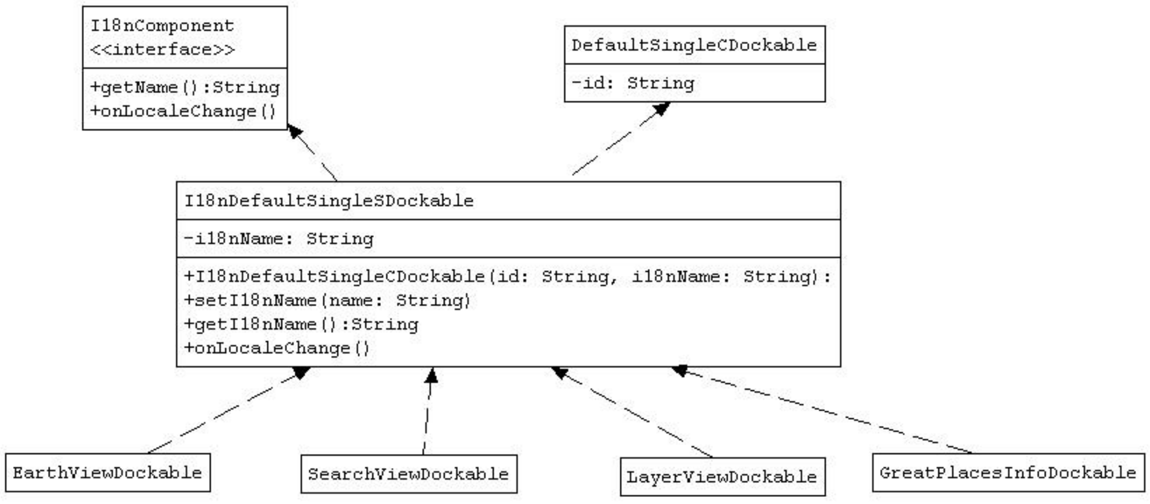


Figure 2.13: A class hierarchy of 4 main windows - `CDockables` in the application.

These four `CDockables` were controlled by creating an instance of `CControl` object, which served as an inter-layer between them and the main frame called `frame` (`frame` was created as shown in Listing 2.4). `CGrid` was used to make a layout of all four components within `frame`. The method `setViewLayout()` (Listing 2.5) shows how the whole process was implemented.

```
private void setViewLayout(){
  ccontrol = new CControl(frame);
  frame.destroyOnClose(control);
  frame.getContentPane().add(control.getContentArea(), BorderLayout.CENTER)
      ;
  frame.setVisible(true);

  earth = new EarthViewDockable(wwd, I18nKeyConstants.VIEW_EARTH);
  search = new SearchViewDockable(wwd, I18nKeyConstants.VIEW_SEARCH);
  layers = new LayerViewDockable(wwd, I18nKeyConstants.VIEW_LAYERS);
  great = new GreatPlacesInfoDockable(wwd,I18nKeyConstants.VIEW_FAVORITE);

  control.addDockable(earth);
  control.addDockable(layers);
  control.addDockable(search);
  control.addDockable(great);

  control.setTheme(ThemeMap.KEY_ECLIPSE_THEME);

  grid = new CGrid(control);
  grid.add(0, 0, 40, 30, search);
  grid.add(40, 0, 100, 100, earth);
```

```
    grid.add(0, 30, 40, 80, layers);
    grid.select(0, 30, 40, 80, layers);
    grid.add(0, 80, 40, 100, great);
    control.getContentArea().deploy(grid);
}
```

Listing 2.5: Setting a layout of the application.

2.5.3 Implementation of World Wind Java technology

World Wind Concept

In order to use the capabilities and functionality of World Wind Java SDK, it is vital to understand how World Wind components work. To display 3D globe and other geographic content within Java application, one or more `WorldWindow` objects have to be inserted into the code. Except for `WorldWindow`, there are several other major World Wind interfaces (Figure 2.14) [39]:

- `Globe` representing the shape and terrain of the planet, having `Tessellator` interface included to generate the terrain;
- `Layer` applying imagery, shapes and other information to the globe;
- `Model` aggregating the globe and its layers;
- `View` determining the user's view of the model and driven by input events from the user via `InputHandler` interface;
- `SceneController` controlling the rendering of `Model` and associating `Model` with `View`.

All World Wind components are extensible, meaning that a concrete class within SDK can be replaced or extended. This functionality gives user a lot of space to "play" with the components. The easiest example of applying these components is a demo `HelloWorldWind.java` included in `gov.nasa.worldwindx.examples` package. An extraction of it is shown in Listing 2.6.

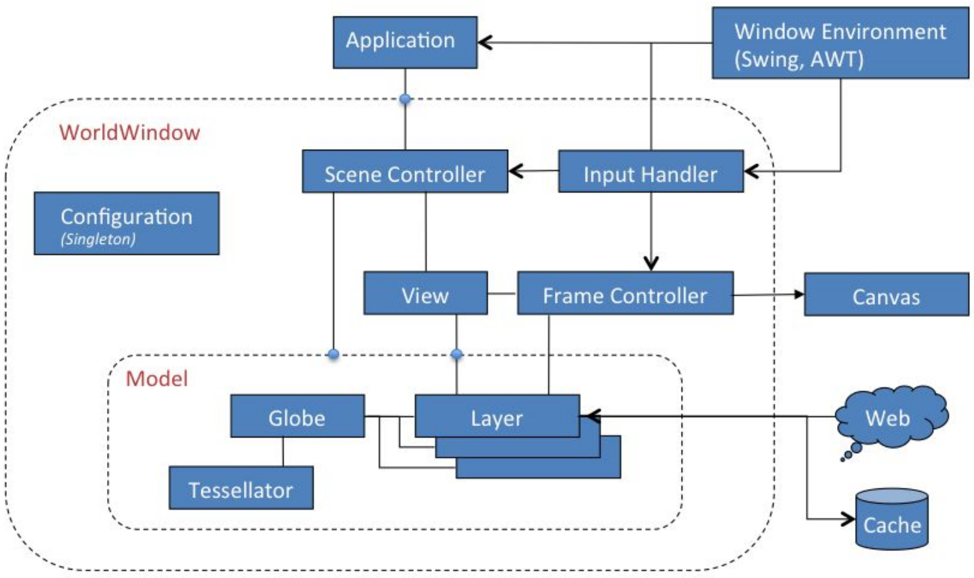


Figure 2.14: The concept of World Wind Java SDK.

```java
    private static class AppFrame extends javax.swing.JFrame
     {
          public AppFrame()
          {
               WorldWindowGLCanvas wwd = new WorldWindowGLCanvas();
               wwd.setPreferredSize(new java.awt.Dimension(1000, 800));
               this.getContentPane().add(wwd, java.awt.BorderLayout.CENTER);
               this.pack();

               wwd.setModel(new BasicModel());
          }
     }

     public static void main(String[] args)
     {

      java.awt.EventQueue.invokeLater(new Runnable()
          {
               public void run()
               {
                    // Create an AppFrame and immediately make it visible. As
                         per Swing convention, this
                    // is done within an invokeLater call so that it executes
                         on an AWT thread.
                    new AppFrame().setVisible(true);
               }
           });

    }
```

Listing 2.6: An extraction of `HelloWorldWind.java`.

From the demo above it can be seen how World Wind components are implemented into Java code. Firstly, an instance of `WorldWindowGLCanvas` object, that is implementing `WorldWindow` interface, is created (line 5). Afterwards, the model is passed to it by calling method `setModel` (line 10). This method has one argument, defining a type of `Model` being used. The most basic model is `BasicModel` and by creating an instance of this object, globe and layers are automatically aggregated into `WorldWindow`.

World Wind's technology implementation into the application

Similarly as in the demo in Listing 2.6, World Wind components were implemented into the application defined in the method `initEarthModel()` (Listing 2.7). There were also additional components added, and so `HighlightController, ToolTipController, HotSpotController` and `BalloonController`. `HighlightController` is used to control highlighting of any shapes in a concrete `WorldWindow`. `ToolTipController` component controls the display of tool tips of picked objects within `WorldWindow`. In case of `HotSpotController`, this component is used to control mouse and keyboard events made within `WorldWindow`. `BalloonController` controls the display of `Balloon` objects (more about `Balloon` in the section 2.5.4).

```java
private void initEarthModel(){
  wwd = new WorldWindowGLJPanel();
  Model model = (Model) WorldWind.createConfigurationComponent(AVKey.MODEL_CLASS_NAME);
  wwd.setModel(model);

     ....

  wwd.addSelectListener(new ClickAndGoSelectListener(wwd, WorldMapLayer.class));

   highlightController = new HighlightController(wwd, SelectEvent.ROLLOVER);
   toolTipController = new ToolTipController(wwd, AVKey.DISPLAY_NAME, null);
   hotSpotCpntroller = new HotSpotController(wwd);
   balloonController = new BalloonController(wwd);
}
```

Listing 2.7: Initializing of World Wind components.

By default, following layers are included in any World Wind application:

- Stars,
- Atmosphere,
- NASA Blue Marble Image,
- i-cubed Landsat,
- USDA NAIP,
- USDA NAIP USGS,
- MS Virtual Earth Aerial,
- Bing Imagery,
- USGS Topographic Maps 1:250K,
- USGS Topographic Maps 1:100K,
- USGS Topographic Maps 1:24K,
- USGS Urban Area Ortho,
- Political Boundaries,
- Place Names,
- World Map,
- Scale Bar,
- Compass,
- Controls.

All the layers are layers of imagery displayed on the globe, except for the last four of them. They serve as "layers" to turn on/off the display of `WorldMap`, `Scale Bar`, `Compass` and `Controls` components within `WorldWindow`, respectively. `World Map` is a map of the world located by default in the north-west corner of `WorldWindow`. Very useful feature of this component is that by user's clicking in to any place on this map, it will automatically zoom in to the same location on 3D globe. To do so, `ClickAndGoListener` has to be implemented (see Listing 2.7, line 8). `Scale Bar` serves to display a scale bar within `WorldWindow` and is located in the south-east corner of it, while `Compass` displays a compass and is put into the north-east corner of the window. Finally, `Controls` is a World Wind component providing a set of tools for zooming in/out, rotating and tilting the view. Its default position is in the south-west corner of `WorldWindow`.

To include a list of layers within `LayerViewDockable` window, firstly, all the layers were retrieved:

```
LayerList layers = wwd.getModel().getLayers();
```

Listing 2.8: A retrieval of the layers.

Afterwards, an instance of `LayerTreeModel` object called `treeModel`, a subclass of `TreeModel` class defined within `java.swing.tree` package was created, taking the list of layers `layers` as an argument. This model was then passed as an argument of an instance of `CheckBoxTree` object, a subclass of `JTree`. Finally, an instance of `JScrollPane`, `treeContainer` was displayed within `LayerViewDockable` window (Listing 2.9).

```
  treeModel = new LayerTreeModel(layers);
  layerTree = new CheckBoxTree(treeModel);
  treeContainer = new JScrollPane(layerTree);

  getContentPane().add(treeContainer, BorderLayout.CENTER);
```

Listing 2.9: Including the list of layers within `LayerViewDockable` window.

To display 3D globe within `EarthViewDockable` window, `wwd`, an instance of `World-WindGLJPanel` object, defined in the method `initEarthModel` (Listing 2.7), was added into a content pane of the window, in a following way:

```
getContentPane().setLayout(new BorderLayout());
getContentPane().add(wwd, BorderLayout.CENTER);
```

Listing 2.10: Displaying 3D globe within `EarthViewDockable` window.

100 Great Places of History as add-on

One of the benefits of World Wind Java technology is that a developer can import his own made plug-in or add-on into the application (see section 1.3.1) meaning that, for example, besides a default set of layers, any other layer can be incorporated and used. Those layers, either point, line or polygon, are imported into World Wind as XML layers. WikiGlobe SDK disposes with a class `WWXMLIconLayer`, a subclass of `IconLayer` defined in `gov.nasa.worldwind.layers` package, that serves for this purpose (Figure 2.15).

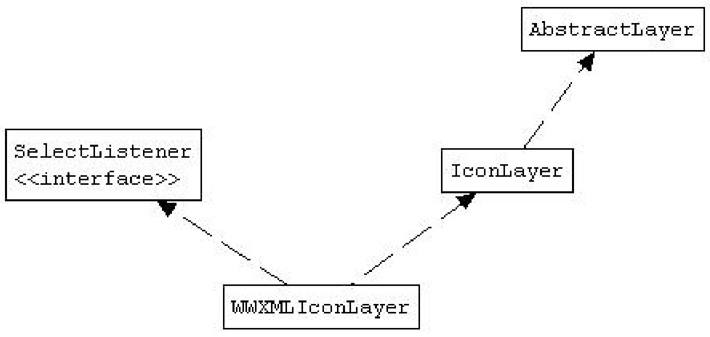


Figure 2.15: Class hierarchy of `WWXMLIconLayer`.

Moreover, a template for XML file, that could be read by the method `readXML(String file)` of `WWXMLIconLayer` class, was developed. Having this, firstly, XML file `GreatPlacesIcons.xml` (Listing 2.11) was created, including all the places that were about to be imported.

```
<?xml version="1.0" encoding="UTF-8"?>
...
  <Icon>
    <Name_e>Pyramid of Khufu and The Sphinx</Name_e>
    <Latitude>
      <Value>29.979</Value>
    </Latitude>
    <Longitude>
      <Value>31.134</Value>
    </Longitude>
    <DistanceAboveSurface>5</DistanceAboveSurface>
    <TextureFilePath>data/icons/1/transp_icon.png</
       TextureFilePath>
    <TextureWidthPixels>128</TextureWidthPixels>
    <TextureHeightPixels>128</TextureHeightPixels>
    <IconWidthPixels>32</IconWidthPixels>
    <IconHeightPixels>32</IconHeightPixels>
    <ClickableUrl></ClickableUrl>
  </Icon>
...
```

Listing 2.11: An extraction of `GreatPlacesIcons.xml`.

Afterwards, an instance of `WWXMLIconLayer` was made and added to the list of layers.

```
 GreatPlacesIcons = new WWXMLIconLayer("config/Earth/GreatPlacesIcons.xml"
     , "Great Places of History", Position.fromDegrees(0, 0))
 ...
wwd.addSelectListener(GreatPlacesIcons);
 GreatPlacesIcons.setName("Great Places");
 GreatPlacesIcons.setEnabled(true);
 layerList.add(GreatPlacesIcons);
```

Listing 2.12: Incorporating `GreatPlacesIcons.xml` into the application.

2.5.4 Implementation of an information window

To implement an information window, which would contain information about every site, firstly, a communication between the database server and the application had to be ensured.

Connecting the database with the application

Generally, to get an access to a database from Java application, JDBC driver and connection string are needed, specific for every database platform [2]. In case of MySQL database, JDBC driver is `com.mysql.jdbc.driver` and the connection string `jdbc:-mysql://server/database_name?characterEncoding=UTF-8`. Adding the driver for the communication with the database server is done by including a library `mysql-connector-java-5.0.7-bin.jar` within the project. Firstly, a configuration XML file `config.xml` was created, in which the connection string to the database stored locally via phpMyAdmin, username and password for accessing it were defined (Listing 2.13). Afterwards, this XML file was read by the method `openDatabase()` included in class `OpenMySql`.

```xml
<?xml version="1.0" encoding="UTF-8" ?>
<config>
  <connecting>
    <url>jdbc:mysql://localhost:3306/greatplaces</url>
    <user>username</user>
    <password>password</password>
  </connecting>
</config>
```

Listing 2.13: A configuration XML file `config.xml`.

`Balloon` interface

In World Wind Java SDK, there are basically two ways how to display additional data within `WorldWindow`:

1. by implementing `Annotation` interface;

2. by implementing `Balloon` interface.

`Annotations` are text labels with support for multi-line text, simple HTML and many styling attributes such as font face, size and color, bubble shapes and background image. These information can be either attached to a particular location on the globe or simply to a point on the screen. The concept of `Balloons` is similar to `Annotations`, however, besides simple HTML, it supports JavaScript and Flash[11] content as well. Since the information about every site will include video as well, `Balloon` interface is a right choice. There are two interfaces implementing `Balloon` interface: `GlobeBalloon` and

[11]Flash is frequently used to add streamed video or audio players, advertisement and interactive multimedia content to web pages. It was created by Adobe Systems, that implemented Adobe Flash platform.

ScreenBalloon. Because the information window should be attached to a particular place on the globe, GlobeBalloon is used. Two classes are implementing this interface: GlobeBrowserBalloon and GlobeAnnotationBalloon, from which the first one is suitable for the purpose of this application. A class hierarchy between Balloon interface and its subclasses is depicted in Figure 2.16.

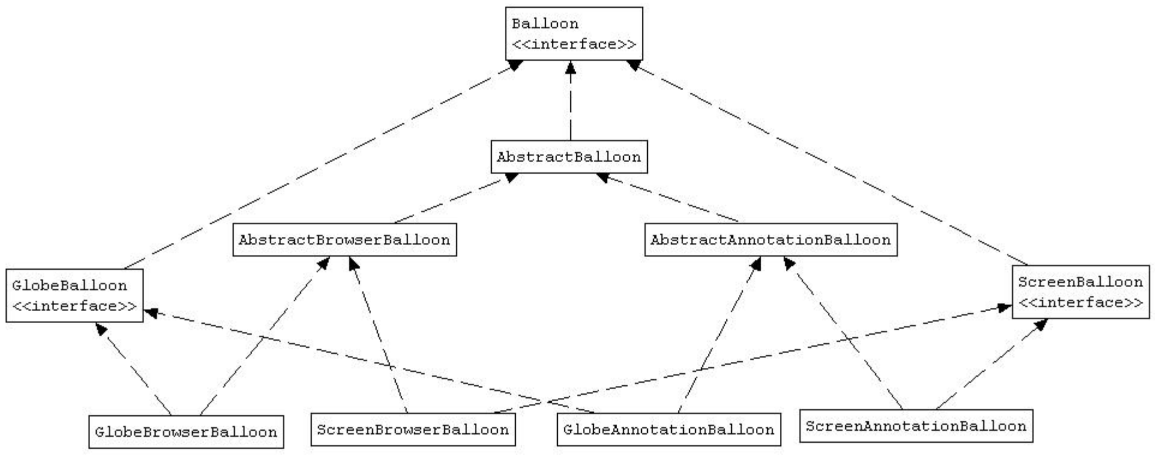


Figure 2.16: Class hierarchy of Balloon.

A constructor of the class GlobeBrowserBalloon, public GlobeBrowserBalloon(String text, Position position), is taking two arguments, where text is of type String and defines the content of the balloon and position says where the balloon should be located, defined by the latitude and longitude. Package gov.nasa.worldwindx.examples disposes with an example Balloons.java (Listing 2.14) showing how one can include a HTML content within the balloon. Firstly, HTML content is read as a byte stream by using classes within gov.nasa.worldwind.util.WWIO package (line 10). This input byte stream is then read into String (line 11) and passed as an argument to create an instance of GlobeBrowserBalloon object (line 23).

```
1  ...
2    protected static final String BROWSER_BALLOON_CONTENT_PATH = "gov/nasa/
       worldwindx/examples/data/BrowserBalloonExample.html";
3
4    String htmlString = null;
5    InputStream contentStream = null;
```

```

  try
  {
    // Read the URL content into a String using the default encoding (UTF
        -8).
    contentStream = WWIO.openFileOrResourceStream(
        BROWSER_BALLOON_CONTENT_PATH, this.getClass());
    htmlString = WWIO.readStreamToString(contentStream, null);
  }
  catch (Exception e)
  {
    e.printStackTrace();
  }
  finally
  {
    WWIO.closeStream(contentStream, BROWSER_BALLOON_CONTENT_PATH);
  }
  Position balloonPosition = Position.fromDegrees(38.883056, -77.016389);

  AbstractBrowserBalloon balloon = new GlobeBrowserBalloon(htmlString,
      balloonPosition);
...
```

Listing 2.14: An extraction of `Balloons.java`.

`MainBrowserBalloon.html`

To create a HTML template `MainBrowserBalloon.html`, three technologies have been used: HTML, CSS and JavaScript. HTML, or HyperText Markup Language, is the main markup language for creating web pages and other information that can be visualized in the web browser [6]. Every HTML document is basically a set of HTML elements, or tags, that define a design of the content. The hierarchy of basic such elements can be seen on Figure 2.17. Every HTML document has to be enclosed by `<html>` tags, inside which there are two main tags included: `<head>` and `<body>`. The content within `<head>` tags is not visible to the user of the page and includes a definition of scripts (such as JavaScript scripts), metada information or defines a style of the page (in charge of CSS). On the other hand, everything put between `<body>` tags will become visible to the "world".

JavaScript (JS) is an interpreted programming language, originally developed as a part of web browsers so the client-side scripts could interact with the user [6]. The syntax of the language is influenced the language C and a lot of names and conventions are copied from Java, however, Java and JavaScript are not related, even though their names

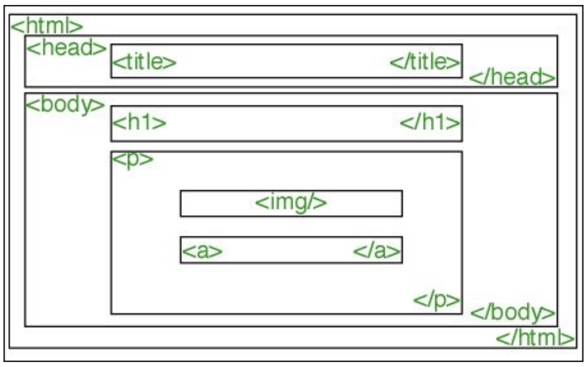


Figure 2.17: A basic hierarchy of HTML elements.

could it possibly evoke. The key design principles are taken from the Self and Scheme programming languages. The purpose of JavaScript included in HTML page is to add an interactivity within this page, being explained on a very basic example (Listing 2.15). Here, the JS function `myFunction()` is defined within `<script>` tags and called every time a user clicks on the button saying "Click Me!". The calling is invoked by setting an additional attribute within `<button>` tag and so `onclick="myFunction"` (line 13).

```
 1 <!DOCTYPE html>
 2 <html>
 3   <body>
 4 
 5     <script>
 6       function myFunction()
 7       {
 8         x=document.getElementById("demo");  // Find the
              element
 9         x.innerHTML="It works!";    // Change the content
10       }
11     </script>
12 
13     <button type="button" onclick="myFunction()">Click Me!</
         button>
14 
15   </body>
16 </html>
```

Listing 2.15: A basic HTML with JS function implemented.

Cascading Style Sheets, or CSS, is a style sheet language used for describing the presentation semantics (the look and formatting) of a document written in a markup language [6]. Its main goal is to design a style of HTML or XHTML[12] documents. The definition of the style of the web page, including elements such as `layout`, `colors` and `fonts`, is managed within the `<head>` elements and thus makes the document content represented by `<body>` tags separated from the content managing the style. This separation provides more flexibility, improves content accessibility and the created CSS template can be interchangeably used between more web pages.

The document `MainBrowserBalloon.html` was designed in a such way that it was containing tab interface with four tabs inside it:

- tab *Info*, including a description of every site;
- tab *Story from TIME*, containing a text from the book *Great Places of History* [5];
- tab *Pictures*, where a photo gallery was implemented;
- tab *Video*, including a video about every site.

To implement such design, two CSS styles' templates, one for the overall design of the document and one for the design of the photo gallery, were used. Moreover, JS functions ensuring the functionality of tab interface were also implemented. The CSS template and JS functions operating the tab interface were a modified version of *JavaScript tabifier* [52] created by Patrick Fitzgerald.

The whole process of creating the information window is depicted in Figure 2.18. It starts with the left mouse click on the desired site on the globe, which we want to display information about. This site is represented by an icon, concretely a class `ClickableIcon`, defined as the inner class of the class `WWXMLIconLayer` (Figure 2.15) and extending the class `UserFacingIcon`, included in `gov.nasa.worldwind.render` package. An instance of `ClickableIcon` object, `icon`, was created as shown in Listing 2.16 (line 9). The mouse left click on it was controlled by the class `SelectEvent`, defined within `gov.nasa.worldwind.event` package. When the user clicked the icon under the cursor,

[12]XHTML (Extensible HyperText Markup Language) is a family of XML markup languages that mirror or extend versions of the widely used Hypertext Markup Language (HTML), the language in which web pages are written.

all select event listeners defined in World Wind SDK were called and recognized by invoking `getEventAction()` method (line 6).

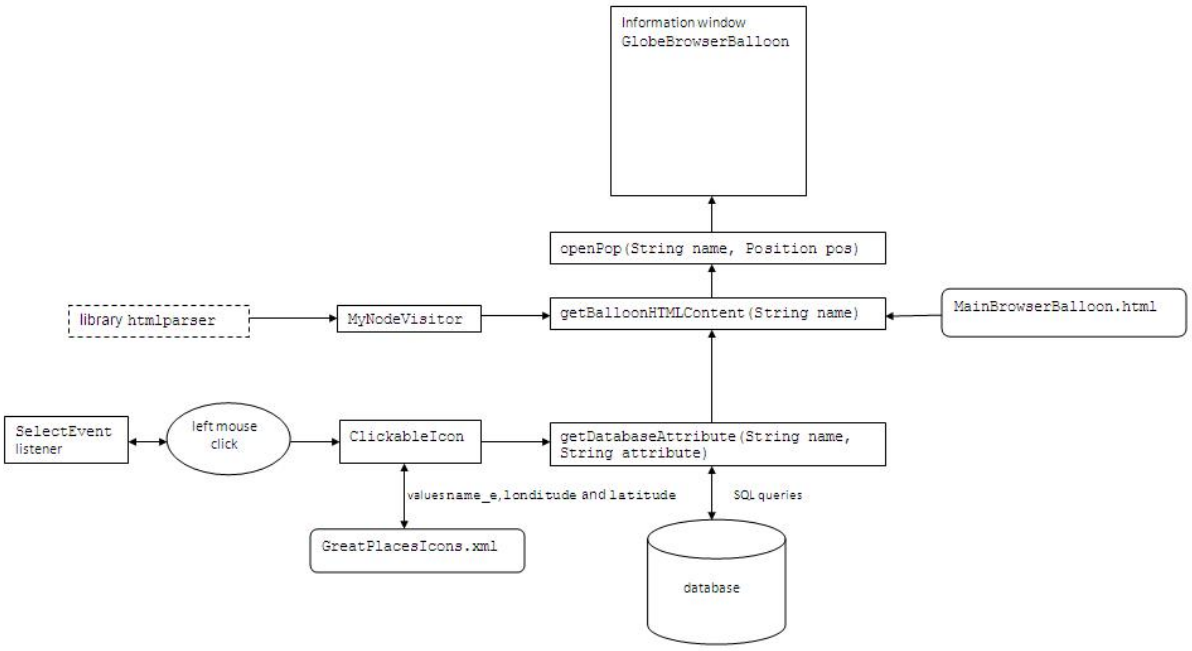


Figure 2.18: The process of creating an information window.

```
 1 GreatPlacesIcons = new WWXMLIconLayer("config/Earth/GreatPlacesIcons.xml",
     "Great Places of History", Position.fromDegrees(0, 0)){
 2     @Override
 3     public void selected(SelectEvent event){
 4       super.selected(event);
 5
 6       if (event.getEventAction().equals(SelectEvent.LEFT_CLICK)) {
 7         if (event.hasObjects()) {
 8             if (event.getTopObject() instanceof ClickableIcon) {
 9               ClickableIcon icon = (ClickableIcon) event.getTopObject();
10               openPop(icon.getName(), icon.getPosition());
11             }
12           }
13         }
14     }
15 };
```

Listing 2.16: An implementaiton of a class `ClickableIcon`

The class `ClickableIcon` disposes with a set of getter and setter methods to retrieve the values (`name_e, longitude` and `latitude`) stored in the XML file `GreatPlacesIcons.xml`

(Listing 2.11). The value `name_e`, referring to the name of the concrete place being clicked, is then used as one of the parameters in the function `getDatabaseAttribute(String name, String attribute)` (Listing 2.17). The second parameter, `attribute`, defines the attribute in the database whose value we want to retrieve.

```
public String getDatabaseAttribute(String name, String attribute)
  {
    String cmdStr = "SELECT * FROM greatplaces WHERE name = '"+name+"';";
    ResultSet rs = ConnectMySql.GetResultSet(cmdStr);

    String resultStr = "";
    try {
        if (rs != null) {
          if (rs.next()) {
            rs.last();

            resultStr = rs.getString(attribute);
          }
        }
     }catch(Exception e){
       e.printStackTrace();
     }
     return resultStr;
  }
```

Listing 2.17: A method `getDatabaseAttribute(String name, String attribute).`

The method `getDatabaseAttribute(String name, String attribute)` was then passed into the method `getBalloonHTMlContent(String name)` (Listing 2.19). Its purpose was to "recreate" the HTML template `MainBrowserBalloon.html` according to the site being clicked. To do that, a method of *parsing* was implemented. *Parsing is the process of analysing a string of symbols, either in natural language or in computer languages, according to the rules of a formal grammar* [6]. To parse the template `MainBrowserBalloon.html` into a set of strings, a class `MyNodeVisitor` (Listing 2.18), extending the class `NodeVisitor` defined within `org.htmlparser.visitors` package, was created. The purpose of this class is to replace the keyword values defined in the template `MainBrowserBalloon.html` with the values of attributes retrieved from the database and thus make a unique HTML content for each of it. For instance, the string `DataName` defined in the template would be replaced by the the string `name`, representing the name of the place being clicked (line 19).

```
  public class MyNodeVisitor extends NodeVisitor {
    String name;
    String text;
    String storyText;
    String videoID;
    ArrayList<String> pictures;


      public MyNodeVisitor(ArrayList<String> Pictures, String Name, String
          Text, String StoryText, String VideoId){
      this.name = Name;
      this.text = Text;
      this.storyText = StoryText;
      this.videoID = VideoId;
      this.pictures = Pictures;
      }

      public void visitStringNode (Text string)
      {
          if (string.getText().equals("DataName")) {
              string.setText(name);
          }

          else if (string.getText().equals("DataText")){
              string.setText(text);
          }

          else if (string.getText().equals("DataStory")){
              string.setText(storyText);
          }
      }

   ...
}
```

Listing 2.18: A class `MyNodeVisitor`.

As has been mentioned, the parsing process was included in the method `getBalloon-HTMlContent(String name)` (Listing 2.19). An instance of `Parser` object, `parser`, was taking as a parameter the byte stream representation of HTML template `MainBrowser-Balloon.html`, `htmlstring` (line 29). Afterwards, an instance of `MyNodeVisitor` object, `nodeVisitor` was created and by method `visitAllNodesWith(NodeVisitor nodeVisi-tor)` also implemented (line 32). Finally, the list of nodes `nl` was converted into string representation by the method `toHtml()` (line 41).

```java
public String getBalloonHTMLContent(String name)
  {
        NodeList nl = new NodeList();
     ...

      String resultStr = getDatabaseAttribute(name,"description_path");
      String resultStr2 = getDatabaseAttribute(name,"name");
      String resultStr3 = getDatabaseAttrinute(name, picture_path);
      ArrayList<String> pictures = this.getPictureFolderContent(name,
          resultStr3);

      String resultStr4 = getDatabaseAttribute(name,"story");
      String resultStr5 = getDatabaseAttribute(name,"video_path");

    try
        {
            // Read the URL content into a String using the default
                encoding (UTF-8).
      contentStream = WWIO.openFileOrResourceStream(BROWSER_BALLOON, this.
          getClass());
            htmlString = WWIO.readStreamToString(contentStream, null);
            contentStream2 = WWIO.openFileOrResourceStream(resultStr, this.
                getClass());
            textString = WWIO.readStreamToString(contentStream2, null);
            contentStream3 = WWIO.openFileOrResourceStream(resultStr4, this
                .getClass());
            storyString = WWIO.readStreamToString(contentStream3, null);

        }
       ...


    try {
      Parser parser = new Parser(htmlString);
      nl = parser.parse(null);
      MyNodeVisitor nodeVisitor = new MyNodeVisitor(pictures, resultStr2,
          textString, storyString, resultStr5);
      nl.visitAllNodesWith(nodeVisitor);

      nl.toString();

    } catch (ParserException e) {
      // TODO Auto-generated catch block
      e.printStackTrace();
    }

    String output = nl.toHtml();

    return output;

    }
```

Listing 2.19: A method `getBalloonHTMlContent(String name)`.

The method `getBalloonHTMlContent(String name)` was finally passed to the method `openPop(String name, Position pos)` (Listing 2.20). An argument `pos` was defined by the values `latitude` and `longitude` derived from the file `GreatPlacesIcons.xml` (Listing 2.11) at the beginning of the process. An instance of `GlobeBrowserBalloon` object, `balloon` was created (line 4) and the information window was opened in the interface.

```
 1 Gpublic void openPop(String name, Position pos){
 2
 3     String content = getBalloonHTMLContent(name);
 4     GlobeBrowserBalloon balloon = new GlobeBrowserBalloon(content,pos);
 5
 6     ....
 7
 8     balloon.setAlwaysOnTop(true);
 9          RenderableLayer layer = new RenderableLayer();
10          layer.setName("Balloons");
11
12          layer.addRenderable(balloon);
13          wwd.getModel().getLayers().add(layer);
14
15   }
```

Listing 2.20: A method `openPop(String name, Position pos)`.

Chapter 3

Results

The following chapter will present the application *Great Places WikiGlobe*, mainly by the screenshots of its GUI, with describing its functionality. When running the application, a splash screen is displayed until the interface is loaded (Figure 3.1).

Figure 3.1: A splash screen of the application.

Once the application is loaded, the main interface is shown (Figure 3.2). The menu bar consists of 5 drop-down menus, and so *File*, *View*, *Tools*, *Settings* and *Help*. In the *File* menu, the user can import a SHP layer or take a screenshot of the depicted area on the globe. An interesting feature included in the *View* menu is a possibility to change the view mode from "Earth" to "Flat" and thus convert 3D globe into 2D map represented by four different projections: Mercator (Figure 3.3), Sinusoidal, Modified Sinusoidal and

Latitude-Longitude. In the *Settings* menu, the language in which the GUI is displayed can be switched between chinese and english.

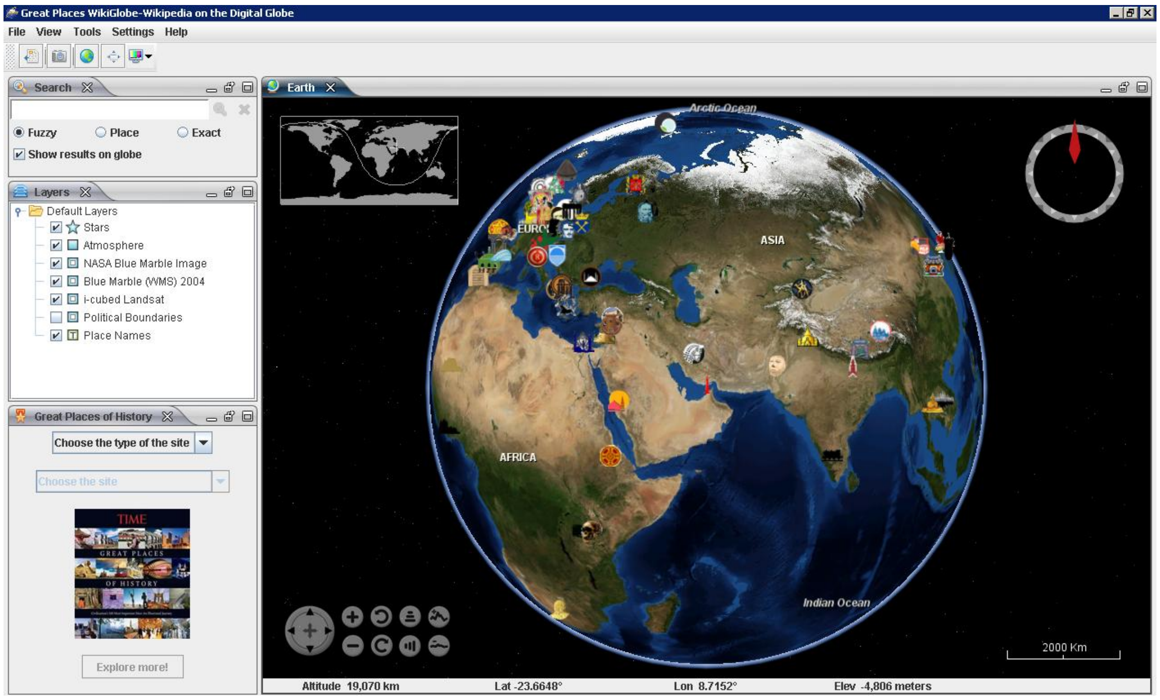


Figure 3.2: The main interface of the application.

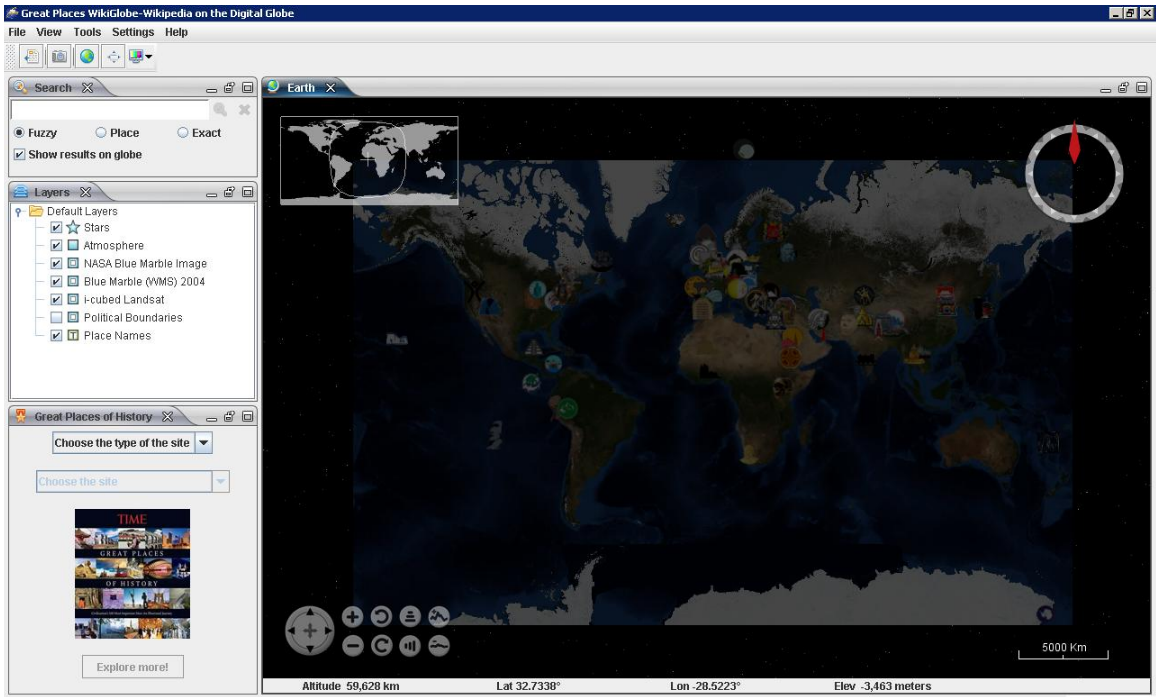
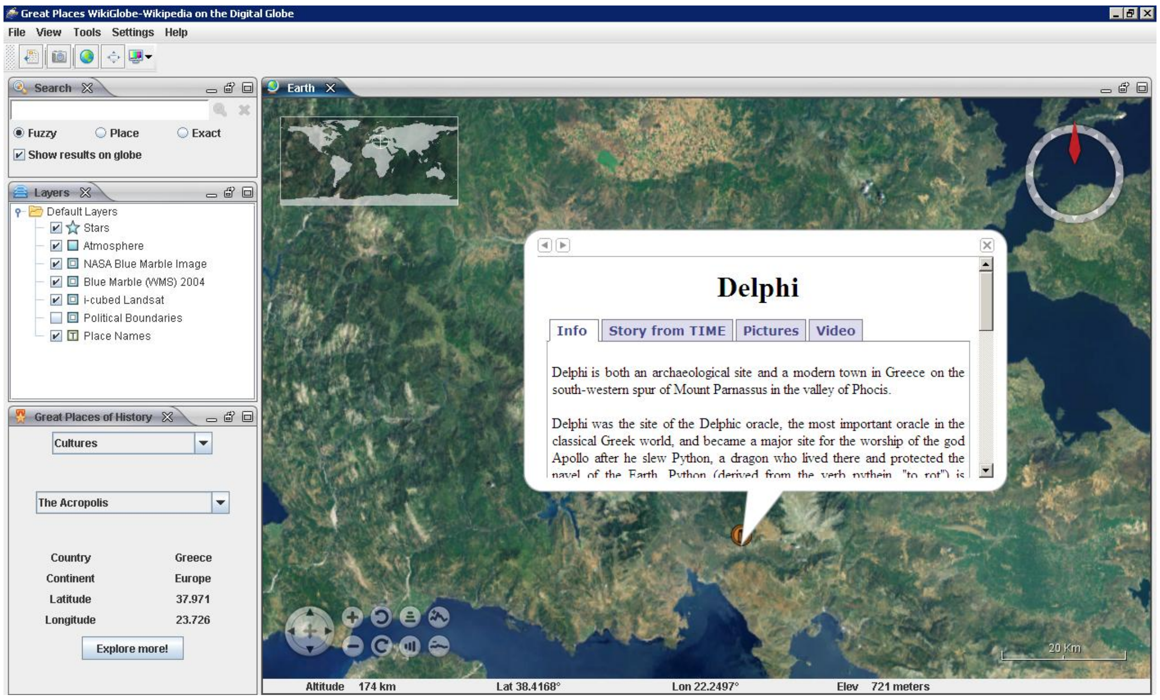


Figure 3.3: 2D view in Mercator projection.

The user can view the concrete place either by zooming manually in to it, or by managing the window *Great Places of History* in the south-west corner of the GUI of the application. There, he firstly chooses from the drop-down list, which type (category) of the site he wants to search for. After selecting an appropriate choice, the second drop-down list will become active, where he will pick the concrete site. Then, the basic information about the place, concretely the country, continent and coordinates will appear in the window. By clicking the button *"Explore more!"*, the user "will fly" to the place he has chosen until a certain altitude above the ground. Then, clicking the icon representing the site, an information window will pop-up (Figure 3.4). It displays following information: in the first tab, it is a description of the site, the second tab contains the text from the book *Great Places of History* [5], the third one includes a photo gallery and the last one a video about the site.



Delphi

Delphi is both an archaeological site and a modern town in Greece on the south-western spur of Mount Parnassus in the valley of Phocis.

Delphi was the site of the Delphic oracle, the most important oracle in the classical Greek world, and became a major site for the worship of the god Apollo after he slew Python, a dragon who lived there and protected the navel of the Earth. Python (derived from the verb pythein, "to rot") is

Country	Greece
Continent	Europe
Latitude	37.971
Longitude	23.726

Altitude 174 km   Lat 38.4168°   Lon 22.2497°   Elev 721 meters

Figure 3.4: An information window about the site *Delphi*.

Chapter 4

Conclusion and Discussion

Today, one of the most current research themes in geoinformatics is how to integrate an information from the wide range of sources with a use of geospatial and geovisualization methods and interpret retrieved data in an understandable way [24]. The main goal of WikiGlobe project, that has been being developed at Beihang University for couple of years, is to provide a set of tools that will allow a developer to merge virtual globe with additional data, such as an extraction from the text, video, audio recordings or pictures in order to find a way how to fulfil the mentioned research direction. *Great Places WikiGlobe* has shown a potential to create an application that can satisfy this criteria and its main goal, incorporating *100 Great Places of History* [5], represented by its description, pictures and video, was convened.

World Wind Java SDK, a development kit that WikiGlobe SDK is based on, is a unique set of tools providing the methods for displaying 3D globe and other features related to it. As the second most used virtual globe these days, with its open-source character and well-developed SDK, it is undoubtedly the best choice for scientific community trying to find new directions in the retrieval of geospatial information. Its API-centric architecture allows World Wind Java to be easily integrated as a plug-in into a numerous of applications and modified according to the developers' needs.

It is true that the similar application, as being developed here, could be made more easily in, for instance, Google Earth, by inputting the set of the points into the application in a form of KML. This solution would be suitable for the user who wants to integrate the mentioned sites to the virtual globe in the easiest way. For the purpose of future research, however, it is vital to use development tools and thus explore the way how the data can be integrated rather than just wait for a solution provided by the commercial sector.

The future directions of this work are strongly connected with a fact that an author of the thesis has been successfully admitted for PhD degree at Beihang University. Thus, he sees this work as just a beginning and one the first steps how his PhD research topic could be directed. Because of that, this application is just in its beta version and is not exactly suited for the user yet. Besides Windows operating system, on which the application's development was undertaken, it has not been tested yet on any other operating system. Another fact is, that the most of the data is stored locally on the disk, while the attributes in the database contain the paths referring to this data. The reason for making such step is that in the future there is expected the data modification and storing data locally is thus a comfortable option how to access and update them easily. The development of the application will continue in Eclipse environment similarly as until now and for the purpose of this work, the project was converted into JAR file in order to provide an easier way of running it than from the IDE itself. Similarly, the database `wikiglobe` was uploaded on the remote server in order to be able to be accessed outside the author's computer.

With the future research on the project, lot of plans are outlined. The author sees the main problem in a small possibility of an interaction between the user and data. Because of that he would like to create an additional window in which one would be able to save the information about the desired site and input his own data into it as well. Moreover, an icon-driven interface, which would be displayed right after the application's loading, providing a list of all the places, is another element that is about to be integrated.

To conclude, this work has fulfilled its requirements. Developing the application *Great Places WikiGlobe* provided a platform for research on geovisualization methods and technology of the WikiGlobe system rather than offered a final solution for the possible user of the application. In the later stage of its development, an emphasis will be put on merging the research direction with user's requirements, what could put a new, fresh air into this problematics.

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Appendix A

Content of the attached DVD

The attached DVD has following structure:

```
/-- thesis/
/-- text/
```

The folder `thesis` contains the source code of the application, together with the data stored. The folder `text` contains the text of the thesis in `pdf` format as well as source codes of the typesetting program LaTeX, in which this text was typeset.

Appendix B

Application's guide

B.1 Application's requirements

Following technology has to be accessed in order to run the application:

- Windows operating system;
- JRE 7 installed;
- JDK 7.0.01 (or any other higher subversion) installed;
- Adobe Shockwawe Player installed;
- 1.10 GB of free space on the disk `C:`;
- a connection to the internet.

B.2 Running the application

To run the application, first off, the user is required to copy the folder `thesis` from the attached DVD into its `C:\` directory such that the following path in his file system will be created: `C:\thesis`. Then, he can run the application in two ways:

1. By running it from any IDE software (preferably Eclipse).
   To perform that, import the folder `eclipse_ws` stored in `C:\thesis\100GreatP` as a project into the IDE. Then, two sub-projects will appear, `Docking Frames` and `test`. Go to `test\src\org\cnstar\wiki\app` and run `GreatPlaces.java` file from there.

2. By running an executable `jar` file `GreatPlaces.jar` stored in the folder `C:\thesis\100GreatP\eclipse_ws\test`.

Appendix C

TIME's Great Places of History

Cultures
Pyramid of Khufu and The Sphinx
Ayutthaya
Confucius Temple
The Acropolis
Machu Picchu
Kathmandu Valley
Imperial Rome
Easter Island
Nazca Lines
Ronda
Roskilde
Historic Damasqus
Historic Kyoto
St. Petersburg

Table C.1: Cultures' sites.

Innovation
Segovia Aqueduct
Reims Cathedral
Chateau de Chenonceau
Imperial Vienna
Grand Place
Jefferson´s Virginia
Mountain Railways of India
Iron Bridge
Skyscrapers Of Chicago
Panama Canal
Brooklyn Bridge
Hoover Dam
Bauhaus School
City of Arts and Sciences
CCTV Headquarters
Burj Khalifa

Table C.2: Innovation's sites.

Society
Olduvai Gorge
Mohenjo-Daro
Altamira Cave
Skara Brae
Avebury
Knossos
Persepolis
Olympia
Aachen Cathedral
Cahokia Mounds
Australian Penal Sites

Table C.3: Society' sites.

Politics
The Forbidden City
Tikal
Red Square
Hill of Tara
Edinburgh Castle
Chateau de Fontainebleau
Revolutionary Philadelphia
Brandenburg Gate
Cape Coast Castle
Robben Island

Table C.4: Politics' sites.

Battles
Masada
The Plains of Abraham
Concord Bridge
Gettysburg
Trenches of World War I
Pearl Harbor
Normandy beaches
Hiroshima
Auschwitz

Table C.5: Battles' sites.

Arts
Renaissance Florence
Mozart's Salzburg
Shakespeare's Globe
Dickens' London
The Strausses' Vienna
Wagner's Bayreuth
Yasnaya Polyana
Monet's Garden
Burning Man

Table C.6: Arts' sites.

Inquiry
Medina of Fez
Jagiellonian University
Mosques of Timbuktu
Royal Observatory
Bodleian Library
Royal Botanic Gardens
Galápagos Islands
Lowell Observatory
Svalbard Global Seed Vault
McMurdo Station

Table C.7: Inquiry's sites.

Civilizations
Hadrian's Wall
The Great Mosque of Córdoba
Historic Istanbul
The Silk Road
The Great Wall of China
Lindisfarne
Crac des Chevaliers
L´Anse aux Meadows
The Ghetto, Venice
Mostar Bridge

Table C.8: Civilizations' sites.

Religion
Lalibela
Temple Mount
Mecca
Delphi
Historic Cairo
Angkor Wat
Vatican City
Potala Palace
Santiago de Compostela
The Golden Temple
Varanasi

Table C.9: Religion's sites.

Cultures			
Sites by country		**Sites by continent**	
Country	Number of sites	Continent	Number of sites
Peru	2	Europe	5
Russia	1	Asia	5
Egypt	1	South America	3
Thailand	1	Africa	1
China	1		
Greece	1		
Nepal	1		
Chile	1		
Italy	1		
Spain	1		
Denmark	1		
Syria	1		
Japan	1		

Table C.10: Cultures' sites – countries and continents.

Religion			
Sites by country		**Sites by continent**	
Country	Number of sites	Continent	Number of sites
India	2	Asia	6
Spain	1	Europe	3
China	1	Africa	2
Italy	1		
Cambodia	1		
Egypt	1		
Greece	1		
Saudi Arabia	1		
Israel	1		
Ethiopia	1		

Table C.11: Religion's sites – countries and continents.

Society			
Sites by country		**Sites by continent**	
Country	Number of sites	Continent	Number of sites
Greece	2	Europe	6
Pakistan	1	Asia	2
Spain	1	Africa	1
Scotland	1	North America	1
England	1	Australia	1
Iran	1		
Germany	1		
United States of America	1		
Australia	1		

Table C.12: Society's sites – countries and continents.

Politics			
Sites by country		**Sites by continent**	
Country	Number of sites	Continent	Number of sites
China	1	Europe	5
Guatemala	1	North America	2
Russia	1	Africa	2
Ireland	1	Asia	1
Scotland	1		
France	1		
United States of America	1		
Germany	1		
Ghana	1		
South Africa	1		

Table C.13: Politics' sites – countries and continents.

Civilizations			
Sites by country		**Sites by continent**	
Country	Number of sites	Continent	Number of sites
England	2	Europe	6
China	2	Asia	3
Turkey	1	North America	1
Canada	1		
Italy	1		
Syria	1		
Bosnia and Herzegovina	1		
Spain	1		

Table C.14: Civilizations' sites – countries and continents.

Battles			
Sites by country		**Sites by continent**	
Country	Number of sites	Continent	Number of sites
United States of America	3	North America	4
Canada	1	Europe	3
France	1	Asia	2
Japan	1		
Israel	1		
Belgium	1		
Germany	1		

Table C.15: Battles' sites – countries and continents.

Innovation			
Sites by country		**Sites by continent**	
Country	Number of sites	Continent	Number of sites
United States of America	5	Europe	8
France	2	North America	5
Spain	2	Asia	3
Panama	1		
Germany	1		
India	1		
Austria	1		
Belgium	1		
United Arab Emirates	1		
China	1		

Table C.16: Innovation' sites – countries and continents.

Arts			
Sites by country		**Sites by continent**	
Country	Number of sites	Continent	Number of sites
Austria	2	Europe	8
England	2	North America	1
Italy	1		
France	1		
Russia	1		
Germany	1		
United States of America	1		

Table C.17: Arts' sites – countries and continents.

Inquiry			
Sites by country		**Sites by continent**	
Country	Number of sites	Continent	Number of sites
England	3	Europe	5
Ecuador	1	Africa	2
Norway	1	South America	1
Morocco	1	North America	1
Mali	1	Antarctica	1
Poland	1		
Antarctica	1		

Table C.18: Inquiry' sites – countries and continents.