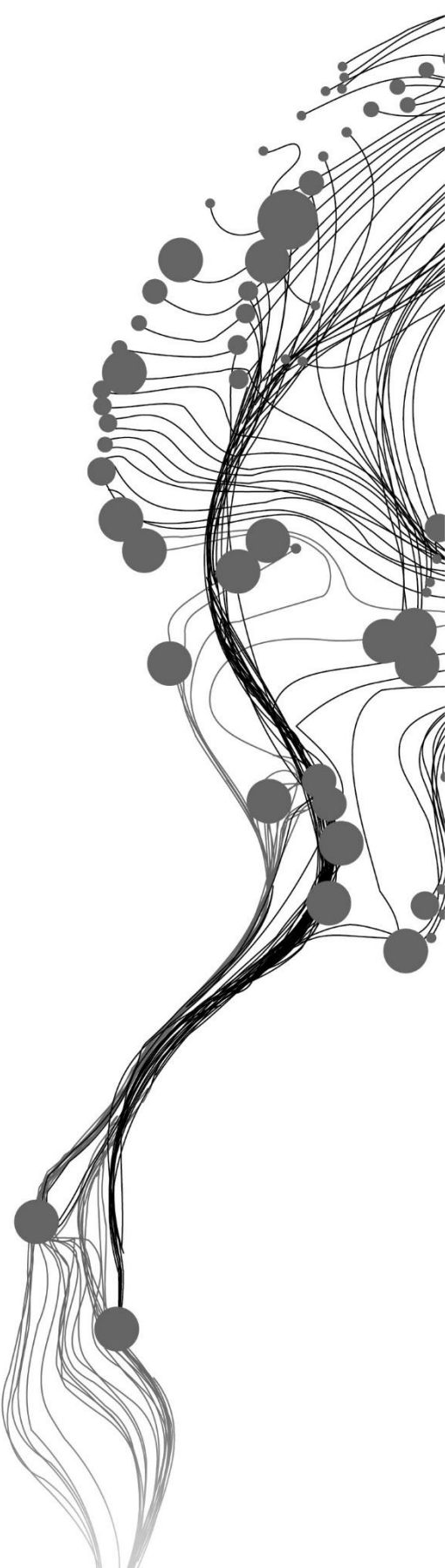


DESIGN AND APPLICATION OF CONCEPT GRAPHS IN GEOINFORMATICS EDUCATION

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March, 2016

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Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.

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This document describes work undertaken as part of a programme of study at the Faculty of Geo-Information Science and Earth Observation of the University of Twente. All views and opinions expressed therein remain the sole responsibility of the author and do not necessarily represent those of the Faculty.

ABSTRACT

This research studies the design and application of ontologies in geo-information education. The notion of this research is creating a prototype concept graph and a visualisation of it (in the form of a concept browser) in the context of a textbook (the ITC core module book) used in geo-informatics education

The study is motivated towards improving the student's learning experience in Geo-information education set up by designing and finding the best way of validating the concept ontology, identify ways to create it (machine-readable ontology) and visualise it as a concept graph.

To achieve the goals of this study, firstly, there was a need for creation and validation of an appropriate ontology. This involved a combination of manual and automated data extraction of important concepts which were used in the building of a sketch ontology. After that, it was validated by domain experts (ITC – Lecturers) and a machine readable ontology was created using an ontology editor (Protégé). Secondly, there was a need to visualize the machine readable ontology. WebVOWL was settled for due the fact that it met the requirements and needs for tools applicable to visualizing ontology. Lastly, it was important to know if the prototype (WebVOWL-CG) served the purpose it was developed for, i.e., improving the learning experience for students. For this, usability testing was carried out. It involved comparing it with another educational tool (ITC-Wiki) and comparing with another visualization tool (GIS&T-BoK).

The results of this study showed that WebVOWL-CG performed better in both. Under education tools, WebVOWL-CG has the highest in effectiveness (92%), highest in efficiency (shortest time to complete the user tasks) and highest in satisfaction (84%) compared to the ITC-Wiki. This makes WebVOWL-CG the better educational tool for the particular tasks (concerning conceptual understanding) as performed in this study. Moreover, comparing the two visualisation tools, again, WebVOWL-CG has the highest in effectiveness (92%), highest efficiency, and highest in satisfaction (88%) compared to the GIS&T-BoK. This makes WebVOWL-CG the preferred visualisation tool for the performed user tasks in this study.

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1. Introduction

1.1. Motivation and problem statement

The world we live in is dynamic, and on a daily basis, enormous amounts of data are either produced directly or indirectly by human beings. As a consequence, data is emerging at a fast rate, for example, “90% of the data in the world today has been created in the last two years alone” IBM (2012). Therefore, there is a need to find an efficient and effective way of managing such vast amounts of data, so that it is useful to society. To better understand and get insight in this enormous data being produced in the world today, there is a need for visual representation, also referred to as visual analytics. Visual analytics is "the science of analytical reasoning facilitated by interactive visual interfaces" (Thomas & Cook, 2006).

Visualization is beneficial for the first stage of exploration – pattern recognition. Visualising the information allows the user to see patterns and connections that otherwise go unnoticed with statistical methods of analysing huge data. “The main objective of visualization is to provide insight that is useful, facts, or knowledge concerning the data under analysis. Hence, visualizations must take into account the rules of the human visual system to accurately portray the characteristics of the data which are important for the analysis and to avoid misleading their users” (Boyandin, 2013). To come to a good visualisation of large data, a semantic model is necessary.

According to Lemmens (2006), the goal of semantic modelling is to make available a conceptual model of a domain by way of formalising the semantics of the concepts and their inter-concept relationships within the domain. The author further explains the concept of ontology as being one of the cornerstones of the semantic web. Uitermark et al. (1999), defines ontology as “a structured, limitative collection of unambiguously defined Concepts. This definition covers four elements: 1.) an ontology is a collection of concepts. 2.) The concepts are to be unambiguously defined. 3.) The collection is limitative. Concepts not in the ontology cannot be used. 4.) The collection has structure. Structure means that the ontology contains relationships between the concepts”.

Mohaqqei et al. (2009) defined a concept graph as “a graph that represents the relationships between language concepts. In this structure, the relationship between any two words is demonstrated by a weighted edge such that the value of this weight is interpreted as the degree of the relevance of two words.” While Soltanpoor et al. (2010) described a concept graph as a “big dictionary in which related terms are linked together (rather than having a flat structure). Each word is a vertex in the graph and the relationship between two words is shown by a weighted edge between them”. Concept graphs (also called concept maps) normally comprises of network nodes and links. According to Lanzing, (1997), typically each node denotes a concept whereas each link denotes a relationship between concepts.

To effectively achieve user’s needs, a user-centered design approach must be considered. This design process starts with identifying the need for user-centered design, followed by the analysis of requirements (for the user), and then by, producing design solutions (which includes conceptual design and prototype) and finally, evaluation of designs and creating or producing the design that satisfies the requirements, van Elzakker (2015).

“Since its inception, the World Wide Web (WWW) has possessed the potential for becoming a ‘watershed’ medium for conveying complex, structured information across vast temporal and geographical barriers” (Chu & Chan, 1998). Since then a number of applications to better the lives of humanity have been employed to utilize the unique abilities of the internet such as in education, telecommunication, etc. The knowledge-based economy in recent years has revealed a pervasive and continually increasing demand for innovative ways of providing education, which has led to dramatic changes in learning technology and organizations (Zhang, Zhao, Zhou, & Nunamaker, 2004).

Already, the Faculty of Geo-Information Science and Earth Observation of the University of Twente (ITC), is working on a new implementation of the core module learning material. This then entails developing the core module as e-learning material in the form of the wiki. A wiki is a database or a piece of server software, which allows collaborative modification, extension, or deletion of its content and structure (Britannica, 2007). In doing this, there are problems being faced which need immediate attention. The core book to start has some issues (challenges) such as duplication of topics in different parts of the book; the text is not always in a structured manner. On the wiki development side, it is not easy to determine and define the semantics and the relationships between concepts. This becomes difficult or rather confusing for the student to understand concepts that enhance their learning experience and also time-consuming for the teacher to organise course material be it for teaching or setting exercises.

Considering the problems provided above, the study is motivated towards improving the student’s learning experience in Geo-information education set up by designing and finding the best way of validating the concept ontology, identify ways to create it (machine-readable ontology) and visualise it as a concept graph.

1.2. Research objectives

The principal matters addressed in the current research can further be defined by the following objectives and research questions.

1.2.1. Main objectives

The objective of the research is to design and apply an ontology in geo-information education. The notion of this research is creating a prototype ontology and a visualisation of it (in the form of a concept browser, such as the aqua-browser) in the context of a textbook (e.g., the ITC core module book) used in geo-informatics education as shown in figure 1. An aqua-browser “is a fresh interface with a single search box, allowing users to find quickly relevant results” (ProQuest, 2015). Concepts from the book (e.g., scale, quality, coordinates, polygon, pixel, raster) and their relationships appear in such a concept browser, and a user (e.g. student and academic staff) can explore these concepts and the accompanying text from the textbook.

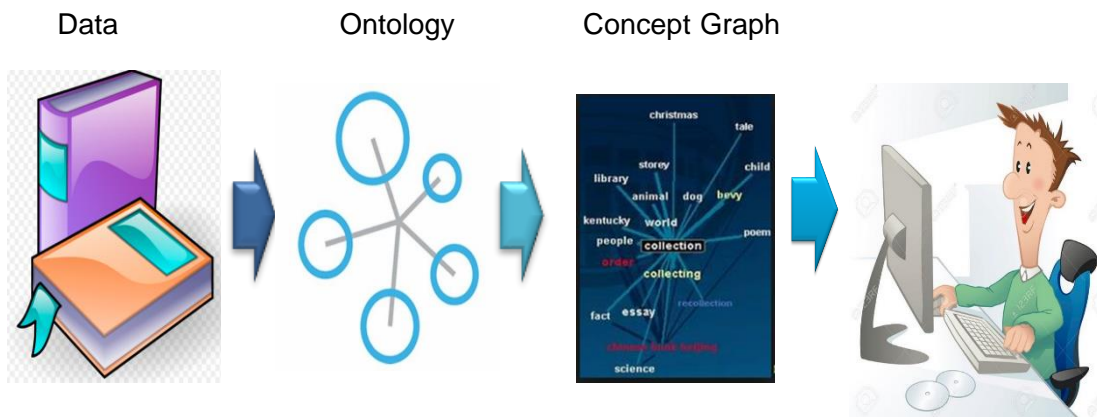


Figure 1 – Graphical representation of the main objective.

1.2.2. Sub-objectives

- a) To identify the potential use of an ontology (with GI concepts and their relationships) in geoinformatics education.
- b) To identify ways to create a machine-readable ontology (the stored model of GI concepts and their relationships) based on the user requirements and the sources available.
- c) To find the best way to integrate the ontology and visualise it as a concept graph with the current educational environment (wiki).

1.3. Research questions

1. Related to sub-objective a:
 - Who are the potential users of the ontology and its visualisation?
 - For what purposes could they use this ontology?
2. Related to sub-objective b:
 - What are the characteristics of the ontology; what are relevant concept types and inter-concept-relationship types?
 - How can the concept types and inter-concept-relationship types be stored, so that the software can use them for further processing or visualisation?
 - How can we deploy existing automated ways (e.g., keyword mining) and non-automated ways of producing the ontology?
3. Related to sub-objective c:
 - How can the ontology best be visualised for our users?
 - In which software can the visualisation best be developed, so that it fits the user environment?
 - How do users interact with the concept graph?
 - What are points of improvement for the ontology and its visualisation?

1.4. Research workflow

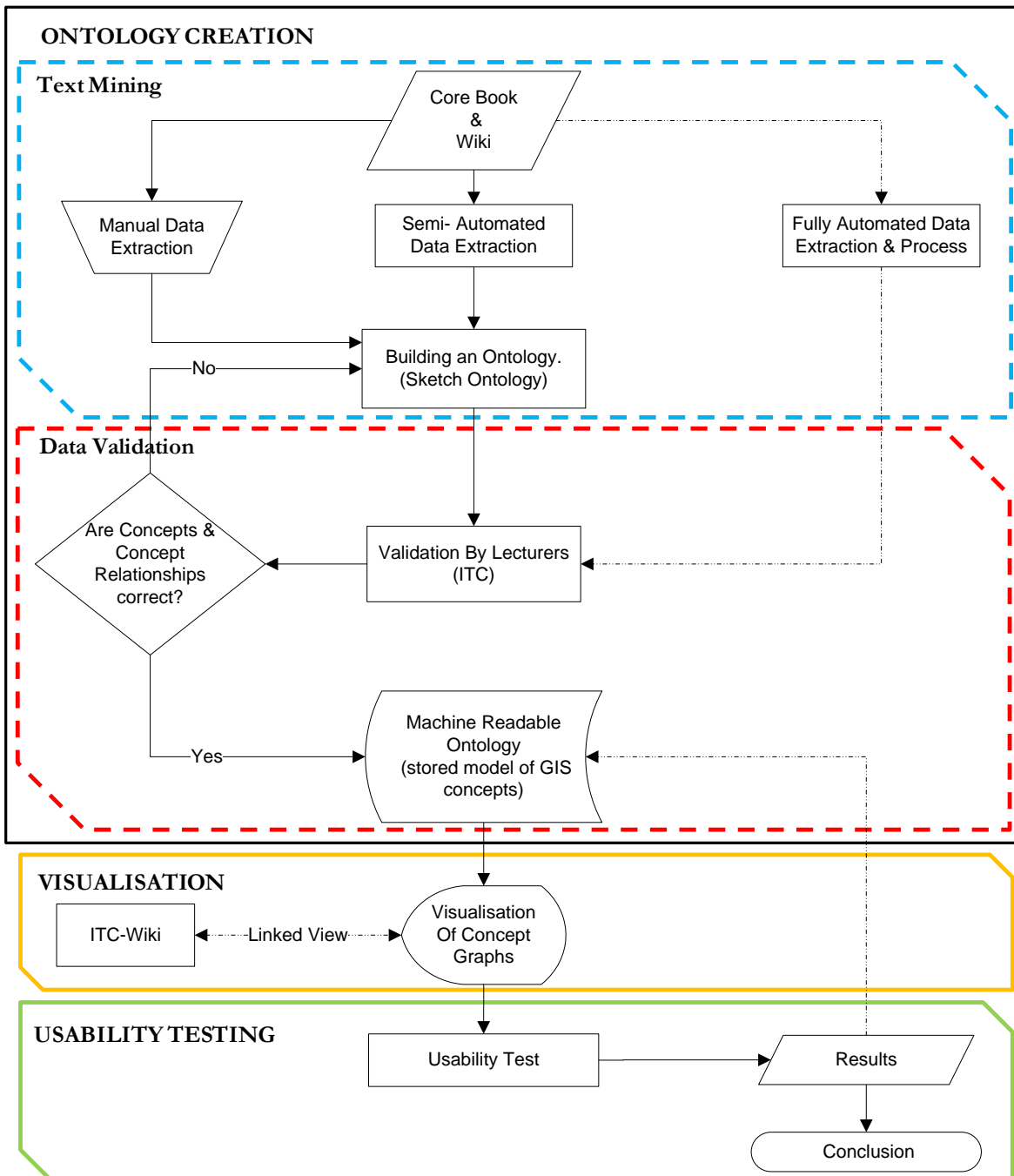


Figure 2 – Research workflow and its activities

The research workflow in figure 2 shows all the activities/tasks to be done to achieve the research objective although tasks that are connected with dashed lines are not going to be addressed in this study.

1.4.1. Creation and validation of ontology

With reference to figure 2, this method starts with the data extraction from the book (The core of GIScience – a process-based approach) (Stein & Tolpekin, 2012) and ITC-Wiki then followed by building the ontology. Building the ontology involves Text Mining, which is carried out in two ways (using existing semi-automated and manual data extraction means). After that, the manual ontology creation (sketch ontology) will be carried out. After that, the manually created ontology will be validated by the experts (Lecturers – ITC). Once it is corrected or proved correct, it will then be stored (as a machine-readable ontology) ready to be visualised.

1.4.2. Visualization

This activity involves finding a suitable visualization tool(s).that will enable users to visualize the machine readable ontology. As earlier mentioned in section 1.1, visualising the information allows the user to see patterns and connections that otherwise go unnoticed.

1.4.3. Usability testing

The objective is to improve the way of understanding the topic of this course, which is GIS. The question that comes up when this ontology is created, validated and visualized is, does it help the user? To answer this question, Usability testing is used to determine whether prototype helps the user in term of effectiveness, efficiency and satisfaction. Devi et al., (2012) defines UCD as a “ philosophy and a process that places the person at the centre and focuses on cognitive factors as they come into play during peoples interactions with things. It concerns and can improve itself with both usefulness and usability.”

2. Theoretical framework

The previous chapter introduced the research topic and outlined the objectives and the research related to them. This chapter discusses the theoretical background of this research in details. It starts by presenting the wiki-based education (2.1) and then looks at what an ontology is (section 2.2). It also focuses on basics of Resource Description Framework (RDF) and Web Ontology Language (OWL). It further dives into data extraction, ontology creation and visualization to decide on the text extraction tool, ontology creation methodology and the visualisation tool to be used.

2.1. Wiki-Based Education

“A wiki is a group of web pages that allows users to add content, similar to a discussion forum or blog, but also permits others (sometimes completely unrestrictedly) to edit the content” (Duffy & Bruns, 2006). According to Parker & Chao, (2007) a wiki is one of Web 2.0 components that can be utilized to improve the learning process. The wiki is also a web communication and collaborative tool that can be utilized to involve students in learning with others.

Duffy & Bruns, (2006) highlight some typical characteristics and possible educational uses of the wiki as indicated in Table 1

Table 1 – Some typical characteristics and possible educational uses of a wiki (Duffy & Bruns, 2006)

Characteristics of a wiki	Educational uses of wikis
<ul style="list-style-type: none"> • A wiki a website that allows a user to add content, but also allows that content to be edited by any other user. • Wikis can be personal, but are usually open to collaboration. • They involve the creation of documents (individual pages as well as the entire wiki) without a detailed technical knowledge of HTML being required by the user. • They tend towards expressing ideas as relationships between pages, thus creating a network of interrelated topics that is based on a ‘typical’ approach. • Wikis are a-temporal; that is, the nodes (or interlinking textual references) change not according to time, but by way of development of the evolving and edited text. 	<ul style="list-style-type: none"> • Students can utilize a wiki to develop research projects, with the wiki acting as ongoing records of their work. • Wikis can be used for students to add summaries of their thoughts from the prescribed readings, building a collaborative annotated bibliography. • In distance learning environments, the tutor can publish course resources like syllabus and handouts, and students can edit and comment on these directly (for all to see). • Wikis can be used as a knowledge base for teachers, allowing them to share reflections and thoughts regarding teaching practices and allowing for versioning and documentation; essential to the usability of such a resource is that it is searchable, has easy navigation and categorisation, and file management, all of which current wiki environments provide.

- They track the changes to individual pages over time and allow users to browse the development history of a page.
 - They inspire cross-linking and are dominantly spatial in structure.
 - Wikis provide a space where knowledge becomes networked (situated, contextualized) but remain ephemeral, meaning it changes, and can be modified and mediated by the community
- Wikis can be used to map concepts: they are useful for brainstorming, and authoring a wiki on a given topic produces a linked network of resources.
 - A wiki can be used to facilitate a presentation in place of conventional software, like Keynote and PowerPoint, and (given a suitable working environment) students can directly comment on and revise the presentation while it takes place.

2.1.1. ITC-Wiki

ITC-Wiki is a pilot of the online wiki version of the ITC core book (the core of GIScience - a process based approach – see subsection 2.1.1.1) being used by students. The interface for the ITC-Wiki is as shown in figure 3. The user interfaces consist: a viewer displaying the pages (inside the red box), a table of contents (represented by a green box) for the page displayed in the viewer, and the wiki sections (in the yellow box) which allows you to navigate to a particular concept of interest and Text search (in a blue box)

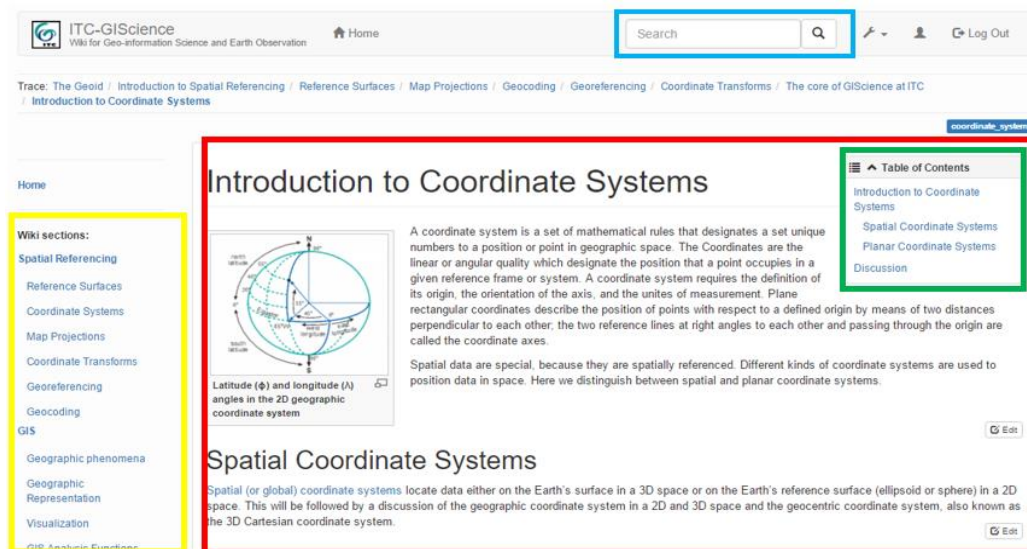


Figure 3 – Screenshot of the user interface of ITC-Wiki.

2.1.1.1. The core of GIScience: A Process-Based Approach

The core of GIScience: A Process-Based Approach (Stein & Tolpekin, 2012) mostly referred to as “the core book” is a hard and softcopy book. It is one of the main material used to teach the Master of Science, Master and Postgraduate Diploma courses at ITC. The core book aids in achieving the objective of the core module as tabulated in Table 2. This is according to the Learning Guide Core Curriculum (ITC, 2013) and the core book (Stein & Tolpekin, 2012);

Table 2 – The main core module objectives

<i>No</i>	<i>Main Core Module Objectives</i>
1	Explain the main processes in System Earth;
2	“Use Earth Observation by remote sensing to acquire geospatial data and produce information about System Earth.”
3	Process, generate, integrate, analyse and disseminate spatial data;
4	Understand the use of process and observation models to describe Earth processes;
5	“Describe the role of human beings as 'the users' at different levels of scale in the System Earth.”
6	“Have basic academic thinking, communication and learning skills”.
7	Explain the main processes in System Earth;

It should be that the ITC-Wiki is based on this book. The drawbacks the core book were discussed in the first chapter.

- **Challenges being face with the ITC-Wiki and the Core Book**

As mentioned in chapter 1, there are problems being faced which needs immediate attention. The core book to start with has some issues (challenges) such as duplication of topics in different parts of the book; the text is not always written in a structured manner. On the wiki development side, it is not easy to determine and define the semantics and the relationships between concepts. It sometimes becomes difficult or rather confusing for the student to understand concepts and enhance their learning experience and it is also time-consuming for the teacher to organise course material for teaching or setting exercises.

2.2. What is an Ontology?

Guarino et al., (2009) observed that different communities use the of word “ontology” with a different meaning. In the first case, it is referred to as a philosophical discipline that deals with the nature and structure of reality. It is traditionally a study of being, in other words, it is the study of existence (Sanders, 1997).

In the second case, it is an ontology which reflects the most widespread use in Computer Science, Guarino et al., (2009) refer to an ontology as “a special kind of information object or computational artefact”. This research uses the word ontology as described in the second case.

Gruber, (1993) defined an ontology as an “explicit specification of a conceptualization”. The author further defines conceptualization as an “abstract, simplified view of the world that we wish to represent for some purpose.” Genesereth & Nilsson, (1987) claim that “A body of formally represented knowledge is based on a conceptualization: the objects, concepts, and other entities that are assumed to exist in some area of interest and the relationships that hold among them. A conceptualization is an abstract, simplified view of the world

that we wish to represent for some purpose. Every knowledge base, knowledge-based system, or knowledge-level agent is committed to some conceptualization, explicitly or implicitly.”

2.2.1. Why develop an ontology?

In this study, the purpose of building an ontology-based concept graph is to share a common understanding of GIScience effectively, and that can be used or understood by human beings as well as machines. Bermejo, (2007) states that there are so many reasons researchers claim ontology development is beneficial when one looks at literature, but these reasons can basically be summarized as:

- To share a common understanding of the domain and the related information both among humans (the initial purpose) and among software agents.
- To be able to reuse knowledge.
- To separate domain knowledge from an operational one.
- To analyse domain knowledge.

2.3. Resource Description Framework and Web Ontology Language

2.3.1. Resource Description Framework (RDF)

According to Cambridge Semantics (2015), There are three (3) underlying principles of Semantic Web technologies and these are Resource Description Framework (RDF), SPARQL (used to express queries over diverse data sources natively stored as RDF (Harris, Garlik, & Seaborne, 2013)) and the Web Ontology Language (subsection 2.3.2). Cambridge Semantics further describes RDF as a graph data model/data model of the Semantic Web. It, therefore, means that data in Semantic Web technologies is represented as Resource Description Framework (RDF). For Instance, if someone queries (typically using SPARQL) or stores Semantic Web data, the data is in RDF.

RDF is a graph data model, and its data are directed labelled graphs as described by Cambridge Semantics (2015). A single edge in an RDF graph is a three (3) – tuple called triple or statement. This statement or triple can describe any concept/a thing /relationship that exists. Pan & Horrocks (2007) also describes RDF as a basic statement of the form (subject – predicate – object) as shown in Figure 4. In this case a simple state is constructed: Kelvin likes Geography where Kelvin is a Subject, Likes is a Predicate and Geography is an Object. Using this construct or simple idea, anything can be described.

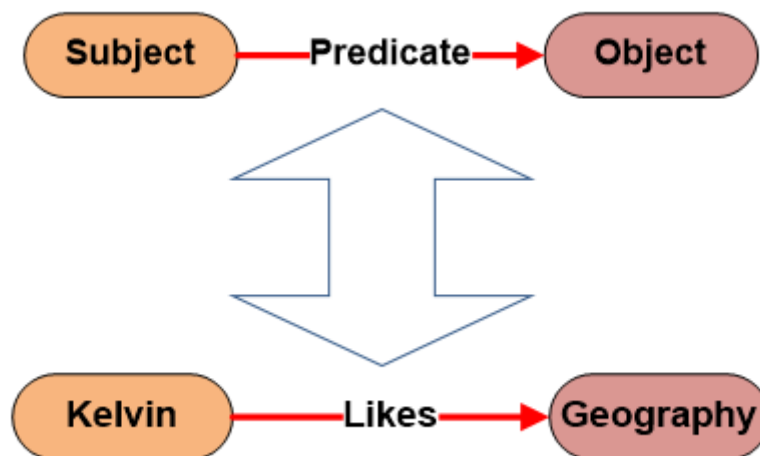


Figure 4 – Example of a triple/statement

It is based on the idea of identifying things using URIs (Uniform Resource Identifiers) and describing the resources (subject/Kelvin) in terms of properties (predicate/likes) and their property values (object/Geography).

It should be noted that “RDF data is annotated with semantic metadata using two principal syntaxes: RDFS and OWL. Both RDFS and OWL are W3C specifications”(Linked Data Tools, 2015). OWL will be explained further in the next section (2.3.2).

2.3.2. Web Ontology Language (OWL)

According to the World Wide Web Consortium (2004), the Web Ontology Language(OWL) is a language for defining and instantiating Web ontologies. An ontology, OWL to be precise, may have descriptions of classes, properties and their instances (individuals).

OWL is the World Wide Web Consortium (W3C) recommended language for expressing ontologies for the Semantic Web. “W3C standards define an Open Web Platform for application development that has the unprecedented potential to enable developers to build rich interactive experiences, powered by vast data stores that are available on any device. W3C publishes documents that define Web technologies. These documents follow a process designed to promote consensus, fairness, public accountability, and quality. At the end of this process, W3C publishes Recommendations, which are considered Web standards”(World Wide Web Consortium, 2015).

Antoniou & van Harmelen (2004) describes OWL as existing in three species (OWL Lite, OWL DL and OWL Full) while World Wide Web Consortium (2004b) describes OWL as having three sublanguages namely OWL Lite, OWL DL and OWL Full. Web Ontology language provides three (3) increasingly expressive sublanguages intended for use by specific communities of implementers and users.

OWL Lite: offer support to users wanting a classification hierarchy and simple constraints. It should be mentioned that the formal complexity of OWL Lite is lower when compared to OWL DL. It is also a subset of OWL DL.

OWL DL: is the part of Owl that’s is known to have decidable reasoning. It offers support to users interested in the higher level of expressiveness while holding computational completeness and decidability. OWL DL (where DL stands for Description Logic) is so called because it corresponds with description logics, which is a field that has studied the logics which forms the basis of OWL.

OWL Full: is another part of OWL that is fully upward compatible with RDF and offers a higher level of expressiveness and the syntactic freedom of RDF without computational guarantees to its users. OWL Full permits an ontology to augment the definition of the pre-defined (Resource Description Framework or Web Ontology Language) vocabulary. It is, therefore, doubtful that any cognitive software will be capable of supporting a complete reasoning for each feature of OWL Full.

2.4. Selection of data extraction tool

The section presents two data extraction tools licenced under the GPL/GNU General Public License. The tools are then compared in order to selection a tool be used in this study. The process of choosing a tool that is capable of meeting requirements is challenging for many organisation. It requires a design that describes the issues and factors that need to be considered during a software selection (Patel & Hlupic, 2002). The authors further state that the methodology is not intended to be a rigid structure that must be followed without any consideration of change, but it is intended to serve as recommendations or guidelines and help that can be adapted according to the requirements at hand.

An example of such a method is given by Jadhav & Sonar (2009) who states that “stage-based methodology for selecting software packages was described in 27 different studies, out of which 7 studies concentrate on COTS (Commercial - Off - The - Shelf) component selection and remaining concentrate on selection of specific type of the software package.” Based on this review, the Authors proposed a more general stage based methodology for selection of any software application/package to consist of seven (7) stages which are (see table 3);

Table 3 – Stages for selection of any software application/ package

No.	STAGES FOR SELECTION OF ANY SOFTWARE APPLICATION
1	Determining the need for purchasing the system and preliminary investigation of the availability of packaged software that might be a suitable candidate, including high-level investigation of software features and capabilities provided by the vendor.
2	Short listing of candidate packages
3	Eliminating most candidate packages that do not have the required feature or do not work with the existing hardware, operating system and database management software or network
4	Using an evaluation technique to evaluate the remaining packages and obtain a score or overall ranking of them.
5	Doing further scrutiny by obtaining a trial copy of top software packages and conducting an empirical evaluation. Pilot testing the tool in an appropriate environment.
6	Negotiating a contract specifying software price, a number of licenses, payment schedule, functional specification, repair and maintenance responsibilities, the timetable for delivery, and options to terminate any agreement.
7	Purchasing and implementing most appropriate software package

The selection process presented in Table 3 is guideline used to ease the process of choosing a software that is fit for purpose. In this study, not all the selection stages were used but just a few to serve as a start point in the selection process. For instance, stages 1 to 4 were used (implicitly and others explicitly). From about twenty (20) free text analysis applications (Predictive Analytics Today, 2015), two applications were selected using Table 3 for further comparison (subsection 2.4.3).

2.4.1. Lightside

This is an application developed by Carnegie Mellon University’s Language Technologies Institute. It is licensed under the GPL / GNU General Public License. Lightside is an open-source platform, it consist of machine-learning and feature-extraction core as well as the researcher's workbench user interface. It is funded in part through the developers “Carnegie Mellon University, in particular by grants from the National Science Foundation and the Office of Naval Research” (Lightside, 2014). Lightside tool characteristics are as indicated in Table 4 (Edutech Wiki, 2014b).

Table 4 – Lightside tool characteristics (Edutech Wiki, 2014b).

TOOL CHARACTERISTICS			
Usability:	Tool orientation:	Data mining type:	Manipulation type:
somewhat difficult to use	designed for general purpose analysis	made for Text Mining	designed for Data Analysis
Tool Can Perform			
<i>Data analysis of type:</i>	Data mining methods and algorithms		
ABOUT USERS			
Tool is suitable for:		Required skills:	
<i>Students/Learners/Consumers</i>	✘	<i>Statistics</i>	Basic
<i>Developers/Designers</i>	✘	<i>Programming</i>	Basic
<i>Researchers</i>	✓	<i>System Administration</i>	Basic
<i>Organisations/Institutions/Firms</i>	✘	<i>Data Mining Models</i>	Medium
<i>Teachers/Tutors/Managers</i>	✘		

2.4.2. KH Coder

Koichi Higuchi develops this application software. The application, KH Coder, is licensed under the GPL / GNU General Public License. This application can be used for quantitative content analysis, text mining or corpus linguistics. KH Coder can handle Japanese, English, French, Germany, Italian, Portuguese and Spanish language data. For further KH Coder tool characteristics, see Table 5.

Functionalities like KWIC (Key Word In Context) or simply concordance, collocation statistics, co-occurrence networks, self-organizing map, multidimensional scaling, cluster analysis and correspondence analysis functions using back-end tools such as Stanford POS Tagger, Snowball stemmer, MySQL and R are carried out by inputting raw text. (Edutech Wiki, 2014a).

Table 5 – KH Coder tool characteristics (Edutech Wiki, 2014a).

TOOL CHARACTERISTICS			
Usability:	Tool orientation:	Data mining type:	Manipulation type:
Rather easy to use.	Designed for general purpose analysis	Made for Text Mining	Designed for Data Analysis & Data visualisation.
Tool Can Perform			
<i>Data analysis of type:</i>	Data mining methods and algorithms, Basic statistics and data summarization		
<i>Data visualisation of type:</i>	Sequential Graphic, Chart/Diagram, Map, Tag Cloud		
ABOUT USERS			
Tool is suitable for:		Required skills:	
<i>Students/Learners/Consumers</i>	✓	<i>Statistics</i>	Medium
<i>Developers/Designers</i>	✘	<i>Programming</i>	None
<i>Researchers</i>	✓	<i>System Administration</i>	None
<i>Organisations/Institutions/Firms</i>	✘	<i>Data Mining Models</i>	Medium
<i>Teachers/Tutors/Managers</i>	✓		

2.4.3. Lightside and KH Coder comparison

The two data extraction tools were compared base on the characteristics (Edutech Wiki, 2014a) and (Edutech Wiki, 2014b) provided in Table 6.

Table 6 – KH Coder and Lightside tool characteristics comparison

	KC Coder	Lightside
Analysis orientation:	General analysis	General analysis
Analysis type:	Data mining methods and algorithms and Basic statistics and data summarization	Data mining methods and algorithms
Data manipulation type:	Data analysis and Data visualisation	Data analysis
Data tool type:	Application software	Application software
End user type:	Students/Learners/Consumers , Teachers/Tutors/Managers and Researchers	Researchers
Free software license:	GPL / GNU General Public License	GPL / GNU General Public License
Has completion level:	Medium	Low
Has interface usability:	rather easy to use	somewhat difficult to use
Is developed by:	Koichi Higuchi	Carnegie Mellon University's Language Technologies Institute
Last edition:	21 March 2014	22 September 2014
License type:	Free & Open source	Free & Open source
Mining tool type:	Text mining	Text mining
User data mining models level:	Medium	Medium
User programming level:	None	Basic
User statistics level:	Medium	Basic
User system engineering level:	None	Basic

After careful comparison between Lightside and KH Code. KH Coder was selected to be ideal for Text analysis tool due to the fact that it has more functionalities needed for this study and that it is relatively easy to use compared to Lightside application.

2.5. Ontology Creation and Development Procedure

Nowadays, there are numerous methods of developing ontologies, but no single method has yet emerged as a clear reference (De Nicola, Missikoff, & Navigli, 2009). Developing an ontology or domain model is now widely recognised to be a vital step in the development of knowledge-based systems (Jones, Benchapon, & Visser, 1998). The authors go on to say that, there are several methodologies that are specifically coming up to address not only the issue of the development but also maintenance of ontologies. It should also be noted that there are no specific procedures or steps for ontology (Jusoh, Ibrahim, Othman, & Omar, 2013).

Why this question:

This question is meant to see if the Test person can use the Text search tab, zoom, pan functions and refer to the sidebar to get the define of the term.

Expected answer; refer to figure 16.

PC – ZM – SC – ES – CD

Horizontal datum (also called geodetic datum) is an ellipsoid but positioned and oriented in such a way that it best fits the area or country of interest. Worldwide there are several hundred of these local horizontal datums defined

w4).Find the relationship between to the terms ‘Ellipsoid’ and ‘Geoid Separation’.

Why this question:

Similar to the reasons given for questions 1, but the purpose of this question is to see if the test persons use the mouse hover over to get the answer. The test person only gets this answer correct when the mouse is over the property defining the relationship between the said terms.

Expected answer; refer to figure 16.

PC – ZM – SC – PP – SP

isPartlyDefinedBy

w5).Which common projection is Tangential, Cylindrical as well as normal?

Why this question:

This question is meant to check if the Test Person would explore application content to find the answer to indirection question requiring reasoning rather than just the use of text search window.

Expected answer; refer to figure 16.

PC – ZM – SC – ZM – PP

- *Mercator Projection*

5.4.2. Test Questions and the Questionnaire (Appendix 7)

The test questions were organized into two sessions, each session having two parts. Each application tool had two warm-up questions, three test questions, and a questionnaire as indicated in Appendix 7. The test questions were set in such a way that they increase complexity (ease to difficult).

To avoid learning bias two group were formed as indicated in Table 10. Furthermore, the sequencing of applications to the tested differed for each group. For example, Group A - part 1 started [WebVOWL-CG] then followed by [ITC-Wiki]. Part 2 started with [WebVOWL-CG] and ended with [GIS&T-BoK] whereas the order in Group B was reversed. Part 1 started with [ITC-Wiki] then followed by [WebVOWL-CG]. Part 2 started with [GIS&T-BoK] and ended with [WebVOWL-CG].

It should be noted the questions asked were similar but structured differently for both Part1 and Part2. An example of such a question is; define the term Orthometric height Part 1 and for Part 2; what is meaning of the concept Geoid?

Lastly, Questionnaires were included to capture how the user feels about the application (user opinion) and suggestion on how to improve the application.

5.5. Test procedure and execution

5.5.1. Test Environment

The usability testing was conducted in the cartographic laboratory of the Faculty of Geo-information Science and Earth Observation of the University of Twente. The laboratory is equipped with a desktop computer (64-bit operating system, intel® CPU ES-2630v3 @2.40 GHz, 64GB Installed Memory, a 24-inch flat panel display with resolution (1680 x 1050 pixels), High Definition (HD) camera, Tobii X60 hardware and Tobii Studio software 3.4.3 (figure 17).



Figure 17 – Configuration of test equipment with one of the test persons executing the test at ITC

5.5.2. Test Procedure

As illustrated in figure 17. The Project was organised with the help of Tobii Studio. Each test created contained four media elements known as stimuli. For this test, the stimuli used were websites as listed:

- <http://vowl.visualdataweb.org/webvowl/#file=ITCgis-CoreOnto.owl> for WebVOWL-CG (prototype). It should be noted that a machine readable (ITCgis-CoreOnto.owl) had to be loaded to full access to the prototype.
- https://itc-giscience.utwente.nl/doku.php?id=introduction_to_spatial_referencing for ITC-Wiki. ITC-Wiki is password protected. To access it one need permission the ITC-Wiki administrator.
- <http://gistbok.org/bokwiki/index.html> for GIS&T-BoK.

The stimuli were arranged in a single linear timeline for each test as indicated in shown the figure18. Note that for each test session, the warm-up questions, test questions, questionnaires and test instruction were presented on paper to avoid test persons constantly switching between the test question and the application interfaces.

What remained was to carry out the pilot test to check if the test set-up run as planned.

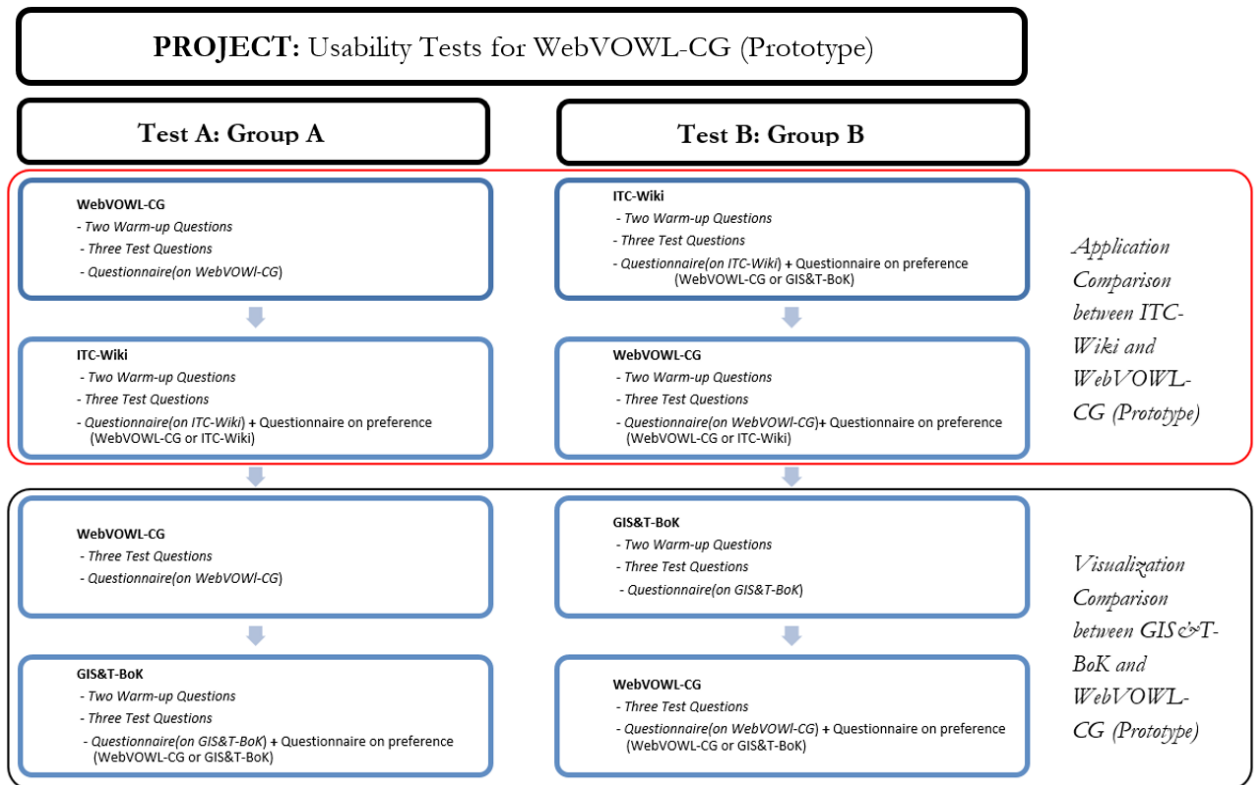


Figure 18 – Configuration of test equipment with one of the test persons executing the test at ITC

5.5.3. Pilot Test

The purpose of undertaking the pilot test was to check how long the test was taking and to detect imperfection in the overall test process and procedure which included the test scenarios. The test scenarios (Appendix 5) were used as guidelines for performing certain functions as outlined:

- To prepare the laboratory before the test person arrived
- On how to treat the test persons when they just walk in the laboratory to take tests
- On what to do during and after the test

In summary, the test scenarios ensured that all test persons received the courtesy and equal treatment. The pilot test was carried out with an assistant professor at ITC, and it went on well though minor flaws were detected like repetitions of test instructions. The other important thing that was missing was asking the participants for suggestions.

All the comments and corrections received as a result of the pilot test were implemented before the actual tests were undertaken. The time that it took to execute test was 60 minutes on average.

5.5.4. Test Execution

A total number of eight (8) test persons participated in the usability tests. All the Test Persons were Students of ITC (University of Twente) pursuing their Master of Science (MSc) degree programme. The eight

participants were then divided into two (2) groups, each group consisting of four (4) participants. To effectively undertake the tests, test scenarios (Appendix 5) were as guidelines.

During the test executions of the tests, everything went well although most often, participants had to be reminded to think aloud. Moreover, no major drawback occurred during the usability testing.

5.6. Test results

This section presents test results and then dives into the analysis the results. The subsection (test results) is divided into four parts. The first part is performance test results which look at how many question were answered correctly and which one were wrongly answered. The second part is the performance test results with time which highlights on how long it took the TPs to answer each question. The third part is the satisfaction response for each application, and the last fourth part is the functionality test performance results which look at how users performed the tasks with WebVOWL CG (prototype).

5.6.1. Performance Test Results

Presented in Tables 11 and 12 are the results of the usability test and their graphical representations in Figures 19 and 20 for group A and B respectively. In these tables, all TP initials or abbreviations stand for test persons (e.g., TP 1, TP3 and so on), all bold lower case alphabet letters (e.g., w3,i8,g16 and so on) represents tasks (test questions) per tool as indicated in both tables 12 and 14 (See Appendix 8 for further description of the tasks). “Total Cor.” Represent the total correct answers per task for each group while “percentage(%)” represents the success rate (in percentages) of each task per group. In the graphs/charts, tasks are represented a little different in that they all start with a group letter then followed by the tool being used and then the task numbers (e.g., “A_w3” in table 19 means: task 3 was worked on by group A using WebVOWL_CG(prototype)). Note that one (1) and zero (0) represents “correct responses” and “wrong responses” respectively.

In short A and B are groups, “w” is for a prototype (WebVOWL-CG), “g” is for GIS&T-BoK and numerals (3,4,5 and so on) are for task numbers (see figure 19 and 20)

Table 11 – Success of test question execution for group A

	Group A											
	Part 1						Part 2					
	WebVOWL-CG			ITC-Wiki			WebVOWL-CG			GIS&T-BoK		
	w3	w4	w5	i8	i9	i10	w11	w12	w13	g16	g17	g18
TP1	1	1	1	1	0	0	1	1	0	0	0	1
TP3	1	1	1	1	1	0	1	1	1	1	1	1
TP7	1	1	1	1	1	0	1	1	1	1	1	1
TP9	1	1	1	1	0	0	1	1	1	1	1	1
Total Cor.	4	4	4	4	2	0	4	4	3	3	3	4
Ave.Percentage (%)	100	100	100	100	50	0	100	100	75	75	75	100

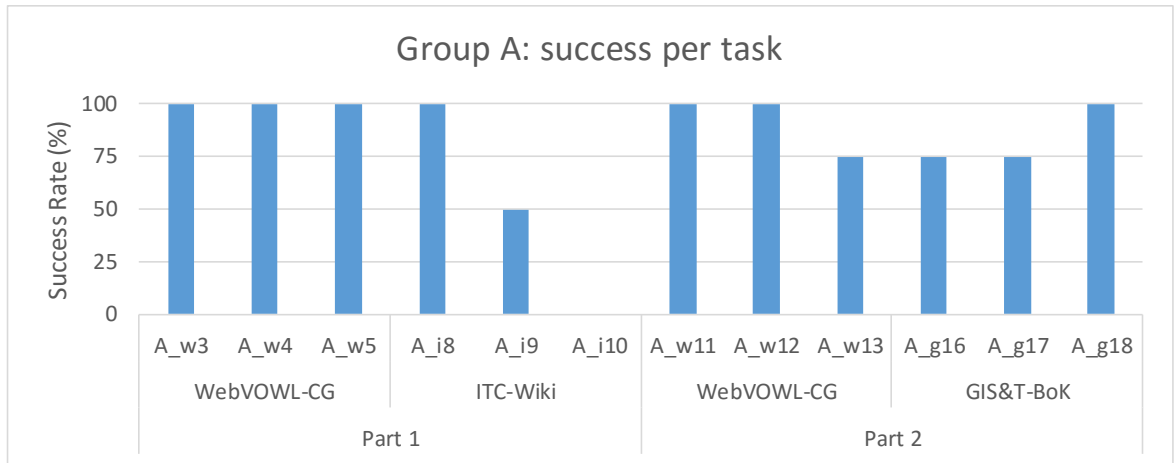


Figure 19 – Graphical representation of group A test results (see Table 11)

Table 12 – Success of test question execution for group B

	Group B											
	Part 1						Part 2					
	WebVOWL-CG			ITC-Wiki			WebVOWL-CG			GIS&T-BoK		
	w3	w4	w5	i8	i9	i10	w11	w12	w13	g16	g17	g18
TP2	1	1	1	1	1	0	1	1	1	1	1	0
TP4	1	1	1	1	0	0	1	1	0	1	1	1
TP6	1	1	1	1	1	1	1	1	1	1	1	1
TP8	0	1	0	1	1	0	1	1	1	0	1	1
Total Cor.	3	4	3	4	3	1	4	4	3	3	4	3
Percentage (%)	75	100	75	100	75	25	100	100	75	75	100	75

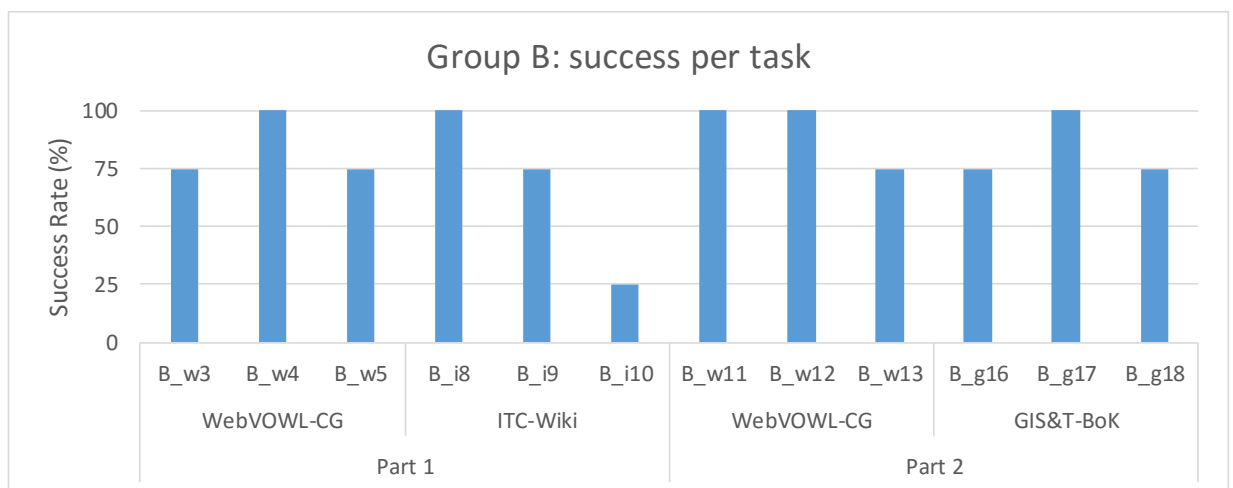


Figure 20 – Graphical representation of group B test results (see Table 12)

5.6.2. Performance Test results with Time

The section presents the cost time taken for tasks in seconds. Table 13 and 14 show the results of the usability test and their graphical (charts) representations indicated in Figures 21 and 22 for group A and B respectively. The Tables and charts present detailed information on how long it took each TP to complete a given task. The average time cost per task shown as “Ave. time cost per task” in tables 13 and 14 is the time derived from averaging the time taken to complete task (say task “w3”) for all the four TPs (e.g. the average time cost per task for task “g16”, (refer to Table 13), is calculated by adding the time taken by TPs 1, 3, 7, and 9 to complete their task; and then dividing by the number of TPs $(56+252+106+41)/4 = 114$). The average time cost per task was calculated for all the tasks in the two groups (A and B) and presented as indicated in Figures 21 and 22.

Table 13 – Time cost of test question per TP for group A.

	Group A											
	Part 1						Part 2					
	WebVOWL-CG			ITC-Wiki			WebVOWL-CG			GIS&T-BoK		
	w3	w4	w5	i8	i9	i10	w11	w12	w13	g16	g17	g18
TP1	133	137	189	163	64	174	40	178	126	56	155	163
TP3	213	87	203	189	208	638	156	77	106	252	82	150
TP7	72	48	141	34	169	86	34	48	82	106	44	27
TP9	196	56	155	33	62	248	62	38	62	41	46	31
Ave. time cost per task	154	82	172	105	126	287	73	85	94	114	82	93

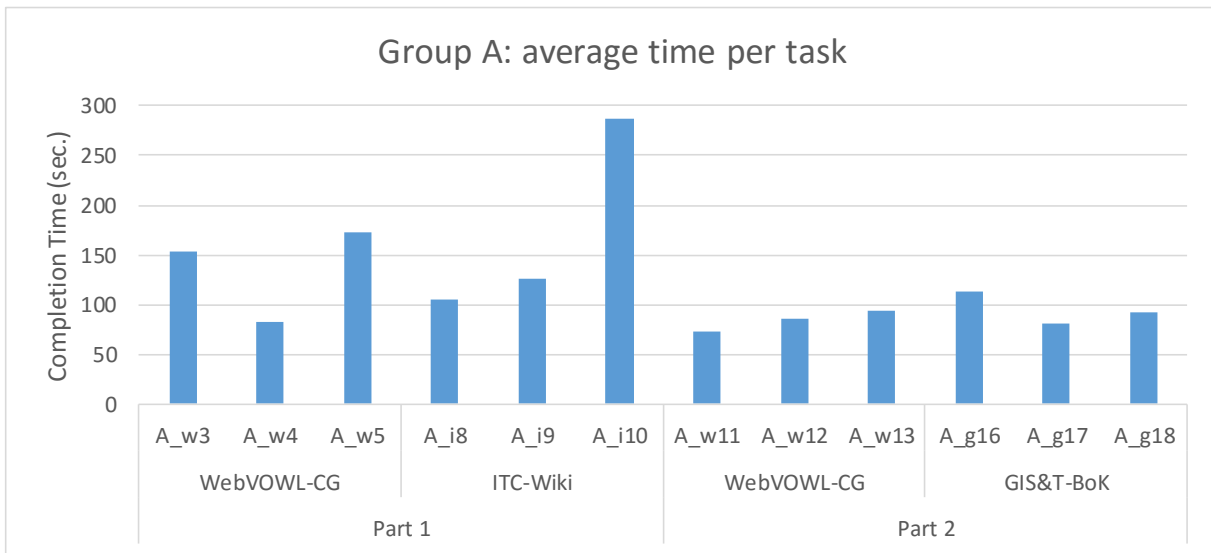


Figure 21 – Graphical representation of group A test results (see Table 13).

Table 14 – Time cost of test question per TP for group B.

	Group B											
	Part 1						Part 2					
	WebVOWL-CG			ITC-Wiki			WebVOWL-CG			GIS&T-BoK		
	w3	w4	w5	i8	i9	i10	w11	w12	w13	g16	g17	g18
TP2	30	56	165	65	144	349	61	43	48	192	65	117
TP4	96	49	115	68	256	152	46	43	46	65	40	43
TP6	83	72	122	126	70	184	61	50	46	83	108	54
TP8	146	63	229	95	102	578	63	75	79	75	25	55
Ave. time per task	89	60	158	89	143	316	58	53	55	104	60	67

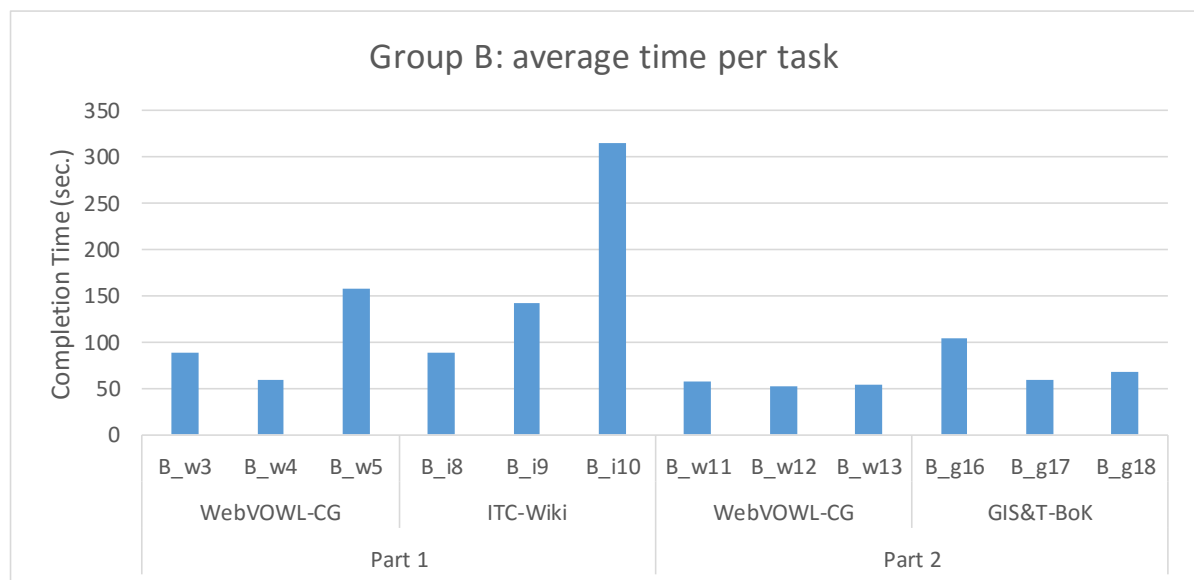


Figure 22 – Graphical representation of group B test results (see Table 14).

5.6.3. Satisfaction

Table 16 and 17 together with their corresponding charts (figure 23 and 24) represents the answers to satisfaction questions for each task per group.

The Likert scale (rating scale) was used to answer the satisfaction questions, and it was interpreted as follows. Strongly disagree (SD), disagree (D), moderate (M), agree (A) and strongly agree represents (SA) scores of 1, 2, 3, 4 and 5 respectively.

The number of questions on satisfaction was six (6), which meant that the highest scores that a test person could get were thirty (30). Table 15 shows how the satisfaction rate was calculated for TP2 using the Likert scale: for instance ITC-Wiki's satisfaction rate was calculation by adding all the Likert scale responses provided by TP2 (e.g. easy to use = M (moderate) = 3scores, easy to learn = M (moderate) = 3scores, easy

to find what I want = A (agree) = 4 scores and so) and divide by 30 and then multiply the answer by 100 $([(3+3+2+4+4+3)/30]*100 = 63\%)$ (Zelalem, 2015). This was applied to all TPs in both groups (A and B), and the results are presented in Tables 16 and 17 with their respective charts in figure 23 and 24.

Table 15 – Scale rating (Likert scale) interpretation example.

	Group B: TP2																			
	WebVOWL-CG					ITC-Wiki					WebVOWL-CG					GIS&T-Wiki				
<i>Satisfaction Questions</i>	<i>SD</i>	<i>D</i>	<i>M</i>	<i>A</i>	<i>SA</i>	<i>SD</i>	<i>D</i>	<i>M</i>	<i>A</i>	<i>SA</i>	<i>SD</i>	<i>D</i>	<i>M</i>	<i>A</i>	<i>SA</i>	<i>SD</i>	<i>D</i>	<i>M</i>	<i>A</i>	<i>SA</i>
1-Easy to use					5			3							5					4
2-Easy to learn					5			3							5				3	
3-Easy to find what I want				4	5		2		4						5		2			
4-Easy to understand				4					4						5				3	
5-Information is clear															5				3	
6-Overall I'm satisfied with it					5			3							5				3	
Satisfaction Rate (%)	$(28/30) * 100 = 93$					$(19/30) * 100 = 63$					$(30/30) * 100 = 100$					$(16/30) * 100 = 53$				

Table 16 – Scale rating response of group A

	Group A			
	Part 1		Part 2	
	WebVOWL-CG	ITC-Wiki	WebVOWL-CG	GIS&T-BoK
TP1	83	90	77	80
TP3	90	67	100	87
TP7	83	63	83	67
TP9	80	70	80	93
Satisfaction Rate (%) per Group	84	73	85	82

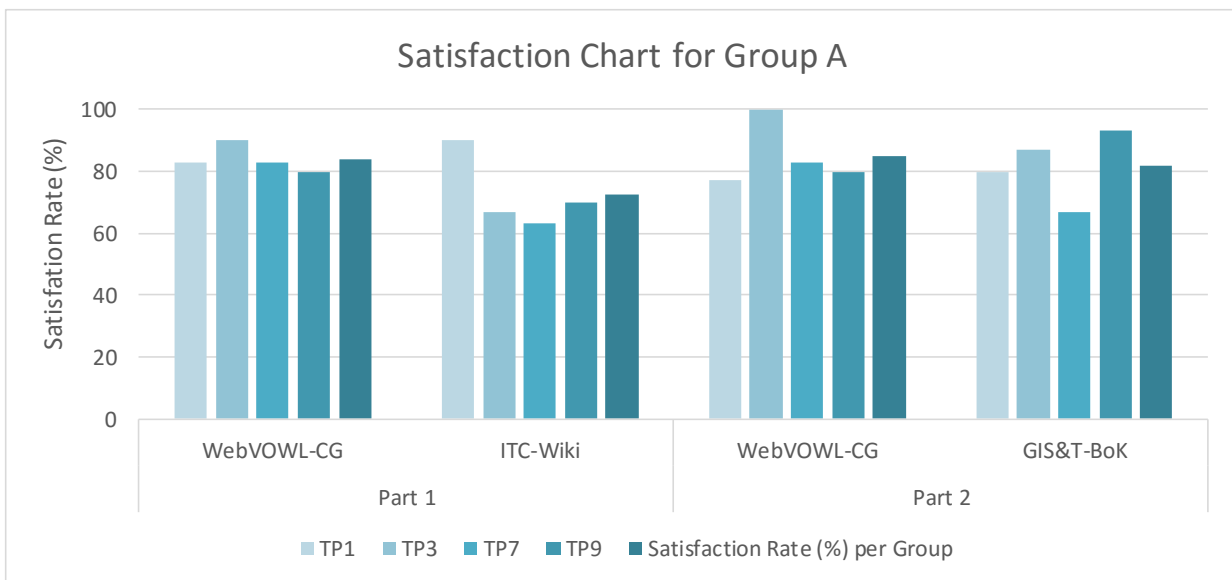


Figure 23 – Scale rating graphical representation of group A test results

Table 17 – Scale rating (Likert scale) response of group B

	Group B			
	Part 1		Part 2	
	WebVOWL-CG	ITC-Wiki	WebVOWL-CG	GIS&T-BoK
TP2	93	63	100	53
TP4	90	67	97	67
TP6	80	47	80	60
TP8	73	73	90	97
Satisfaction Rate (%) per Group	84	63	92	69

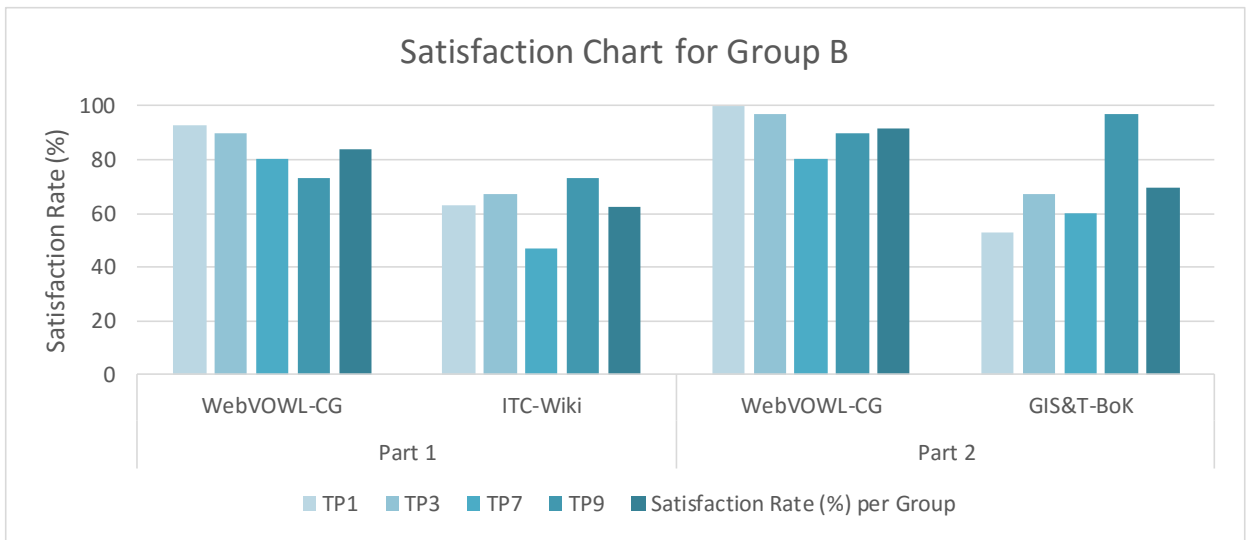


Figure 24 – Scale rating graphical representation of group B test results

5.7. Analysis and discussion of Test results

This section looks at the analysis and discussion of test results for the Test Persons. The analysis and discussion of the test results (Section 5.6) are presented regarding effectiveness (calculated based on the number of correct answers of TPs), efficiency (calculated based on the average shortest period taken to complete tasks per group) and satisfaction (calculated based on TPs’ response with respect to the Likert scale questions). Lastly, functionality test performance results are presented.

5.7.1. Effectiveness

The results of the test are provided in figure 25. The results presented for group A and B are average percentages for each task calculated from TPs in each group (e.g. for group A see Table 11 for average percentage calculations). Figure 25 also gives an overview of comparison of results between the two groups for each task. For instance, the success rate for group A performance with respect to task “w3” is 100% meaning all test persons in this group got task w3 correct whereas group B’s success rate is 75% meaning one group member got one of the question wrong.

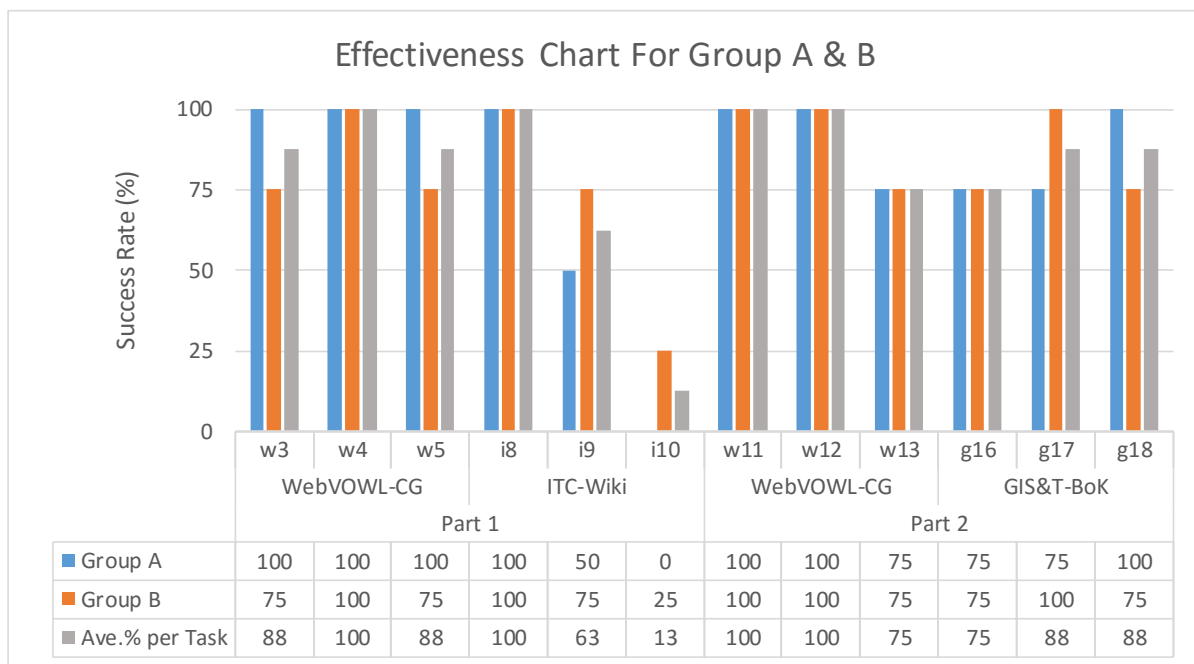


Figure 25 – Showing the success rate of group A and B test results

As stated in the introduction, this study is motivated towards improving the student’s learning experience. One way to achieving this is to know how effective the prototype(WebVOWL-CG) is. In figure 26 WebVOWL-CG (Prototype) is compared with the ITC-Wiki to find the effective educational tool. This is achieved by further finding the group averages for each task and then find the highest success rate for each application. For this comparison, the group average success rate for WebVOWL-CG is 92% $[(88+100+88)/3=92]$, whereas the group average success rate for ITC-Wiki is 58% $[(100+63+13)/3=58]$

The overall success rate presented above may have been as a result of the following reason(s) taken from Test Person’s think aloud and video recordings. For example, Task “w5” and Task “i10” (see Appendix 7.3 and 7.7 respectively) were equivalent in terms the level of difficulty and complexity. TPs had difficulties to find the correct answer to this tasks. This was because it required a bit of reasoning, reading and

understanding of the concepts (three concepts to precise) to get it correct when using ITC-Wiki. Moreover, when it came to using WebVOWL-CG, it was observed to be relatively easy.

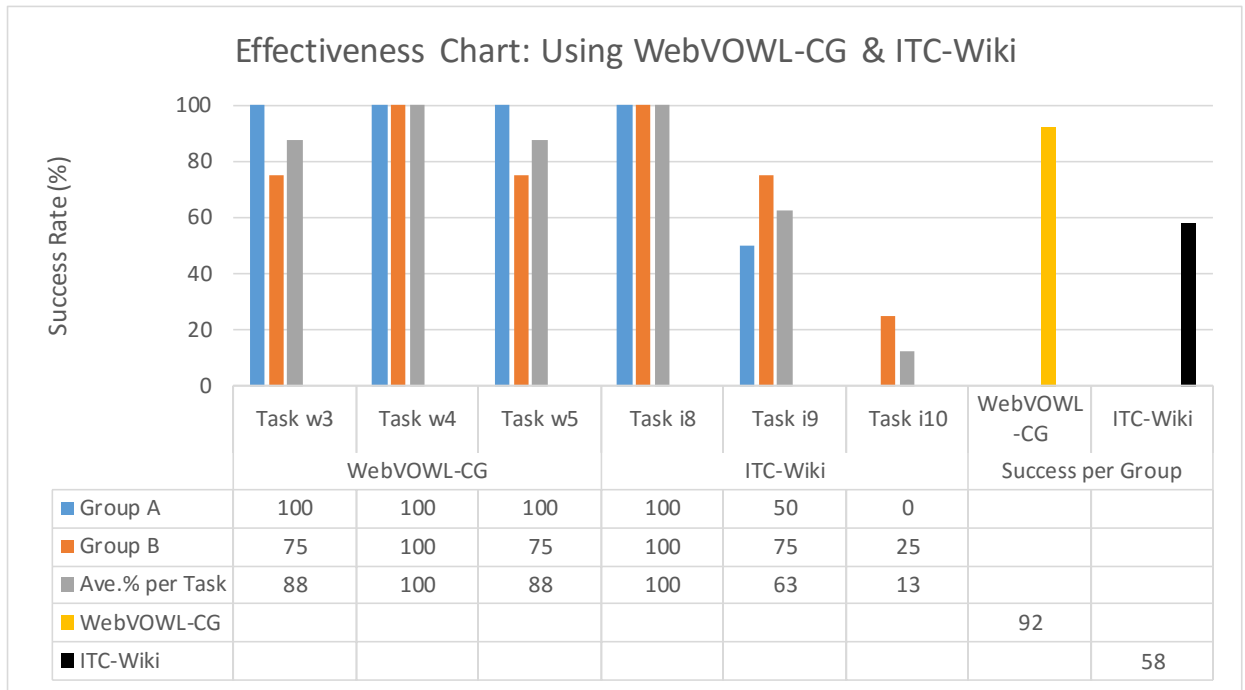


Figure 26 – Effectiveness chart of group A and B when using WebVOWL-CG and ITC-Wiki

The difficulty discussed in the previous paragraph can be noted from the figure 26 where the success rate of task “i10” of group A is 0%, and group B is 25% while the equivalent task “w5” for group A is 100%, and group B is 75%. Moreover, as already stated, the group average success rate for WebVOWL-CG was 92% whereas the group average success rate for ITC-Wiki was 58%. Therefore, the effective educational tool between the WebVOWL-CG and the ITC-Wiki is WebVOWL because it has a higher success rate.

Similarly, the comparison between the WebVOWL-CG and GIS&T-BoK was carried out, and the results are as shown in figure 27. The group average success rates for WebVOWL-CG and GIS&T-BoK is 92% and 84% respectively.

With reference to the recorded think aloud and video data, the insight of why the results are as shown can be explained. For instance, Test Persons found it difficult to find the answers using GIS&T-BoK because answers were either missing or not fully described resulting in getting incorrect answers. This can be observed from figure 27, where on average two TPs got incorrect answers while using WebVOWL-CG and four while using GIS&T-BoK

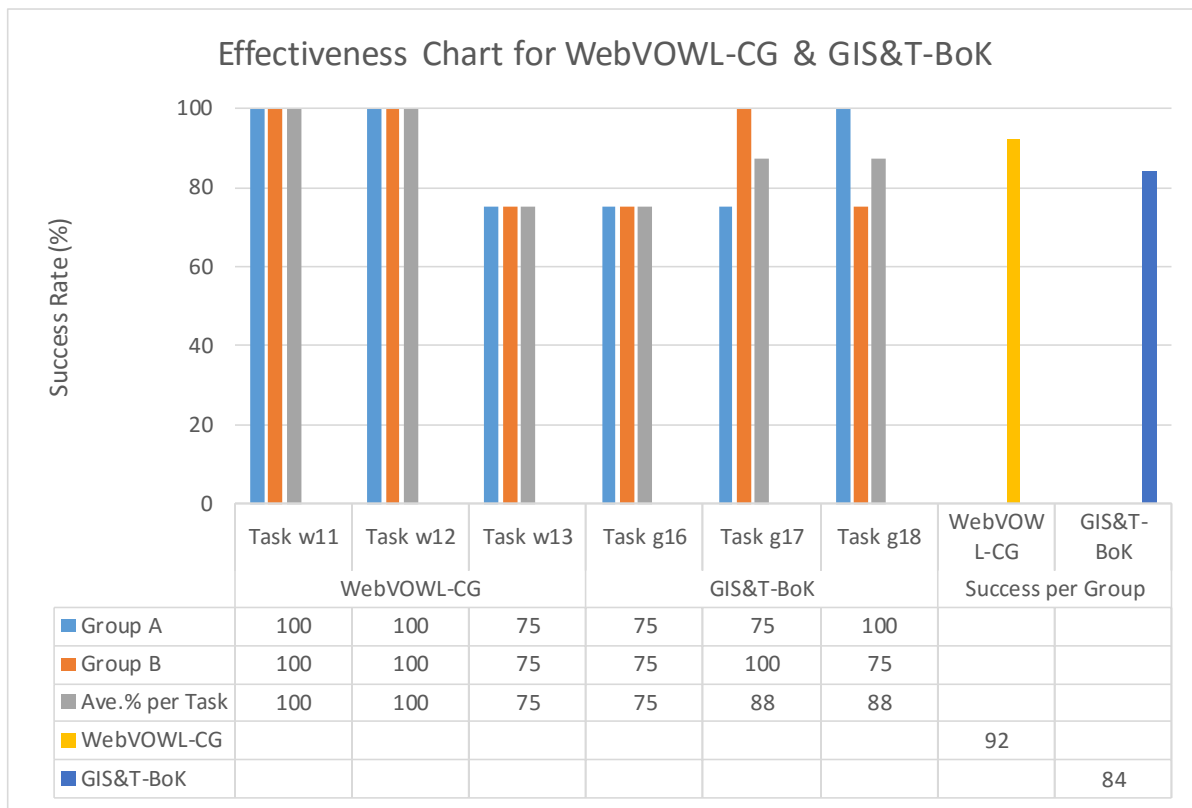


Figure 27 – Effectiveness chart of group A and B when using WebVOWL-CG and GIS&T-BoK

The Test Persons were right in their think aloud recorded data that information in GIS&T-BoK was missing. GIS&T-BoK was not developed to answer such questions in detail but was developed “for use by curriculum planners and evaluators, certification and accreditation bodies, current and prospective students, and geospatial professionals in government, industry, and academia” (DiBiase et al., 2006).

It should be noted that comparing WebVOWL-CG and GIS&T-BoK regarding which educational tool should be used, was not part the objectives of this study, But it was considered to understand why WebVOWL is needed complement GIS&T-BoK.

Therefore in terms, of effectiveness, WebVOWL-CG has a success rate of 92% while GIST&T-BoK has 82%. Hence, WebVOWL-CG is effective.

5.7.2. Efficiency

The results of the test were as shown in figure 28. The results presented for group A and B is average completion time for each task calculated from TPs in each group (e.g. for group B see Table 14 for average time per task calculations). Figure 28 also gives an overview comparison of results between the two groups for each task. For instance, the completion rate for group A performance with respect to task “g17” is 82 seconds whereas group B’s completion rate for the same task is 67seconds, meaning that group B was efficient than group A.

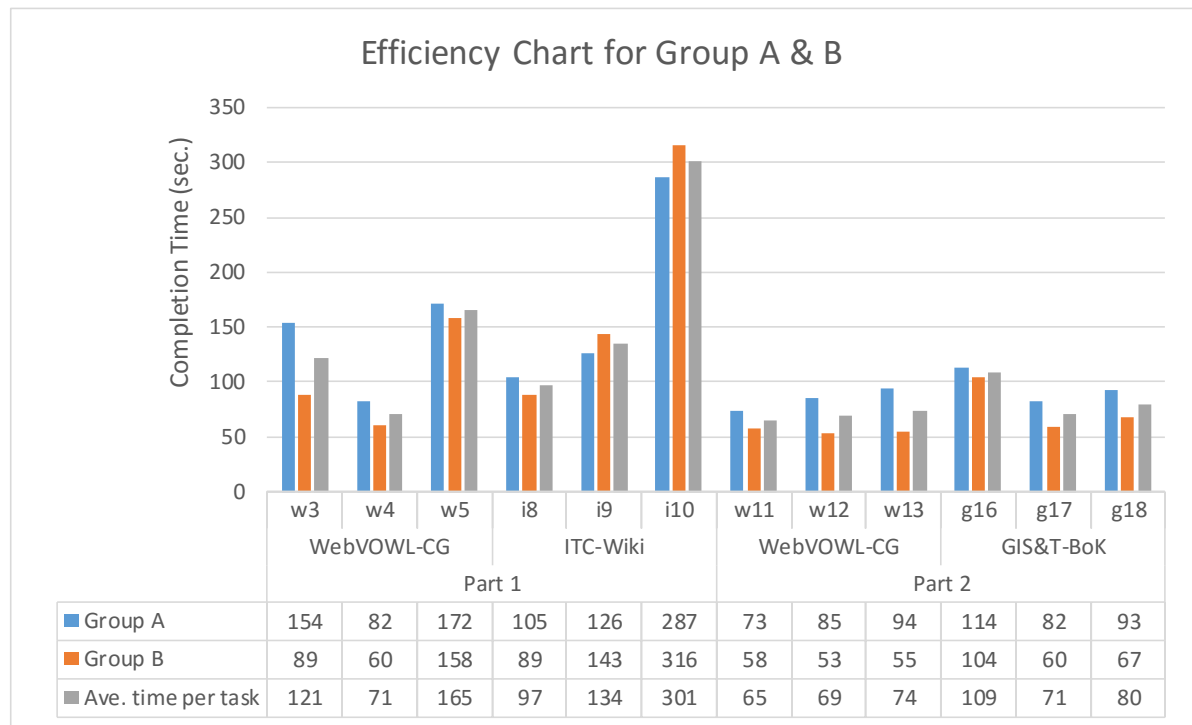


Figure 28 – Showing the completion time of tasks of group A and B

Similarly, this study is motivated towards improving the student's learning experience. One way to achieving this is to know how efficient the prototype (WebVOWL-CG) is. In figure 29 WebVOWL-CG (Prototype) is compared with the ITC-Wiki to find the efficient educational tool. This is achieved by further finding the group averages for each task and then find the shortest completion rate for each application. For this comparison (figure 29), the total group average completion rate for all the tasks in WebVOWL-CG is 357 seconds ($121+71+165=357$), whereas the total group average completion rate for all the tasks in ITC-Wiki is 532 seconds ($97+134+301=532$).

The overall completion rate presented above may have been as a result of the following reason(s) taken from Test Person's think aloud and video recordings. For example, Task "w5" and Task "i10" (see Appendix 7.3 and 7.7 respectively) were equivalent in terms the level of difficulty and complexity. TPs had difficulties to find the correct answer to this tasks. TP3 from group A (Table 13) spent over 638 seconds working on the task "i10". This was because this task unlike others tasks (where text search gets you the answer) required a bit of reasoning, reading and understanding of the concepts (three concepts to precise) to get it correct when using ITC-Wiki. Moreover, when it came to using WebVOWL-CG, it was observed to be relatively easy.

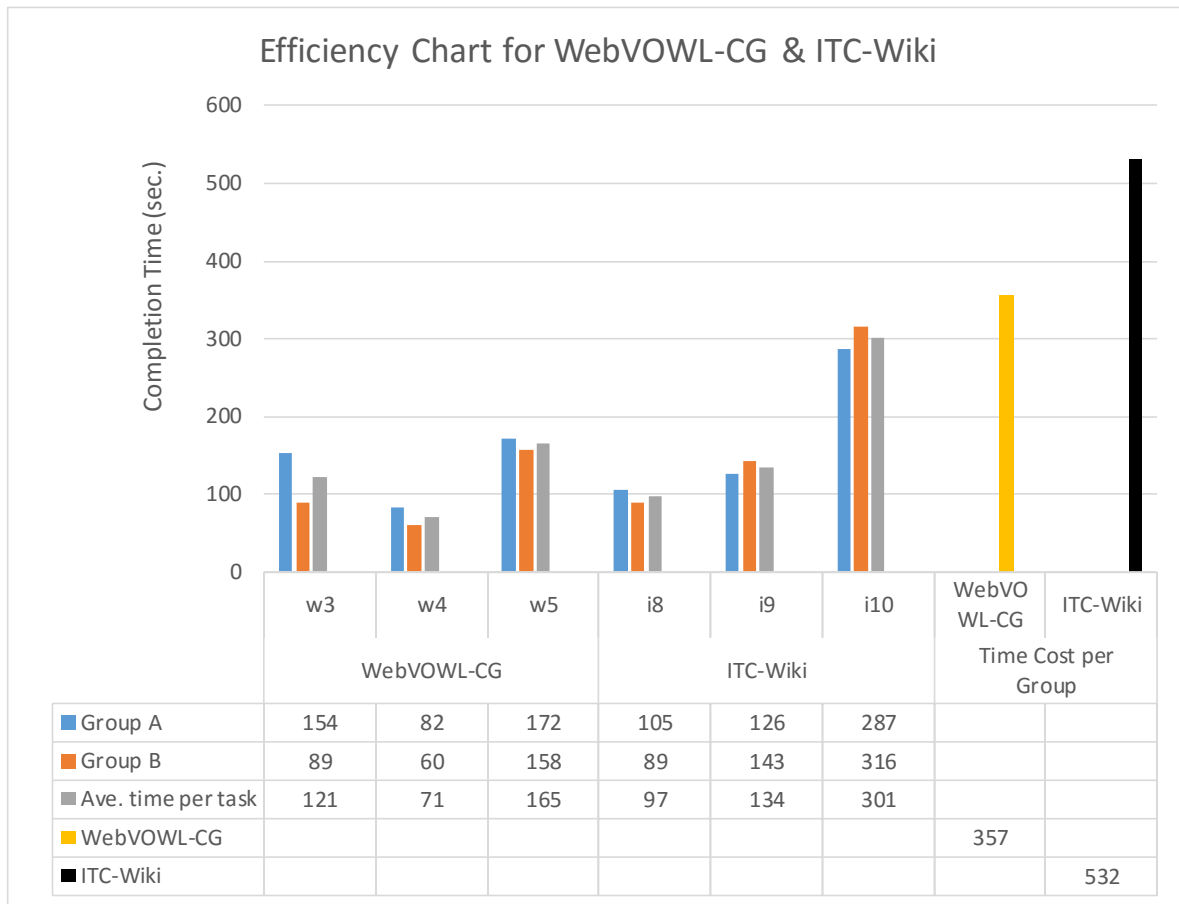


Figure 29 – Completion time of tasks of groupA and B withWebVOWL-CG and ITC-Wiki

The difficulty discussed in the previous paragraph can be noted from the figure 29 where the average completion rate of task “i10” for group A is 287 seconds, and group B is 316 seconds while the equivalent task “w5” for group A is 172 seconds, and group B is 158 seconds. Moreover, as already stated, the group average completion rate for WebVOWL-CG was 357seconds whereas the group average success rate for ITC-Wiki was 532seconds. Therefore, the efficient educational tool between the WebVOWL-CG and the ITC-Wiki is WebVOWL because it has a lower completion rate.

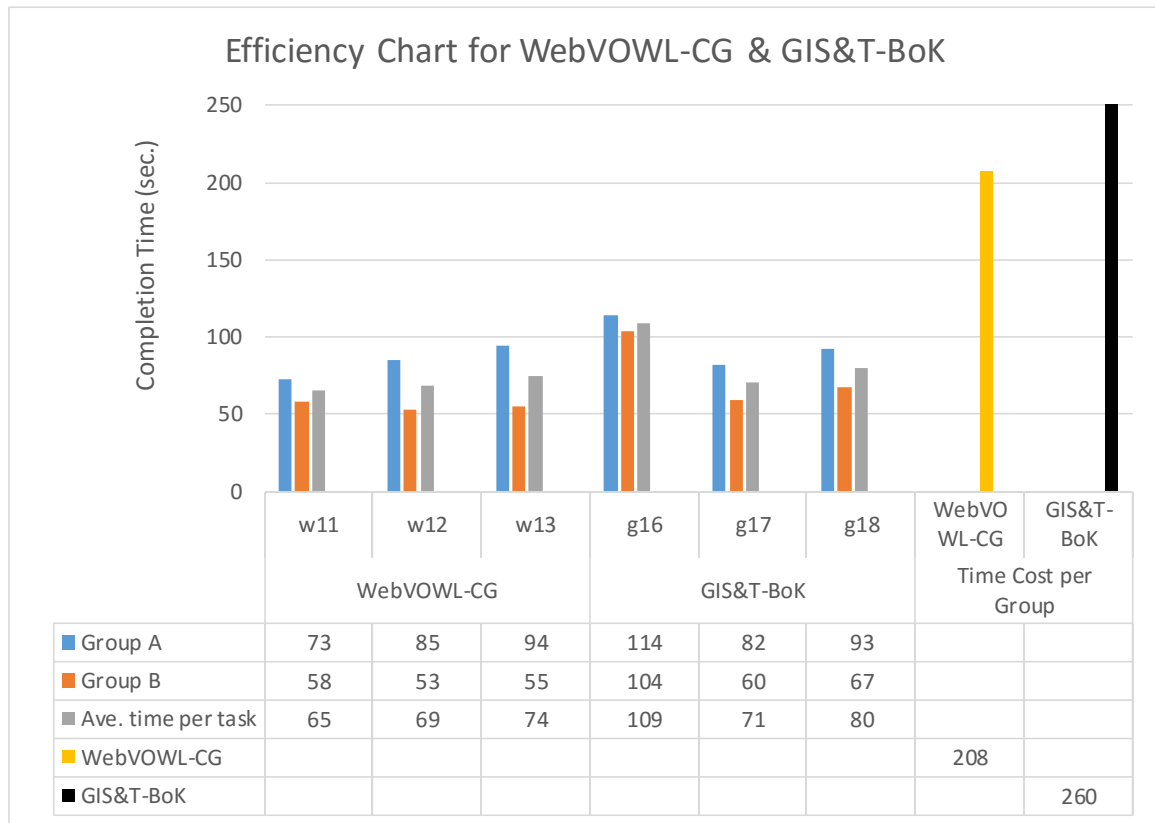


Figure 30 – Completion time of tasks of groupA and B with WebVOWL-CG and GIS&T-BoK

Similarly, as already indicated in figure 30, the group average completion rate for WebVOWL-CG was 208 seconds whereas the group average success rate for GIS&T-BoK was 260seconds. Therefore, the efficient tool between the WebVOWL-CG and the GIS&T-BoK is WebVOWL because it has a lower completion rate of 208 seconds.

5.7.3. Satisfaction

The results of the test are shown in figure 31. The results presented for group A and B is average satisfaction rate for each tool calculated from TPs rates in each group (e.g. for group A and B, see Table 16 and 17 respectively for average satisfaction rate per task calculations). Figure 31 also gives an overview comparison of results between the two groups for each application tool.

For instance, when WebVOWL-CG and ITC-Wiki are compared under the educational tool, the average satisfaction rate for WebVOWL-CG is 84 % whereas the average satisfaction rate ITC-Wiki is 68%, this means that TPs were more satisfied with WebVOWL-CG than ITC-Wiki as can be seen in figure 31.

On the hand, when WebVOWL-CG and GIS&T-BoK are compared under the visual tool, the average satisfaction rate for WebVOWL-CG is 88 % whereas the average satisfaction rate GIS&T-BoK is 76%, this means that TPs were more satisfied with WebVOWL-CG than GIS&T-BoK

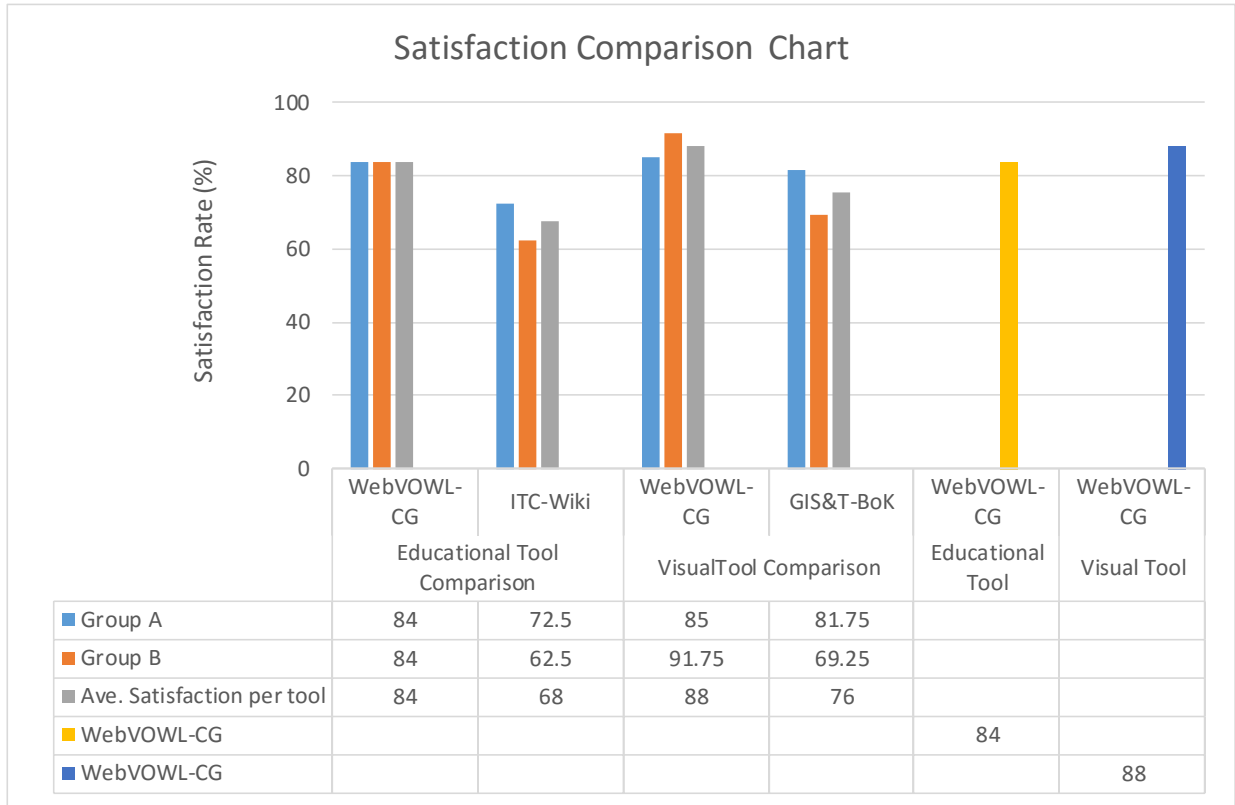


Figure 31 – Showing the satisfaction rates of group A and B

5.7.4. Functionality Test Performance Results

Reference made to figure 16 of subsection 5.4.1. The functionality test of WebVOWL-CG was conducted by observing how the TPs interacted with WebVOWL-CG when answering the test question presented in subsection 5.4.1.

Table 18 – TP’s Successes and Failures in finding answers to tasks in subsection 5.4.1

Test Person	Task -w3	Task -w4	Task -w5
TP1	success	success	success
TP2	success	success	success
TP3	success	success	success
TP4	success	success	success
TP6	success	success	success
TP7	success	success	success
TP8	failed	success	failed
TP9	success	success	success
Success Rate	(7/8) = 88%	(8/8) = 100%	(7/8) = 88%

In Table 18 success refers to the tasks that were correctly carried and as expected, whereas failure refers to those tasks that were answered wrongly.

All the Test Persons except for TP 8 executed their task according to the expected response as can be observed from Table 18 (and also in Table 11 and 12).

TP8's response to the tasks is reconstructed to see how the interaction was with the application. The reconstruction was based on the think aloud and video recording of TP8 when executing "tasks w3" and "w5".

The following were the questions the TP8 got wrong. The answers and user expected interactions with the WebVOWL-CG are all presented below.

- **w3)** What does the term 'geodetic datum' mean?

Why this question:

This question is meant to see if the Test Person can use the Text search tab, zoom, pan functions and refer to the sidebar to get the define of the term.

Expected answer; refer to figure 16.

PC – ZM – SC – ES – CD

- **w5)** Which common projection is Tangential, Cylindrical as well as normal?

Why this question:

This question is meant to check if the Test Person would explore application content to find the answer to indirection question requiring reasoning rather than just the use of text search window.

Expected answer; refer to figure 16.

PC – ZM – SC – ZM (*other combinations are also possible*)

Here is flowchart (response task reconstruction) based on TP8. Please use figure 16 to fully understand flowchart below.

w3) What does the term 'geodetic datum' mean?

Starts with [PC] and types the in text search window "Geodetic" and press enter, looking for the highlighted "Geodetic" on the display. TP8: "I cannot see it), [ZM] TP8 " Mmmm... "I cannot see it" [R] and then [ZM] and lastly tries search physically through the graph concept after concept and relationship after relationship until TP8 gave up and moved to next task.

The summary of the flowchart is PC – ZM – R – ZM. From this flowchart, already it is clear (when compared expected flowchart) that the Test Person started very well to getting the correct answer not until, it was difficult to spot where the concept being sought after was. They are after the Test Person tried to reset and zoom in and out but no answer was found.

w5). Which common projection is Tangential, Cylindrical as well as normal?

Similarly, started with [PC] and types the in text search window "Projection" and press enter, [ZM] looking for the highlighted term "Projection" on the display. TP8: "I can't find it" [PC] and types the in text search window another concept "Cylindrical" and notes that there at least three matches, however, TP8 can't spot

where this term/concept in the graph, [PC] changes search strategy again by typing the text search box “Normal” presses enter on the keyboard nothing happens [ZM] TP8: “I can’t see it” and gave up the search.

The summary of the flowchart is PC – ZM – PC – PC – ZM (comments similar to the one given for task w3)

What do we see from comparing the flow chart based on procedures for the expected with TP8’s solution?

One thing that can be seen is that most of the intended interactions with function (such as zoom in/out, pan, and so on) were used despite failing to find the answer. It was noted from the recordings, that TP8 followed the correct procedure for answering the question.

The reason for TP8’s failure can be attributed to lack of an effective and efficient text search function of WebVOWL-CG. Searching for concepts in WebVOWL-CG was an issue raised by most TPs. It is discussed in the section 5.8 that follows.

5.8. Discussion of general Results

The following comments are based on the test results and analysis presented in section 5.6 and 5.7 respectively, and the think aloud and video record.

WebVOWL-CG

According to the users, WebVOWL-CG was easy to work with. For instance, TP3 commented that “Overall, it was very helpful and interactive, the colours used are friendly, and the process of getting the solutions is like a simple puzzle. I like to puzzle”. Others like TP3 just said “it is easy to use concepts represented graphically” and lastly TP6 had this to say “the visual is good than the normal web page we are used with, which is more like a book....Boring to say”.

On the other hand, about 75% of TPs from group A commented on the highlighting of searched terms were not visible. Other like TP6 suggested that the application should incorporate techniques for zooming in automatically to the concept of interest than zooming in manually.

ITC-Wiki

This application was liked due to its excellent text search function, although when searching for concepts it would bring many options for the user to choose from. About 75% TPs from group B said it was very difficult to find or know how concepts are related to each other. Other TPs said ITC-Wiki had very clear information with diagrams as illustrations.

GIS&T-BoK

This tool was mainly liked because of its efficient text searching function. It has an automatic zoom in function for searching text and autocomplete drop down window for searching. The drawbacks for GIS&T-BoK are that concepts are too close to each other making it difficult to see relationships between concepts. For instance, TP2 commented that “the search is good, but the overlapping of concepts and relationships makes it difficult to see what you want. Besides, some concepts have missing descriptions”.

Application For Enhancing Learning

In order to know the educational tool that would be effective, satisfactory and efficient for improving the learning experience of a student, the WebVOWL-CG and ITC-Wiki were compared. While WebVOWL-CG and GIS&T-BoK are compared in terms of which visualization tool would best visualise the “concept graph”. To achieve this a summary all the findings are presented in Table 19 for easy comparison

Table 19 – Summary of general findings

	Educational Tools		Visualization Tools	
	WebVOWL-CG	ITC-Wiki	WebVOWL-CG	GIS&T-BoK
Effectiveness (%)	92	58	92	84
Efficiency (Sec.)	357	532	208	260
Satisfaction (%)	84	68	88	76

From table 19, under education tools, WebVOWL-CG has the highest in effectiveness (92%), highest in efficiency (357 sec.) and highest in satisfaction (84%) compared to the ITC-Wiki. This makes WebVOWL-CG the better educational tool in this study.

For the visualisation tool, again, WebVOWL-CG has the highest in effectiveness (92%), highest efficiency (208 sec.) and lowest in satisfaction (88%) compared to the GIS&T-BoK. This makes WebVOWL-CG the better visualisation tool in this study.

Therefore, WebVOWL-CG is the tool that can enhance education for the type of (concept related) tasks under study. It should be noted that WebVOWL-CG can only be utilized to its full potential when it is used with other educational based tools like ITC-Wiki. This is the case because WebVOWL-CG for instance gives a quick and clear overview of concepts and their relationships but lacks in pictorial illustrations (available in the wiki) which are also important in the enhancement of learning.

Therefore, WebVOWL-CG should be used as an added value to the existing education tool (ITC-Wiki).

Already, ITC-Wiki has been integrated with WebVOWL-CG (prototype) through links (URLs) in order to fully utilize potential of the tools.

5.8.1. What is the added value of WebVOWL-CG to the Existing Educational tools

To answer this question reference is made the think aloud and video recording of test persons. The added value of WebVOWL can be characterised as follows:

- The behaviour of the TPs, when they came across the concept graph, was that they would be so happy with it. Some TPs would even play with it before they could even start work on their task. An example is TP3, commented the following after working with WebVOWL-CG, “Overall, it was very helpful and interactive, the colours used are friendly, and the process of getting the solutions is like a simple puzzle. I like to puzzle”. With this in mind, it can be said that beauty or the visual attractiveness of graphs motivate and triggers the explorative behaviour.
- People looked at concepts and their relationship in order to know the relation that exists between the concepts. An example is flowchart (see figure 16 to understand this.) of TP 8 when answering Task w3) “What does the term ‘geodetic datum’ mean?” TP8: starts with [PC] and types the in text

search window “Geodetic” and press enter, looking for the highlighted “Geodetic” on the display. TP8: “I cannot see it”, [ZM] TP8: “Mmmm... “I cannot see it” [R] and then [ZM] and lastly tries search physically through the graph concept after concept and relationship after relation until TP8 gave up and moved to next task.

- The concepts graph allowed Test Persons to see things in short time. For instance, the overall efficiency presented in figure 19 shows that task carried in WebVOWL-CG took a shorter time (357second) compared to ITC-Wiki, which took a longer time (532seconds) in executing the same task. With this in mind, WebVOWL-CG indeed can be a useful if a student quickly wants to know something (e.g. description of some concept). WebVOWL-CG has a added value if the student has already read the learning material in detail (say a book), and then they want to learn for the exam at the last moment. All they need is to go through the concepts and learn the forgotten concepts.
- WebVOWL can also be useful for teachers to check quickly 1).what their student know if they want to set an exam and 2)what students have to know if they want to prepare for lectures.

6. Conclusion and Recommendations

6.1. Overview:

The main objective of this MSc research was to design and apply an ontology in geo-information education. The notion of this research was creating a prototype for concept graphs and a visualization of it in the context of a textbook (e.g., the ITC core module book) used in geo-informatics education. This section draws conclusions on the different activities carried out in this study. It also highlights some challenges encountered in carrying out some tasks during the study.

6.1.1. Text Mining

To attain the goals of this study, firstly, there was a need for creation and validation of an appropriate ontology. This involved a combination of manual and automated data extraction of important concepts which were used in the building of a sketch ontology.

About twenty (20) free text analysis applications tools were considered (Predictive Analytics Today, 2015). The process of choosing an automated data extraction tool that is capable of meeting some requirements was a challenge, in that, it took much time looking for the tool that is a free software and capable of meeting the minimum selection requirements is easy (Section 2.4).

Nevertheless, two data extraction tools were considered (Lightside and KH Coder). After comparing Lightside to KH Code. KH Coder was selected to be ideal for Text analysis tool due to the fact that it has more functionalities needed for this study and that it is relatively easy to use compared to Lightside application. Then, KH Coder was used for extracting all keywords words/compounds words from the input text. After that, manual data extraction was used for data extraction of important concepts which were employed in the building of a sketch ontology

The challenge faced in using the KH Coder was that it extracted many keywords (or compound words) making manual data extraction of the important term a time-consuming task. Furthermore, it was noted that the KH Coder was extracting some terms several times e.g. map projection and map projections. The other challenge encounter with when using KH Coder was, it only works with plain text format (*.txt). The solution is to find a way of completely avoiding the manual extraction. The can be achieved by using fully automated data extraction tool.

6.1.2. Data Validation by Experts

After that, it was validated by domain experts (ITC – Lecturers) who check the correctness of concept definitions and their relationships. From literature, this process of data validation is called heuristic evaluation. The overall repose from the domain experts was that they were satisfied the draft ontology (Section 5.2). After the validation process, a machine readable ontology was created in OWL using an ontology editor (Protégé). Protégé was used to define concepts and their relationships.

6.1.3. Visualization of the machine readable ontology

There was a need to visualize the machine readable ontology using a visualization tool that meets the needs of the user (e.g. to be used by students anywhere). Hence, in this study, a web-based ontology visualization tool was considered. Reasons have been that the Internet makes it simple to share results and collaborate over enormous distances and that there is no need to download and install special tools for one to visualize.

The visualization tools that were considered included FlexViz, LodLive, and WebVOWL. FlexViz (Falconer et al., 2010): is founded on technologies like Adobe Flex that needs proprietary browser plugins. LodLive (Camarda et al., 2012): is technically comparable to WebVOWL however, lodLive focuses on the visual exploration of Linked Data and not on the ontology visualizations. Lastly, WebVOWL (Lohmann et al., 2014): is implemented in Java and is independent of any ontology editor. It works with all modern web browsers that implement SVG, CSS, and JavaScript to a sufficient degree.

Therefore, WebVOWL was settled for due the fact that it met these requirements and needs for tools applicable to visualizing ontology.

The main challenge faced with using WebVOWL is its inability to search for data stored in the machine readable ontology file. Instead, it searches the on the rendered web page from the machine readable ontology file using a native web search function (Ctrl+F). Hence, functions like auto-complete search option could not be carried out.

Other visualization tools looked at in this study were the Protégé plugins such as OWLViz and OntoGraf. OWLViz allows class hierarchies in the machine readable ontology to be viewed and navigated in a non-dynamic way (the concept graph is statistic). On the other hand, OntoGraf is a dynamic ontology visualization tool which supports the interactive navigation. The main reason the two visualizations tools were not used considered was they did not meet the user requirement of being web-based tools.

6.1.4. Usability test results and conclusion

Lastly, it was important to know if the prototype (WebVOWL-CG) served the purpose it was developed for, i.e., improving the learning experience for students. For this, usability testing was carried out. It involved comparing it with another educational tool (ITC-Wiki) and comparing with another visualization tool (GIS&T-BoK).

After usability test results analysis had been completed, it was concluded that WebVOWL-CG is the tool that can enhance education for the type of (concept related) tasks under study. It should be noted that WebVOWL-CG can only be utilized to its full potential when it is used with other educational based tools like ITC-Wiki. This is the case because WebVOWL-CG, for instance, gives a quick and clear overview of concepts and their relationships but lacks in pictorial illustrations (available in the wiki) which are also important for the enhancement of learning

6.2. Answers to research questions

A summarised of answers to research questions presented in section 1.3 are as given below.

- **Who are the potential users of the ontology and its visualisation?**

In chapter 3 (Subsection 3.2.1), the potential users of the ontology and its visualization are academic staff and students.

The requirements are creating a prototype ontology and a visualisation of it in the context of a textbook (e.g., the ITC core module book) used in geo-informatics education. Concepts from the book (e.g., scale, quality, coordinates, polygon, pixel, raster) and their relationships appear in such a concept browser, and a user (e.g. student and academic staff) can explore these concepts and the accompanying text from the textbook. The use cases show how the users will be using the ontology and its visualisation. The ‘use’ scenarios of how/what the ontology is intended to be used for are presented;

- **Use case 1 - Student driven: understanding the definition of a term and its -relationship with other terms**

Kebby is a first year MSc GFM student following the ITC core module. His first bachelor degree is in mathematics and statistics. As he is studying, he comes across the phrase “Spatial reference”, he wonders what that term means, and he decides to search for it. Immediately he gets the results in the form of a concept graph. The search results come with 1) The definition of “spatial reference”, 2) where one can find more detailed information about the phrase and 3) All the related words to the phrase in question.

On the graph, he visualises all the other concepts related to “spatial reference” such as coordinate system, map projection, coordinate transformation, reference surface and map. He also visualises the radial lines that show the relationship. So he can tell which concept depends on the other or which one is similar to the other.

- **Use case 2 - Student driven: understanding the relationship between two terms**

Lee is a South Korean national doing an on-line distance course on the principal of GIS at the University of Twente - ITC. She will need to go through the on-line tutorial and each week she needs to write and submit assignments.

She decides to work on one of her assignments. As she is writing the assignment, she does not know which phrase to use between spatial information and geographic information. So she decides to search for it. The search results show graphically that the two (2) phrases or concept are similar. She later then validates the search results with the phrase definitions in the wiki via a link (provided as a web resource in the ontology).

- **Use case 3 – Academic Staff driven: Test/Exam and Lecture Preparations**

Mary is a Lecturer and researcher at ITC. At the moment, Mary’s work hinges upon the principal and fundamentals of GIS and remote sensing that are explained in the core book. Her tasks are to prepare lecture slides and test the student’s their understanding of the core module. In order to achieve her tasks, she looks at the over view of the topics she is working on to ascertain 1)What her student know or covered during lectures if she wants to set an exam and 2)what students have to know if she wants to prepare for lectures.

- **For what purposes could they use this ontology?**

The notion of this research was creating an ontology and a visualisation of it as the context of a textbook used in geo-informatics education. Therefore, Geographic Information Science (GIS) is the domain of the ontology. The ontology is designed to be used for education purpose to improve the learning experience of the student as presented in chapter 3 (Subsection 3.2.1).

- **What are the characteristics of the ontology; what are relevant concept types and inter-concept-relationship types?**

Reference is made to Chapter 3 (Sections 3.3.2 and 3.3.3). The characteristic of the ontologies that are relevant are classes which in this study are referred to as “terms” or “concepts”. The inter-concept relation types used are “subclass relationship” where a subclass depends on the superclass, and there identify by the dashed line in WebVOWL. Other defined inter-relationships type is identified by solid lines (e.g. isPartlyDefinedBy). Example of these inter-relationship are as follows; refer to Figure 10. Coordinate system is a “subclass” of spatial reference and represented by dashed lines. On the other hand geoid is “isPartlyDefineBy” geoid separation and is represented by a solid line (see Figure 11)

- **How can the concept types and inter-concept-relationship types be stored, so that the software can use them for further processing or visualisation?**

Section 4.2: The concept types and inter-concept relationships can be stored in a machine readable language called Web Ontology Language (OWL). To achieve this, an ontology editor Protégé can be used to develop the machine readable ontology and can be further processed or visualized by using a web based ontology visualization tool called WebVOWL.

- **How can we deploy existing automated ways (e.g., keyword mining) and non-automated ways of producing the ontology?**

This can be done by using an automated extraction tool like KH Coder (Section 2.4.2) to generate automatically a list of keywords or compound words. It should be noted that it is from an automatically list where the manual process of selection important concept needed in the ontology. After that, the process of ontology creation can start.

- **How can the ontology best be visualised for our users?**

Section 2.6: The ontology can best be visualised by a visualization tool that meets both the requirements and needs for tools applicable to visualizing ontology such as reducing unnecessary details, particularly in large ontologies and differentiating between the already existing and the imported classes or ontologies (Blundell & Pettifer 2004). This tool is Web VOWL.

The shape and colour for representing concept and relationships (lines between concepts) respectively is an important issue be considered in visualization of ontologies. Only one TP commented on the having different colour to represent property types.

- **In which software can the visualisation best be developed, so that it fits the user environment?**

It should be implemented in Java so that it can be easily used by web based ontology visualisation tools. The visualization can be developed using ontology editor Protégé using OWL, then a converter accesses this ontology representation provided by the OWL API and transforms it into the JSON format required by WebVOWL for visualization. A detailed explanation is given in subsection 4.3.1 on how WebVOWL-CG was implemented.

- **How do users interact with the concept graph?**

Reference is made to figure 16 of subsection 5.4.1. The functionality test of WebVOWL-CG was conducted by observing how the TPs interacted with WebVOWL-CG when answering the test question presented in subsection.

Users looked at concepts and their relationship in order to know the relation that exists between the concepts. According to the functionality test which was performed to check how users interacted the application, it was found that user interacted with the concept graph as explained in Subsection 5.7.4. For instance, if the user want to find the definition of term “Geoid”, the following interaction has to take place: PC (text search for the term “Geoid” from the search window) – ZM (zoon in/out and pan) – SC (Select the term) – ES (explore the sidebar – part of the WebVOWL-CG interface) – CD (Read the definition). To full under the interaction mentioned please refer to Figure 16.

Figure 16 is a flow chart of the exploration possibilities (step diagram) in WebVOWL. It helps to understand how users interact with the application and also gives insight on why user fail to get some tasks presented to them wrong. For example TP 8 in this study: it become clear after checking the interaction between TP8 and WebVOWL-CG using the step diagram together with the recorded eye tracking data that the answers the question TP8got wrong was because the search function was not performing well (see Subsection 5.7.4).

- **What are points of improvement for the ontology and its visualisation?**

The points of improvement are that all the properties defined in the ontology should be described (defined). This was observed when TPs would hover the mouse over the properties waiting for a response, and others would double click on the property several times in anticipation to get more information.

Concerning the visualization, two (2) TPs commented that the use of colour was good to depict classes, but there was also the need to use colour to differentiate property type. The use the line types such as dotted and solid lines with some colour is not enough because depending on the zoom the dashed and solid lines appear the same making it difficult to differentiate the property.

6.3. Recommendations

- Much more research is required to find specifically the best ways WebVOWL-CG (prototype) should be integrated with the ITC-Wiki. This entails finding the best way the ontology (WebVOWL-CG) should be implemented in the ITC-wiki to further improve education. The following is recommended:
 - The applications should be integrated in such a way that it shares a common visualization interface. This means that the integration of the WebVOWL-CG with the ITC-Wiki should be explicitly implemented in one interface. And not in two separate interfaces.
 - The integrated educational platform (WebVOWL-CG and ITC-wiki) should be a web-based implementation, so that anyone, anywhere can access the application (provided there is an internet connection) and not on standalone platforms.
 - Text search functionality should be made user-friendly. This a concern raised by the Test Persons during the usability test conducted in this study.

Since WebVOWL is MIT License (free software), the source code can be accessed. It is from this code where the “small search code” that should be developed is to be integrated. What should be achieved is a functionality that shall be able to highlight concepts being searched, auto-complete the concepts being searched and be able to auto zoom-in to the concept of interest during searching.

- Lastly, user learning assessment should be carried out to ascertain if at all there is improvements in learning when users use the application.

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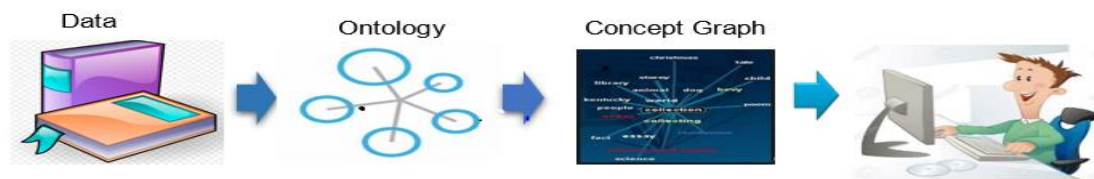
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Appendix 1: Data Validation Invitation Letter: Experts

Dear ITC Staff,

I am an MSc student in the Department of Geo-Information Processing. I am working on the Design and Application of concept graphs in geo-information education under the supervision of Rob Lemmens and Ellen-Wien Augustijn as first and second supervisors respectively.

As part of my research, I am designing and applying an ontology in geo-information education. The notion of this research is creating an ontology and a visualisation of it (in the form of a concept browser, such as the aqua-browser) as the context of a textbook (e.g., the ITC core module book) used in geo-informatics education as shown in the figure.



Concepts from the book (e.g. coordinates, polygon, pixel, raster) and their relationships appear in such a concept browser, and a user (e.g. student / academic staff) can explore these concepts and the accompanying text from the textbook.

The target user of this ontology is any person who is undertaking Geo- information studies (e.g. ITC - core module in this case). In order to know whether this ontology is correct and useful, there is need to validate it. Therefore, I would like to invite you to take part in the validation of this ontology. The Task is mainly to check if concept definitions, descriptions, and their relationships are correct and consistent.

If you are willing to participate, I would like to ask you to complete an online survey first, in which you will be asked questions about your background and the Ontology. Completing the survey before 15th January 2016 will be highly appreciated. Please note that your identity would not be revealed when presenting the results of the research.

Attached herewith the Mid-term presentation (which will give a brief introduction to the research) and the Data for Validation. If these documents are not clear, I can be contacted anytime for further explanation.

Click the link below to commence the survey:

<https://www.surveymonkey.com/r/NFCBVFN>

Thank you in advance for your time and consideration. I will highly appreciate your participation!

Best regards

Kelvin

Appendix 2: Validation Questionnaire: Experts

1. In order to carry out the validation of the ontology, we need your name and email address. Please specify below:

Name:

Department:

E-Mail:

2. Are the definitions and descriptions of the concepts (example – reference surface, Geoid, Global Datum. etc.) Correct according to the reference materials used?

- Correct
- Moderately Correct
- Not Correct

For chosen answer above: (if its not correct, please specify and give guidance on how it should be corrected)

3. Are the relationships (represented by properties) used between the concepts correct?

- Correct
- Moderately Correct
- Not Correct

For chosen answer above: (if its not correct, please specify and give guidance on how it should be corrected)

4. General what would say about the correctness of the graphs ?

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree:
Overall I'm satisfied with it:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

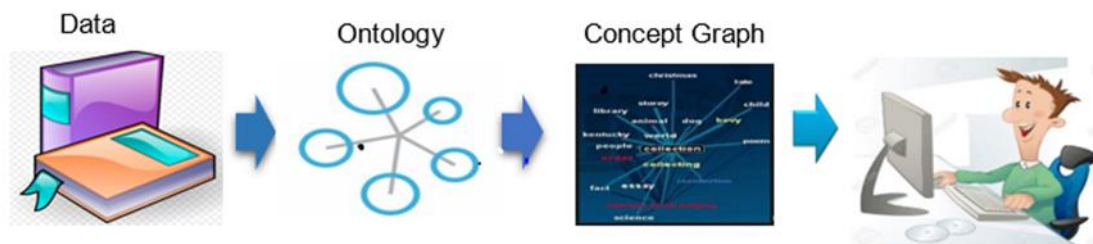
5. Any advice or concerns over this Ontology:

Appendix 3: User Test Invitation Letter: Students(TPs)

Dear ITC student,

I am an MSc student in the Department of Geo-Information Processing. I am working on the Design and Application of concept graphs in geo-information education under the supervision of Rob Lemmens and Ellen-Wien Augustijn as first and second supervisors respectively.

As part of my research, I am to designing and applying an ontology in geo-information education. The notion of this research is creating an ontology and a visualisation of it (in the form of a concept browser, such as the aqua-browser) as the context of a textbook (e.g., the ITC core module book) used in geo-informatics education as shown in the figure.



Concepts from the book (e.g. coordinates, polygon, pixel, raster) and their relationships appear in such a concept browser, and a user (e.g. student / academic staff) can explore these concepts and the accompanying text from the textbook.

The target user of this ontology is any person who is undertaking Geo- information studies (e.g. ITC - core module in this case). In order to know whether this ontology is useful, there is need to test it the students. Therefore, I would like to invite you to take part in a user test that will be held soon in the usability lab of the Geo-Information Processing (GIP) Department room 1-066.

If you are willing to participate, I would like to ask you to complete an online survey first, in which you will be asked questions about your background. Completing the survey before 15th January 2016 will be highly appreciated. Please note that your identity would not be revealed when presenting the results of the research.

Click the link below to commence the survey:

<https://www.surveymonkey.com/r/TLCWX6C>

Thank you in advance for your time and consideration. I will highly appreciate your participation!

Best regards

Kelvin

Appendix 4: User Profile Questions: Students

1. In order to be able to invite you for the actual user test, we need your name and email address. Please specify below:

Name:

E-mail:

2. In which course domain are you studying?

- Applied Earth Sciences (AES)
- Geoinformatics (GFM)
- Land Administration (LA)
- Natural Resources Management (NRM)
- Urban Planning and Management (UPM)
- Water Resources and Environmental Management (WREM)
- Other (please specify)

3. What is your highest education qualification?

- Bachelors
- Masters
- Other (please specify)

4. In what field of study did you obtain this qualification?

Appendix 5: Test Scenario

Before the test start

30 minutes before the Test Person (TP) arrive at the Usability Laboratory, the checklist has to be referred to (Checked), to ensure that all necessary things concerning the test are ready;

- Have access to the Usability Laboratory and switch on the test equipment (desktop and eye tracker).
- Put the copies of the General instructions, specific instructions for each test, warm-up questions and test questions according to groups on the table.
- Make sure that the test equipment (desktop and eye tracker) is ready to use.

Test Person (TP) Welcome and introduction:

Just after the Test walks in the Usability Laboratory, welcome the Test Person and thank the Test Person for coming and ask the TP to take a seat and then, proceed as follows;

- Here is a copy of Generation introduction of the test you will be taking today.
- We will together go through the test procedure I just handed you.
- Let me now show what is expected of you as you answer the question (a demonstration is given by thinking aloud (speak loudly) while performing each given task)
- Do you have a question so far? If you do not have any question or doubts, you can proceed to read and try to acquaint yourself with the test instruction and interface you will be using These can be found on the printed copy provided. [I wait for few minutes for TP go through the instructions].
- Do you have any question? ...Can we proceed to now test?

During the test:

- With the TP, start eye calibration by adjusting their seat and by telling the TP, focus on the screen and follow the red dot.
- Write down the particulars of the test person: participant's ID
- When prompted by the TP to load the WebVOWL file, I help in doing that.
- And after that, recording and answering of the questions can commence.
- After which, the test finally ends.

After the test:

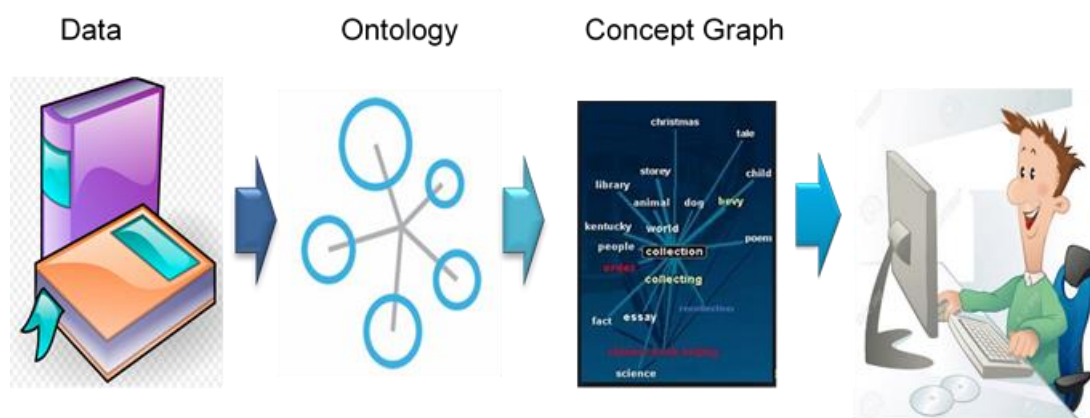
Thanks for the test person;

- Thank you very much for your time, patience and cooperation. I hope you enjoyed it.

Appendix 6: General Test Procedure (TPs)

INTRODUCTION:

As part of the research, I am designing and applying an ontology in geo-information education. The notion of this research is creating an ontology and a visualisation of it (in the form of a concept browser, such as the aqua-browser) as the context of a textbook (e.g., the ITC core module book) used in geo-informatics education as shown in the figure.



Concepts from the book (e.g. coordinates, polygon, pixel, raster) and their relationships appear in such a concept browser, and a user (e.g. student / academic staff) can explore these concepts and the accompanying text from the textbook.

This study is motivated towards improving the student's learning experience of the whole core module set up by using concept graphs in geo-information education. The question is, does it work (helping a student's learning experience)? This is where the usability testing comes in.

In each session will involve: thinking aloud, and eye tracking and video observation usability test methods as well as a questionnaire.

In part 1 of the first session, you will be introduced to two applications (ITC-Wiki and WebVOWL: Concept graphs based on the ontology) where you will be requested to answer the questions that will be presented to you. The questions in this first session are meant to investigate which application (between ITC-Wiki and WebVOWL) is able to improve the student's learning experience in the Geo-information education. While in part 2 of each session two ontology visualization tools will be introduced to you and questions meant to investigate the best visualisation (between the GIS&T-BoK and WebVOWL) will be presented to you.

Lastly, you will be asked to evaluate and decide on the software package you think is good to improve Geo-information education.

The summary of the describe activity is given in the table below:

Table: Summary of the usability testing session

Session	Part	Tools Being Compared	Activity	Reason
1	1	WebVOWL & ITC-Wiki	<ul style="list-style-type: none"> Working on Tasks and questions (involves thinking aloud, and eye tracking and video recording). 	<ul style="list-style-type: none"> To evaluate and decide on the learning environment you think is good to improve Geo-information education.
	2	WebVOWL & GIS&T-BoK	<ul style="list-style-type: none"> Answering the Questionnaire 	<ul style="list-style-type: none"> To allow interaction between the Users and the tool in order to access & decide on the best visualisation tool

During the whole process of the first session, it is expected from you to think aloud (to say what you think) while performing each given task. If needed, you will be reminded by me to do so. Therefore, in the test process, it is required that you speak your thoughts aloud during each task. For instance, you can start by saying "Here I am starting with task number 1", and "I am searching for the term – GEOID - on the screen", "I cannot find it so let me try searching using the text search option", oh.....Finally " this should be the answer "...etc.

Once you think you've found the answer, please record it on the answer sheet provided.

Please Note: If you know the answer to the questions beforehand, we request that you ignore that fact and try to search using the tools provided.

Appendix 7: Test Questions

NOTE

Call the **researcher** to load WebVOWL for you

7.1 INTRODUCTION: WebVOWL:

PART-1

Before we begin, here is a short tutorial on how to use Web Visual Notation for OWL Ontologies (WebVOWL).

WebVOWL is a web application tool that you will use. It is an application for the user-oriented visualization of ontologies. It makes available graphical depictions for elements of the Web Ontology Language (OWL).

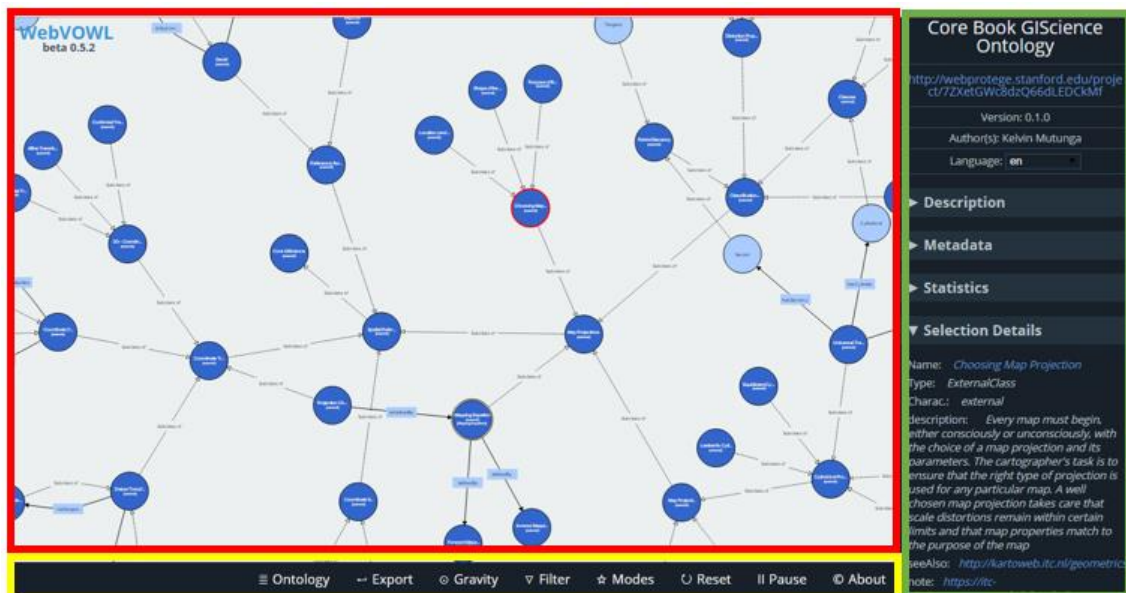


Figure 1: Screenshot of user interface of WebVOWL

The user interface consist of three parts (see Figure 1): A viewer displaying the VOWL visualization (inside the red box), a sidebar listing details about the element that is selected (represented by a green box), and the controls (in the yellow box) allowing to adapt the force-directed graph layout and providing further options, such as a function to adjust the class and datatype distances (can be use when classes represented by circles are clustered, and you want to scatter them a bit in order to easily see the relationship and get answer the questions. Note that, each circle represents concepts and Lines to represent property relations (see figure 2)

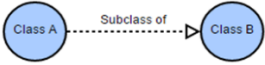
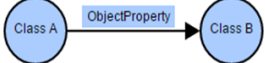
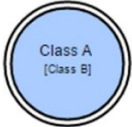
Graphical Representation	Description
 	<p>Class A and B (inside the circle) represents the concepts or terms</p> <p>Subclass of / ObjectProperty represents relationship between classes A and B</p>
	<p>Class A is Equivalent to Class B</p>

Figure 2: Graphical representation of VOWL classes and property

The interactive highlighting assists in the visual exploration of the concept graph by indicating hovered, selected, and related elements as you will notice when to take your test. To perform a **text search**, you are required to press **Ctrl + F** on the keyboard. However, don't worry you will get to familiarise yourself with the application when you take the warm-up test.

It is expected from you to think aloud (speak loudly) while performing each given task. Therefore, in the test process, it is required that you speak your thoughts aloud during each task.

In order to successfully search for concepts or term, reset the concept graph (in the viewer) by using the reset function the control panel, try to have an overview of the entire graph (see figure 4 below) by Zooming out, then type what you are looking for as it appears in the questions.

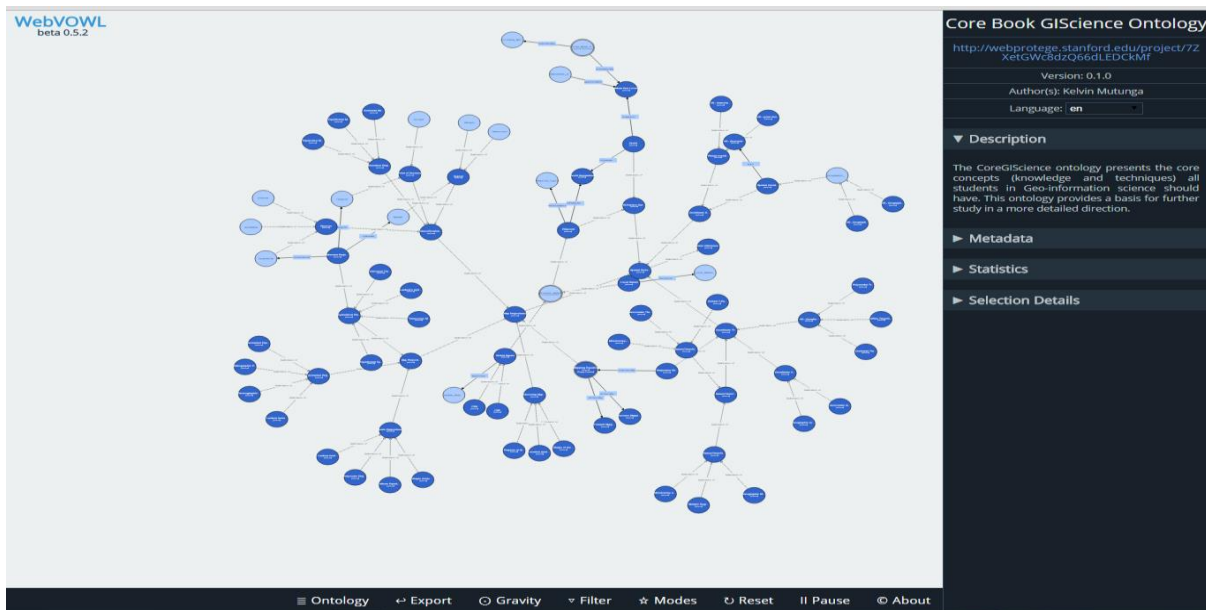


Figure 4: Overview of the concept graph

For instance, for the term 'Forward Mapping Equation', type 'forward' you will 1 match (refer to orange box in figure 5) in a rather unclear manner by means of small white (see red box in figure 5). Pan, zoom in and out without the mouse hovering the highlighted term (concepts).

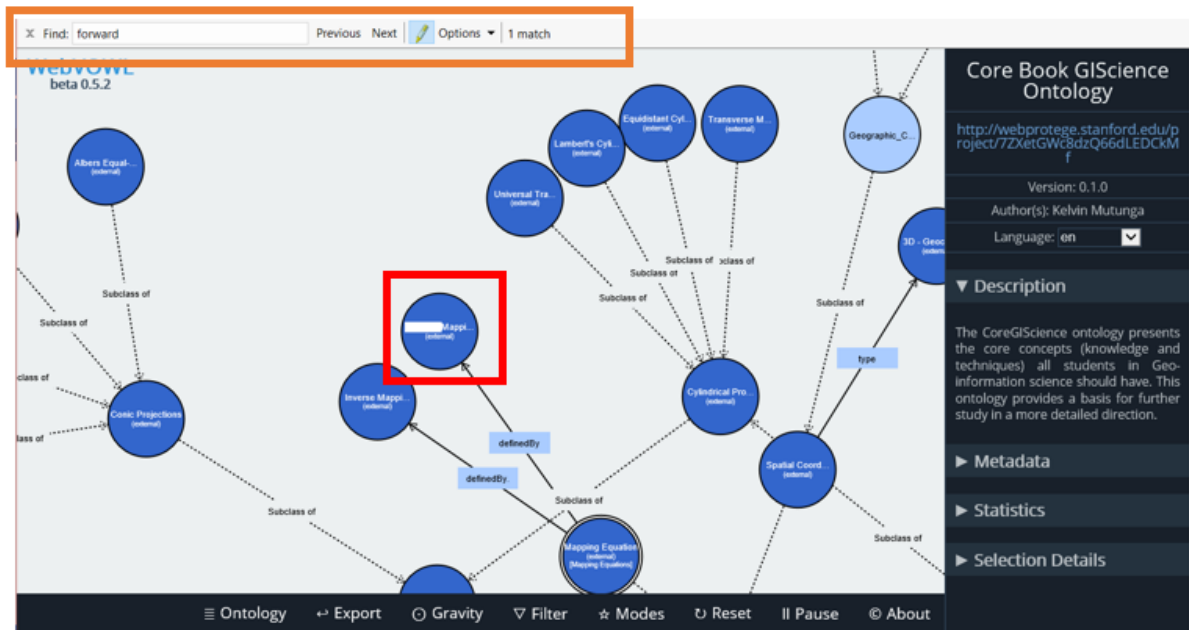


Figure 5: showing match highlight during text search.

It is time to start warm up to test.

7.2 WARM UP TEST

w1). Please describe the concept "Geoid Separation."

w2). What is the relationship between the concepts: "spatial coordinate system" and "3D-geocentric coordinates"?

7.3 TEST QUESTION

w3).What does the term 'geodetic_datum' mean?

w5).Find the relationship between the terms 'Ellipsoid' and 'Geoid Separation".

w6).Which common projection is tangential, cylindrical as well as Normal?

1 Overall, how well did WebVOWL assist you in answering these questions? Any suggestions for improvement?

7.4 QUESTIONNAIRE

Questionnaire: Check (✖) the appropriate circle of your chose.

1. How would you rate WebVOWL?

	Strongly Disagree	Disagree	Moderate	Agree	Strongly Agree
Easy to use	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Easy to learn	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Easy to find what I need	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Easy to understand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Information is clear	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Overall I'm satisfied with it	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

NOTE

To move to the next part of the test **press F10** and Click **login**

7.5 INTRODUCTION: ITC-Wiki:

Before we begin, here is a short tutorial on how to use ITC-Wiki

ITC-Wiki is a pilot of the online wiki version of the ITC core book (the core of GIScience).

“A wiki is a set of related web pages typically served from a single web domain (website) which allows collaborative modification of its content and structure directly from the web browser”, (<https://en.wikipedia.org/wiki/Wiki>)

The screenshot displays the ITC-GIScience website interface. At the top, there is a navigation bar with the ITC-GIScience logo, a home icon, a search box (highlighted with a blue border), and a log out button. Below the navigation bar, a breadcrumb trail indicates the current page: 'Trace: The Geoid / Introduction to Spatial Referencing / Reference Surfaces / Map Projections / Geocoding / Georeferencing / Coordinate Transforms / The core of GIScience at ITC / Introduction to Coordinate Systems'. The main content area is titled 'Introduction to Coordinate Systems' and features a diagram of a 2D geographic coordinate system with latitude and longitude axes. A table of contents (highlighted with a green border) is located on the right side of the page, listing 'Introduction to Coordinate Systems', 'Spatial Coordinate Systems', 'Planar Coordinate Systems', and 'Discussion'. On the left side, a sidebar (highlighted with a yellow border) lists 'Wiki sections' including 'Spatial Referencing', 'Reference Surfaces', 'Coordinate Systems', 'Map Projections', 'Coordinate Transforms', 'Georeferencing', 'Geocoding', 'GIS', 'Geographic phenomena', 'Geographic Representation', and 'Visualization'. The main content area also includes an 'Edit' button next to the text.

Figure 2: Screenshot of user interface of ITC-Wiki

The ITC-Wiki user interface should be relatively easy to use. The user interfaces (see Figure 2) consist: a viewer displaying the pages (inside the red box), a table of contents (represented by a green box) for the page displayed in the viewer, and the wiki sections (in the yellow box) which allows you to navigate to a particular concept of interest and Text search (in a blue box)

If you have never used ITC-Wiki before, don't worry you will get to familiarise yourself with the application when you take the warm-up test.

7.6 WARM UP TEST

i6). Please describe the concept "Geoid Separation."

i7). What is the relationship between the concepts: "spatial coordinate system" and "3D-geocentric coordinates"?

7.7 TEST QUESTION

i8). What does the term 'Orthometric_Height' mean?

i9) Find the relationship between the terms 'Coordinate Systems' and 'Spatial Coordinate System'.

i10). Which common projection is secant, cylindrical as well as transverse?

- Overall, how well did ITC-Wiki assist you in answering these questions? Any suggestions for improvement?

7.8 QUESTIONNAIRE

Questionnaire: Check (✖) the appropriate circle of your chose.

1. How would you rate ITC-Wiki?

	Strongly Disagree	Disagree	Moderate	Agree	Strongly Agree
Easy to use	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Easy to learn	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Easy to find what I need	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Easy to understand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Information is clear	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Overall I'm satisfied with it	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

7.9 Comparison between WebVOWL and ITC-Wiki

1. Please compare the applications you just worked with:

	WebVOWL	ITC-Wiki
Easy to use	<input type="radio"/>	<input type="radio"/>
Easy to learn	<input type="radio"/>	<input type="radio"/>
Easy to find what I need	<input type="radio"/>	<input type="radio"/>
Easy to understand	<input type="radio"/>	<input type="radio"/>
Information is clear	<input type="radio"/>	<input type="radio"/>
which application would you prefer to work with?	<input type="radio"/>	<input type="radio"/>

NOTE

- ✓ To move to the next part of the test **press F10**
- ✓ Call the **researcher** to load WebVOWL for you

7.10 WebVOWL

PART-2

7.11 TEST QUESTION

w11).What does the term 'Planar coordinates System' mean? And give example(s).

w12).Find the relationship between the terms 'Ellipsoid' and 'Ellipsoid_Types'?

w13).What concepts are connected with the concept: 'Point of Secancy'?

1. Overall, how well did WebVOWL assist you in answering these questions? Any suggestions for improvement?

7.12 QUESTIONNAIRE

Questionnaire: Check (✖) the appropriate circle of your chose.

1. How would you rate WebVOWL?

	Strongly Disagree	Disagree	Moderate	Agree	Strongly Agree
Easy to use	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Easy to learn	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Easy to find what I need	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Easy to understand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Information is clear	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Overall I'm satisfied with it	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

NOTE

To move to the next part of the test **press F10**

7.13 INTRODUCTION: GIS&T–BoK visual Wiki:

Before we begin, here is a short tutorial on how to use of Geographic Information Science and Technology Body of Knowledge visual wiki (GIS&T-BoK visual Wiki).

GIS&T-BoKWiki application is a web-based interface for visualising and revising the GIS&T Body of Knowledge. In your case, you will use it as a visualization tool. You will work with a network of graphs based on GIS&T-BoK concepts, view data about individual concepts and the relationship between concepts.

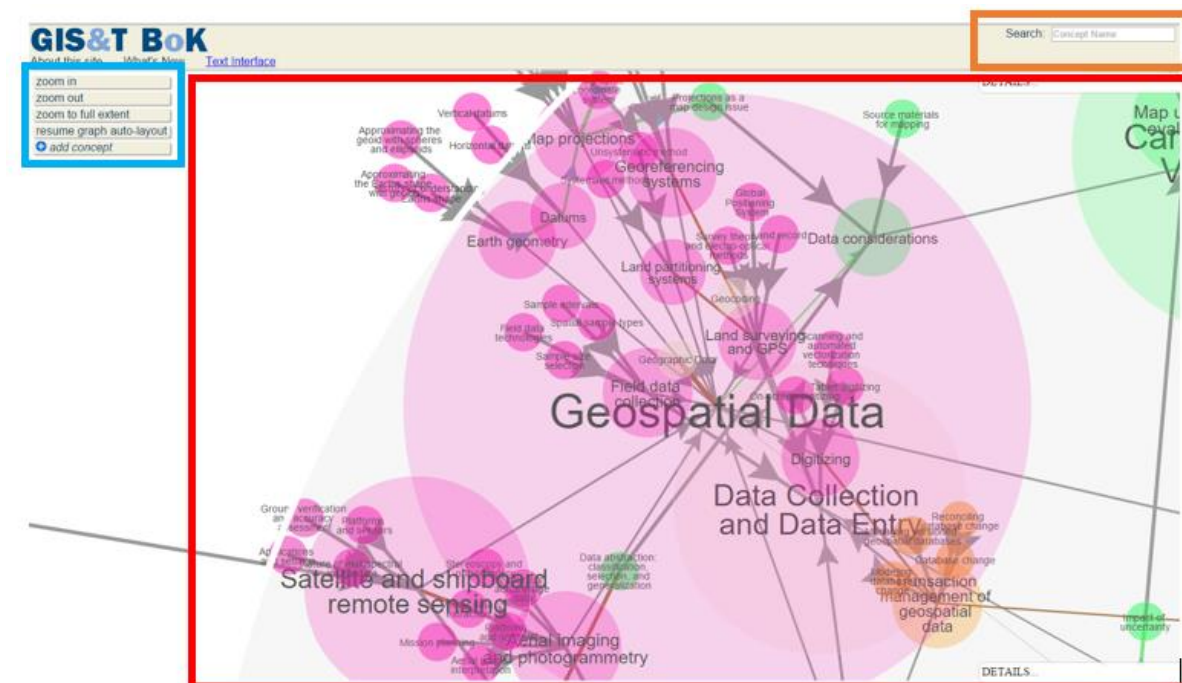


Figure 3: Screenshot of the user interface of GIS&T – BoK visual Wiki.

The user interfaces consist of three parts (see Figure 3): A viewer displaying the network graphs of GIS&T - BoK visualization (inside the red box), a Text search window represented by an orange box, and the controls (in the blue box) allowing to adapt the force-directed graph layout and providing further options, such as a function zoom in / out. Note that, each circle represents concepts and Lines to represent property relations.

The interactive highlighting assists in the visual exploration of the concept-graphs by indicating hovered, selected, and related elements as you will notice when you are taking your test. However, don't worry you will get to familiarise yourself with the application when you take the warm-up test. A pop-up window will be available for further information on GIS&T visual Wiki viewer before the commencement of the test.

It is expected from you to think aloud (speak loudly) while performing each given task. Therefore, in the test process, it is required that you speak your thoughts aloud during each task.

7.14 WARM UP TEST

g14). Please describe the concept "Digitizing."

g15). What is the relationship between the concepts: "Map projection parameters" and "Map projections"?

7.15 TEST QUESTION

g16). What does the term 'horizontal datum' mean? Moreover, give example(s) of 'horizontal datum'.

g17). Find the relationship between the terms 'Map projections' and 'Map projection classes'.

g18).What concepts are connected with the concept: 'Geographic Coordinate System'?

1 Overall, how well did GIS&T-BoK assist you in answering these questions? Any suggestions for improvement?

7.16 QUESTIONNAIRE

Questionnaire: Check (✖) the appropriate circle of your chose.

1. How would you rate GIS & T - BoK?

	Strongly Disagree	Disagree	Moderate	Agree	Strongly Agree
Easy to use	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Easy to learn	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Easy to find what I need	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Easy to understand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Information is clear	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Overall I'm satisfied with it	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

7.17 Comparison between WebVOWL and GIS&T-BoK

1. Please compare the applications you just worked with:

	WebVOWL	GIS&T-BoK
Easy to use	<input type="radio"/>	<input type="radio"/>
Easy to find what I need	<input type="radio"/>	<input type="radio"/>
Easy to understand	<input type="radio"/>	<input type="radio"/>
Information is clear	<input type="radio"/>	<input type="radio"/>
Which visualization tool would you prefer to work with?	<input type="radio"/>	<input type="radio"/>

Appendix 8: Task Description For Groups (A and B).

Table 1 and 2 show the sequence of how the tests were carried out with their related tasks by Test Persons (TPs) in each group. All bold lower case alphabet letters and numbers (e.g., w3, i8, g16 and so on) represents tasks (test questions), were lower case alphabet letters represents the tool being used in the task execution. For instance, “g17” means: task 17 and executed with GIS&T-BoK.

Table 1

Group A												
Part 1						Part 2						
WebVOWL-CG			ITC-Wiki			WebVOWL-CG			GIS&T-BoK			
Tasks	w3	w4	w5	i8	i9	i10	w11	w12	w13	g16	g17	g18

Table 2

Group B												
Part 1						Part 2						
ITC-Wiki			WebVOWL-CG			GIS&T-BoK			WebVOWL-CG			
Tasks	i8	i9	i10	w3	w4	w5	g16	g17	g18	w11	w12	w13

Appendix 9: Test Grouping Schedule

GROUP A – Test A (Session)	GROUP A – Test A (Session)
Part 1: <ul style="list-style-type: none"> • WebVOWL-(CG) • ITC-Wiki 	Part 1: <ul style="list-style-type: none"> • ITC-Wiki • WebVOWL-(CG)
Part 2: <ul style="list-style-type: none"> • WebVOWL-(CG) • GIS&T-BoK 	Part 2: <ul style="list-style-type: none"> • GIS&T-BoK • WebVOWL-(CG)

CG stands for Concept Graph developed in Web Ontology Language (OWL)

Appendix 10: Data for Validation: Spatial Referencing

1. Introduction

The two visualisation tools being used in this data validation are WebVOWL and Protégé ontology visualisation plugin called OntoGraf.

This validation data is organised as indicated in figure 1.1;

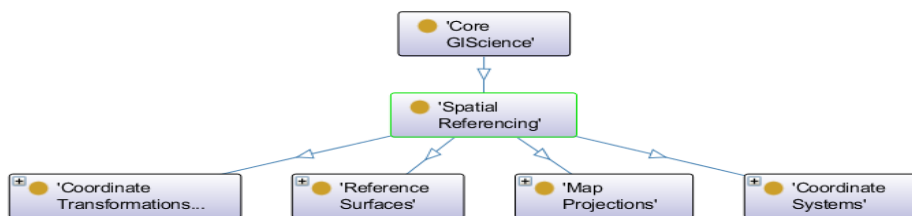


Figure 1.1: showing graphical Hierarchical Relationships of concepts in Protégé (OntoGraf)

The Spatial referencing is divided into coordinate transformations, reference surfaces, map projections and coordinate systems. For each division, important terms are enumerated. the Enumeration was carried out after the keywords were extracted. Data extraction involved two data extraction techniques: using manual and automated means. Refer to figure 1.2.

Visualisation tool: OntoGraph

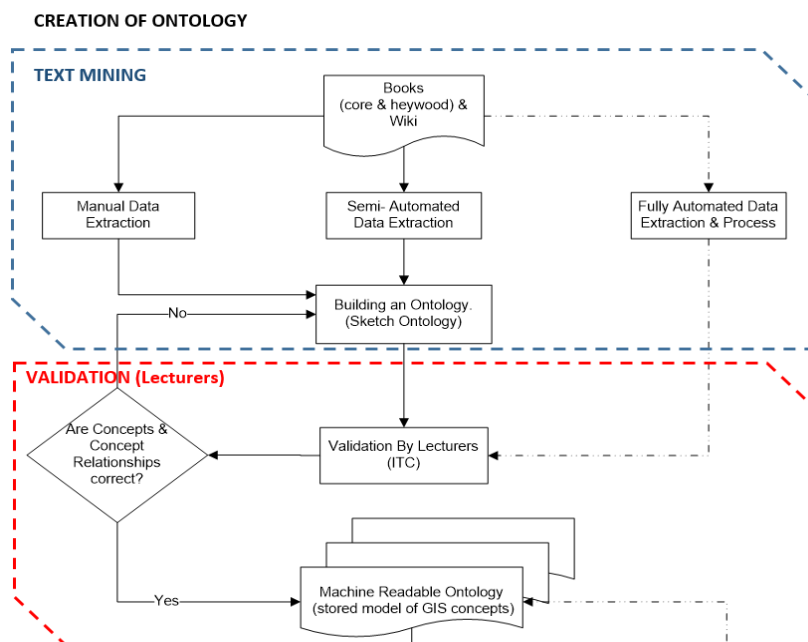
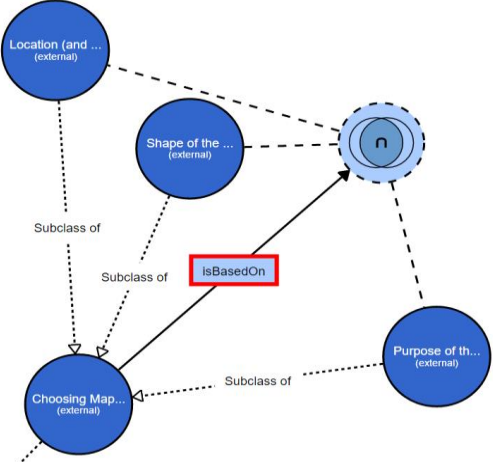
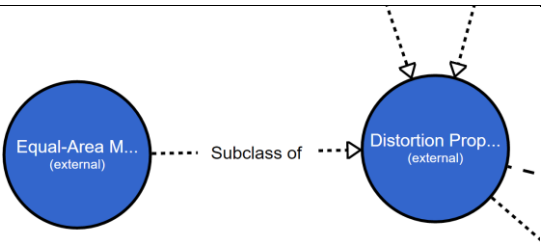
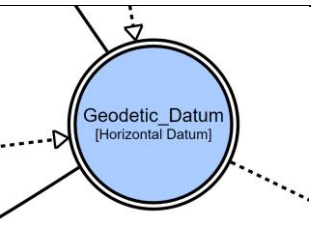
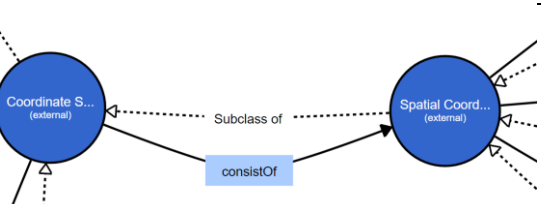


Figure 1.2: showing part of research workflow and its activities

Interpretation of graphical relationship between concepts

Table: Graphical representations of classes and properties in WebVOWL

Graphical Representation	Description
 <p>The diagram shows a central concept 'Choosing Map...' (external) represented by a blue circle. It has three dashed arrows pointing to it from 'Location (and ...)' (external), 'Shape of the ...' (external), and 'Purpose of th...' (external), all labeled 'Subclass of'. A solid arrow points from 'Choosing Map...' to a blue circle with 'n' inside, labeled 'isBasedOn' (highlighted in a red box).</p>	<p>This means that the concept ‘Choosing Map projection’ has two properties: subclassOf and isBasedOn.</p> <p><u>Comment:</u> The selection of a map projection for a particular area can be made on the basis of i)the shape of the area, ii) the location (and orientation) of the area and iii)the purpose of the map.</p>
 <p>The diagram shows 'Equal-Area M...' (external) on the left and 'Distortion Prop...' (external) on the right. A dashed arrow with an arrowhead points from 'Equal-Area M...' to 'Distortion Prop...', labeled 'Subclass of'.</p>	<p>This indicates the hierarchical relationship between “Equal area map projection” and “Distortion property”. Dotted line starting at the subclass with an arrowhead. “Equal area map projection” is a subclass of “Distortion property”.</p>
 <p>The diagram shows a blue circle with a double border containing the text 'Geodetic_Datum [Horizontal Datum]'. Dotted arrows point to it from the left and right, and a solid arrow points to it from the top.</p>	<p>This indicates equivalent concepts: Geodetic datum is also called horizontal datum.</p> <p><u>Comment:</u> Horizontal datum (also called geodetic datum) is an ellipsoid but positioned and oriented in such a way that it best fits the area or country of interest.</p>
 <p>The diagram shows 'Coordinate S...' (external) on the left and 'Spatial Coord...' (external) on the right. A dashed arrow with an arrowhead points from 'Coordinate S...' to 'Spatial Coord...', labeled 'Subclass of'. A solid arrow points from 'Coordinate S...' to 'Spatial Coord...', labeled 'consistOf' (highlighted in a blue box).</p>	<p>Indicates property between the concepts. It is represented by a continuous line with an arrowhead.</p>

2. PART – 1 – Reference Surface

DATA EXTRACTION: Keywords;

Reference Surface

The Geoid

Mean Sea Level

The Ellipsoid

Horizontal Datum (Geodetic Datum)

Local horizontal datum

Global Datum

Geoid

Mean Sea Level

Orthometric Height

Local Vertical Datum (Local Mean Sea Level)

Geoid Separation (Geoid undulation)

International Terrestrial Reference System (ITRS).

International Terrestrial Reference Frame (ITRF)

SKETCH ONTOLOGY

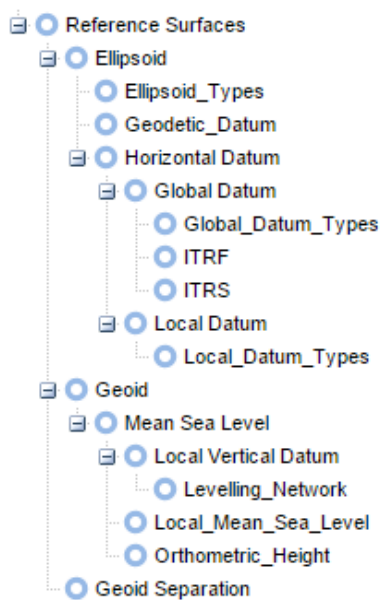


Figure 2.1: showing Hierarchical Relationships of concepts.

Visualisation tool: OntoGraph

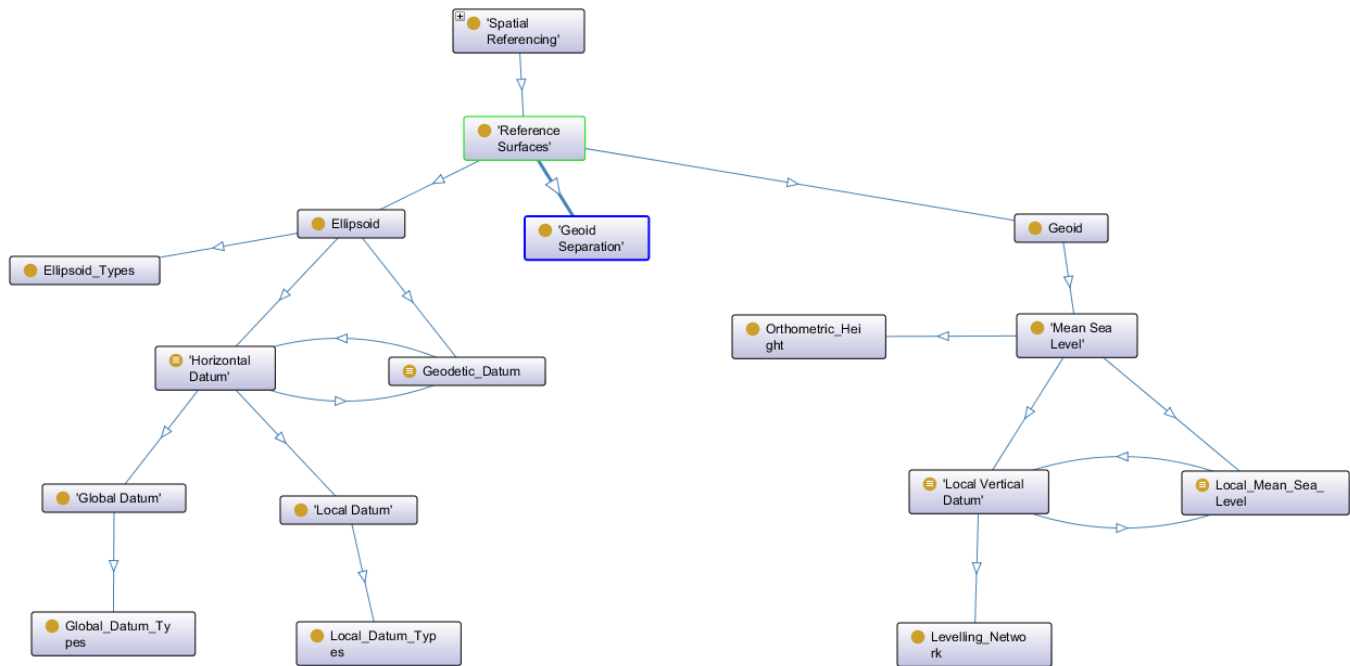


Figure 2.2: showing graphical Hierarchical Relationships of concepts

Visualisation tool: WebVOWL

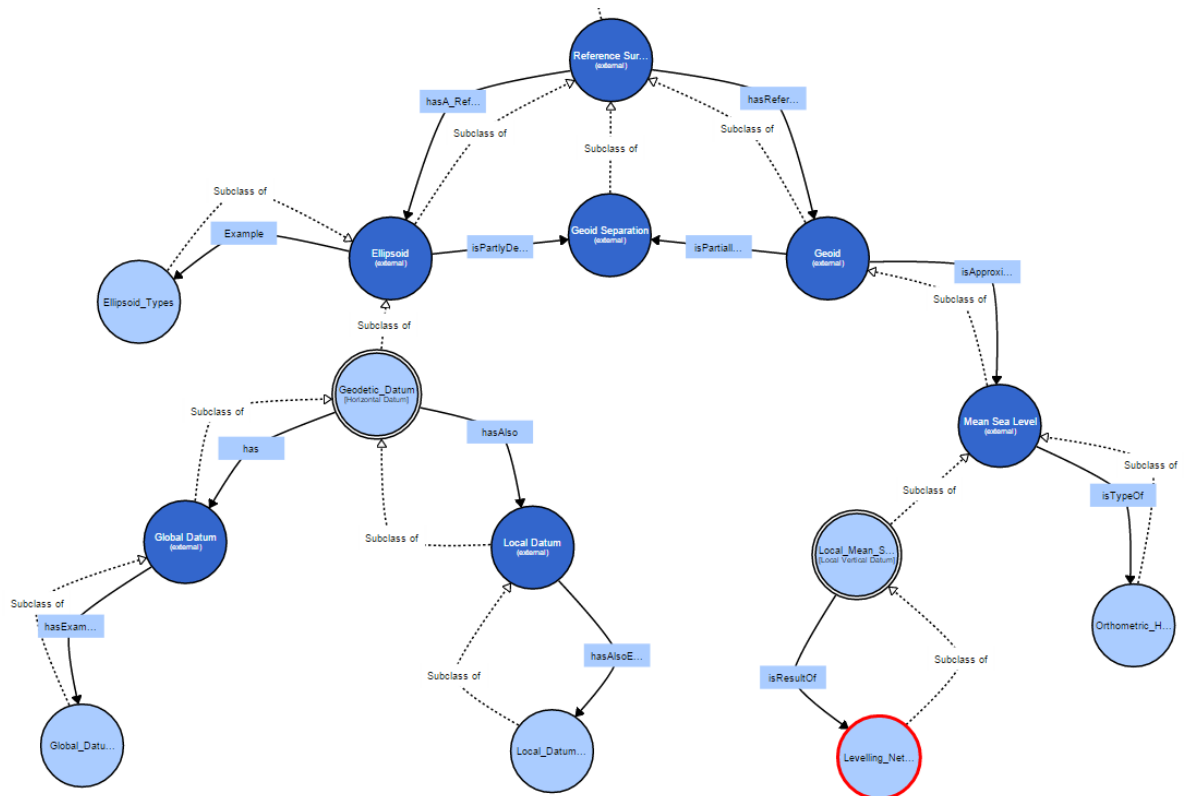


Figure 2.3: showing graphical Hierarchy of term and Relationships between concepts

DESCRIPTION OF TERMS

Reference Surface

A reference surface is a datum that provides a reference point to the Earth's surface. There are horizontal datums; that describe the position on the Earth's surface and vertical datums that describe elevation. Two main reference surfaces have been established to approximate the shape of the Earth: one is called the Geoid, the other the ellipsoid.

The Geoid is a surface defined by the height of the ocean as it would be only affected by gravity. The Geoid is used to describe heights

Mean Sea Level

In order to establish the Geoid as a reference for heights, the ocean's water level is registered at coastal locations over several years using tide gauges (mareographs). Averaging the registrations largely eliminates variations in sea level over time. The resultant water level represents an approximation to the Geoid and is termed mean sea level.

The Ellipsoid

The Ellipsoid is one of the main horizontal datums or reference surfaces. An ellipsoid is formed when an ellipse is rotated about its minor axis. The ellipsoid (also called spheroid) is a mathematical surface.

It is used for geodetic computations and to define locations, the geographic latitude (φ) and longitude (λ) of points of interest. These locations are then projected from the ellipsoid (or sphere) onto a mapping plane.

There are many different ellipsoids defined in the world; some well-known are the WGS84, GRS80, International 1924 (also known as Hayford), Krasovsky, Bessel, and the Clarke 1880 ellipsoid.

Horizontal Datum (Geodetic Datum)

Horizontal datum (also called geodetic datum) is an ellipsoid but positioned and oriented in such a way that it best fits the area or country of interest. Worldwide there are several hundred of these local horizontal datums defined. There are local horizontal datums and global horizontal datums.

Local horizontal datum

The Local Horizontal Datum or Local ellipsoids have been established to fit the Geoid (mean sea level) well over an area of local interest (Ellipsoid regionally best fitting to the Geoid), which in the past was never larger than a continent. This meant that the differences between the Geoid and the reference

ellipsoid could effectively be ignored, allowing accurate maps to be drawn in the vicinity of the datum. Local horizontal datum is determined by a triangulation network

Global Datum

With increasing demands for global surveying, work is underway to develop global reference ellipsoids. In contrast to local ellipsoids, which apply only to a specific country or localized area of the Earth's surface, global ellipsoids approximate the Geoid as a mean Earth ellipsoid (Ellipsoid globally best fitting to the Geoid).

Geoid

The Geoid is a surface defined by the height of the ocean as it would be only affected by gravity. The Geoid is used to describe heights. In order to establish the Geoid as a reference for heights, the ocean's water level is registered at coastal locations over several years using tide gauges (mareographs). Averaging the registrations largely eliminates variations in sea level over time. The resultant water level represents an approximation to the Geoid and is termed mean sea level

Given

Mean Sea Level

The Geoid is used to describe heights. In order to establish the Geoid as a reference for heights, the ocean's water level is registered at coastal locations over several years using tide gauges (mareographs). Averaging the registrations largely eliminates variations in sea level over time. The resultant water level represents an approximation to the Geoid and is termed mean sea level. Several definitions of local **mean sea levels** (also called local vertical datums) appear throughout the world.

Orthometric Height

Orthometric Height (height H above the Geoid) is the height determined with respect to tide-gauge.

Local Vertical Datum (Local Mean Sea Level)

Several definitions of local mean sea levels (also called local vertical datums) appear throughout the world. They are parallel to the Geoid but offset by up to a couple of metres to allow for local phenomena such as ocean currents, tides, coastal winds, water temperature and salinity at the location of the tide gauge. Care must be taken when using heights from another local vertical datum. This might be the case, for example, in areas along the border of adjacent nations. The local vertical datum is implemented through a levelling network, which consists of benchmarks whose height above mean sea level has been determined through geodetic levelling

Geoid separation (Geoid undulation)

Geoid separation (N) is the deviation between the Geoid and a reference ellipsoid.

International Terrestrial Reference System (ITRS).

The most important global (or geocentric) spatial reference system for the GIS community is the International Terrestrial Reference System (ITRS). It is a three-dimensional coordinate system with a well-defined origin (the centre of mass of the Earth) and three orthogonal coordinate axes (X, Y, Z). The Z-axis points towards a mean Earth north pole. The X-axis is oriented towards a mean Greenwich meridian and is orthogonal to the Z-axis. The Y-axis completes the right-handed reference coordinate system.

International Terrestrial Reference Frame (ITRF)

The ITRS is realized through the International Terrestrial Reference Frame (ITRF), a distributed set of ground control stations that measure their position continuously using GPS. Constant re-measuring is needed because of the addition of new control stations and ongoing geophysical processes (mainly tectonic plate motion) that deform the Earth's crust at measurable global, regional and local scales. These deformations cause positional differences over time and have resulted in more than one realization of the ITRS.

3. PART – 2 – Coordinate Transformation

Data Extraction: Keywords

Coordinate Transforms

Coordinate Conversion

Geographic to Geocentric Conversion

Geocentric to Geographic Conversion

Datum Transform

Datum Transform via Geocentric Coordinates

Geocentric Translation

Helmert 7-Parameter Transformation

Molodensky-Badekas 10-Parameter Transformation

Datum Transform via Geographic Coordinates

Geographic Offsets

Molodensky and Abridged Molodensky Transformation

Multiple Regression Transformation

2D - Coordinate Conversion

Conformal Transformation

Affine Transformation

Polynomial Transformation

Projection Change

Forward Mapping Equation

Inverse Mapping Equation

SKETCH ONTOLOGY

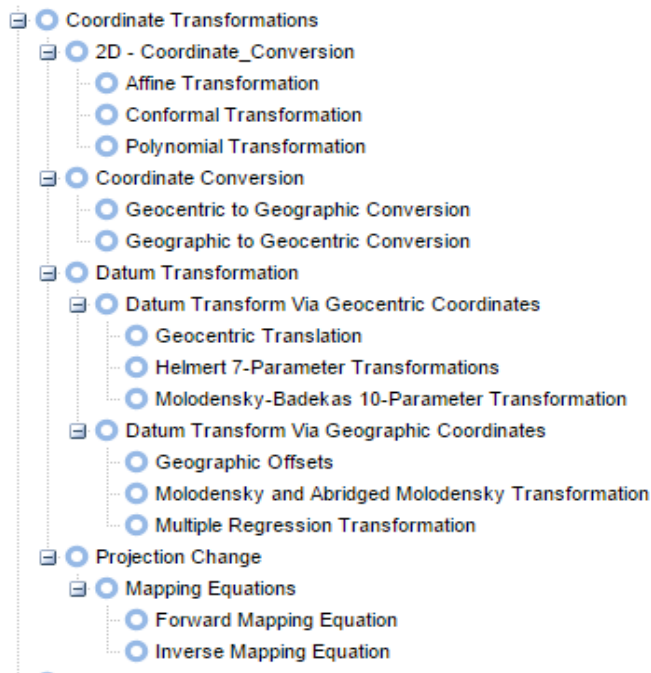


Figure 3.1: showing Hierarchical Relationships of concepts.

Visualisation tool: OntoGraph

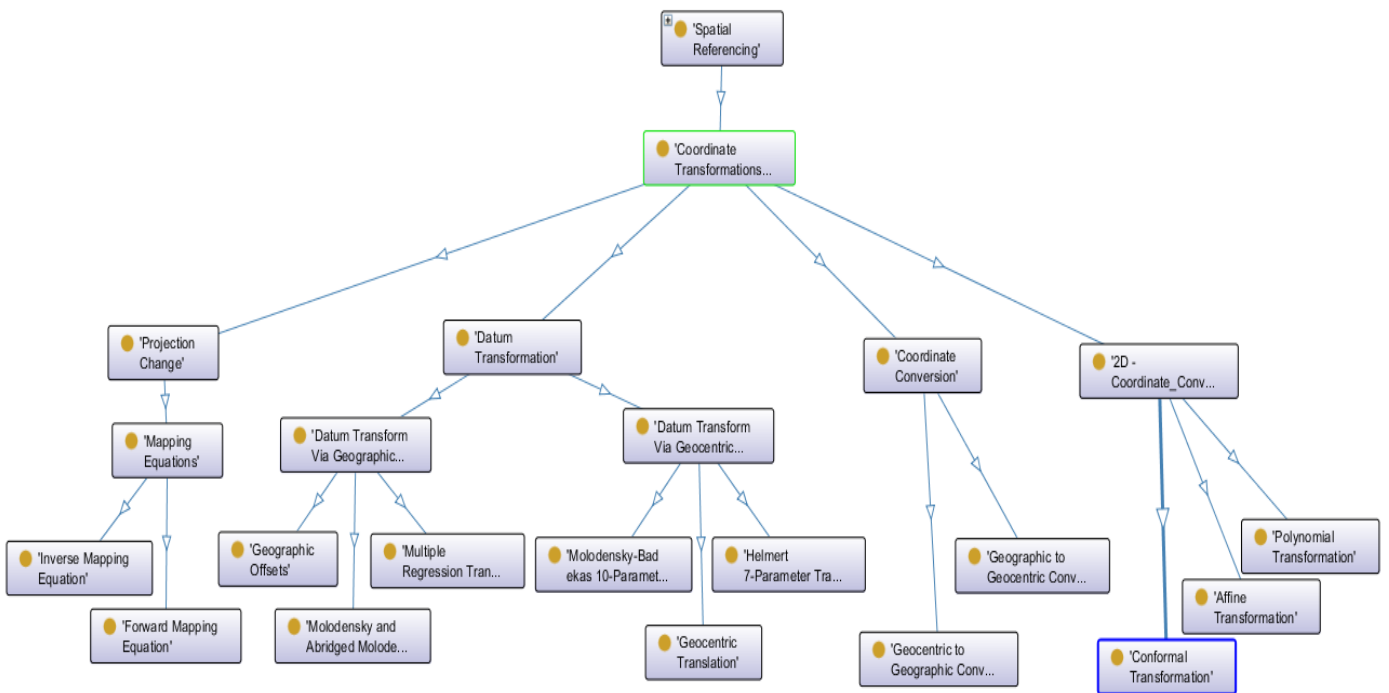


Figure 3.2: showing graphical Hierarchical Relationships of concepts

Visualisation tool: WebVOWL

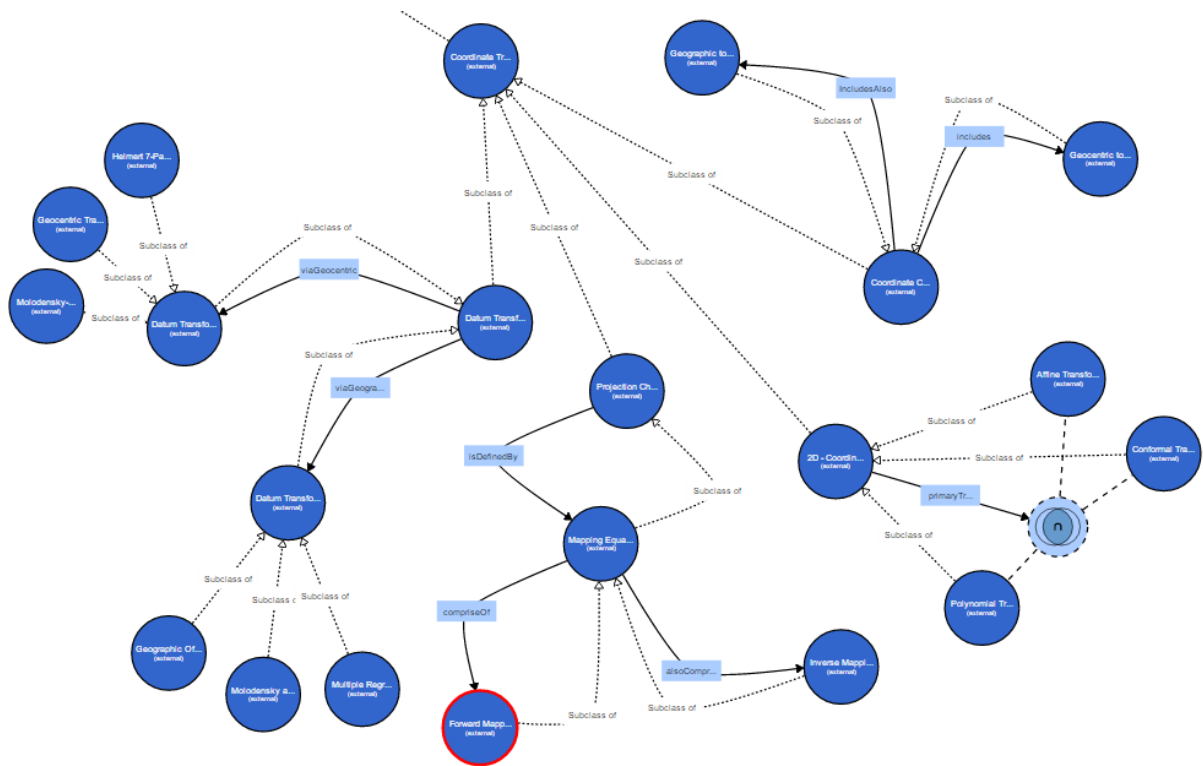


Figure 3.3: showing graphical Hierarchy of term and Relationships between concepts

DESCRIPTION OF TERMS

Coordinate Transforms

Coordinate Transforms are transformations from a particular 2D coordinate system to another system. This includes the transformation of polar coordinates into Cartesian map coordinates or the transformation from one 2D Cartesian (x, y) system of a specific map projection into another 2D Cartesian (x', y') system of a defined map projection.

Coordinate Conversion

The three geocentric transformations are usually combined with conversions between the geocentric coordinates (x,y,z) and the ellipsoidal latitude and longitude coordinates and height (h) in both datum systems.

Geographic to Geocentric Conversion

The conversion from the latitude and longitude coordinates into the geocentric coordinates is rather straightforward and turns ellipsoidal latitude (f) and longitude (l), and possibly also the ellipsoidal height (h), into X , Y and Z , using 3 direct equations.

Geocentric to Geographic Conversion

The inverse equations for the reverse conversion are more complicated and require either an iterative calculation of the latitude and ellipsoidal height, or it makes use of approximating equations like those of Bowring.

Datum Transform

A datum transform involves the change of the horizontal datum which is often accompanied by a change of map projection. This is the case when the source projection is based on a different horizontal datum than the target projection. If the difference in horizontal datums is ignored, there will not be a perfect match between adjacent maps of neighbouring countries or between overlaid maps originating from different projections. It may lead to differences of several hundreds of metres in the resulting coordinates. Therefore, spatial data with different underlying horizontal datums may require datum transformation.

Datum Transform via Geocentric Coordinates

Datum transformations via the geocentric coordinates (x,y,z) are 3D similarity transformations. Essentially, these are transformations between two orthogonal 3D Cartesian spatial reference frames together with some elementary tools from adjustment theory.

Geocentric Translation

The geocentric translation relates two datum systems through three translations. The method applies a shift between the centres of the two geocentric coordinate systems. This shift is defined by the parameters DX , DY and DZ (or X_0 , Y_0 and Z_0).

Helmert 7-Parameter Transformation

The Helmert 7-parameter transformation relates two datum systems through a rotation, an origin shift and a scale factor. The transformation is expressed with seven parameters: three rotation angles (a,b,g), three origin shifts (DX , DY and DZ) and one scale factor (s).

Molodensky-Badekas 10-Parameter Transformation

The Molodensky-Badekas 10-parameter transformation relates two datum systems through a rotation, an origin shift and a scale factor. This is the same as for the Helmert transformation methods, but instead of deriving the rotations about the origin of the geocentric coordinate system, they are derived

from a location within the points used in the determination of the parameters. Three additional parameters, the coordinates of the rotation point (X_p , Y_p , Z_p), are then required. The transformation is therefore expressed with 10 parameters: three rotation angles (a, b, g), three origin shifts (DX , DY and DZ), one scale factor (s) and the coordinates of the rotation point (X_p , Y_p , Z_p) given in the source geocentric coordinate system.

Datum Transform via Geographic Coordinates

Datum transformations via the geographic coordinates directly relate the ellipsoidal latitude (f) and longitude (l), and possibly also the ellipsoidal height (h), of both datum systems.

Geographic Offsets

The simplest method uses geographic offsets. It relates both datum systems with only two parameters, the difference in the geographic latitude and the difference in the geographic longitude. The ellipsoidal height (h) is mostly not included. The method is only used for purposes where low accuracy can be tolerated.

Molodensky and Abridged Molodensky Transformation

A second method of directly transforming latitude, longitude, and height is the standard Molodensky and Abridged Molodensky transformation (it should not be confused with the Molodensky-Badedas transformation). The standard equations directly relate ellipsoidal latitude and longitude coordinates and ellipsoidal height of two datums by deriving the geographic coordinate offsets. The abridged form is found by dropping any terms that are second order in small parameters, and the ellipsoidal height (h) is ignored.

Multiple Regression Transformation

A third method uses multiple regression equations. A series of best-fit equations provide the local shifts in latitude and longitude as a function of position. It is commonly used to relate ellipsoidal latitude and longitude coordinates of continental size datums to those of the WGS84 datum and involve polynomial expressions in the two ellipsoidal coordinates which go up to degree 9 for the time being. The coefficients (transformation parameters) are determined on the basis of coordinate differences of a set of selected points whose coordinates are known in both datum systems.

2D - Coordinate_Conversion

2D Cartesian coordinate transformations can be used to transform 2D Cartesian coordinates (x, y) from one 2D Cartesian coordinate system to another 2D Cartesian coordinate system. The three primary transformation methods are - the conformal transformation, the affine transformation, and the polynomial transformation.

Conformal Transformation

A conformal transformation is a linear (or first-order) transformation and relates two 2D Cartesian coordinate systems through a rotation, a uniform scale change, followed by a translation. The rotation is defined by one rotation angle, and the scale change by one scale factor (s).

Affine Transformation

An affine transformation is a linear (or first-order) transformation and relates two 2D Cartesian coordinate systems through a rotation, a scale change in x- and y-direction, followed by a translation. The transformation function is expressed with 6 parameters: one rotation angle, two scale factors, a scale factor in the x-direction and a scale factor in the y-direction, and two origin shifts (x_0 , y_0).

Polynomial Transformation

A polynomial transformation is a non-linear transformation and relates two 2D Cartesian coordinate systems through a translation, rotation and a variable scale change. The transformation function can have an infinite number of terms.

Projection Change

Forward and inverse mapping equations are normally used to transform data from one map projection into another. The inverse equation of the source projection is used first to transform source projection coordinates (x , y) to geographic coordinates (φ , λ). Next, the forward equation of the target projection is used to transform the geographic coordinates (φ , λ) into target projection coordinates (x' , y'). The first equation takes us from a projection A into geographic coordinates. The second takes us from geographic coordinates (φ , λ) to another map projection B.

Forward Mapping Equation

A forward mapping equation transforms the geographic coordinates of a point on the curved reference surface to a set of planar Cartesian coordinates (x,y), representing the position of the same point on the map plane

Inverse Mapping Equation

Inverse mapping equation transforms mathematically the planar Cartesian coordinates (x,y) of a point on the map plane to a set of geographic coordinates on the curved reference surface:

4. PART – 3 – Coordinate System

DATA EXTRACTION: Key terms

Coordinate System

Planar Coordinates

2D - Cartesian coordinate system

2D - Polar Coordinate System

Spatial Coordinates

2D - Geographic Coordinates

3D - Geographic Coordinates

3D - Geocentric Coordinates

SKETCH ONTOLOGY

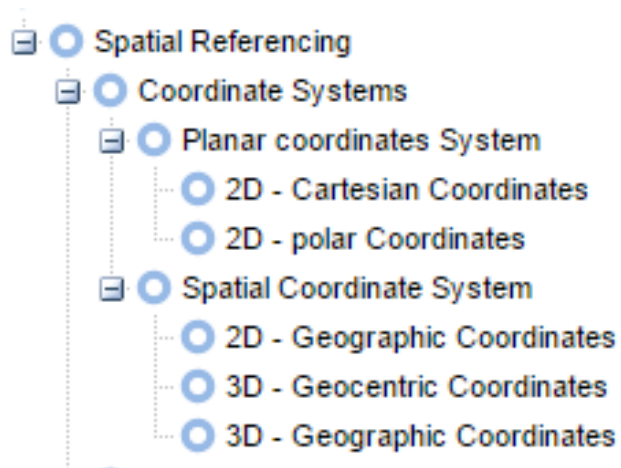


Figure 4.1: showing Hierarchical Relationships of concepts.

Visualisation tool: OntoGraph

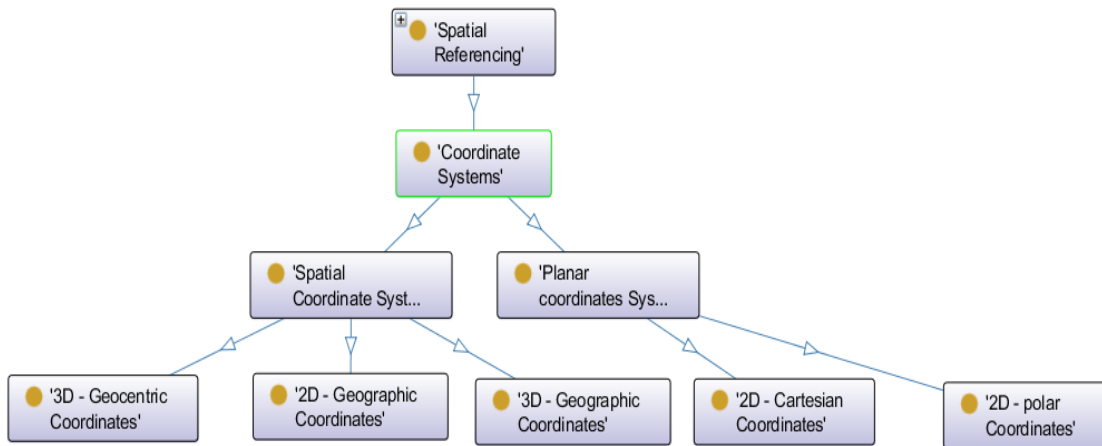


Figure 4.2: showing graphical Hierarchical Relationships of concepts

Visualisation tool: WebVOWL

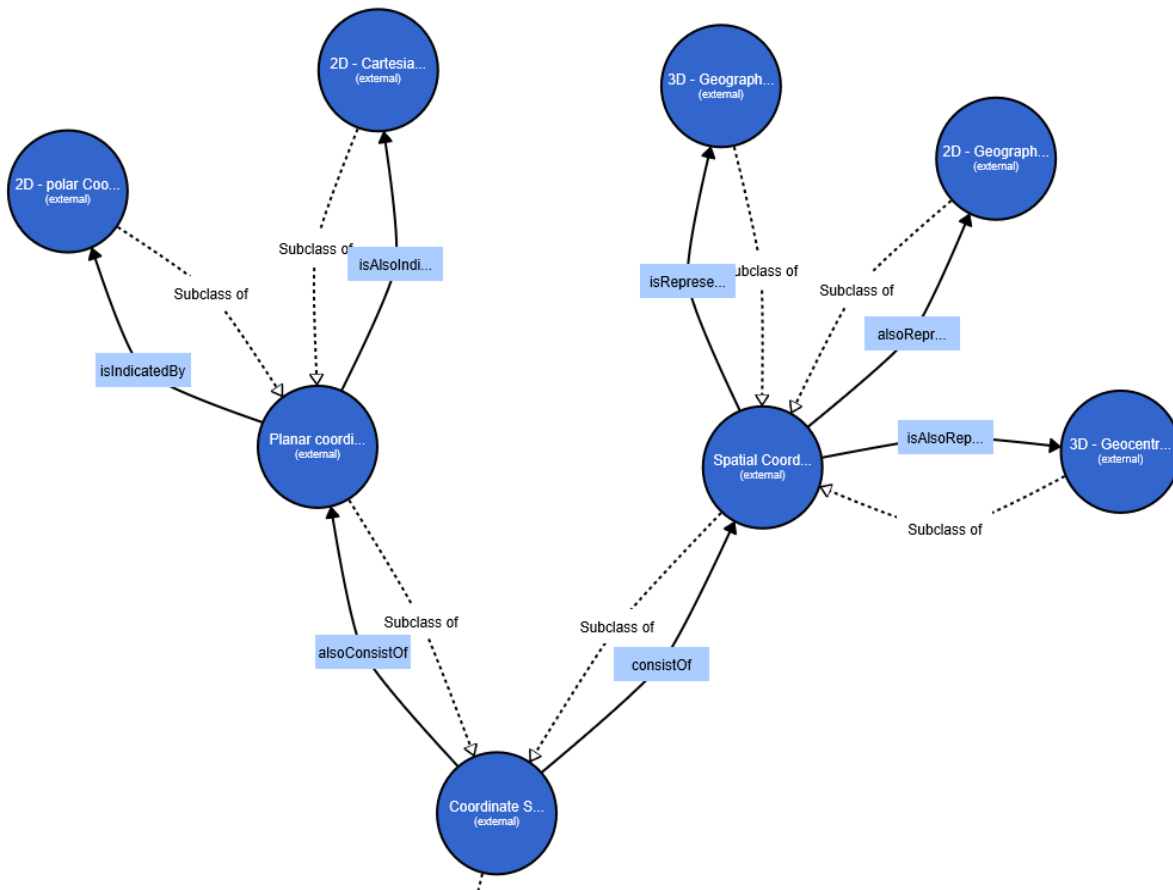


Figure 4.3: showing graphical Hierarchy of term and Relationships between concepts

DEFINITION AND DESCRIPTION OF TERMS

Coordinate System

A coordinate system is a set of mathematical rules that designates a set of unique numbers to a position or point in geographic space. The Coordinates are the linear or angular quality which designates the position that a point occupies in a given reference frame or system. A coordinate system requires the definition of its origin, the orientation of the axis, and the units of measurement.

Planar Coordinates

Planar coordinates are coordinate used to locate objects on the flat surface of the map in 2D space. Examples are the 2D Cartesian coordinates and the 2D polar coordinates.

2D - Cartesian Coordinate System

The 2D - Cartesian coordinate system is one of intersecting perpendicular lines with the X-axis and the Y-axis as principal axes. The X-axis (the Easting) is the horizontal axis and the Y-axis (the Northing) is the vertical axis with an intersection at the origin. The plane is marked at intervals by equally-spaced coordinate lines that together form the map grid.

2D - Polar Coordinate System

Another way of defining a point in a plane is by using polar coordinates. This is the distance d from the origin to the point concerned and the angle α between a fixed (or zero) direction and the direction to the point. The angle α is called azimuth or bearing and is measured in a clockwise direction. It is given in angular units while the distance d is expressed in length units.

Spatial Coordinates

Spatial coordinates (also known as global coordinates) are used to locate objects either on the Earth's surface in 3D space, or on the Earth's reference surface (ellipsoid or sphere) in 2D space. Specific examples are the geographic coordinates in a 2D or 3D space and the geocentric coordinates, also known as 3D Cartesian coordinates.

2D - Geographic Coordinates

The most widely used global coordinate system consists of lines of geographic latitude (ϕ or φ or Φ) and longitude (λ or λ). Lines of equal latitude are called parallels. They form circles on the surface of the ellipsoid. Lines of equal longitude are called meridians and form ellipses.

3D - Geographic Coordinates

3D geographic coordinates (φ , λ , h) are obtained by introducing ellipsoidal height (h) into the system. The ellipsoidal height (h) of a point is the vertical distance of the point in the question above the ellipsoid. It is measured in distance units along the ellipsoidal normal from the point to the ellipsoid surface.

3D - Geocentric Coordinates

An alternative method for defining a 3D position on the surface of the Earth is to use geocentric coordinates (X , Y , Z), also known as 3D Cartesian coordinates. The system's origin lies at the Earth's centre of mass, with the X and Y axes on the plane of the Equator. The X -axis passes through the meridian of Greenwich, and the Z -axis coincides with the Earth's axis of rotation. The three axes are mutually orthogonal and form a right-handed system. Geocentric coordinates can be used to define a position on the surface of the Earth.

5. PART – 4 – Coordinate System

Data Extraction: Keywords

Map Projection

Choosing Map Projection

Location (and Orientation) of the Area

Purpose of the Map

Shape of the Area

Classification of Map Projections

Aspect

Class

Point of Secancy

Distortion Property

Conformal Map Projection

Equal-Area Map Projection

Equidistant Map Projection

Map Projections in Common Use

Azimuthal (or Zenithal or Planar) Projections

Stereographic Projection

Orthographic Projection

Azimuthal Equidistant Projection

Lambert Azimuthal Equal-Area Projection

Conic Projections

Lambert Conformal Conic Projection

Simple Conic Projection

Albers Equal-Area Projection

Polyconic Projection

Cylindrical Projections

Mercator Projection

- Transverse Mercator Projection
- Universal Transverse Mercator (UTM) Projection
- Equidistant Cylindrical Projection
- Lambert's Cylindrical Equal-Area Projection
- Mapping Equation

SKETCH ONTOLOGY

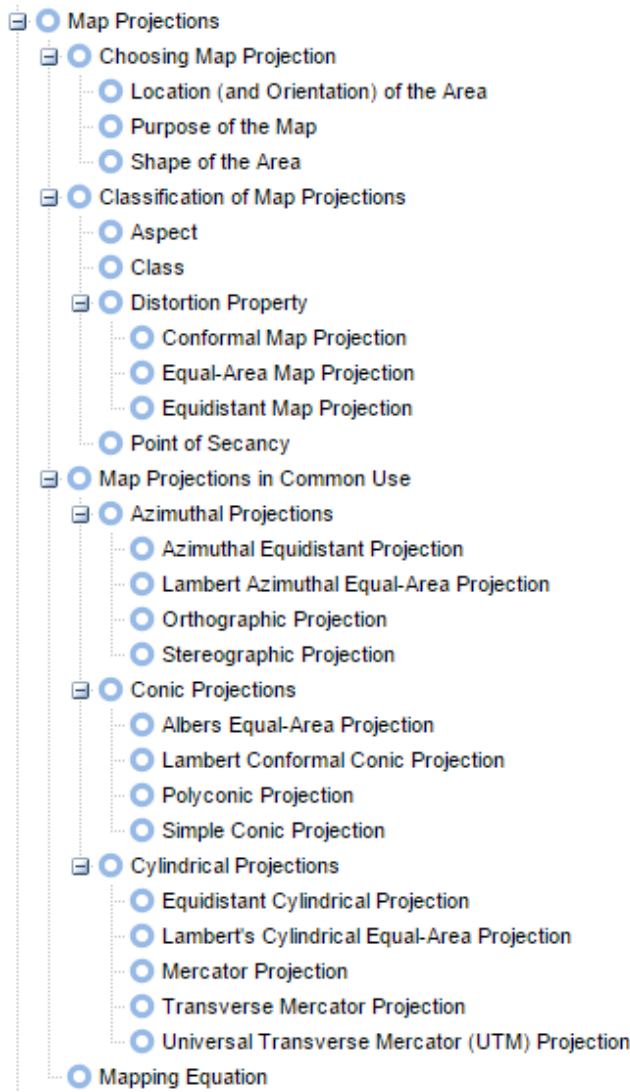


Figure 5.1: showing Hierarchical Relationships of concepts.

Visualisation tool: OntoGraph

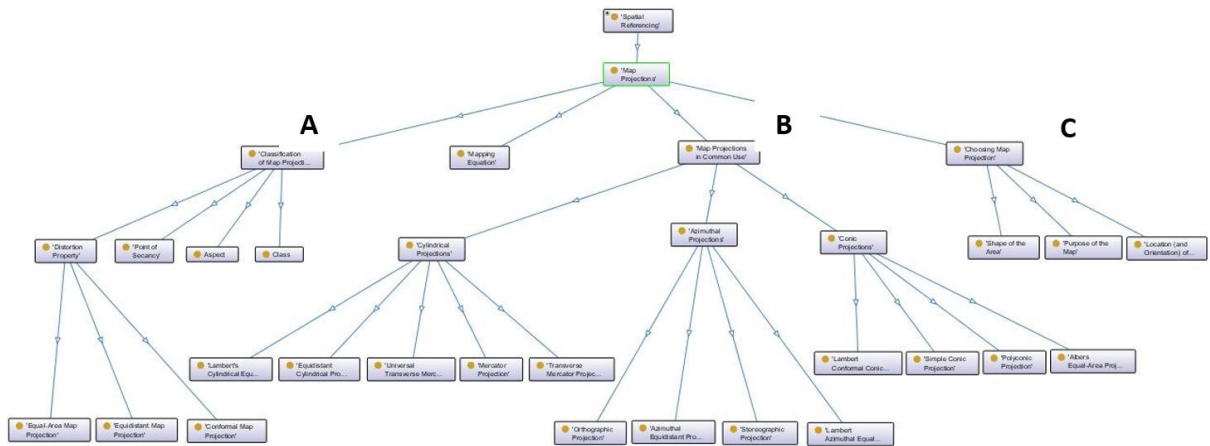


Figure 5.2: showing overview of graphical Hierarchical Relationships of concepts

Visualisation tool: WebVOWL

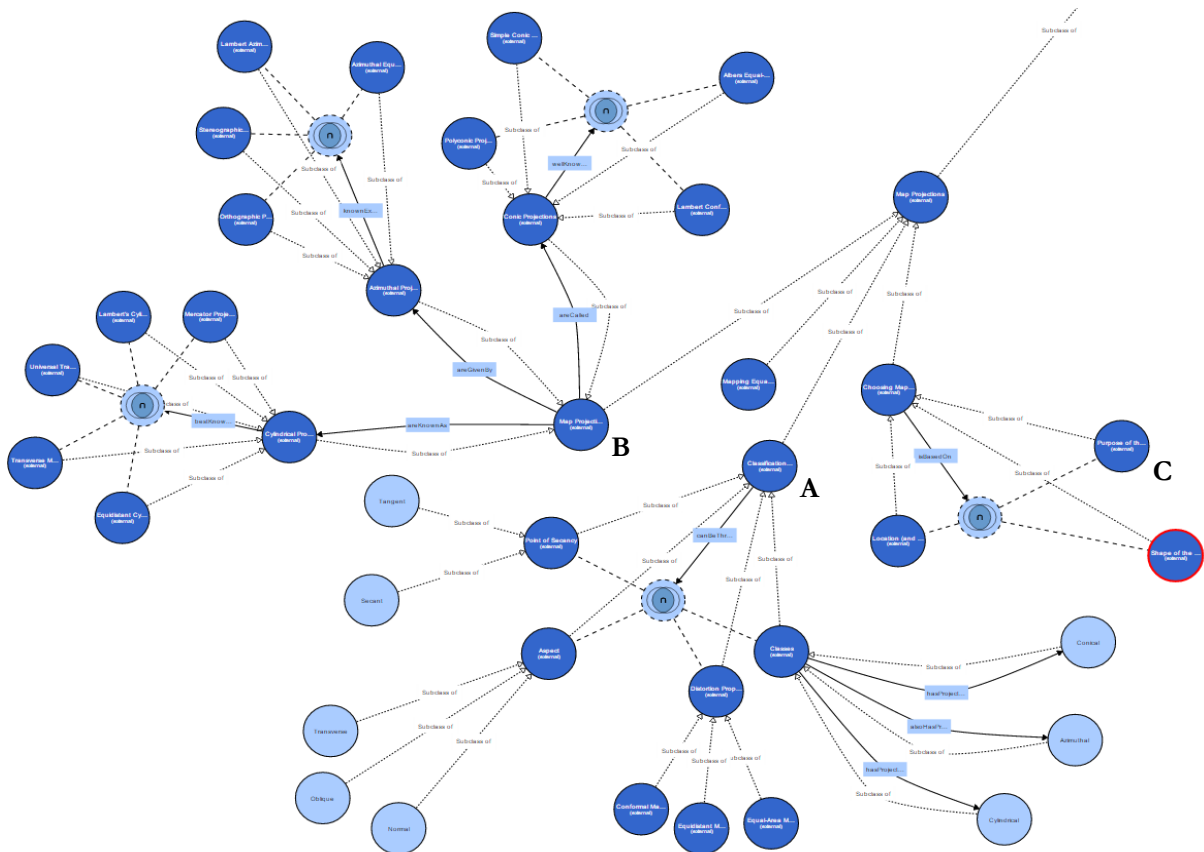


Figure 5.3: showing an overview of graphical Hierarchy of term and Relationships between concepts

Visualisation tool: OntoGraph

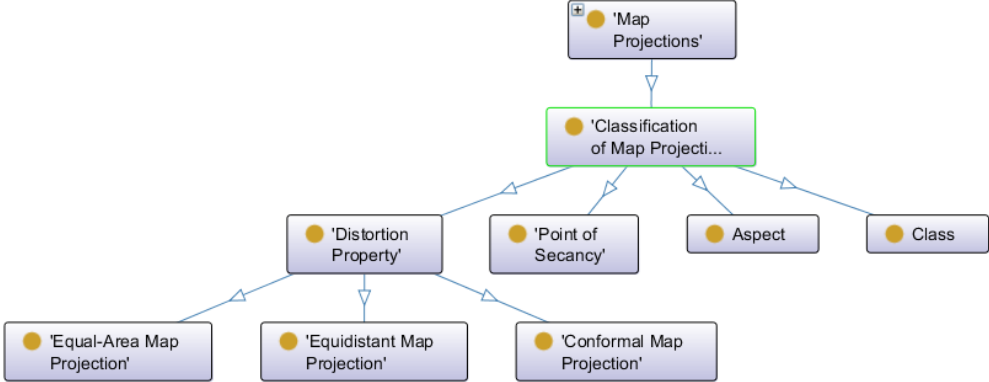


Figure 5.4: showing tree A (refer to Figure 5.2) of graphical Hierarchical Relationships of concepts

Visualisation tool: WebVOWL

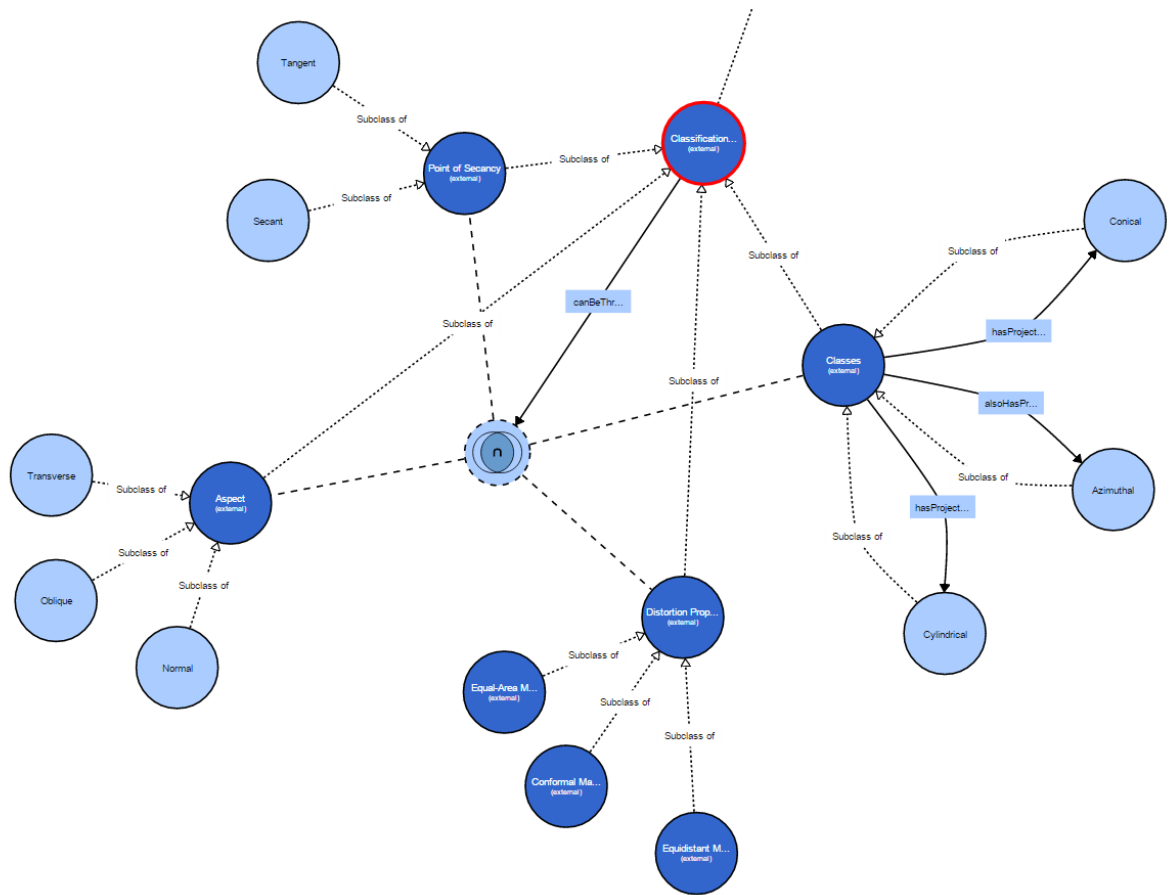


Figure 5.5: showing tree A (refer to Figure 5.3) of graphical Hierarchy of term and Relationships between concepts

Visualisation tool: OntoGraph

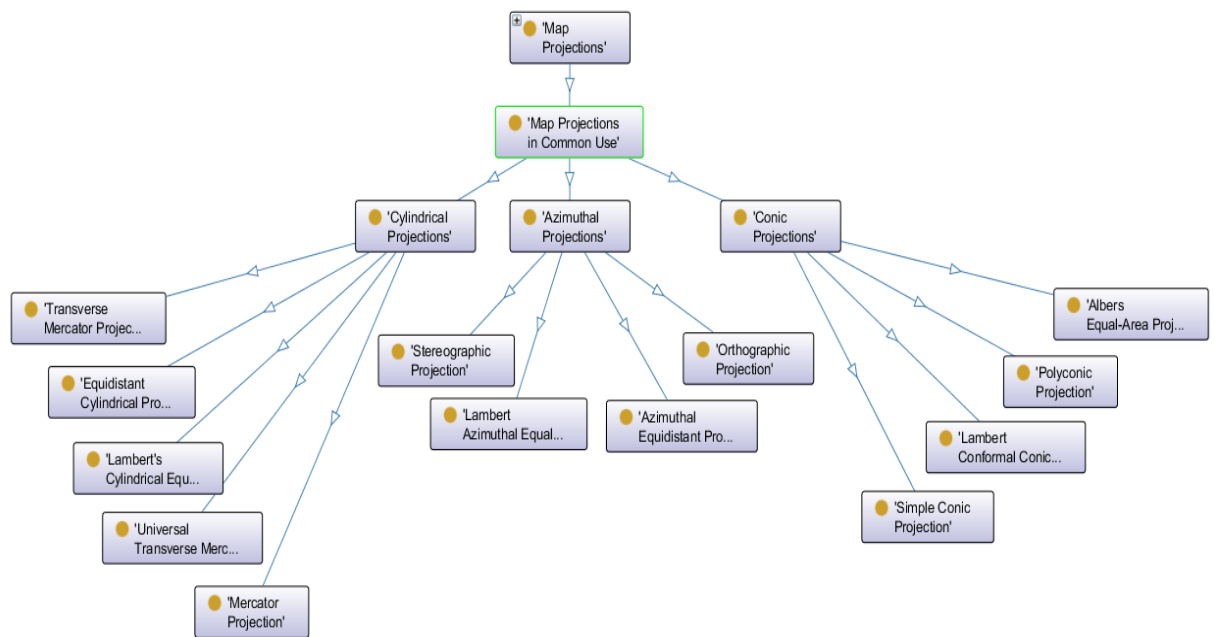


Figure 5.6: showing tree B (refer to Figure 5.2) of graphical Hierarchical Relationships of concepts

Visualisation tool: WebVOWL

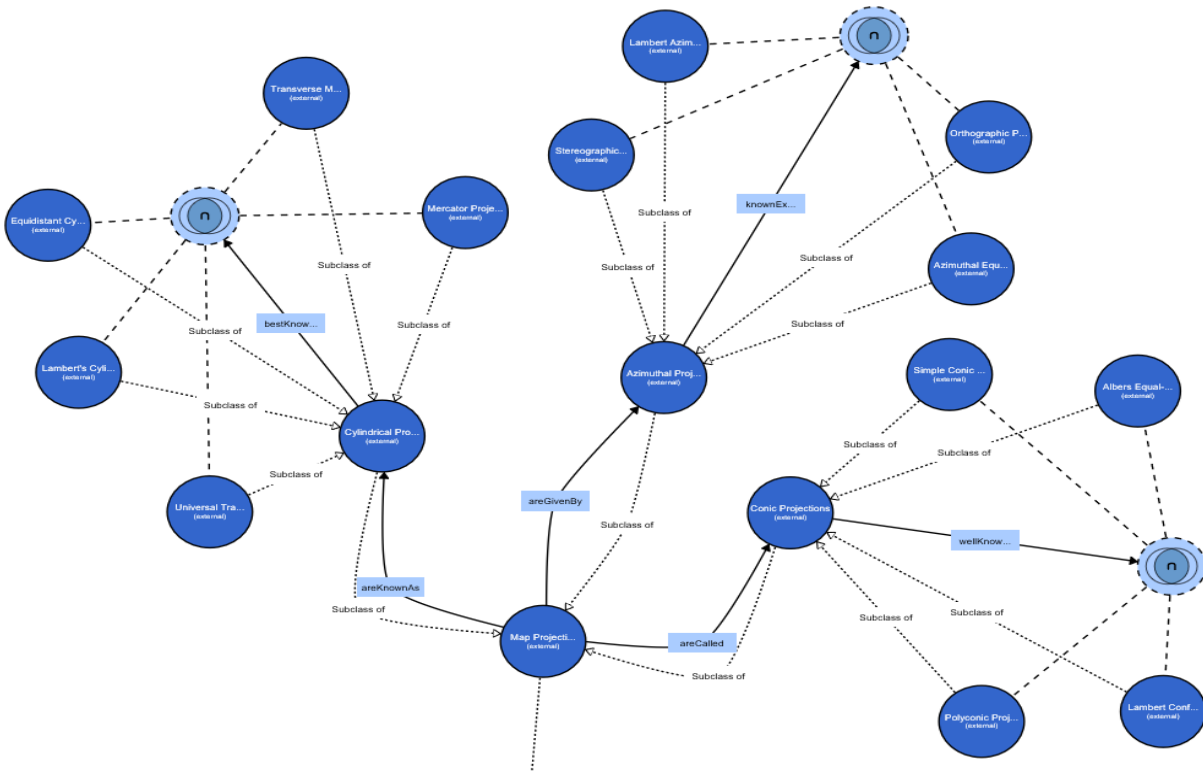


Figure 5.7: showing tree B (refer to Figure 5.3) of graphical Hierarchy of term and Relationships between concepts

Visualisation tool: OntoGraph

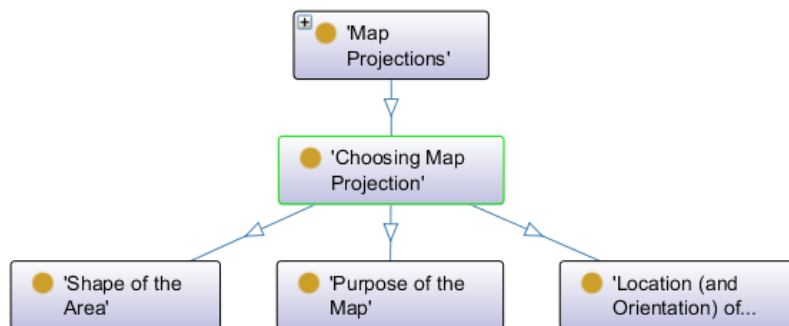


Figure 5.8: showing tree C (refer to Figure 5.2) of graphical Hierarchical Relationships of concepts

Visualisation tool: WebVOWL

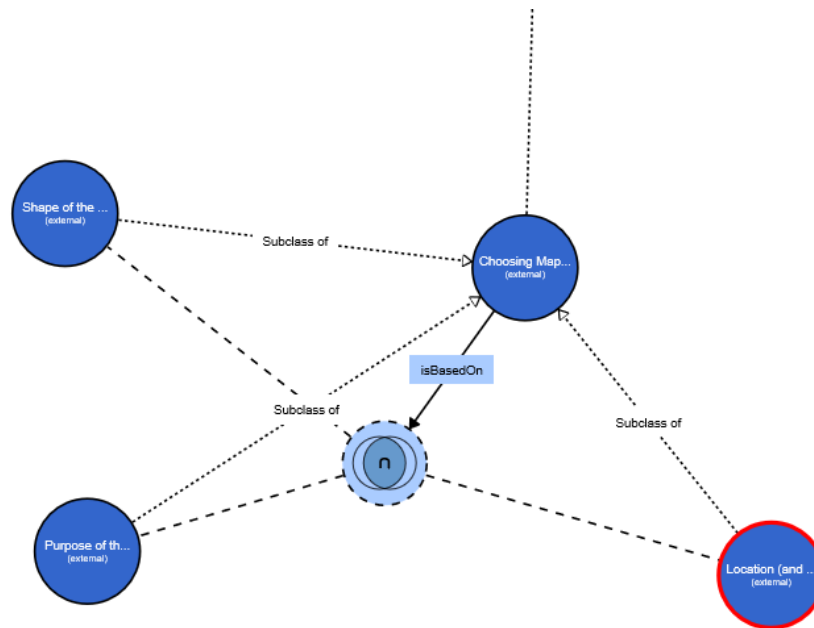


Figure 5.9: showing tree C (refer to Figure 5.3) of graphical Hierarchy of term and Relationships between concepts

DEFINITION AND DESCRIPTION OF TERMS

Map Projection

A Map Projection is a mathematically described technique for representing the Earth's curved surface on a flat map. To represent the specifically curved Earth's surface, a map needs to be a flattened representation of a part of the planet. Map projection concerns itself with ways of translating the curved surface of the Earth into a flat, 2D map. Projections can be classified by Classification can be through Geometry, Symmetry, or Distortion.

Choosing Map Projection

Every map must begin, either consciously or unconsciously, with the choice of a map projection and its parameters. The cartographer's task is to ensure that the right type of projection is used for any particular map. A well-chosen map projection takes care that scale distortions remain within certain limits and that map properties match to the purpose of the map

Location (and Orientation) of the Area

The choice of the aspect of a map projection depends largely on the location (and orientation) of the geographic area to be mapped. Optimal is when the projection centre coincides with the centre of the area, or when the projection plane is located along the main axis of the area to be mapped.

Purpose of the Map

Once the class and aspect of the map projection have been selected, the distortion property of the map projection has to be chosen. The most appropriate type of distortion property for a map depends largely on the purpose for which it will be used.

Shape of the Area

Ideally, the general shape of the mapping area should be well-match with the distortion pattern of a specific projection. If an area is approximately circular, it is possible to create a map that minimizes distortion for that area on the basis of an azimuthal projection. A cylindrical projection is best for a rectangular area and conic projection for a triangular area.

Classification of Map Projections

Many map projections have been developed, each with its own specific qualities. It is these qualities that make the resulting maps useful for certain purposes. By definition, any map projection is associated with scale distortions. There is simply no way to flatten an ellipsoidal or spherical surface without stretching some parts of the surface more than others. The amount and kind of distortions a map has depends on the type of map projection.

Classification can be through: - class (cylindrical, conical or azimuthal), - point of secancy (tangent or secant), - aspect (normal, transverse or oblique), - distortion property (equivalent, equidistant or conformal)

Aspect

Projections can also be described in terms of the direction of the projection plane's orientation (whether cylinder, plane or cone) with respect to the globe. This is called the aspect of a map projection. The three possible aspects are normal, transverse and oblique. In a normal projection, the main orientation of the projection surface is parallel to the earth's axis. A transverse projection has its main orientation perpendicular to the earth's axis. Oblique projections are all other, non-parallel and non-perpendicular, cases.

Class

The three classes of map projections are cylindrical, conical and azimuthal. The Earth's reference surface projected on a map wrapped around the globe as a cylinder produces a cylindrical map

projection. Projected on a map formed into a cone gives a conical map projection. When projected directly onto the mapping plane it produces an azimuthal (or zenithal or planar) map projection.

Point of Secancy

The azimuthal, conical, and cylindrical surfaces in are all tangent surfaces, i.e. they touch the horizontal reference surface at one point (azimuthal), or along a closed line (cone and cylinder), only. Another class of projections is obtained if the surfaces are chosen to be secant to (to intersect with) the horizontal reference surface. Then, the reference surface is intersected along one closed line (azimuthal) or two closed lines (cone and cylinder). Secant map surfaces are used to reduce or average out scale errors since the line(s) of intersection are not distorted on the map

Distortion Property

We have not specified how the Earth's reference surface is projected onto the plane, cone or cylinder. How this is done determines which kind of distortion properties the map will have compared to the original curved reference surface. The distortion properties of the map are typically classified according to what is not distorted on the map: conformal, equal-area or equidistant map projections.

Conformal Map Projection

A Conformal Map Projection is when the angles between lines in the map are identical to the angles between the original lines on the curved reference surface. This means that angles (with short sides) and shapes (of small areas) are shown correctly on the map.

Equal-Area Map Projection

Equal-Area Map Projections are when the areas in the map are identical to the areas on the curved reference surface (taking into account the map scale), which means that areas are represented correctly on the map.

Equidistant Map Projection

An Equidistant map projection is when the length of particular lines in the map are the same as the length of the original lines on the curved reference surface (taking into account the map scale).

Map Projections in Common Use

A variety of map projections have been developed, each with its own specific qualities. Only a limited amount are frequently used. Here are some well-known projections described and illustrated. They are grouped into cylindrical, conical and azimuthal projections.

Azimuthal (or Zenithal or Planar) Projections

Azimuthal (or zenithal or planar) projections are made upon a plane tangent (or secant) to the reference surface. All azimuthal projections possess the property of maintaining correct azimuths, or true directions from the centre of the map. In the polar cases, the meridians all radiate out from the pole at their correct angular distance apart. A subdivision may be made into perspective and non-perspective azimuthal projections. In the perspective projections, the actual mapping can be visualized as a true geometric projection, directly onto the mapping plane.

Two well-known non-perspective azimuthal projections are the azimuthal equidistant projection (also called Postel projection) and the Lambert azimuthal equal-area projection.

Stereographic Projection

Apparently invented by Hipparchus (2nd-century bc). Used in combination with UTM projection as Universal Polar Stereographic (UPS) for mapping poles and in navigation charts for latitudes above 80°. Recommended for conformal mapping of regions that are approximately circular in shape; a modified version of the stereographic projection is used in the Netherlands for large-scale and topographic maps.

Orthographic Projection

Known by Egyptians and Greeks 2000 years ago. The map is perspective and neither conformal nor equal area. Only one hemisphere can be shown. The Earth appears as it would on a photograph from space.

Azimuthal Equidistant Projection

Distances measured from the centre of the map to any point are correct, and the bearing of any point from the center is correct (this applies to all azimuthal maps). Commonly used in the polar aspect for maps of Polar Regions and the Northern and Southern hemispheres. The oblique aspect is frequently used for world or air route maps centred on important cities and occasionally for maps of continents.

Lambert Azimuthal Equal-Area Projection

Used for maps of continents and hemispheres. Also suited for regions extending equally in all directions from a centre point, such as Asia and the Pacific Ocean. Recommended to the European Commission for statistical analysis and display.

Conic Projections

Four well-known normal conical projections are the Lambert Conformal Conic Projection, the Simple Conic Projection, the Albers Equal-Area Projection and the Polyconic Projection. They give useful maps of mid-latitudes for countries which have no great extent in latitude.

Lambert Conformal Conic Projection

Lambert conformal conic, also called conical orthomorphic (Lambert, 1972). Extensively used for large-scale mapping of regions predominantly east-west in extent. Further widely used for topographic maps.

Simple Conic Projection

Also known as equidistant conic. Meridians are true to scale (i.e. no distortion in a north-south direction). The most common projection in atlases for small countries.

Albers Equal-Area Projection

It is equal to Lambert's equal area conic but has two standard parallels (secant cone). Excellent for mid-latitude distribution maps. The projection does not contain the noticeable distortions of the Lambert projections. Frequently used for maps of the United States, for thematic maps and world atlases.

Polyconic Projection

Also known as American Polyconic (Hassler, ± 1820). The map is neither conformal nor equal area, but each parallel is true to scale. The sole projection used for large scale mapping of the United States by the USGS until the 1950's.

Cylindrical Projections

Probably one of the best known cylindrical projection is Mercator's cylindrical projection. The transverse case and occasionally the oblique case of the Mercator projection are used in several countries for topographic mapping purposes. The Transverse Mercator and Universal Transverse Mercator (UTM) projection are the best-known examples. Two other well-known normal cylindrical projections are the equidistant cylindrical (or Plate Carrée) projection and Lambert's cylindrical equal-area projection. Normal cylindrical projections are typically used to map the world in its entirety (in particular areas near the equator are shown well).

Mercator Projection

Conformal map projection. Designed for navigational use; standard for marine charts. Recommended use for conformal mapping of regions predominantly bordering the equator. Often inappropriately used as a world map.

Transverse Mercator Projection

Also called Gauss Conformal or Gauss Krüger. Transverse form (transverse cylinder) of the Mercator projection. Used for topographic maps at scales from 1: 20,000 to 1: 250,000. Recommended for conformal mapping of regions that are predominantly north-south in extent.

Universal Transverse Mercator (UTM) Projection

A version of the Transverse Mercator, but one with a secant map surface. It divides the world into 60 narrow longitudinal zones of 6 degrees. Widely used standard for topographic maps and military maps.

Equidistant Cylindrical Projection

Also known as simple cylindrical or Plate Carrée. The projection is equidistant in the direction of the meridians. Parallels and meridians (half as long as the parallels) are equally spaced straight lines forming square blocks. This projection maps longitude and latitude directly into x and y, hence is sometimes called the latitude-longitude projection. In Google Earth used for display of imagery. The transverse version is known as the Cassini projection.

Lambert's Cylindrical Equal-Area Projection

The Lambert's cylindrical equal-area projection represents areas correctly, but it does have rather noticeable shape distortions towards the poles. It is of little use for world maps because of the distortions. Mainly used for educational purposes.

Mapping Equation

The actual mapping cannot usually be visualized as a true geometric projection, directly onto the mapping plane. Rather, it is achieved through mapping equations.

To represent parts of the surface of the Earth on a flat, printed map or a computer screen, the curved horizontal reference surface must be mapped onto a 2D mapping plane. The reference surface for large-scale mapping is usually an oblate ellipsoid; for small-scale mapping, it is a sphere. Mapping onto a 2D mapping plane means transforming each point on the reference surface with geographic coordinates (φ , λ) to a set of Cartesian coordinates (x , y) that represent positions on the map plane