DEVELOPMENT OF SOURCE-DISTRIBUTED E-LEARNING MODULES FOR GIS AND REMOTE SENSING FOCUSING ON 3-D MODELS

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Zusammenfassung

E-Learning ist sowohl in der akademischen Welt als auch in der fortbildungsorientierten Industrie ein sehr aktuelles Thema. Die Vermittlung und gegebenenfalls auch die Prüfung von Kenntnissen durch asynchrones verteiltes Lehren und Lernen ist in vielen Bereichen denkbar und kann auf eine Vielzahl von Themen zugeschnitten werden. Um dieser Aufgabe gerecht zu werden, steht eine enorme Vielzahl kommerzieller und nicht-kommerzieller E-Learning-Plattformen zur Verfügung. Diese Vielfalt führt zu dem wichtigsten Problem des gesamten e-Learning - basierten Sektors: Die Inkompatibilität der Anwendungen und Inhalte.

Das Vorkommen nicht verträglicher, nicht interoperabler Inhalte behindert den reibungslosen Fluss des Informationsaustausches zwischen den einzelnen Plattformen, was in Bezug auf verteilte, service-orientierte Plattformen immer mehr an Bedeutung gewinnt. Eine mögliche Lösung dieses Problems ist in Form von internationalen Standards – sowohl bezüglich der Struktur der Lehrinhalte bzw. Anwendungen als auch der e-Learning Software selbst - zu finden. Standards und Normen unterstützen eine gemeinsame Basis des Prozesses des Informationsaustausches.

Wegen dieser Schwierigkeiten ist der Hintergrund dieser Arbeit mit folgenden Forschungsschwerpunkten verknüpft: Standardisierung von e-Learning und e-Learning-Plattformen, e-Learning im Anwendungsbereich „Lehre der Geoinformatik“ und 3D-Visualisierung. Ziel dieser Arbeit ist eine Synthese aller vier genannten Bereiche in Bezug auf die Standardisierung von e-Learning Software im Bereich der Ausbildung in Geoinformatik. Die Komponenten eines solchen Systems sollten die Möglichkeit der Visualisierung von 3D Modellen bieten, wie beispielsweise die selbst entwickelte 3D-visualisierungs-Software *ISVisualisation*.

Die methodische Gliederung dieser Arbeit orientiert sich an den zuvor genannten Schwerpunkten. Ein erster Schwerpunkt umfasst die Analyse und Bestimmung der derzeit diskutierten internationalen Standards im Bereich e-Learning. Ausgewählte e-Learning Plattformen werden unter diesen Gesichtspunkten miteinander verglichen. Durch die Bestimmung des besten Standardisierungsmodells soll für den weiteren Auswahlprozess eine solide und objektive Basis gegeben werden.

Ein zweiter Schwerpunkt, direkt abgeleitet vom ersten (so war Standardisierung das Hauptkriterium der Auswahl) umfasst die Analyse und Auswahl der geeignetsten e-Learning

Plattformen für das NaturNet-Redime-Projekt. Die Ergebnisse führen schließlich zu standardisierten e-Learning Plattformen deren Charakteristiken relevant für das Projekt selbst sind. Auch eine Durchführung von Experteninterviews spielt eine wichtige Rolle bei der Identifizierung einer passenden Plattform.

Mit dem Erreichen dieser zwei Unterziele werden die Voraussetzungen zur Realisierung des bereits genannten Hauptziels gegeben sein. Bei der Entwicklung von e-Learning-Modellen im Bereich der Geoinformatik spielt die Visualisierung von 3D-Modellen eine entscheidende Rolle. Aus diesem Grund bezieht sich das vierte und letzte Ziel auf die Entwicklung einer 3D-Visualisierungssoftware mit der sowohl die Visualisierung von Roh-Daten, als auch die Visualisierung von bereits erstellten 3D-Modellen möglich ist.

Die selbst entwickelte 3D-Visualisierungssoftware (*ISVisualisation*) wurde objekt-orientiert entwickelt. Die Software basiert auf Java und verschiedenen Spezialbibliotheken wie VisAD, Java3D, JUMP, deren Kombinierung eine effiziente Visualisierung nicht nur von LIDAR Rohdaten, sondern auch von bereits berechneten Daten in Form von digitalen Höhenmodellen (DEMs) aus zum einen LIDAR-Daten, aber auch Satellitendaten oder Luftbildern ermöglicht. Außerdem wurde die 3D-Visualisierung durch Computer-Simulationen, die vor allem dazu benutzt wurden um verschiedene Ansichten und Positionen bezüglich des e-Learning-Inhaltes darzulegen, unterstützt.

Die Diskussion fasst die hauptsächlichen Probleme und Schwierigkeiten (beispielsweise die Differenzen zwischen dem Begriff „Standard"), die durch die verschiedenen Auswahl-Prozesse entstanden sind, zusammen. Die Ergebnisse der Analysen wurden, beruhend auf deren Relevanz bezüglich des Themas dieser Arbeit, quantitativ und qualitativ interpretiert. Die Zusammenfassung bezüglich der weiterführenden Forschung stellt die praktischen Ergebnisse in einen größeren Forschungszusammenhang, zu dem spezifische e-Learning Merkmale (beispielsweise Glossare) und die Software *ISVisualisation* zweifellos gehören.

Summary

E-Learning is an up-to-date issue both in the academic world and the e-Learning-oriented industry branches. E-Learning content can be conceived and adapted to a variety of topics and, in order to accomplish this task, it has a large number of existing commercial and non-commercial e-Learning software platforms at its disposal. This variety, however, leads to the most serious problem of the entire e-Learning-based sector: content incompatibility. The existence of incompatible contents interferes with the necessity of information interchange (between platforms) which has been more and more often associated with the modern world learning system. The solution to this problem would be the creation of content and e-Learning software standardization models which will eliminate all the inconveniences emerging from information exchange processes.

That is why the study objectives of the present work are closely related to following research areas: e-Learning standardization, e-Learning platforms, e-Learning in Geoinformatics education and 3D visualization. The primary goal of the thesis is the realization of standardized e-Learning modules for the Geoinformatics education; these modules should be able to encapsulate 3D model visualization possibilities, such as the self-developed 3D visualization software ISVisualisation.

The entire methodological structure of the study centres around its predefined objectives. The first step consists in the analysis and determination of the best existing e-Learning standardization models. In order to achieve this, a contrastive evaluative investigation between selected e-Learning platforms will be performed. By choosing the best standardization model, it is intended to provide the further selection processes in the study with a solid objective basis of comparison. A second objective, directly derived from the first one (i.e. standardization was the main criterion of selection), concerns the analysis and determination of the best suitable e-Learning software platform for the NaturNet-Redime Project. The results will eventually point to the standardized e-Learning platform that presents characteristics which are relevant to the aims of the project itself. The expert-interview procedure will also play an important role in identifying the appropriate platform. After accomplishing these two objectives, the premises for the realization of the already mentioned main objective will be created. In the process of developing e-Learning models in the field of Geoinformatics, the visualization of 3D models plays a very important part. That is why the fourth and last objective focuses on the development of a 3D visualization software that is able to visualize raw and processed data in form of 3D models.

For the three-dimensional self-developed visualization software (ISVisualisation), an object-oriented programming solution was developed. The software is based on the Java technology and several special libraries like VisAD, Java3D, JUMP, whose combination allowed the efficient visualization not only of raw LIDAR data but also processed data, in form of digital elevation models (DEMs) resulting either from LIDAR, satellite data or aerial photographs. The 3D visualization has also been made possible through the usage of computer simulations which have been mainly used for explaining different notions and situations inside the e-Learning content.

The final discussion summarizes the main problems and difficulties (e.g. the misunderstanding of the notion of "standard") appearing during the various selection processes. The results of the analyses are quantitatively and qualitatively interpreted, insisting on their relevance to the topic under investigation. The concluding remarks on future research are meant to place the theories exploited and their practical outcomes into a larger research context, to which specific e-learning features (e.g. glossaries) and the ISVisualisation software definitely belong.

Rezumat

E-Learning este o tema actuală atât în mediul universitar cât şi în domeniul privat de pregătire profesională. Conținut e-Learning se generează pe teme diferite utilizând un număr mare de platforme e-Learning comerciale sau non comerciale. Cea mai importantă problema a întregului sector e-Learning este, în momentul de fata, incompatibilitatea conținutului între diferite platforme când nevoia schimbului de informații a devenit o condiție obligatorie în e-Learning. Soluționarea acestei probleme este posibila prin realizarea de conținut şi software e-Learning standardizat, fapt care va elimina toate inconveniențele existente în prezent.

Teza de fata este un studiu interdisciplinar care conectează metodologia de învățământ la distanța prin intermediul e-Learning cu teme ca GIS şi teledetecție, precum şi vizualizarea de modele tridimensionale provenite din prelucrarea diverselor tipuri de date, dar în speță date LIDAR.

Obiectivele tezei sunt strict legate de standardizarea e-Learning, platforme e-Learning, e-Learning în educația geoinformatică, precum si de vizualizare 3D. Obiectivul principal al acestei teze este realizarea de module standardizate e-Learning pentru educația în geoinformatică, capabile sa integreze diferite metode de vizualizare a modelelor 3D de genul software-ului ISVisualisation dezvoltat în cadrul acestui studiu de doctorat. Pe lânga obiectivul principal mai exista câteva obiective secundare, iar unul dintre aceste obiective secundare este este determinarea si studiul celui mai cuprinzător standard e-Learning existent. Rezultatul acestui prim obiectiv secundar va fi folosit în împlinirea celorlalte obiective ale tezei. Al doilea obiectiv secundar este determinarea si analiza celei mai potrivite platforme e-Learning pentru proiectul NaturNet-Redime prin intermediul unui complex proces de selecție în trei trepte de intensitate. Realizarea acestor doua obiective secundare creaza premisele pentru realizarea obiectivului principal, deja menționat, al prezentei teze. În procesul de realizare a acestui fel de module vizualizarea modelelor 3D joacă un rol important si din acest motiv al patrulea si ultimul obiectiv secundar se concentrează pe dezvoltarea unui software de vizualizare 3D capabil sa vizualizeze date 3D neprocesate precum si procesate anterior.

ISVisualisation a fost dezvoltat în limbajul de programare Obiect Orientat Java cu ajutorul mai multor biblioteci ca VisAD, Java3D, JUMP, combinație care permite vizualizarea eficientă a datelor provenite din prelevări LIDAR, imagini de satelit, aerofotograme procesate anterior si disponibile sub forma unor digital elevation models (DEM) precum si a datelor LIDAR neprocesate sub forma de nori de puncte.

1 Preamble

1.1 Living in three dimensions

"*E pur si muove*" said Galileo Galilei in front of the Court of Inquisition, in the mater of the Earth rotating around the Sun. It is already common knowledge that Galilei was a visionary of the Middle Ages, who discovered the Earth's rotation around the Sun, the Sunspots, the Moon Mountains, and of course the four biggest natural satellites of Jupiter, also called the Galilean Moons. Even if what he discovered is basic information for the modern people, without Galileo, the first man that thought three dimensionally, it may have probably taken a bit of time till somebody else would have made the same discovery.

Why is the third dimension so important then? A basic answer would be that we people naturally think in three dimensions and we therefore automatically know that an object has to have three dimensions, even when reality is deceiving: a piece of paper has three dimensions even if the third one (height) has such a small value that it gives us the false impression that it is inexistent. Garzt (2001) said that "people are so used to seeing three dimensionally that we always look for a three dimensional solution in which an object is positioned behind or face to face with another object".

When referring to the Earth's visualization, the third dimension is very important for determining points on the Earth's surface. For a long time, two dimensional maps and cartographic plans have been the most widespread reference material concerning the Earth's surface and the objects on it. In the last years, however, together with the development of better and better computer hardware and software, the visualization of geographical data has taken on the World Wide Web (www). In 2002, we already had sixty 3D city models that could be accessed through an Internet browser (Baty & Smith 2002).

Nowadays, the visualization of Remote sensing and GIS (Geographical Information System) data is also possible through 3D viewers. In practical terms, this means that cities and communities can receive authentic information based on the real situation in the field and consequently take the appropriate measures able to solve the newly identified problems. An interesting up-to-date topic of this type can be, for instance, the analysis of the catastrophical effects of the floodings caused by rivers, hurricanes or even seismic sea waves.

Three-dimensional object recognition concerns the recognition and localization of those objects of interest in a scene from input images. This matter is one of both theoretical and practical importance. On the theoretical side, it is an ideal vehicle for the general study of the computer vision area since it deals with several important issues correlated with computer vision - for example, issues such as feature extraction, acquisition, representation of proper knowledge [...] *On the practical side, it presents a wide range of applications in areas such as robot vision, autonomous navigation* [...] (Suk & Bhandarkar 1992: 3).

It can be assumed that three dimensional (3D) modeling and visualization are, as shown in the quote upper-page, fruitful research domains, which have become, in the last years, increasingly important to all directions of activity planning[1]. One obvious reason for that, which also represents the motivational background of my PhD project, is the fact that 3D modeling and 3D data have been approached earlier by an exclusively small number of researchers, respectively their projects. That is why this thesis aims mainly at offering the possibility to students and normal citizens, as well as to other interested parts, of acknowledging 3D visualization as a basis for e-Learning strategies.

1.2 PhD general background

The development in the e-Learning area moves towards the use of specific methods applied on datasets which are made available through Internet access. E-Learning should be seen not only as a dynamic process but also through its three-dimensional use potential. Moreover, this should be achieved by the means of advanced visualization. Because, in any type of spatial planning application, such visualization procedures are very useful especially when wanting to achieve a better understanding of the given theoretical concepts. In addition to that, distributed datasets allow the application of the same methods to various already existing datasets, which makes possible the use of real data for the analysis of the regional landscape. In the following, the key research areas of the thesis will be briefly outlined:

E-Learning

E-Learning may be defined as a learning, training or information acquisition activity which involves the use of electronic devices. It is the way to teach different subjects using the computer but, at the same time, it may refer to the connection between several computers that

1 Activity planning is defined as the drawing up of a detailed plan to achieve the goals of the milestone plan (Masuru 2006: 47).

share information. E-Learning software solutions were developed because of the increasing interest of learners from different age levels. School children, students or lifelong learners[2] wish to be able to connect to the Internet from home and access e-Learning through the internet. The development of the Internet infrastructure has not only increased the number of users but also the possibility of interchanging huge amounts of information instantly.

From this perspective, the primary foci of the thesis will be (a) *e-Learning standardisation* investigation, *e-Learning software choice* based on rigorous selection criteria backup by *expert interviews*, (b) the structuring of the necessary information, i.e. theoretical knowledge, and (c) the design of the educational i.e. subject-specific methodological strategies strongly connected with the *e-Learning pedagogy*, which can deal with practical problems of spatial planning by using tools as GIS, multimedia, virtual presentation etc.

Distributed datasets

Absolutely new on the Internet market is the intention of using e-Learning for existing distributed datasets. For this exact purpose, fully inter-operable services, used in accordance with the EU concept INSPIRE, are needed. In the frame of an e-Learning process, the above-mentioned provided access to existing datasets can provide the teacher/learner/user with realistic application examples. In addition, in the case of GIS-based applications, it will facilitate the understanding of the regional landscape structure as part of an e-Learning training lesson.

Computer visualization techniques of *status quo* developments get increasingly important in the decision planning domain. In this area, visualization may again help in the direction of understanding the interrelationships between the various environment elements such as temperature and altitude. This is especially true in the case of lecturing on the topic of environmental impact and spatial planning. It is widely recognized that the use of visual communication techniques can explain complex matters and make them more understandable.

2 The Lifelong Learning Concept states that "it's never too soon or too late for learning" : http://en.wikipedia.org/wiki/Lifelong_Learning

3D models

The 3D models are the result of a three-dimensional object recognition process and consist in the recognition and localization of an object from a given raster[3] dataset. Three dimensional models can also be generated from other datasets than raster, as presented in Chapter 3 of the present work. The 3D models used in this dissertation are mainly used for terrain visualization and they are produced either through the means of computer simulations or through a real-time visualization made possible by the self-developed visualization software.

Environmental impact

The ***Environmental Impact Assessment*** is a procedure belonging to the ***EU Development Strategies***. More precisely it ensures that the environmental implications of certain decisions are well analyzed before these decisions are made. The process involves:

- analysis of the possible effects on the environment
- recording those effects in a report
- undertaking a public consultation exercise on the report
- taking into account the comments and the report when making the final decision
- informing the public afterwards about that decision

The environmental impact assessment process can be successful realized by using GIS and Remote Sensing techniques. Such an environmental impact assessment has been made for the study region Waldkirch which is the study region for the present thesis.

Spatial planning

Spatial planning at the European level is a current problem. Simultaneously with the economic growth and social integration of the Member States, internal borders are increasingly losing their separating character and more intensive relationships and inter-dependencies are emerging between cities and regions of these States. Long-term spatial development trends in the EU are predominantly influenced by three factors:

3 A raster refers to a data structure representing a generally rectangular grid of pixels (Source: www.wikipedia.org)

- The progressive economic integration and related increased cooperation between the Member States;
- The growing importance of local and regional communities and their role in spatial development;
- The anticipated enlargement of the EU and the development of closer relations with its neighbors.

Guidelined by the above-described research framework, the PhD Thesis research work was carried out (mostly) inside the EU Project NaturNet-Redime (http://www.naturnet.org): the study area chosen for exemplification is the region of Waldkirch city and its outskirts, the forested areas along the Dettenbach River.

The results of the whole research process are expected to be useful, at a general level, in different types of decision-making fields, generally associated with high-technology activities, and, more specifically, in performing an optimal educational 3D-based training.

1.3 Literature overview

It hat been generally accepted that it is not easy to design convincing learning environments whose practical outcomes, no matter whether planned for classroom or multimedia delivery, should lead both to the successful solving of specific workplace tasks and to the improvement of the enterprise's/institution's organizational performance. In order to reach such higher-order problem solving skills, the designer must first define which these skills are. Expertise research, for instance, shows that these skills are job-specific. In other words, "the knowledge basis characterizing a great physician is different from one that makes a master programmer" (Clark & Mayer 2003: 24). Before applying these considerations to the domain of landscape visualization, one must first consider the fact that the research field itself is still young and evolving:

There is much that we need to learn about how visualizations work in practice, and how emerging techniques will affect forest decision-making. While much more research is needed, the speed with which new visualization technologies are becoming available means that practicing forest managers cannot wait for research results, but must proceed under interim precautionary principles (Sheppard & Salter 2004: 485).

That means that already existing information is not only insufficient but it is also submitted to the risk of becoming rapidly obsolete. These being said, much care should be taken when using reference in the area of 3D/visualisation e-Learning strategies.

On the other hand, approaching the e-Learning technology does not only refer to visualization strategies but also to the platform to be used during the teaching process. An e-Learning strategy generally uses a platform based on content manager software (e.g. SCORM). Literature often pointed to WebCT, which is a private service and is used by a lot of higher education institutions and not only. For example, the University of Aveiro, Portugal has designed such an e-Learning model based on WebCT platform (cf. Ramos 2005). The module aimed at educating people that are unable to get a face-to-face education and, at the same time, at making accessible the information provided by fully specialized higher education teachers who are normally unavailable because of their location on the globe.

Gil & Garay (2004) provide another e-Learning strategy, which is clearly described in their paper: “a case-study teaching experience developed during an educational informatics course for engineering instructors students who learn to create a type of hypermedia intelligent tutoring system with a system approach. This experience has been developed for more of six years at Havana Polytechnic Institute” (Gil & Garay 2004: 1). In the light of such an example, it can be easily deducted that improvement in the quality of instructional processes stimulates the development of active teaching methods based on “learning by doing” principles.

However, more important than the description of the platform applicability seems to be the selection of an appropriate e-Learning platform, which is an important aspect of the e-Learning module development. Different authors have therefore approached this problem, such as Donati et al. (2004), Karrer (2007) and others, who have presented various methods of selection or comparison regarding e-Learning platforms. In broad lines, most of these comparison and selection strategies focus on the “power” of the e-Learning software and not intensively on the standardization of the e-Learning modules resulted in the development process.

That is why, in the search for appropriate standards, the present paper has selected that kind of literature able to reflect the following assumption: one goal in the future would be to create a software environment that enables not only an automatic and complete recording but also the digitization of complex 3D objects, where the 3D objects should be realistic. In order to obtain such realistic 3D objects, realistic surface properties and textures have to be included. What literature underscores in this direction is that the PM (progressive mesh) structure does not allow partial information loss, but in realistic scenarios this loss cannot be ignored. Such generalizations are necessary since the information increment of including animations into digital documents is comparable to the increment that arises when 2D pictures are extended to video sequences. These techniques will enable a practical integration of dynamic simulations in digital documents such as crash simulations (Schneider, Kobbelt & Seidel 2004: 1).

1.4 Objectives

Considering the range of key-topics to which the thesis intends to make reference and the literature backgrounding them, the following primary objective of this thesis can be outlined:
As the realization of standardized e-Learning modules for the Geoinformatics education which are able to encapsulate 3D model visualization possibilities, such as the self developed 3D visualization software ISVisualisation. The subsequent main goals are related to the three different important sections of the dissertation:

(1) selection of the most appropriate e-Learning standard and platform for teaching GIS and Remote Sensing;
(2) creation of e-Learning models in two different e-Learning platforms based on a GIS and Remote Sensing content that has been conceived in a prior stage of development;
(3) realization of 3D models and the optimization of already existing 3D models;
(4) realization of a viewer for the online visualization of the 3D models.

Before initiating the research proper, I considered the following research questions as the starting point in my investigation:

- Which are the most efficient and generally accepted e-Learning standards?

- Which are the most suitable e-Learning platforms for the educational field of Geoinformatics?

- What new possibilities (e.g. content design) does e-Learning offer to the educational field of Geoinformatics?

- To what conclusions brings us the ILIAS - MOODLE comparison?

- Is it possible to develop a 3D Viewer based on Java3D and VisAD for the visualization of LIDAR data online?

- What conclusions can be drawn for future research?

2 E-Learning insight

2.1 Introduction

2.1.1 E-Learning basic terminology

The notion of *e-Learning* is generally interpreted as the process of learning with the help of software that is installed locally on the learner's computer. It can be defined as "learning over the Internet" (Baumgartner et al. 2002) as well. In this dissertation thesis, I will use the term *e-Learning platform* when referring to the Internet-based e-Learning software solution which does not need an extra local installation. Additionally, I will mention *learning programs* that need to be seen as other e-Learning software which are not connected to the internet and therefore have no web interactivity and distributed resources.

Historically speaking, the actual e-Learning platforms have their origin in the *electronic learning*, like Computer- Based Learning (CBL) and Computer Based Training (CBT), in which learning is blended with computer based activities. These activities have either the role of teaching, as in the case of CBL, or to train students through the means of a CBT, as the US AirForce did for training pilots. The broadest e-Learning utilization nowadays is the *Learning Management System* (LMS), which is considered, in the view of the International Forum of Educational Technology & Society (IFETS), as "a collection of e-Learning tools available through a shared administrative interface. A Learning Management System can be thought of as the platform in which online courses or online components of courses are assembled and used from" (cf. Nichols 2003).

Structurally perceived, e-Learning is an integrative part of the Information Technology field. It is systematically classified, together with other technologies belonging to the communication sector, under the subcategory of *Information and Communication Technology* (ICT).

From the neighboring-field perspective, we can mention terms like *New Media* and *Multimedia*, which are very often used in connection with e-Learning. *New Media* was explained, for instance, as "communication through the means of computers and different coding systems that are used for the information to be transmitted" (Strittmatter & Niegemann 2000: 120).

2.1.1 E-Learning on GIS and Remote Sensing: basic questions

What is Geoinformatics?

„Geoinformatics is a science which develops and uses information science infrastructure to address the problems of geosciences and related branches of engineering"[4]. This is a definition that seems to be correct, but we have to ask ourselves the question: which geosciences and branches of engineering are meant here? Geosciences like physics, geography, geology, forestry, etc. represent only a minimal part of those domains which are connected with Geoinformatics. Wanting to locate an object on the Earth's surface will automatically make reference to knowledge in this field. These being said, we can estimate that the use of geoinformation, of any kind, will enlarge the interdisciplinary spectrum of Geoinformatics.

Why GIS?

GIS as an important key-topic in the area of Geoinformatics and it has reached such a development over the last years that regular people, that have absolutely no idea about topography, photogrammetry, GIS or programming, use products of the Geoinformatics industry (e.g. GPS receivers). A better understanding of the background of GIS and Geoinformatics in general will bring an enormous advantage to scientists, decision makers, students and lifelong learners[5].

Why is e-Learning important for the study of Geoinformatics?

The evolution of the Geographical Information System (GIS), Remote Sensing and finally Geoinformatics as educational field began to flourish with the use of online e-Learning. A large number of e-Learning modules are available on the World Wide Web. Some of these modules are even offered to the public for free. GIS, Remote Sensing and Geoinformatics as a whole are based nowadays on the use of various computer hardware(s) and software(s), which means that the use of traditional learning techniques is rather inappropriate for this field. Projects like FerGI, Geoinformation, Gimolus, Webgeo, GITTA or LEAP which contain a "large collection of learning materials on the Geoinformation theme" (Katterfeld & Kremeike

4 Source: http://en.wikipedia.org/wiki/Geoinformatics

5 Source: http://en.wikipedia.org/wiki/Lifelong_learning

2004) give the possibility to students via e-Learning to better understand Geoinformatics and its principles.

Which e-Learning design for GIS modules?

In the e-Learning modules that were designed for this dissertation, the information provided is based on GIS, Remote Sensing and data visualization programming. There are two types of module-sets which have been designed for this thesis. The first e-Learning modules, realized in the ILIAS e-Learning platform, refer strictly to GIS notions and they take the learner on the journey of discovering the basics and special features of GIS by presenting him/her general notions, theories, practices and examples of GIS software. The second set of Remote Sensing modules is available on the MOODLE e-Learning platform and is supposed to help specialists or people with remote sensing knowledge in selecting the best methods for LIDAR data acquisition, processing and information acquirement.

2.2 Learning and e-Learning theories and principles

2.2.1 Learning theories

For a better understanding of how the process of learning works, some relevant learning theories in the fields of education and psychology will be enunciated: Behaviorism, Constructivism and Cognitivism.

Behaviorism

Behaviorism is a psychology-related theory based on the presumption that one's behavior can be scientifically explained without having to regress to internal mental states. “The central tenet of behaviorism is that thoughts, feelings, and intentions, mental processes, all, do not determine what we do. Our behavior is the product of our conditioning. We are biological machines and do not consciously act; rather we react to stimuli" (Cohen 1987). In the following lines, the development of the theory will be briefly described.

Behaviorism mainly relies on the work of Ivan Pavlov (1849-1936), who initially investigated *classical conditioning*. Pavlov analyzed the reaction of a dog when combining an independent stimulus, such as a ringing bell, with a biological stimulus, such as food. Every time Pavlov fed the dog, he rang the bell. As a physiological response, the dog salivated when the bell rang.

It was Watson who introduced the notion of behaviorism, in 1913, and his work had been much influenced by the work of Pavlov. Most of Watson's work was comparative and focused on the adjustment of the organisms to their environment. At that time, Watson's theory was a breakthrough and totally different from the structuralist psychology, that was introspective.

Skinner, considered the best known behaviorist, developed a different type of behaviorism, the so called *radical behaviorism* or the *Skinnerian behavior*, being, in this way, credited for having created a new version of psychological science. Skinner claimed that "the experimental analysis of behavior has led to an effective technology, applicable to education, psychotherapy, and the design of cultural practices in general, which will be more effective when it is not competing with practices that have had the unwarranted support of mentalistic theories" (Skinner 1974).

Cognitivism

In psychology, *cognitivism* is considered a theoretical approach of understanding how human mind works. It has two dominant components, the methodological and the theoretical. The methodical cognitivism subscribes to the *positivist*[6] belief, which sustains that psychology can be explained through the means of experiments, measurements and scientific methodologies. Theoretical cognitivism replaced behaviorism, at the end of the 20th century, and it was considered the most important paradigm for understanding human mental functions. Another supporter of cognitivism (preferred to behaviorism) was Noam Chomsky[7], who argued that pure conditioning will not be able to sustain the development of a language and that this is only possible through internal mental states.

6 Positivism is a philosophy that states that the only authentic knowledge is scientific knowledge, and that such knowledge can only come from positive affirmation of theories through strict scientific method (Source: http://en.wikipedia.org/wiki/Positivist)

7 Avram Noam Chomsky is the Institute Professor Emeritus of linguistics at the Massachusetts Institute of Technology. Chomsky is credited with the creation of the theory of generative grammar, considered to be one of the most significant contributions to the field of theoretical linguistics made in the 20th century.

Constructivism

The *constructivist* theory is attributed to Jean Piaget who, intrigued by the answers children gave at a logical question, developed the theory of *genetic epistemology*. Constructivism is also called *cognitive development* and is often confused with *maturationism*. It "is based on the idea that the dialectic or interactionist process of development and learning through the student's active construction should be facilitated and promoted by adults" (DeVries et al. 2002).

Constructivists understand learning as an active learning process that builds new ideas on already existing knowledge, better said "learning involves constructing one's own knowledge from one's own experiences" (Ormrod 2003: 227). A series of constructivism-based specific approaches to education have been developed. The most important of them are presented as follows:

<u>Constructionism</u>
It was developed at Massachusetts Institute of Technologies under the leadership of Seymour Papert. Papert worked with Piaget in Geneva and he embraced all the traditional constructivist theories, supplementing them with the fact that learning happens only when people construct something.

<u>Anchored Instruction</u>
The learning process is built around "anchors", which are case-studies or problem solvers that allow interactivity. Bransford and the Cognition and Technology Group at Vanderbilt (CTGV) argued that "our goal was to create interesting, realistic contexts that encouraged the learners' active construction of knowledge. Our anchors were stories rather than lectures and were designed to be explored by students and teachers" (CTGV 1993: 52).

<u>Cognitive Apprenticeship</u>
This theory sustains that the implicit skills needed for solving certain complex tasks can often be misacted by professionals that later fail to forward the information to their students. In order to eliminate such inconveniences, cognitive apprenticeships have been "designed, among other things, to bring these tacit processes into the open, where students can observe, enact, and practice them with help from the teacher…" (Collins, Brown & Newman 1987: 4).

Cognitive Flexibility

Cognitive flexibility refers to the ability to represent knowledge from different conceptual and case perspectives and then, when knowledge must later be used, the ability to construct from those different conceptual and case representations a knowledge ensemble tailored to the needs of the understanding or problem-solving situation at hand (Spiro et al. 1992: 58).

2.2.2 The way to an e-Learning theory

Perraton (1981: 13) noted that “distance education has managed very well without any theory” and he was probably right. But e-Learning is a far more complicated case and to let it “manage” by itself would be a mistake. Given the major interest in e-Learning and the enormous amount of work invested in the development of e-Learning courses, a unifying e-Learning theory, which would establish a connection between all e-Learning content sharing platforms, would be extremely important.

“There has been much written about e-Learning practice however little attention has been given to e-Learning theory” (Nichols 2003). Indeed, theory in e-Learning was surpassed by the practice and it can be said that no theory exists for e-Learning. At an international level, it has been recognized that, for further development, e-Learning needs a theory that will help practitioners in all situations. In the first place, anyway, the concept of “theory” itself has to be clarified:

“Theory”

A theory is a well-substantiated explanation of some aspects of the natural world, an organized system of accepted knowledge that applies in a variety of circumstances to explain a specific set of phenomena; "theories can incorporate facts and laws and tested hypotheses"[8].

Practitioners use a theory as a basis for the development of an application, but, at the same, theorists also find it dynamic and challenging. “It is theory that provides a coherent ordering of relevant variables and relationships to guide both practitioners and researchers” states Garrisson (2000).

8 Source: http://dictionary.reference.com/search?q=theory

"E-Learning theory"

Generally speaking, for a theory to be well understood, a common set of terms is needed. In the case of "e-learning theory", the following set of terms (see Table 1) was submitted for approval and implementation - inside the (IFETS)[9] - in 2003:

Table 1. E-Learning terms

Term	Explanation
Online learning	This term describes education that occurs only through the Web, that is, it does not consist of any physical learning materials given to students or actual face to face contact. Pure online learning is essential to the use of e-Learning tools in the distance education mode, by using the Web as the sole medium for all student learning and contact strategies.
Mixed-mode/blended/ resource-based learning	These terms interchangeably describe an approach to education that combines face to face and distance approaches to education, in that an instructor or tutor meets with students (either in a face to face mode or through a technological means) and a resource-base of content materials and learning activities is made available to students. In addition, some e-Learning approaches might be used.
e-Learning	The use of various technological tools that are either Web-based, Web-distributed or Web-capable for the purposes of education
Learning object (LO)	A digital file or tool that can be reused in e-Learning contexts
Learning Management System (LMS)	A collection of e-Learning tools available through a shared administrative interface. A learning management system can be thought of as the platform in which online courses or online components of courses are assembled and used.
Interactive	There are two types of interactivity, indicative and simulative. Indicative interactivity is typified by the use of button rollovers and site navigation. Clicking a button to start an animation or turn the page is indicative interactivity. Simulative interactivity is interactivity that enables students to learn from their own choices in a way that provides some form of feedback. The ability to select between different Web pages is indicative interactivity; the ability to fly a virtual plane in a realistic virtual environment is simulative interactivity.
Pedagogy	This term is traditionally understood to refer to teacher-oriented instruction, however it is now increasingly used to describe the application of sound education practice (which encompasses so-called 'androgogy'). In the present paper, it is used in the latter sense.

The e-Learning theory proposed by the International Forum of Educational Technology & Society in 2003, after long online debates, was in fact a combination of a set of ten hypotheses/statements, also called "fundamental principles for e-Learning" (see Table 2):

9 "The International Forum of Educational Technology and Society (IFETS) encourages discussions on the issues affecting the educational system developer (including AI) and educational communities."(IFETS website: http://ifets.ieee.org/)

Table 2. E-Learning theory hypotheses

No.	Statement
1	*E-Learning is a means of implementing education that can be applied within varying education models (for example, face to face or distance education) and educational philosophies (for example behaviourism and constructivism).*
2	*E-Learning enables unique forms of education that fit within the existing paradigms of face to face and distance education.*
3	*Whenever possible, the choice of e-Learning tools should reflect rather than determine the pedagogy of a course; however, as a general rule, how technology is used is more important than which technology is used.*
4	*E-Learning advances primarily through the successful implementation of pedagogical innovation.*
5	*E-Learning can be used in two major ways: the presentation of education content and the facilitation of education processes.*
6	*E-Learning tools are best made to operate within a carefully selected and optimally integrated course design model.*
7	*E-Learning tools and techniques should be used only after consideration has been given to online vs. offline trade-offs.*
8	*Effective e-Learning practice considers the ways in which end-users will engage in the learning opportunities provided to them.*
9	*The essential process of education, that is, enabling the learner to achieve planned learning outcomes, does not change when e-Learning is applied.*
10	*Only pedagogical and access advantages will provide a lasting rationale for implementing e-Learning approaches.*

As soon as the theory was stated, the members of the consortium aroused a series of other questions during their discussions. The theory is, from an objective point of view, still at its development stage, meaning that there is place for further changes. Nevertheless, the core statements are already formulated, which represents a solid starting point for the development of e-Learning strategies.

At this stage, the existing e-Learning theory seems to be a standardized form of the already existing definitory characteristics on which e-Learning was initially based. Now that the theory was elaborated, developers can easier create systems that follow the same regulations. Consequently, most e-Learning developers have followed these ten statements, consolidated through theory, without having them as foundation though. Because of the standardization process and due to the active content interchange between institutions and platforms, the emerged e-Learning theory has become the most important source of reference in modern education.

2.3 E-Learning: design principles and content elaboration

Most e-Learning principles for have been generally developed on the basis of various opinions and assumptions. This means that the topic has not yet been approached through classic research, may that be empirical or theoretical.

However, there are studies where e-Learning has been described through systematic task-oriented research. Clark and Mayer (2002) elaborated a set of five e-Learning principles for the proper design of e-Learning models and content in general. These five principles are not only based on empirical research but also on psychological theories analyzing the way in which the cognitive process works for human beings. In this dissertation, I used the five principles as reference points for the elaboration and design of a specific e-Learning content, able to create a proper learning environment.

The Multimedia Principle

This principle is based on the cognitive theory describing the human learning system and it makes reference to the above-mentioned research evidence (i.e. Clark and Mayer 2002):

It seems almost trivial that a combination of text and image is better than a raw text. The real challenge here is not the simple combination of text with image, but the combination of meaningful text with the relevant graphics. This principle sustains that learners will engage in active learning by connecting word and graphics. Graphics that just style the page do not influence the learning process.

The Multimedia Principle is based on the cognitive learning theory, in which information is to be delivered by the means of active learning. Active learning is the process that helps the learner mentally connect visual and verbal learning material. In other words, cognitive learning will concentrate on making the learner understand the new information received by connecting it to his already existing knowledge.

The learning content integrated in this thesis will adapt to the previously described theory of cognitive learning, because my strong belief is that words alone, as the information delivery theory[10] stipulates, are not able to transmit information as fast as words combined with images, presentations, etc.

The Contiguity Principle

Words and corresponding graphics should be placed near each other for the realization of a contiguous space. Having connected words and figures separated form one another creates a distortion in the learning process by obliging the learner to develop distributive attention. This, of course, will reside in diminishing the learning process and instead of acquiring information the learner will have to structure and connect the information in order to absorb it.

The model created for this dissertation thesis is based on the contiguity theory. By applying it, we will focus on a better visualization of all elements, which is concretized through the splitting of the screen into three windows. Those three windows (see Figure 38) represent as follows:

- upper right corner - a multimedia window where the simulation is displayed;
- lower right corner - the glossary is presented;
- left side - text and multimedia together.

The Modality Principle

The Modality Principle is also based upon the cognitive principle and it stipulates that an explanatory video text should be presented in an audio-format as well. This means that when we want to explain the content of the graphic(s), we should rather use sound than text. The motivation would be that graphics and text will overwhelm the learner's visual channel[11], making the use of the auditory channel a more appropriate descriptive strategy.

The same principle has been used for the thesis, especially when elaborate graphics had to be presented, so that the screen will still be able to display all the needed information for a specific lesson. An obvious disadvantage of the audio presentation is that it is extremely time-consuming.

10 The information delivery theory stipulates that teaching consists in providing information and learning consists in absorbing information and that, as long as the information is delivered, the presentation form is not important.

11 Visual and auditory channel are two separate cognitive channels.

The Redundancy Principle

The Redundancy Principle stays in direct connection with the Modality Principle. A redundant onscreen text is, for example, a text that already exists in an audio format which explains a graphic found on the same screen. The psychological theory backgrounding this principle is the *learning styles hypothesis* (cf. Ramos 2005) which presumes that learners have different learning styles, some visual, some auditory. This theory is somehow anchored in the *cognitive learning theory*, which is based on the following assumptions:

(a) all individuals have separate learning channels (as in visual and auditory);
(b) channels have a limited material procession at one time;
(c) learners create models through connections between visual and auditory material.

Exceptions to these rules can appear when, for example, on the screen there are no multimedia elements displayed so that the actual text will not appear as redundant. The onscreen printing is not redundant either when the pace of the lesson is not so rapid. When designing the learning material/content of this thesis, text was displayed in a different frame of the same screen, which will always allow the learner to separate multimedia from text and, in this way, to efficientize the usage of the visual learning channel.

The Coherence Principle

In the case of this principle, it is always the *cognitive learning theory* which draws the main guidelines. The focus lays, this time, on the fact that adding interesting new material that will spice up the content can be harmful for the learning process. In other words, adding background music or other sounds that may distract, will eventually disrupt the learning process and cause dropout. Presenting interesting but not essential learning material, like background music, stories or detailed text description, harms learning. *Distracting* from important to non important material, *disrupting* by eliminating the linkage between important materials presented and *seducing* by presenting unimportant material before an important one, are methods which may cause ineffective learning and e-Learning dropout.

3 Materials

This chapter describes the necessary material for the development of the e-Learning modules characteristic for two different types of content: GIS and Remote Sensing. We will also present detailed information on the investigation area of Waldkirch, which represents the data-resource (LIDAR-based) case-study for the e-Learning modules developed in this paper. Finally, reference will be made to the large spectrum of software (detailed description of the self-developed ISVisualisation software) which has been used for the processing of such materials.

3.1 Content sources for the GIS and Remote Sensing e-Learning modules

3.1.1 The content for the GIS e-Learning modules

The content of the GIS lessons was created on a new structure designed and applied to a special type of e-Learning platform. The resources backgrounding the construction of the e-Learning modules on GIS were manifold: the learning material at FeLIS[12], international GIS publications, Internet resources, etc. The learning material present at FeLIS is the actual material taught to the student during the regular learning process.

Table 3. Succession of e-Learning modules in ILIAS

No. L/M	Topic of the Module/Lesson	Task	Time estimated in min.
1	Introduction	Understanding GIS	30
2	GIS Practical Structure	Understanding GIS	30
3	Earth’s Geographic Coordinate System	Understanding GIS	30
4	Maps and GIS	Understanding GIS	30
5	GIS Data Models	Data in GIS	30
6	The Object Data-model Concept	Data in GIS	30
7	The Thematic Geodata Model	Data in GIS	30
8	The Database Concept	Data analysis	30
9	Data and Data Aquisition	Data analysis	30
10	Data evaluation in GIS – part I	Data analysis	30
11	Data evaluation in GIS – part II	Data analysis	30
12	Errors in GIS	Errors	30
13	Spatial Analyst	Data analysis	30
14	Earth’s Flattening Exercise	Understanding GIS	15

12 Source: http://portal.uni-freiburg.de/felis

In Table 3, the GIS e-Learning modules which have been designed in ILIAS (see Chapter 6 for details on the platform selection) are briefly presented. They are divided into 4 groups, depending on the difficulty level and connection to one another.

Together with the responsible for the GIS education in our department, Dr. C.P. Gross, I conducted traditional GIS classes, being, in this way, directly confronted with difficulties that students have in understanding GIS theory and praxis. That is why the content of the GIS e-Learning modules has been a combination of personal experience in the field of GIS (60%) and, at a lower degree (40%), international literature[13].

3.1.2 The content of the Remote Sensing e-Learning modules

The content enclosed in the Remote Sensing e-Learning modules was designed in MOODLE (see Subchapter 4.1.6.2.) and is based on data from the so-called Waldkirch Scenario[14]. At a generally level, the design and the succession of the lessons was conceived in such a way as to match the general-to-precise (or: background-to-specific) information course strategy (see Table 4 below).

Table 4. Succession of e-Learning modules in MOODLE

No. M/L	Topic of the Module/Lesson	Activity	Time M/L
1	"Waldkirch Scenario"	▪ presentation of the region of Waldkirch	25
2,3	"LIDAR equipment" "LIDAR system selection problems"	▪ short introduction to LIDAR ▪ documentation on aircrafts ▪ documentation on LIDAR systems ▪ problems occurring during LIDAR system usage	25
4,5	"Laser data acquisition" "Laser data acquisition – data structure"	▪ scanning planning ▪ data structure elements	25
6	"Strip Adjustment"	▪ data processing	25
7	"Error compensation"	▪ information about data positioning errors, distance errors and laser beam related errors in LIDAR data	25
8	"ALS data filtering" (Part I)	▪ methodological approaches for the filtering of errors from LIDAR data	25
9	"ALS data filtering" (Part II)	▪ further methodological approaches for the filtering of errors from LIDAR data	25
10	"Visualization"	▪ visualization and processing of the LIDAR-based software	25

13 One of the most important books used in the development of the e-Learning module development was Concepts and Techniques of Geographic Information Systems (Lo, C.P. & Albert K.W. Yeung 2002), which is a complete overview of the GIS theoretical frame and practical instructions.

14 The Waldkirch scenario is the case study presented in the MOODLE e-Learning modules.

In the first lesson, the region of Waldkirch was described based on information found in Wikipedia[15] and on the town's website[16]. Being relevant to the topic as well, the information on the problematic of flooding and its alternative solutions - also related to the town of Waldkirch - were presented based on a report elaborated in cooperation with two institutes: *IPTA*[17] *Informationsverarbeitung* and *COOPERATIVE Infrastruktur und Umwelt*[18] (Stradt Waldkirch 2006). Additionally, we used images of the affected region (Iercan et al. 2007) processed in our department, pointing in this way at the implication of FeLIS in the Waldkirch scenario. A short introduction to LIDAR was also provided based on information coming from NASA[19].

The second module focused on the documentation upon aircrafts, which was made available by service and hardware providers such as RIEGL[20] or Helicam. For instance, the information on LIDAR equipment (e.g. range finder LIDAR) came from different hardware provides: *IGI - Ingenieur-Gesellschaft für Interfaces* from Germany, *Laseroptronix* from Sweden, *Leica Geosystems* from Switzerland, *Riegl Laser Measurement Systems* from Austria, *TopoSys* from Germany and *Optech* from Canada. Research Institutes, such as the Institute for Navigation at the University of Stuttgart[21], also helped us with information (e.g. DIAL LIDAR systems).

In addition to that, we constantly referred to specific literature in the field when approaching the design of the e-Learning modules. For instance, the LIDAR data acquisition process, and especially the LIDAR point determination, was inspired by the work of Katzenbeisser (2003). In order to explain the coordinate system used for data determination, Iercan's (2003) and Großmann's (1976) papers were used, the former to explain the World Geodetic System (WGS 84) and the latter for details related to the 2D coordinate system Gauss-Krüger. The LIDAR system calibration was inspired by Lindenberger's (1993) work whereas the LIDAR specific data format description was based upon the work of ASPRS (2003). LIDAR point determination, orientation data acquisition and orientation accuracy are all based on the paper of Wehr and Lohr (1999). Cramer's (2004) study inspired the description of the digital

15 Source: www.wikipedia.org
16 Source: http://www.stadt-waldkirch.de/
17 Institut für Physikalisch Technische Auftragsforschung (see: http://www.ipta.de/Geschichtliches.html)
18 Detailed information: http://www.cooperative.de
19 Source: http://www.ghcc.msfc.nasa.gov/sparcle/sparcle_tutorial_moreLIDAR.html
20 Source: http://www.riegl.com, http://www.helicam.ch/
21 Source: http://www.nav.uni-stuttgart.de/navigation/forschung/flugzeug_laserscanner/

airborne cameras and their calibration. The exemplification of the described cameras was based on articles in Sandau (2005).

The next step, after data acquisition, is data processing, which aims at systematically eliminating errors that can intervene from various reasons. The “one dimensional error adjustment model”, “the area adjustment approach” described in the paper from Brenner and Vosselman (2006) and the “homologous features”, present in Kager’s (2004) work, set the lines for the strip adjustment methods presented in the lesson called “Strip Adjustment”.

For the lesson “Error compensation”, information about data positioning errors, distance errors and laser beam related errors in LIDAR data was generated on the basis of Katzenbeisser’s (2003) study on the calibration of LIDAR sensors.

Lessons nine and ten called “ALS data filtering” Part I respectively Part II, present a large spectrum of methodological approaches for the filtering of errors from LIDAR data. The methods presented in the two lessons are inspired from the work of various authors, as follows:

- Robust Interpolation Filter – cf. Kraus & Pfeifer 2001;
- Progressive TIN Densification – cf. Axelsson 1999/2000;
- Modified Slope Based Filter – cf. Roggero 2001;
- Modified Slope Based Filter - cf. Vosselman & Sithole 2001;
- Active Contours – cf. Elmqvist 2001;
- Regularization Method – cf. Sohn 2002;
- Hierarchical Modified Block Minimum – cf. Wack & Wimmer 2002;
- Spline Interpolation – cf. Brovelli 2002;
- Hierarchic Robust Interpolation – cf. Pfeifer & Briese 1998/2001.

Lesson eleven, called “Visualization”, presents the visualization and processing of the LIDAR data based on software, which has been developed at FeLIS. Detailed information on this software can be found in Weinacker and Koch (2004) and Iercan (2007).

3.2 Investigation site Waldkirch

Waldkirch is a small town of 20,000 inhabitants located in the south-west of Germany, in the Black Forest region, at the altitude of 260m ASL (Above the Sea Level). Three rivers flow through Waldkirch: Elz, Altersbach and Dettenbach.

Elz and Altersbach are well dammed and under control. Dettenbach became a problem as soon as town's infrastructure started to flourish and it is nowadays considered a flood risk factor. Dettenbach's hydrographical basin is situated at an altitude varying between approximately 260m and 1050m. It is captured into an open cannel that is supposed to transport it to the River Elz.

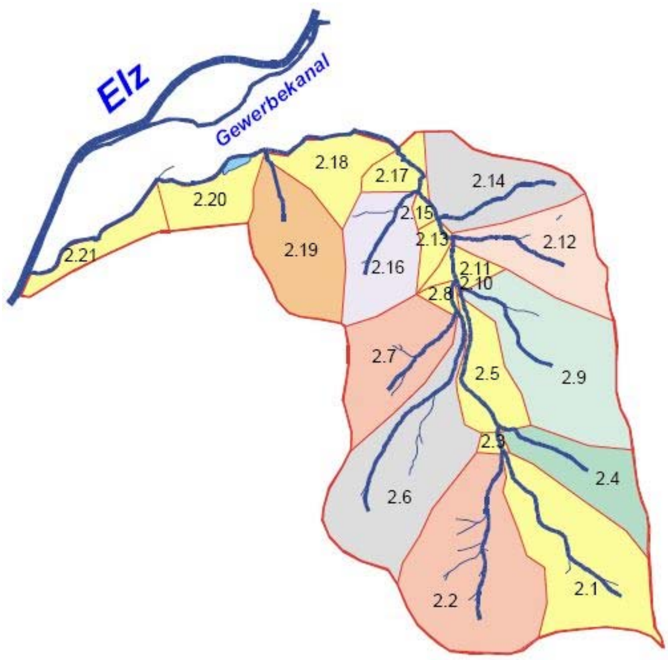


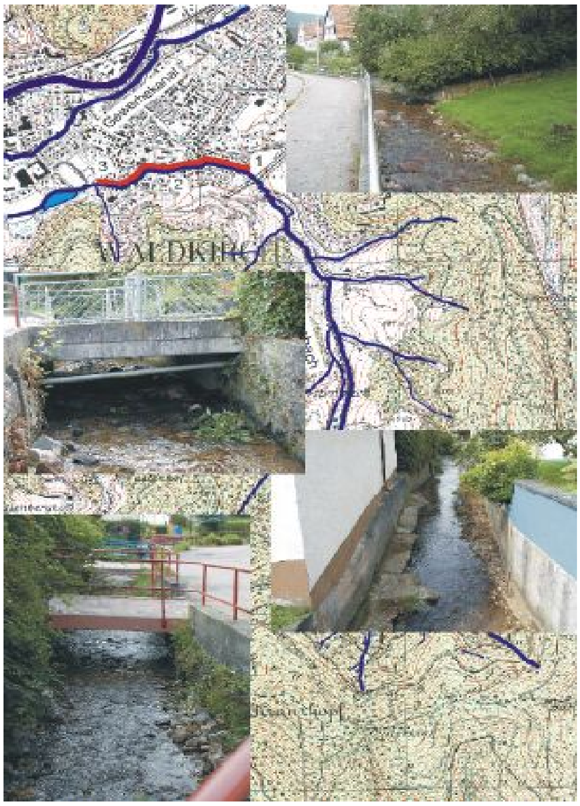
Figure 1. The Dettenbach basin (cf. Stadt Waldkirch 2006)

The entire river basin has a surface of 622ha and it is divided into 21 sub-basins as shown in the above figure. The medium slope gradient is 20%, but in some of the sub-basins it can reach up to 40%. The headwater sums 90% of the entire basin whereas the middle and the lower ditch of Dettenbach represent only 10%. These latter have values ranging from 4% to 6%. Knowing these values, we can easily speculate that a flood in the lower ditches of the basin can happen any time the weather conditions favor it. The lower ditches of the Dettenbach River are located in the town of Waldkirch, where the river is captured by a channel that has the role of transporting it to the collecting River Elz.

The transportation capacity of the cannel is overpassed very often and numerous houses suffer damages. In 2002, Waldkirch was flooded by the Dettenbach River, which flows directly through the city (see Figure 2). The City Hall decided to take action in eliminating the causes for such an undesirable effect. Several experts were contacted in order to find a solution to the problem. In fact, the solution to the problem is of hydrological origin and the options that the hydrologists gave to the City Hall were rather practice-oriented than aesthetic. However, since the region of Waldkirch is a touristic area, such a solution would have been inappropriate.

The experts proposed two solutions. The first one implied the construction of transversal concrete dams in order to block the flood. Their water-retaining capacity would be based on a water quantum approximation valid for a rain with a time-span probability of one hundred years (HQ100). But such dams were not the solution that the City Hall had in mind, because of the discrepancies with the neighboring landscape. The solution was actually considered as "the last resource". The second option was to create water accumulation whose effect would be the speed reduction of the water masses. But the question now was "How to measure the volume of these ditches?" Well, the solution is LIDAR.

Figure 2. Dettenbach channel (Waldkirch 2006)



Using the LIDAR technique, not only that the three dimensional view of the landscape would be available, but, through a very sophisticated simulation method elaborated at the University of Stanford, the water flow during the flood could be quantified.

Wanting to contribute to the research and/or information campaign to the benefit of the local population, decision makers and all interested, the University of Freiburg decided to become a part of the project and help the city of Waldkirch in visualizing the relief of the problematic region. Through specially designed tools, we could actually visualize the dimensions of the dams that could be created and the form of the relief in the region. For this precise purpose, the Department for Remote Sensing and Landscape Information systems (FeLIS) has developed specific visualization software to be used online as well as offline:

1. The **TreesVis software** is an offline-software developed at FeLIS, which is used for visualizing and manipulating LIDAR data.

2. Another software program that was developed at FeLIS for the present dissertation project is the **ISVisualisation**, which can be used for visualizing LIDAR data online.

3.3 LIDAR technology and data

LIDAR is an acronym for Light Detection and Ranging whose guiding principles, the same as in the case of normal RADAR, can be briefly explained as follows: a beam, in our case a laser beam, is “shot” out of an emitter (also called laser scanner) and then this beam of light travels to the surface of the earth and hits objects on the surface. The beam is partially absorbed and partially backscattered to the LIDAR system, which contains a range unit that will detect the beam and its characteristics. When the beam of light contacts a specific object, its spectral composition or, better said, the wave length, change. In this way, when the scattered beam is captured, some properties of the object can be detected. The distance between the emitter and the target can be determined by counting the time that the beam takes to travel to the target and back.

3.3.1 LIDAR vs. RADAR

As already mentioned, a Laser Radar System (or Light Detection and Ranging - LIDAR System) is very similar to the regular RADAR system. The obvious difference between them is the wave length used: LIDAR uses a wave length 10 to 100,000 shorter than the one used by regular RADAR. LIDAR scanning method can be pulsed and continuous wave, where the pulsed can be mono or multi-pulse, i.e. from one to four pulses per scanning process. The modern LIDAR systems, called Coherent Laser Radars (CLR), record, apart from the regular intensity and time delay, the phase of the backscattered radiation as well.

3.3.2 LIDAR technology classification

Time of flight is the most commonly used LIDAR technology. It makes use of the so called pulses to determine the distance between the scanner and the target object. Knowing the speed of light, the big challenge would be to count the pulses emitted and received.

Multiple frequency phase-shifts technology uses the wave length differences to determine whether an object is solid or has a different type of aggregation form. In fact the wave-length changes appear after the emitted wave has been backscattered by an object. This technology is also used for determining position as well as for detecting specific characteristics of the objects.

Interferometry is the most practical technique for measuring high resolution information on astronomical objects.

In radar, one use of interferometric techniques is to determine the angle of arrival of a wave by comparing the phases of the signals received at separate antennas or at separate points on the same antenna. Another interferometric application is to shape and steer the beams of phased- array antennas by adjusting the phases of the different elements of the array. [22]

3.3.3 LIDAR system classification

Range finders

The *range finder* LIDAR systems are the simplest LIDAR systems and they are normally used for measuring distances to a specific solid target. This type of LIDAR systems represent the most spread LIDAR sensing techniques and they are also known as *time-of-flight* scanners. Compared to other LIDAR systems, they are considered to be the most suitable for developing digital elevation models for cities or open landscape forms, being, at the same time, the most economical ones.

DIAL

DIAL is an acronym for *Differential Absorption LIDAR.* This type of LIDAR is used for determining chemical concentration of a specific *Element of Interest* (EOI) in the atmosphere.

By using this kind of LIDAR, measurements for determining the concentration of pollutants in the atmosphere have become easier. The quantification process is based upon the difference in signal intensity between two absorption processes: (1) a laser beam with a wave length that will be absorbed by the EOI and (2) a beam that is characterized by a wave length with no absorption for the EOI.

Doppler LIDAR Systems

Doppler LIDAR Systems are used in order to calculate the speed of an object or atmospheric suspensions. The emitted laser beam will be backscattered and modified by the element of interest (EOI). The speed is measured by using, in the first place, the time elapsed from the emission till the detection of the laser beam and, secondly, the wave length differences or shifts, also called the Doppler Shifts, intervening in the process. The wave length is modified depending on the direction and sense of motion of the EOI. If the EOI moves towards the LIDAR system, the wave length will be shorter and vice versa: if the EOI moves away from the LIDAR system, the wave length will be longer. The two deviances have specific names: *Blue Shift* for the shifts with a resulting lower wave length and *Red Shift* for the resulting higher wave length. The Doppler LIDAR is often used by the police force in building speed traps but it is also very used in meteorology to determine the speed of atmospheric anomalies such as hurricanes.

3.3.4 LIDAR data storing standardization

When scanning an area with any laser scanner, the resulting data has to be stored on the scanner's hard disks. Different vendors have been using different data containers (file types) for data storage. Since 2005, a standardized file type has been used that should satisfy the needs of every vendor. This new file type is called LAS and it was first brought to the public in March 2003, being afterwards updated in March 2005. The data is encoded in an open source binary format and it is meant to provide all vendors with similar output data. It consists of three blocks: public header block, variable length records and point data.
The public header contains general information on the data, such as number of points, or supplementary information on the boundaries of the coordinates in which the data is recorded.

22 Source: the American Meteorology Society Glossary (http://amsglossary.allenpress.com/glossary/browse?s=i&p=29)

PUBLIC HEADER BLOCK:

Item	Format	Size	Required
File Signature ("LASF")	char[4]	4 bytes	*
(1.1) File Source ID	unsigned short	2 bytes	*
(1.1) Reserved	unsigned short	2 bytes	
(1.1) Project ID - GUID data 1	unsigned long	4 bytes	
(1.1) Project ID - GUID data 2	unsigned short	2 byte	
(1.1) Project ID - GUID data 3	unsigned short	2 byte	
(1.1) Project ID - GUID data 4	unsigned char[8]	8 bytes	
Version Major	unsigned char	1 byte	*
Version Minor	unsigned char	1 byte	*
(1.1) System Identifier	char[32]	32 bytes	*
Generating Software	char[32]	32 bytes	*
(1.1) File Creation Day of Year	unsigned short	2 bytes	
(1.1) File Creation Year	unsigned short	2 bytes	
Header Size	unsigned short	2 bytes	*
Offset to point data	unsigned long	4 bytes	*
Number of variable length records	unsigned long	4 bytes	*
Point Data Format ID (0-99 for spec)	unsigned char	1 byte	*
Point Data Record Length	unsigned short	2 bytes	*
Number of point records	unsigned long	4 bytes	*
Number of points by return	unsigned long[5]	20 bytes	*
X scale factor	double	8 bytes	*
Y scale factor	double	8 bytes	*
Z scale factor	double	8 bytes	*
X offset	double	8 bytes	*
Y offset	double	8 bytes	*
Z offset	double	8 bytes	*
Max X	double	8 bytes	*
Min X	double	8 bytes	*
Max Y	double	8 bytes	*
Min Y	double	8 bytes	*
Max Z	double	8 bytes	*
Min Z	double	8 bytes	*

Table 5. LIDAR data public header block (cf. ASPRS 2005)

The variable length record header is also used for storing all kinds of projection information. This allows for a later definition of different projections, even custom ones. The header has a mandatory record, the GeoKeyDirectoryTag.

VARIABLE LENGTH RECORD HEADER

Item	Format	Size	Required
(1.1) Reserved	unsigned short	2 bytes	
User ID	char[16]	16 bytes	*
Record ID	unsigned short	2 bytes	*
Record Length After Header	unsigned short	2 bytes	*
Description	char[32]	32 bytes	

Table 6. LIDAR data variable length (cf. ASPRS 2005)

The defined variable length records are used for the storing of georeferencing information. In order to georeferenciate a LAS format, the GeoTIFF mechanism is used. The GeoTIFF key tag of a TIFF file will be contained in the variable length header section of the LAS format.

In the following table, the actual data are saved: coordinates, pulse return numbers, the direction in which the scanner mirror was traveling at the time of the output pulse, point classification, etc.

POINT DATA RECORD FORMAT 0:

Item	Format	Size	Required
X	long	4 bytes	*
Y	long	4 bytes	*
Z	long	4 bytes	*
Intensity	unsigned short	2 bytes	
Return Number	3 bits (bits 0, 1, 2)	3 bits	*
Number of Returns (given pulse)	3 bits (bits 3, 4, 5)	3 bits	*
Scan Direction Flag	1 bit (bit 6)	1 bit	*
Edge of Flight Line	1 bit (bit 7)	1 bit	*
(1.1) Classification	unsigned char	1 byte	*
(1.1) `Scan Angle Rank (-90 to +90) – Left side	char	1 byte	*
(1.1) User Data	unsigned char	1 byte	
(1.1) Point Source ID	unsigned short	2 bytes	*

Table 7. LIDAR data point data record (cf. ASPRS 2005)

3.3.5 LIDAR data in use

The scanners used in order to obtain the data from the Waldkirch region belong to the category of Range Finder LIDAR Systems. The first dataset, collected in 2002 by the *Landesvermessungsamt Baden-Württemberg* (LV-BW), used an ALTM 1225 LIDAR system, which is developed by the firm Optech in Canada.

Table 8. System details ALTM 1225

LIDAR System	ALTM 1225
Altitude	900-2000 m
Range measurements	up to 2 pulses
Scanning frequency	max. 25 Hz
Scanning angle	+/- 20^{o}
Maximum Pulse Repetition Frequency	up to 25 kHz

LV-BW normally collects data in wintertime because they are interested only in generating Digital Elevation Models (DEMs) of the terrain and not so much in analyzing vegetation. In other words, their primary goal is to generate Digital Terrain Models (DTMs) that represent Earth's surface without any vegetation or human interference, i.e. buildings, bridges, etc.

Optech is the manufacturer of the Airborne Laser Scanning System (ALSS), the Airborne Laser Terrain Mapper Series (ALTM) and the SHOALS Airborne Laser Bathymeters System.

Figure 3. ALTM (cf. *Optech*)

In August 2005, the *Ingenieur-Gesellschaft für Interfaces* (IGI) organized the second data acquisition flight, by using a LiteMapper 5600. Given the fact that this flight had a scientific purpose, it was the Fullwave Data Scanning Method [23] which prevailed. On the basis of the information extracted with the help of the Fullwave data Digital Surface Models (DSMs) and Digital Terrain Models (DTMs) were generated so that further analyses on vegetation could be carried out.

IGI is the manufacturer of the LiteMapper systems: the LiteMapper 2400 and the LiteMapper 5600. The LiteMapper 5600 is the solution for high resolution laser data, as it can record all echo wave forms and can be mounted on airplanes and helicopters. It can provide relevant data for 3D information and is suitable for vegetation mapping.

Figure 4. LiteMapper (cf. *IGI*)

23 Fullwave scanning is a airborne laser scanning technique.

The two above-mentioned LIDAR systems use scanners from the Austrian laser scanner manufacturer *Riegl*. LiteMapper 5600 uses the Riegl LMS Q560, which has the following technical characteristics:

Table 9. System details LiteMapper 5600

LIDAR System	**LiteMapper 5600**
Laser Wavelength	1550 nm
Altitude	30-1850 m
Range measurements	Fullwave form
Scanning frequency	max. 160Hz
Scanning angle	+/- 30^{o}
Maximum Pulse Repetition Frequency	up to 100 kHz
Beam divergence	0,5 mrad
Beam pattern	parallel scan lines

3.4 Software

A series of software has been used either for the realization of the e-Learning content adapted to the ILIAS and MOODLE platform or for the development of the ISVisualisation. The range of the most important software, adapted to the goals of this dissertation, is presented in the following:

Java

Java was originally developed by James Gosling under the name Oak. Later on it was taken over by SUN Microsystems and in 1995 released as SUN Java.

The language derives much of its syntax from C and C++ but has a simpler object model and fewer low-level facilities. Java applications are typically compiled to byte-code which can run on any Java virtual machine regardless of computer architecture. Java now forms the core of Sun's Java platform[24].

Java is an object-oriented program language. Most distributed programming applications are written in Java and new technologies allow its utilization on mobile devices such as mobile telephones, electronic agendas or palmtops. In this way, at the programmer's level already, a

24 Source: www.wikipedia.org (http://en.wikipedia.org/wiki/Java_(programming_language))

common platform is created that rules upon a heterogeneous and extremely diverse environment. The advantage of using Java is evident for programmers who “write once and execute on a random Java Virtual Machine (JVM) (Grigoraş 2003)” but also for users that will benefit from a large spectrum of services. Hence, it should be pointed out that “Java is a winner in the volatile world of information technology” (cf. ibid.)

The Java language is often referred to as a very practical support tool in terms of complex Web applications. The main characteristic in its favor is the user-friendliness by which the development, maintenance and updating of the applications can be approached. More than that, it disposes of a complete package of features which makes it attractive to users: platform independence, easy reutilization of code, Internet-available documentation etc.

When describing the Java technologies used in web applications, one has to bear in mind various technical aspects. In the first place, it is important to establish the way the web-application development software is installed and configured. In this respect, there are some Java technologies which are worth mentioning especially because of their rapid and simple implementation: Servlets, Java Server Pages, Taglibs, Struts, Spring, Hibernate and Java Server Faces. Secondly, it is important to emphasize the fact that these technologies are also - or especially - addressed to the beginner-programmer, who has a minimum of necessary knowledge of Java language and Web applications.

It is therefore recommended that the users first undergo a trial-and-error phase when working with Java: for instance, to realize projects which range from easy to complex applications (Tănasă & Olaru 2005). In addition to that, one of the strategies during the Java-use learning process is problem-solving, which implies the confrontation with a specific problem, the choice of an appropriate approach, the analysis of the given conditions and the selection of the implementation possibilities. Another aspect to be taken into consideration here is the necessity of thinking the given problem correctly so that the application can be easily implementable and improvable.

In conclusion, it can be said that using Java for the development of a three dimensional viewer for Remote Sensing data is a pertinent way of making data available to the public. The Java programming language represents the general reference point on which ISVisualisation relies, whereas the core of the application development was inspired by the VisAD library, which will be presented later.

NetBeans IDE

NetBeans IDE is an open source Integrated Development Environment (IDE), property of Sun Microsystems, that has been developed in Java on the basis of the NetBeans Platform. Being based upon the NetBeans platform, the IDE has a modular structure, in which a module is represented by a Java archive. For the sake of concision, we will use both terms in this thesis: NetBeans and NetBeans IDE. However, it should remain clear that they will be both understood as NetBeans IDE, because the NetBeans platform was not actually and directly used in the development of ISVisualisation. Generally speaking, NetBeans is an out-of-the-box product used for the development of all Java applications such as J2SE, Web, EJB or mobile. By using add-ons, it can be also used as a development environment for other programming languages such as C/C++, Ruby, Visual web, etc.

The usage of an IDE for the development of ISVisualisation, on the other hand, was mandatory because of the multitude of Java libraries that needed to be loaded in order to have a functional application. NetBeans made the connection between libraries such as VisAD, Java3D, ImageJ, JGrass, Jump, etc. possible. NetBeans also contributed to the development of the ISVisualisation software by reducing the debugging and processing procedures. Debugging in NetBeans is very efficient because the developer does not have to compile a programme in order to find the syntax errors: they are automatically marked in red. Processing is made easy by eliminating command-line routines for memory management.

VisAD

VisAD is an acronym for the Visualization for Algorithm Development and it is a Java-based library which enables scientists to conduct collaborative work by sharing routine data inside projects (Hibbard 2002). The VisAD development system was founded upon object-based technology and it is meant to be used for distributed objects that are present in the www and not necessarily on a singular server.

The VisAD Java class library can be defined through four object categories: *data objects, display objects, computation objects* and *user interface objects*. *Data objects* are containers for numerical data such as images, series, grids or simple numbers. They can be depicted as *display objects* in visualization windows. *Computational objects* are used for calculations that use data objects as raw material. *User interface objects* are the connectors used between the user and the program and are represented by buttons, icons, etc. (Hibbard 2002).

The VisAD data model was developed in order to be able to recognize any type of hierarchically organized data (Murray et al 2001). Such a feature can be realized by defining classes that are able to handle all numerical data in the same way, rather than defining specific classes for each type of data. VisAD data model contains a meta-data processor which allows the recognition of the correct data schema that should be used in displaying the data. VisAD does not consider this metadata functionality as mandatory for displaying a data package. In any case, when distributed data is loaded on a display, it is imperative to use metadata for differentiation and emphasis, which can be achieved by positioning and pointing out relationships between two or more datasets.

Java 3D

Java 3D is a Java-based library that is used in developing, manipulating and displaying three dimensional graphics inside Java applications. It is also a scene-graph based three-dimensional application programming interface for Java. Java 3D inherits from Java all the functionalities that are available through OpenGL or DirectX renderers and offers an easier object-oriented program scheme.
The rendering speed for programs using Java 3D offers them the potential of being as quick as applications written in C or C++ using OpenGL or DirectX renderers.

TreesVis

TreesVis is a powerful processing, analysis and visualization software for LIDAR data developed at FeLIS (University of Freiburg). TreesVis was developed in order to be able to simultaneously visualize several datasets in real-time. This was made possible without the use of large video hardware resources. The combination of the DirectX digital library with specific computer graphics methods such as CLOD[25], culling[26], ROAM[27], Quad tree, Geo-

25 CLOD - Continuous Level Of Detail – represents a procedure which can be described as follows: the switch from one LOD to another is visible very often, especially during camera movements, because it creates a strong plopping. This effect can be avoided through continuous form changes (morphing), which makes the level fit continuously.

26 Generally speaking, culling means the masking of render objects. All these elements will not be transferred to the graphic processing unit (GPU).

27 ROAM - Real-time Optimal Adapting Meshes

Mapping made the success of the software development possible (Weinacker, Koch & Weinacker 2004).

TreesVis is a LIDAR-oriented software that handles data resulted from pulsed laser scans (first-last pulse or intermediate pulsed) as well as data resulted from continuous scans (full-wave). The raw data must be read and buffered by TreesVis in order to be further processed. The processing can include the calculation of Digital Elevation Models (DEMs) under the form of Digital Terrain Models (DTMs) or of Digital Surface Models (DSMs). The software was initially designed for working with forestry data, but in the meantime TreesVis has been further developed so that now also city data can be processed and analyzed with its tools. The software offers the possibility of eliminating noise from data, such as shadows, buildings (from the DTMs) or simply objects that are not part of the intended result.

TreesVis provides the comfort of a graphical user interface (GUI) as well as the control over an output-shell able to monitor the various processing steps. GUI itself comes in common Windows style and is easy to use due to its self-explanatory menus.

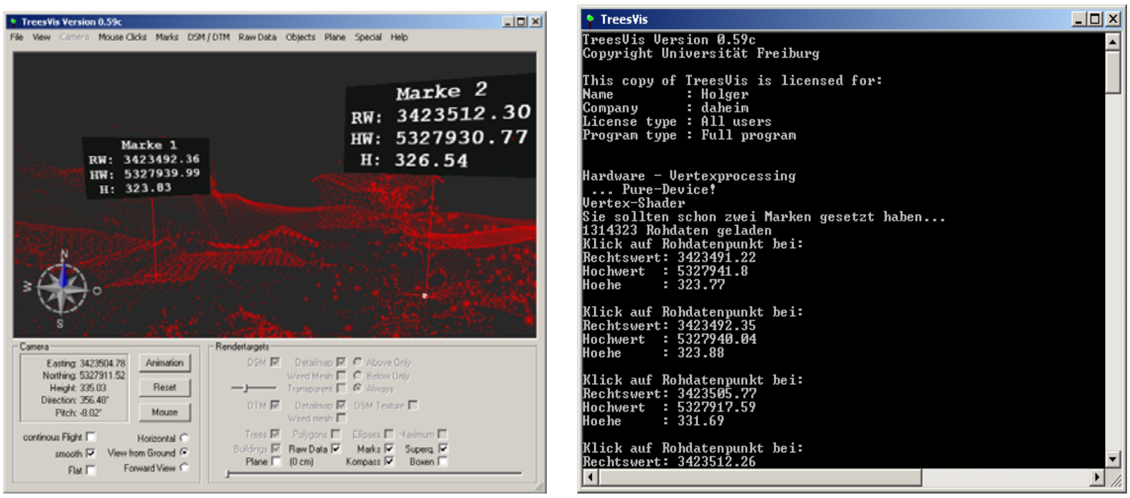


Figure 5. TreesVis - LIDAR Raw data and terrain marks (left); Output shell (right)

Geographical Information Systems (GIS) software

When presenting GIS data, the first GIS software vendor that comes in discussion has to be the Environmental Systems Research Institute Inc. (ESRI). The firm sells its products at a large scale in Germany and covers a huge market space. For this reason, ESRI is well represented in the learning process at the University of Freiburg. It means that students already have basic knowledge of ESRI software. In such context, it is perfectly justifiable why the simulations presenting GIS data are based on this type of software.

Table 10. GIS Software used in e-Learning module development

Software	Observations
ArcView 8.2 & 9	Desktop product part of the ArcGIS software package
3D-Analyst (ArcScene)	3D visualization in ArcGIS

ArcInfo is the high-end GIS software that has been used in this dissertation in order to develop the simulations on which the e-Learning GIS content is based. The software package ArcInfo offers the possibility of visualizing DEM in a three-dimensional view by using a large spectrum of processing possibilities, such as ArcGlobe. For the simulations on satellite data, both LIDAR processed data and vector data have been used.

ISVisualisation

ISVisualisation (see subchapter 4.3.3.) is a visualisation software developed within this PhD project for the visualisation of LIDAR raw and processed data as well as 3D models with other provenience and stored in Tiff data format.

Adobe Captivate

Adobe Captivate is a former Macromedia product based on Flash technology, which easily allows the user to create simulations, scenario-based training or quizzes, without previous programming knowledge. With the help of this software, entire processing steps can be followed and memorized. By using this functionality, students can see how a processing step actually works, by giving them the possibility to access the presentation as often as needed. Flight simulations of the LIDAR data collection processes can also be realized within this software.

Other software

Another software program which can be used as a basis for various e-Learning platforms is *Apache Server*, a SQL database which sets in fact system requirements for the installation of the two e-Learning platforms ILIAS and MOODLE. The types of software used for the content development were: *Enterprise Architect* (*EA*), used for the realization of the UML scheme of the Waldkirch Scenario's Workflow; *eXe* was used for the development of SCORM exercises; *Open Office* was used in connection with *iLAIX* and *ILEX* for the development respectively packaging of the e-Learning content.

4 Methodology

4.1 Analysis and selection of the e-Learning standard and platform

Books have been the most important information and data containers for the last two millenniums. They are still important but, nowadays, the electronic storing mediums are much more flexible and easier to store than a book. The content of thousands of books can be stored on a hard-drive that has just about the size of one A5 format book. Each of these books can be accessed in real-time and specific quotes can be searched at once.

Returning to books, they consist of pages - just like e-Learning content does - which are composed of paragraphs, lines, etc. Books are afterwards sorted by genre or author or another selection criterion and put on a shelf in a library. The shelf is part of a library wing where, let’s just say, technical books are present. In the same section of the library, we will find books on mechanics or computer programming, which are sorted on different shelves according to their bibliographical annotation. By expanding the comparison, we can imagine that the e-Learning content is organized in a specific way. Let's just presume that e-Learning is another method of collecting and storing data and information, exactly like books are. Does not e-Learning need then specific categorizations for the sake of the organizational aspect of the e-Learning library?

The answer to this question is directly connected to the problematic of establishing e-Learning standards, which is definitely an up-to-date debatable topic. In this context, the need of an e-Learning standardization is perfectly justified. The major argument in favor of the development of such standards is in fact the necessity of having an overview of the content and processes that handle e-Learning content. Moreover, it is not only the development of the content itself (and the processes that accompany it) which counts when framing a standardization pattern, but also the content interchange and the content export, which are of utmost importance for the evolution of e-Learning.

The other dimension supporting the utility of having standardized norms for e-Learning refers to the nature of e-Learning itself: having its roots in CBL (Computer Based Learning), electronic learning is nowadays understood as online learning by the means of the World

Wide Web. The standardization of e-Learning is therefore even more necessary because of the amount and variability of content exchange that could be realized between the many e-Learning platforms and versions all over the world. In order to go through a productive and structured process, the e-Learning content interchange should apply to *Learning Objects*[28] .

Much like the e-Learning theory (Nichols 2003), the e-Learning standardization has been developed after the e-Learning software already existed. Being industrially and economically conditioned, the different developers had no interest in developing standardizations that would encourage content interchange between their e-Learning platforms. Nowadays content development is more important than platform development since platforms are already available in a multitude of forms and they are also partially free of charge. Even more important than content development is the possibility of using already existing content on different platforms without having to convert them to the new system.

At the moment, e-Learning standardization appears in different variants released by some platform developers such as IMS (Instructional Management System), AICC (Aviation Industry Computer Based Training (CBT) Committee), O.K.I. (The Open Knowledge Initiative), etc. The work done by these e-Learning platform providers has been independently conducted and is therefore very much differentiated. Acknowledging the need of unifying these distributed standardizations, the Department of Defense (DoD) of the United States Army has decided to initiate and support the project called Advanced Distributed Learning (ADL).

4.1.1 E-Learning standardization selection process

E-Learning standards are differentiated into *de jure* and *de facto*. Standards are *de jure* when a specification is certified by an accredited body, like IEEE, ISO or CEN/ISSS. The *de facto* standards are those that are adopted and used by the majority of the users. I am on the search of an e-Learning standard that could, first of all, satisfy the latter condition, but it would be great if it would also satisfy the former.

E-Learning standardization is, at the moment, the most important challenge in the field of electronic learning. “Most Learning Management System (LMS) or content vendors today

28 Explained in detail in Chapter 4.1.1.

claim some sort of compliance or conformance with the latest learning standards" (MASIE 2002). What compliance or conformance means and how standards are understood by the LMS developers differs from one vendor to the other. Because of this "lack of standardization" in defining which platform complies with what standard, the users that have to select an e-Learning platform are confused. The guarantee of compliance with a specific version of a standard is the certification given to the LMS by the authority in the field, such as IEEE, ISO or CEN/ISSS.

E-Learning standards are needed for the description of a series of specific characteristics of the Internet learning nowadays. An e-Learning standard has to fulfill the following five characteristics: accessibility, adaptability, affordability, durability and interoperability .The first of these characteristics would be the *accessibility* aspect. Accessibility is considered as the ability to locate and access instructional components from one remote location and deliver them to other locations. The second aspect would be *adaptability*, which is delineated as being an ability to tailor learning instructions to individual and organizational needs. The third characteristic is the ability to increase efficiency and productivity by reducing the time and costs involved in delivering instructions. This characteristic is named *affordability* of an e-Learning standard. The fourth characteristic is *durability* and can be understood as the fact that an e-Learning standard can be used an indefinite time and is not affected if the software changes in time. The fifth characteristic is *interoperability*. The meaning of interoperability is that the standard is independent from hardware, operating systems as well as from web browsers. Another important characteristic would be *reusability*: it gives you the opportunity to use various development tools in order to obtain a better version of the standards.

4.1.1.1 E-Learning standards

Intending to find the best suitable e-Learning standard for the future e-Learning platform of the NaturNet-Redime project, I began searching for possible candidates. In Appendix I, there is a list of e-Learning platforms that were included in the selection[29]. As it will be presented later on (Chapter 6.1), e-Learning standardization criteria have been thoroughly analyzed. The standard specifications with the highest impact were the following: IEEE LOM, IMS Content packaging, AICC RTE and SCORM (as a reference model to integrate the specifications

29 The e-Learning platform list was created by searching for platforms on the Internet on different websites like: www.elearningeuropa.info , www.campussource.com , www.wikipedia.org , http://ec.europa.eu/education/index_en.html

above) (cf. Neumann & Geys 2005). The main organizations that contribute to the development of e-Learning standardization are:

Table 11. E-Learning standards

Standard	
ADL/SCORM	Advanced Distributed Learning/Sharable Courseware Object Reference Model
AICC	Aviation Industry Computer Based Training(CBT) Committee
ARIADNE	Alliance of Remote Instructional Authoring & Distribution Network for Europe
DC	Dublin Core
IEEE/LOM	Institute of Electrical and Electronic Engineers/Learning Object Metadata
IMS	Instructional Management System
SIF US	k12 XML and Infrastructure specifications
O.K.I	Open Knowledge Initiative - application/service functional interoperability standards

After a selection period, in which all of the above-named standards were described and evaluated, I drew the conclusion that SCORM is the standard that will be studied. The decision was rather easy to take since SCORM is not actually a standard but a collection of specifications and standards. SCORM is considered the solution to future e-Learning standards and, not surprisingly, lots of scientific articles have SCORM (and the usage of SCORM in e-Learning) as target. Selecting SCORM as a standardization model turned it automatically into the basic selection factor for the e-Learning platform that had to be chosen as a software tool in the NaturNet-Redime Project. The software issue was accordingly discussed at FeLIS, during a technical Workshop, and the software approved.

In order to better display and contrast the properties of the analyzed standards, I conceived a connection schema (Figure 6), between the main e-Learning standards and SCORM. On the left side of the image DC, ARIADNE and IMS are connected, pointing, at the same time, to IEEE LOM. The latter is the result of the cooperation between IMS and ARIADNE, whose joined effort determined the creation of this standard. On the other hand, DC also contributed with metadata elements to the IEEE LOM (Stratakis et al. 2003). The connection between IEEE LOM and SCORM Metadata Specifications reside in the mapping of the IEEE LOM to SCORM and further on in the usage of the results in the Content Packaging Metadata of SCORM. The AICC provided the Content Structure Format to ADL, this content being later integrated in SCORM CSF. The Content Packaging standardization of SCORM is the result of embedding IMS CP into SCORM in combination with AICC CMI and IEEE LOM.

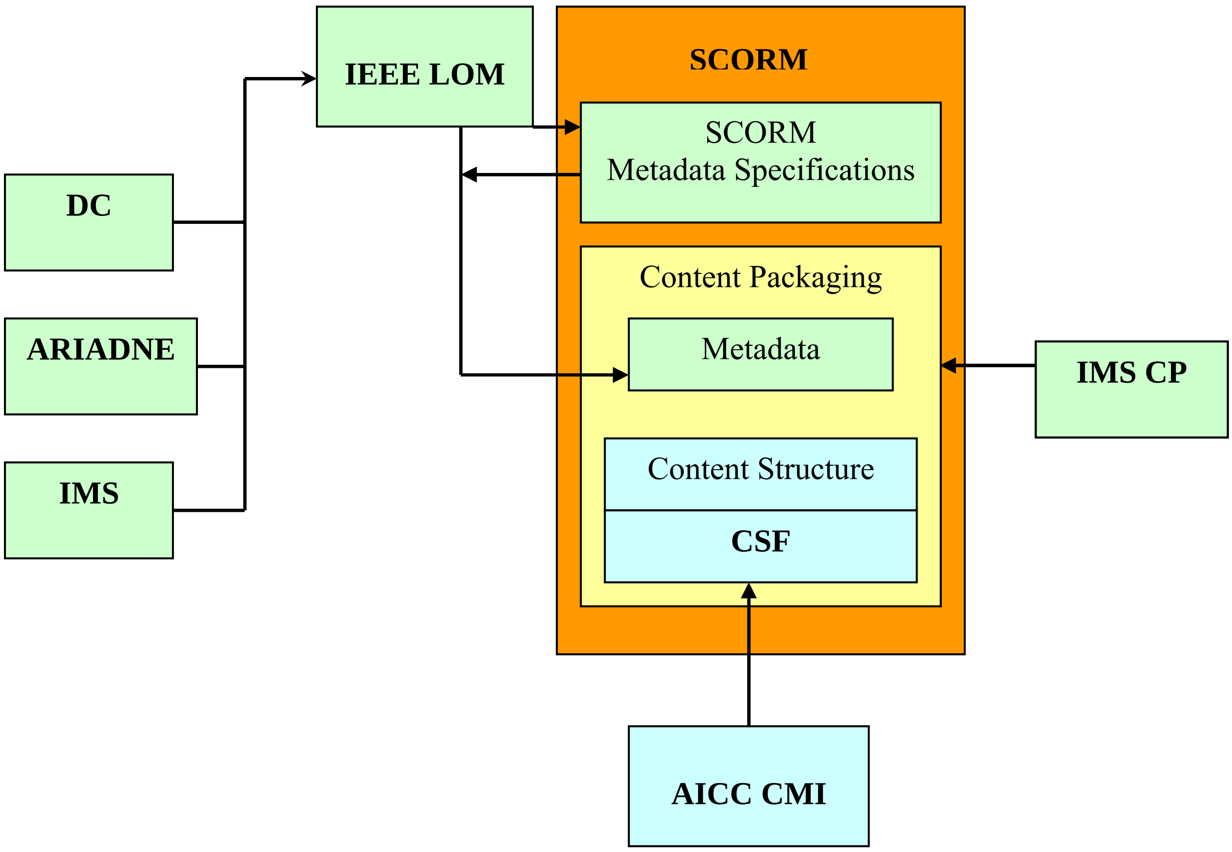


Figure 6. Main e-Learning standards having as central subject the SCORM Standard

4.1.1.2 Elements of interest for the e-Learning developers at European level

At European level, an interesting EU research initiative proposed the analysis and evaluation of various research projects, under the *Thematic Monitoring* of the *Leonardo da Vinci Program*. This analysis involved 149 projects spread in 27 countries around the European Union. All the projects were in some way related to e-Learning and, in addition to that, the monitoring team wanted to emphasize the clear relationship of each of these projects with e-Learning. The team established a set of questions that would most likely give an overview of the situation. The following image is a graphical representation of the responses to the question: *Which elements of chain receive the most attention within the specific project?*

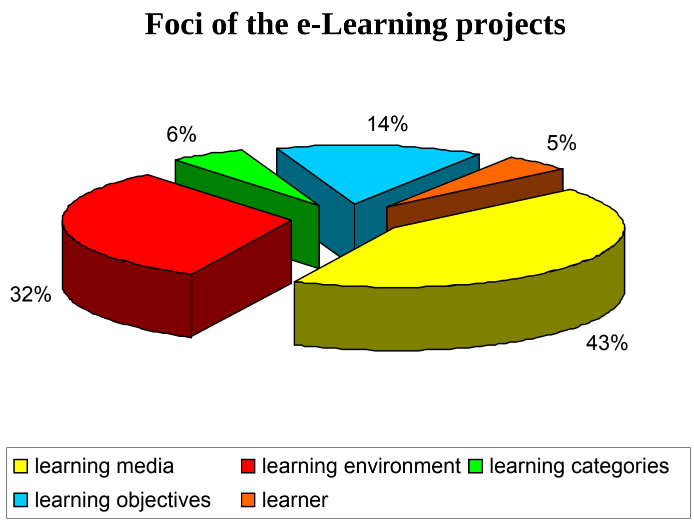


Figure 7. Distribution of attention foci (cf. *E-Learning in Europe*)

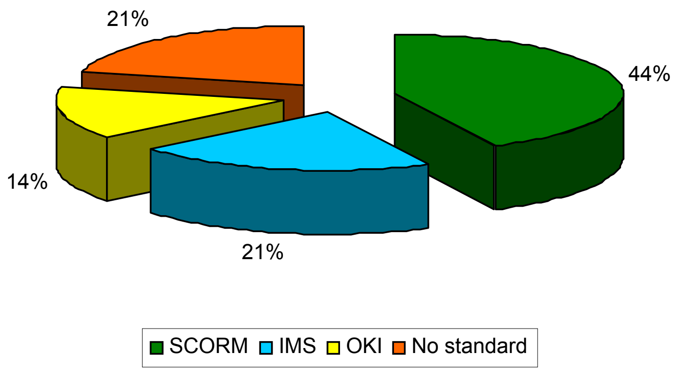
As we can clearly see in the figure above (Figure 7), attention is drawn to the technological part of the development of e-Learning projects: 43% is allocated to the learning media and 32% to the learning environment. But what percentage of this total of 75% is allocated to the standardization of the e-Learning platforms? This question is of practical interest to all e-Learning users and developers since the whole world is longing for data and information interchange. However, answering it is a challenge that this dissertation is not going to pursue. Rather than doing that, after establishing a list of the most important e-Learning platforms existing on the market, this thesis is going to determine for how many platforms the content standardization is of major importance.

4.1.1.3 Standardization of the open source e-Learning platform content

Appendix I presents, as already mentioned, the e-Learning platforms that have been selected, from the large offer present on the Internet, for further analysis. It actually contains a list of open source e-Learning platforms as well as a list of commercial e-Learning platforms.

In this part of my analysis there are the open source platforms which will be set under the "magnifying glass". The list sums 14 open source e-Learning platforms: 21% of them are not standardized or offer no information on the standardization that has been applied in developing the platform. It must be mentioned here that some e-Learning platforms, either open-source or commercial ones, offer almost no information regarding their standardization, development language, internal features, etc. Back to the list, we notice that other 21% of the platforms are IMS standardization compliant, 14% are OKI standardization compliant (both platforms were developed in Japan under the lead of the OKI consortium) and the majority of 44% are SCORM compliant. The compliancy with the SCORM standardization is either done through the SCORM 1.2 compliance or SCORM 2004, but most of the platforms are already SCORM 2004 compliant. Whether the platforms comply with one or the other standardization was not tested (i.e. installment on a server), because the vendors' official descriptions were taken for granted.

Figure 8. Open source e-Learning platform standardization



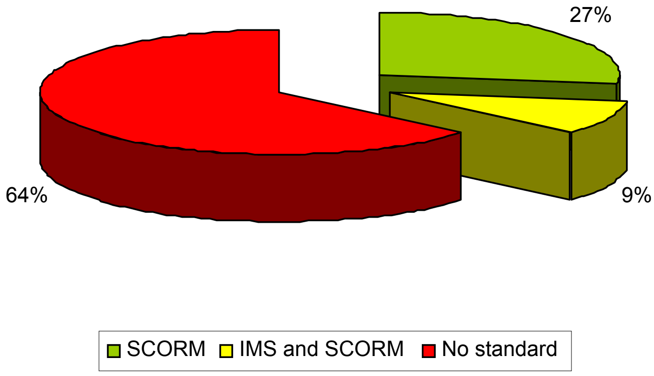
Open source platform developers are interested in the SCORM compliancy because of the facilities emerging from sharing content between many e-Learning projects that offer their contents free of charge. At the European level, the need of information exchange is enormous and the European Union manifests an increasing interest in free e-Learning content at the service of the European citizens. From this perspective, the NaturNet-Redime project also takes active part in the further development of free e-Learning content which can be used by all European citizens.

4.1.1.4 Standardization of the commercial e-Learning platform content

Commercial e-Learning platforms present less interest than the open source platforms in generating standardized e-Learning content. The statement is based on the fact that, from the 22 commercial e-Learning platforms present in Appendix I, 14 have no standardization or do not offer any information on their standardization. In the following chart (see Figure 9), it is easy to distinguish the majority of 64% of the above-mentioned platform category. The rest of

36% is divided between SCORM and IMS standardization. The 27% represent the SCORM-compliant e-Learning platforms. The last category is represented by the 9% IMS- and SCORM-compliant platforms. In this category, the “big players” in the e-Learning industry are included, namely Blackboard and WebCT. The most important commercial e-Learning platforms are both IMS and SCORM compliant, fact stating that the importance of the e-Learning standardization is well taken into consideration not only in the commercial sector of the e-Learning technology but also in the open-source sector.

Figure 9. Standardization of the commercial e-Learning platforms

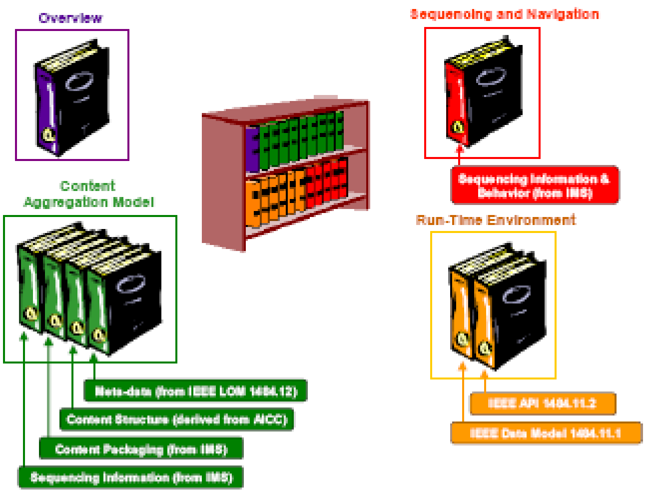


4.1.2 SCORM

SCORM is a collection of specifications and standards that have been bundled into a collection of “technical books.” Each of them can be viewed as a separate book, but gathered together they grow into a library. Nearly all specifications and guidelines are taken from other organizations (ADL 2004).

The Sharable Content Object Reference Model (SCORM) is divided into four books: Overview, Content Aggregation Model, Run Time Environment and Sequencing and Navigation.

Figure 10. SCORM Books



(cf. *Advanced Distributed Learning (ADL), Sharable Content Object Reference Model*, 2004)

The *Overview* book provides an overview of the SCORM documentation suite, covering its roots, vision, aims and goals. In fact this book is more about the concept of the entire standard and provides at the same time the terminology used for the standard.

Table 12. SCORM books content

SCORM Books	Concepts covered	Key SCORM technologies covered	Overlapping areas
Overview	High-level conceptual information	Introduction to numerous high-level elements of SCORM terminology	- Covers areas of CAM, RTE, and SN books at a high level
Content Aggregation (CAM)	Assembling, labeling and packaging of learning content	SCO, Asset, Content Aggregation, Package, Package Interchange File (PIF), Meta-data, Manifest, Sequencing Information, Navigation Information	- SCOs and manifests - SCOs communicate with an LMS via RTE - Manifests contain Sequencing and Navigation information
Time Environment (RTE)	LMS's management of the RTE, which includes Launch, content to LMS communication, tracking, data transfer and error handling	API, API Instance, Launch, Session Methods, Data Transfer Methods, Support Methods, Temporal Model, Run-Time Data Model	- SCOs are described in the CAM book as content objects which use RTE
Sequencing and Navigation (SN)	Sequencing content and navigation	Activity Tree, Learning Activities, Sequencing Information, Navigation Information, Navigation Data Model	-Sequencing and Navigation affects the way in which content is assembled in a manifest

(cf. *Advanced Distributed Learning (ADL), Sharable Content Object Reference Model*, 2004)

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The *SCORM Content Aggregation Model* (CAM) book describes the component of the e-Learning system that is used in the learning process, the component packaging and the export of data from one platform to another. It also describes the navigation and search inside the system as well as the sequencing of the components. The CAM was created as a bundle from the following standards:

- Meta data from IMS (IEEE LOM 1484.12)
- Content structure (AICC)
- Content Packaging Information Model (IMS)
- Sequencing Information (IMS)

For the realization of a Content Package, the rules presented and described by the standard manifest are followed. The manifest is the core of the SCORM Content Package and is represented by a file called *imsmanifest.xml* written in Extensible Markup Language (XML). This xml file describes the contents of a package and it can also describe the structure of the package. A package in the SCORM standardization can be a course but it may also be a simple collection of objects connected to each other (ADL 2004). The SCORM Content Packaging specification was created on the basis of the IMS Content Packaging Information Model. Because of this, each package is composed of: (a) an xml document, *imsmanifest.xml*, which is the descriptor of the package and sets its organization and (b) the *learning material*, composed of text, media or other types of files.

As presented in Figure 11, the manifest is composed of metadata, organizations and resources. The *metadata* element is a XML component which describes the manifest by using a metadata standard such as SCORM Metadata, IMS Metadata or IEEE LOM. The *organizations* component of the manifest is also a XML element that is used for structuring the content resources in order to present them. Structuring means, for example, that we can use Table of Contents (TOC), AICC CMI, SCORM CSF or other variants. *Resources* is a section which contains references to all the actual resources and media elements needed for a manifest (including metadata) and designed to describe resources, references to any external files and sub-manifests[30].

30 They can contain zero or more logically nested manifests.

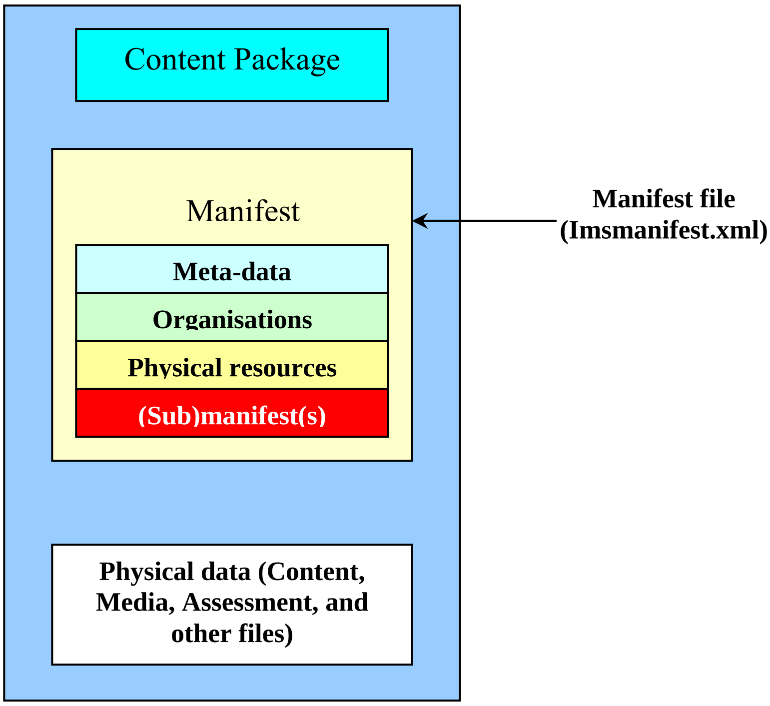


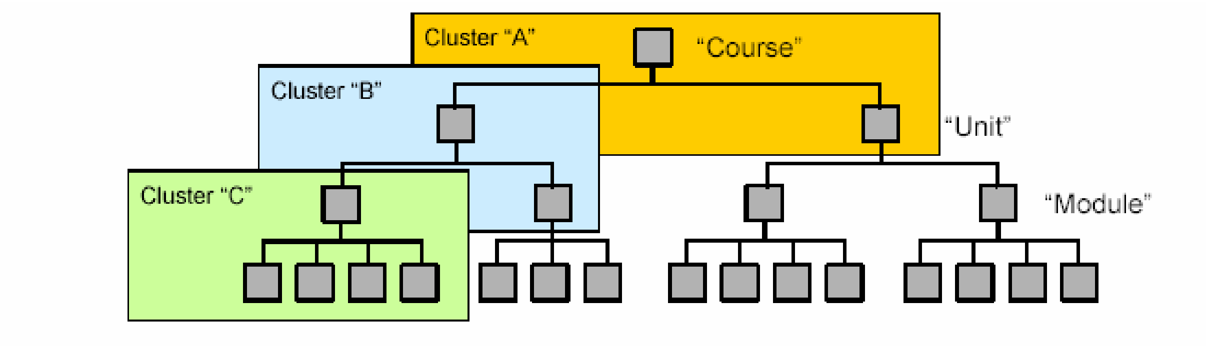
Figure 11. Conceptual Content Package

The aggregation and unfolding of content is facilitated by the manifest. All packages contain a head-manifest file which could contain sub-manifests. The sub-manifests are connected with parts of the contents encapsulated in a package. For a better understanding of the packaging, try to imagine that a content editor would like to export a series of courses, each of them having a manifest file. When bundling together the separate courses with their manifests, a top-level manifest that will encapsulate all other manifests could be created. Packages can be interpreted as regular directories, which contain: a manifest file (imsmanifest.xml), format control documents for the manifest (e.g., DTD, XSD), and a set of sub-directories containing the physical files and a single file (e.g., .zip) where the logical directory of the package is placed. This last file is named Package Interchange File (PIF) (cf. Stratakis et al. 2003).

The *SCORM Run-Time Environment* (RTE) book describes the Learning Management System (LMS) requirements for managing the run-time environment (i.e. content launching processes, communication between content and LMS and standardized data model elements used for passing information about the learner) (ADL SCORM 2004)**.** The RTE is based upon two IEEE standards, the IEEE 1484.11.2 API (Application Program Interface) and the IEEE 1484.11.1 Data Model for Content Object Communication, which give the user the opportunity of having an API and a data model for managing SCOs.

The *SCORM Sequencing and Navigation* (SN) book describes how content could be accessed through learner or system navigation and it accordingly states if the content would be conform to the SCORM standardization. This book also describes the tree structure of the content and the workflow, which includes a series of activities. It also gives details on the reaction of the SCORM-compliant LMS system when the sequencing rules are launched by navigation events initiated by the user of by the system itself. The SCORM Sequencing and Navigation is based on the IMS Simple Sequencing Information and Behavior. An Activity Tree is a conceptual structure of learning activities managed by the LMS, for each learner (ADL SCORM 2004), as shown in Figure 12. SCORM SN has inherited from IMS SS the sequencing of content for the benefice of the learner. A learning activity may have content objects that are referenced and delivered to other players than the learner, even though the roles and behaviors are not explicitly defined for other actors.

Figure 12. Activity Tree Concept



(cf. *Advanced Distributed Learning (ADL), Sharable Content Object Reference Model*, 2004)

4.1.3 Learning Objects

Learning Objects (LOs) were defined by the Learning Technology Standards Committee (LTSC[31]) of the IEEE (Institute of Electrical and Electronics Engineers) as follows: "a Learning Object can be any entity, digital or not, that can be used or referenced in the technology-supported learning."

31 Source: http://ltsc.ieee.org

4.1.3.1 Learning Objects Metadata

Describing Learning Object by using metadata is a reasonable solution for storing information about existing learning resources. It means that important information about the learning process, such as language, duration, editor identity, etc. is already available inside LO.
The most important metadata standardizations are: ARIADNE Metadata, IMS Metadata and Dublin Core Metadata. The first two standards fused together and the result was IEEE LOM 1484.12. Dublin Core was also involved in the unification process by providing different basic elements (DC.descripton, DC.identifier, DC.language, and DC.title) for the definition of the IEEE LOM elements.

IEEE LOM is a standard that specifies the syntax and semantics of LO Metadata by using XML DTDs. It also defines the attributes required to describe a LO, which can be composed of multimedia content, instructional content, learning objectives, instructional software, software tools, persons, organizations or events. IEE LOM focuses on the minimal set of attributes that favor the evaluation, location and management of LOs (Stratakis et al. 2003). The attribute examples for the LO description may be: type of object, author, owner, terms of distribution and format. Other possible attributes of the Learning Object Metadata are: teaching or interaction style, grade level, mastery level and prerequisites. The IEEE LOM takes into consideration nine optional categories for the metadata elements that are directly related with the LOs.

Table 13. IEEE LOM categories

Categories	Functions
General	✓ groups general information describing a LO as a whole
Life Cycle	✓ describes the history and current state of a LO and those affecting the LO during its evolution
Meta-Metadata	✓ describes specific information on the metadata record itself (e.g. who created this record, how and when)
Technical	✓ describes the technical requirements and characteristics of a LO
Educational	✓ describes the key educational or pedagogic characteristics of a LO
Rights	✓ describes the intellectual property rights and conditions of use for a LO
Relation	✓ defines the relationship between a LO and other targeted LOs (if any)
Annotation	✓ provides comments on the educational use of a LO, on the person who created this annotation and on the time when that happened
Classification	✓ describes where a LO is placed within a particular classification system

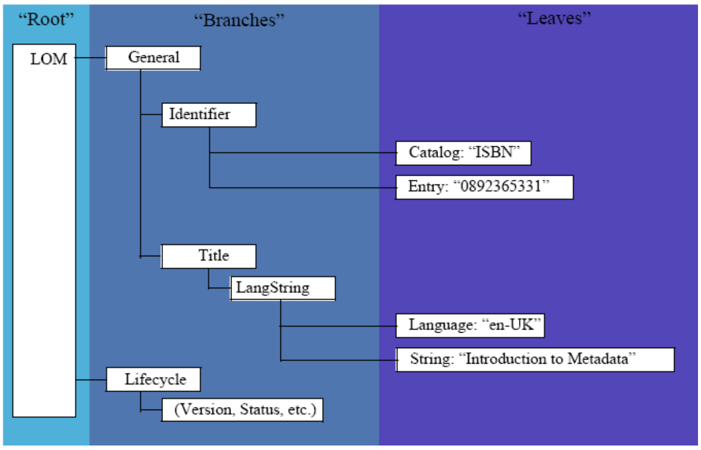
(cf. Stratakis et al. 2003)

Metadata structure definition

The actual status of the metadata standards for e-Learning is quite clear and well documented. A universally accepted metadata standard is IEEE 1484.12.1-2002 Standard for Learning Object Metadata. This standard was adopted by both IMS and SCORM and seems to be the best option for all e-Learning platforms. That is why, in the following, this standard will be presented in detail.

From the beginning, we notice that the IEEE conceptual metadata scheme definition is a hierarchical one. As any hierarchical structure (see Figure 13) it has a "root", "branches" and "leaves". The "root" has numerous sub-categories that are called "branches" and these have sub-categories as well. The categories that have no sub-categories are called "leaves".

Figure 13. The hierarchical structure of the IEEE LOM

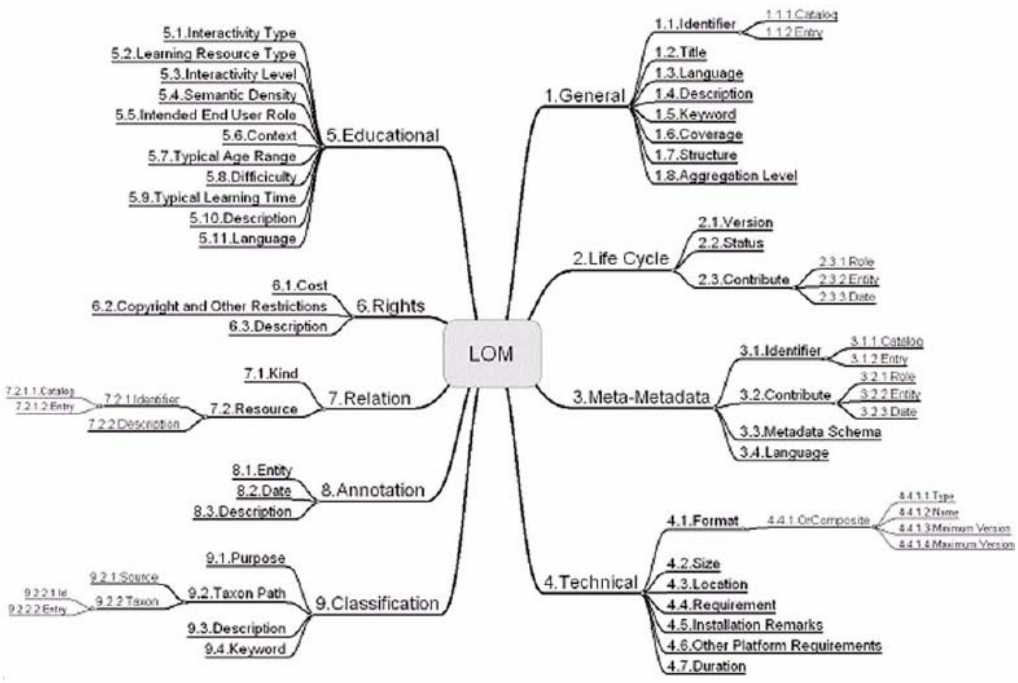


(cf. *IMS Learning Resource Meta-Data Best Practice and Implementation Guide*)

IEEE LOM Metadata Elements and Structure

Elements are grouped into nine main categories: General, Life Cycle, Meta-Metadata, Technical, Educational, Rights, Relation, Annotation and Classification. As already seen in the hierarchical metadata structuring, (Figure 13), LOM is root and it has nine branches and many other sub-branches and leaves. The next figure (Figure 14) shows the tree-display of the metadata element of LOM.

Figure 14. LOM detailed structure



(cf. *IMS Learning Resource Meta-Data Best Practice and Implementation Guide*)

The conceptual data schema above does not show some of the other elements that describe data types and value spaces. Each element of LOM conceptual data schema has a data-type and a value-space. The data-types and value-spaces describe the encoding method used for the data element of LOM. These two can also influence the access to elements and how elements can be used.

The *General* branch of LOM is the one that groups information describing the Learning Object as a whole. This branch is a single instance, meaning that it can be found only once inside a LO description. The *Life cycle* branch of LOM is responsible for the logging of the history of LO and for the current state of resources. It is a single instance, as all the other primary branches. The *Meta-metadata* is a branch that deals more with description rather than with resources. The *Technical* branch is the one concerned with the technical features of the learning object. This branch will be closely looked into in the next subchapter.

Now we will have an overview of the LOM "way of working". The *Educational* branch deals with the educational or pedagogical features of the learning object. The *Rights* branch is the one responsible for the resource conditioning affiliated with the e-Learning activity. The *Relation* branch refers to the resource features in relationship with other learning objects. The *Annotation* branch provides comments on the educational use of the learning object. It is organized in an unordered list and it permits only 30 item entries. The *Classification* branch realizes a taxonomical description of the resource characteristics.

4.1.3.2 SCORM Metadata

The SCORM Metadata is based on the IEEE LOM and follows a three-learning-content element (LCE) structure. It provides the connection between the metadata and the content management models. The three LCE's are considered to be SCORM's granularity levels. In descendant order these are: Course, Content, Raw Media.

SCORM proposes three metadata types: Assets Metadata, SCO Metadata and Content Aggregation Metadata aiming at the reuse and discoverability of learning resources. In the image below (Figure 15), a metadata scheme in XML format is presented.

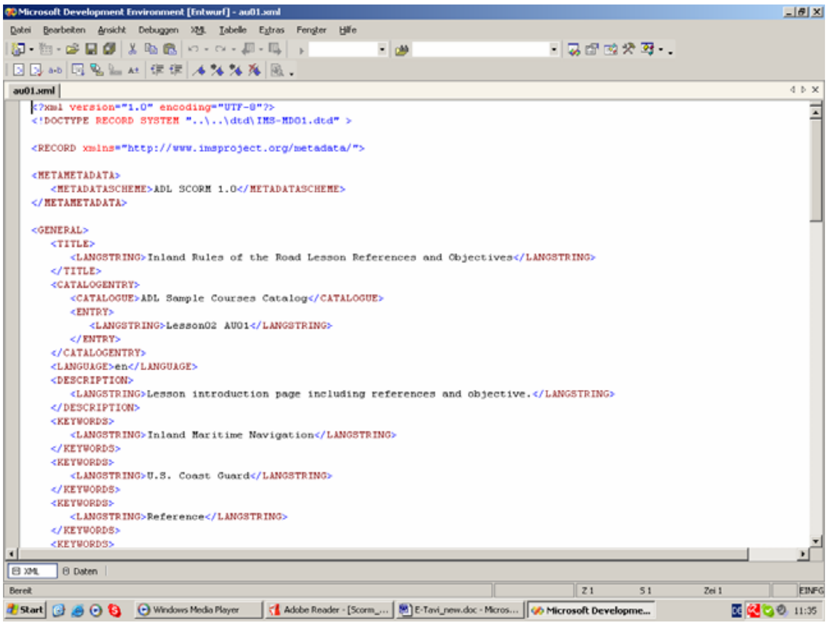


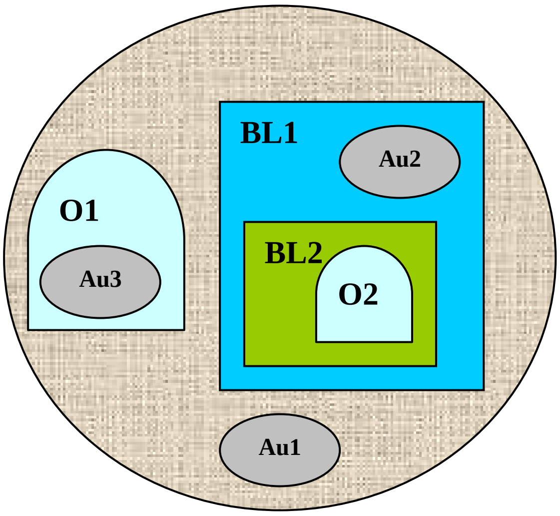
Figure 15. XML example of the SCORM Metadata

4.1.3.3 Content structure modeling

As already shown in Figure 6, the content structuring of the SCORM standardization has been realized through the means of the AICC CMI standard. The AICC content management standard is divided into three types of element entities:

- **Assignable Units (AU)** – the smallest learning entity that can be used in the learning process
- **Blocks** – nesting elements that could nest AUs or Blocks (also called nested blocks)
- **Objectives** – the course exigencies and goals to be reached.

Figure 16. Course structure example



AICC CMI offers interoperability guidelines for the e-Learning content structure. The CMI specification provides a Content Structure Model having the interoperability function. A CMI model is a complex combination of Objectives, Blocks or Aus. The image above maps the AICC CMI structure.

Table 14. AICC CMI structure elements

Assignable Units (AU)	Au 1,2,3
Block (BL)	Bl1,2
Objectives (O)	O1,2

The interoperability is realized through the *prerequisites* definition, i.e. relationships between the elements: e.g. Au1 could be a prerequisite of Bl1 or O2 could be one for O1 and so on. Due to the nesting function of CMI, AICC established ten Granularity Levels. They are presented in the following table:

Table 15. AICC Granularity Levels

Level	Content	Description
First level (higher)	Curriculum	➢ a grouping of related courses
Second level	Course	➢ a complete unit of training
Third level	Chapter	➢ a meaningful division of a course ➢ a grouping of subchapters or lessons (high level block)
Fourth level	Subchapter	➢ a meaningful division of a chapter ➢ a grouping of lessons or modules (middle level block)
Fifth level	Module	➢ logical group of lessons (one or more) ➢ a meaningful division of a course, chapter or subchapter (low level block)
Sixth level	Lesson/AU	➢ a meaningful division of learning that is accomplished by a student in a continuous effort ➢ a grouping of instructions that is controlled by a single executable computer program ➢ a unit of training is a logical division of a subchapter, chapter or course
Seventh level	Topic	➢ logical divisions of a lesson
Eighth level	Sequence	-
Ninth level	Frame/Screen	-
Tenth level (Lower)	Object	➢ component of a screen or frame

(cf. *SeLeNe- Self E-Learning Networks E-Learning Standards*, 2003)

In Table 15, the granularity levels of AICC and IEEE LOM, fulfilling four capital functions of the LO structure, are compared.

Table 16. AICC vs. IEEE LOM LO Granularity

Function	AICC	IEEE LOM (IMS)
Outer Container	Course	Course
Nesting Container	Block	Unit
Content Aggregate	AU	Lesson
Reusable Media Element	Object	-

(cf. Stratakis et al. 2003)

The granularity structure of a LO is similar in the two standards. An analogy between the granularity of AICC with the blocks and the units of IEEE LOM already exists (see Stratakis et al. 2003). However, up to the present time, the reusable media element present in the AICC standard has no correspondent in the IEEE LOM.

4.1.4 The methodology of the expert interview

The Expert Interview is one of the many types of interviews (e.g. problem-centered interview, focused interview, ethnographic interview, group discussion methods) applied as investigation strategies in different research fields.

There has been often stated that expert interviews sometimes lack the methodological foundation, meaning that they are "often applied, rarely reviewed" (cf. Bogner & Menz 2005: 33). Moreover, they cannot be accurately described and prescribed so their status as part of the whole methodological approach is more or less an anecdotic one (cf. Bogner & Menz 2005: 17).

On the other hand, it is clear that any expert interview has to be conceived as an argumentation chain in which the value system, motives, meaningful knowledge, positioning, interaction effects play an important role. At the same time the interviewer has to pay attention to the degree of subjectivity conveyed during the interview so that it may be able to lead, through a complex and context-sensitive background, to expert responses (cf. Bogner & Menz 2005: 15).

Definition

Although it is rather difficult to define expert interviews, because of the variety of possible approaches to it, there are, however, three main theoretical dimensions which can bring some light into describing such interviews: the relational notion of expert, the contextuality of the research application and the continuum from structuring to directness. These three aspects can be correlated in a flexible way, resulting in a different realization and treatment of the interview. From this perspective, one can simply draw the conclusion that expert interviews cannot be defined, especially because on both levels, the implementation-of-the-interview level and the text-analysis level, the same continuum between structuring and directness can be encountered (Krause 2006). At the implementation-of-the-interview level, the continuum ranges from directness and non-influence (characteristic of the reconstructive interview research) to discursive-argumentative committed implementation, i.e. narrative vs. argumentative-discursive conversation.

On the basis of such description, the expert interview can be seen as a hybrid-method. Although sometimes presented as an independent approach (cf. Meuser & Nagel 1991), most scholars consider it as an adjacent method to some other approaches forming the qualitative paradigm of a research process. The reason for not treating it as a separate relevant research method is the fact that it does not have a method in itself; even if it is conducted through a "method", "not everything that involves method, also has method" (Kassner & Wassermann 2005: 95). What distinguishes it actually from the other interviews is the target group (cf. Bogner & Menz 2005:108).

Evaluation

The same variation as above (see: continuum) can be noticed here: evaluations can be perceived as reconstructive-hermeneutic or content-analytic up to 'rather impressionistic' (Kruse 2006).Mauser and Nagel consider the existence of three types of expert interviews: explorative, systematic and theory-generated.

- <u>The explorative expert interview</u> – it explores unknown inventories of knowledge or research fields through thematic targeting. The expert serves as deliverer of all important information and facts. The interview's role can be either to serve as source of information or to become a scientific article. It may be direct but not narrative whereas the interviewer can be direct but reserved, showing his competence in the field.

- <u>The systematic expert interview</u> – it is especially designed to inquire on exclusive professional knowledge and that is why it is the most used type of expert interview. The expert appears here as counselor, giving objective-factual and pertinent answers. As counterpart, the questions are structured, underlying the main parts of the interview. The interviewer is the "co-expert" who conducts an argumentative-discursive discussion.

- The theory-generated expert interview – their purpose is to render the communicative development and the analytical reconstruction of the “subjective dimension” related to the expert knowledge (cf. Bogner & Menz 2005: 38). The focus is on the implicit knowledge and the action routines which are relevant to the “functioning” of the expert actions. The role of the interviewer is the one of a competent partner of discussion.

We have seen that the differences between the expert interview types are tightly related to the interview target group. This fact forces us to formulate the following question:” What is actually an ‘expert’?” There are many notions belonging to the semantic area of “expert”: “specialist”, “the well-informed citizen”, “master”, “evaluator” etc. Literature also makes the distinction between:

- “voluntary expert”	➢ reconstructs subjective representations
- “constructivist expert”	➢ has to be appointed through research-relevant and methodical questions (i.e. methodic-relational approach) or through social expertise (i.e. social-representational approach).
- ”knowledge-sociological expert”	➢ disposes of “special knowledge” which can be applied to a wide but at the same time specific domain.

Table 17. Types of “experts”[32]

Now that we know what an expert is, we probably need to get an answer to a second question: “What is ‘expert knowledge’?” The problematic of the “expert knowledge” terminology refers, again, to various perceptions: (a) it can be seen as the domain-specific in contrast to the knowledge-sociological term; or as (b) “analytical construction” (Bogner & Menz 2005: 43). What is important to underline at this point is that “there are not the high-symbolical special knowledge in itself that makes the expert knowledge interesting, but rather its social effectiveness” (Meuser & Nagel 2005). There are three main dimensions of expert knowledge:

32 Source: Bogner & Menz 2005

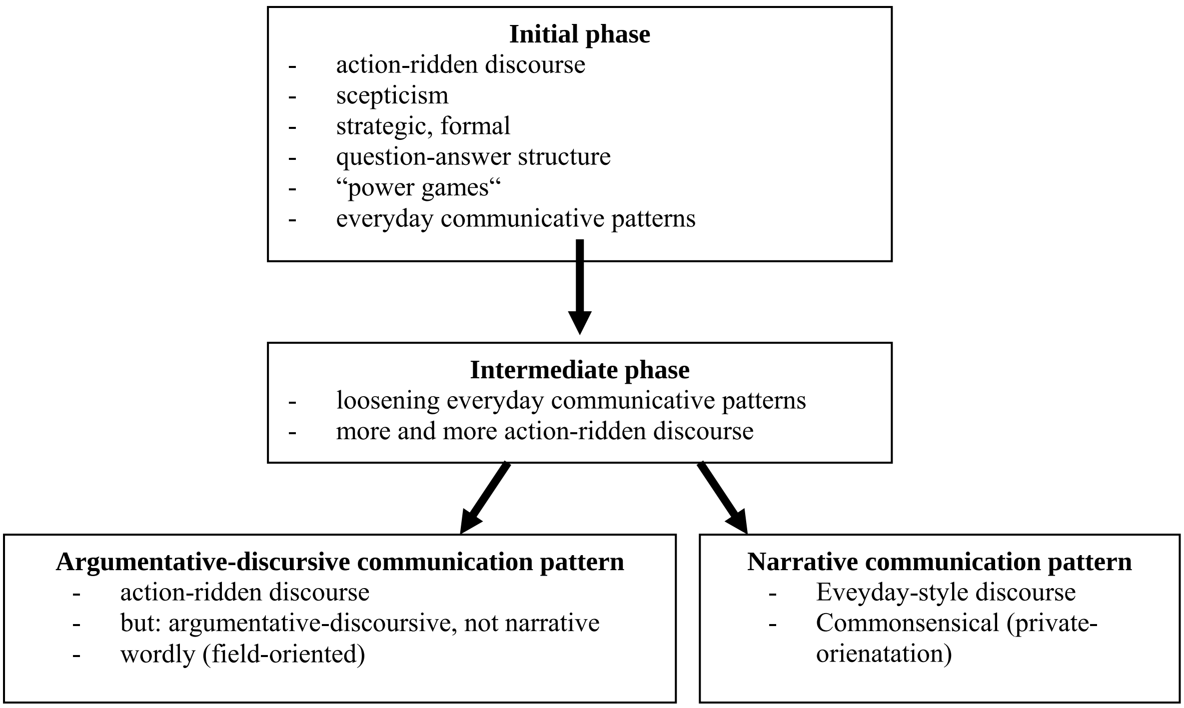
1. technical knowledge, which accounts for the explicit objective knowledge
2. process knowledge referring to informal knowledge, practical experience knowledge or implicit knowledge
3. meaningful knowledge similar to subjective knowledge

Furthermore, Meuser and Nagel (2005: 75) define and describe knowledge management (i.e. self-reflexive knowledge) in comparison to context knowledge (i.e. reflexive assessing knowledge).

Interview content

The most relevant aspects to be considered in an expert interview refer to the thematization and the conducting of the discussion. They are supposed to create the most confident communicative situation possible (cf. Pfadenhauer 2005: 118). In addition to that, there has been often noticed that the narrative elements can influence the discourse in a positive way (cf. Bogner & Menz 2005). However, the narration has to be led in a discursive-argumentative style.

Figure 17. The thematization-structure of the expert interview includes



(cf. Trinczek 2005: 216)

The interview has to respect the so-called “key-principle” (Hoffman-Riem 1980: 346) which states that “the researcher has access to relevant data only when he/she has a communicative relation to the research topic approached”. Based on that, a list of interview-conducting criteria can be set, such as: discursive-argumentative, thematically focused, use of specific terminology, use of the indexed discussion markers, high language economy and habitus (i.e. well educated and self-confident persons who know how to deal with inquisitive situations and complex correlations).

From the archaeological to the interactional model of expert interview
(cf. Bogner & Menz 2005: 47)

The archaeological model of the expert interview starts from context-independent approaches, situational definitions and orientations which are part of the deep human knowledge and aims at bringing them at light with the help appropriate interview techniques (ibid. 47). In this way, the focus of the interaction is on the “data extraction”.

In an interesting way, the interactional model denies the findings of interactionism and social-constructivism: communication always depends on the context and interactions. The expert interview appears as a constant exchange of expectations between the interviewer and the expert, leading to a “text production” (cf. Helfferich 2005). The main elements on which the quality of the interaction depends are: conversation style (open vs. committed), roles and role expectations, sex, age, general expectations, assignments, discussion dynamics etc.

From the expert’s perspective, the typology of interviewer (in an expert interview) follows the pattern indicated by the enumeration below:

- Interviewer as co-expert
- Interviewer as expert of another knowledge culture
- Interviewer as layman
- Interviewer as authority
- Interviewer as potential critic
- Interviewer as accomplice

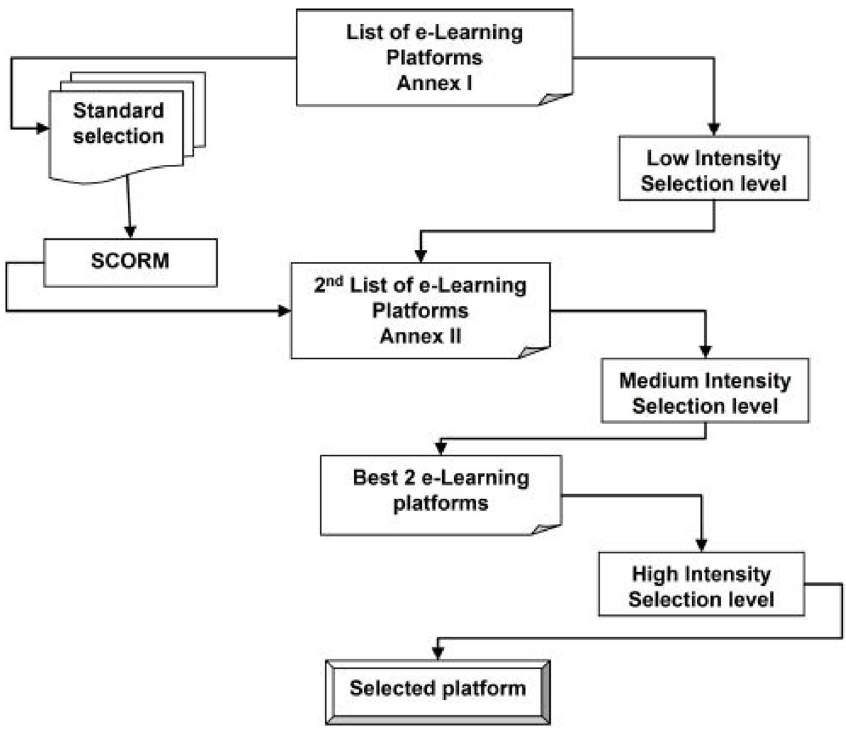
The multitude of variables involved in the problematization of the expert-interview issue leads to the conclusion that the matter should take into account elements of interaction analysis, conversation analysis and positioning analysis (cf. Kruse 2006).

4.1.5 Platform selection process and testing

E-Learning platforms have different nomenclatures and can also be found under such names as Computer-Mediated Communication (CMC), Course Management System (CMS), Learning Management System (LMS), Online Education (e-Learning) or Virtual Learning Environments (VLE).

Before selecting the appropriate e-Learning platform for the chosen modules, I first had to create a list of possible candidates for this job. For this purpose, I started from the same list (see Annex I) of 36 platforms, both commercial and non-commercial, on which the standardization analysis was based.

Figure 18. E-Learning platform selection scheme



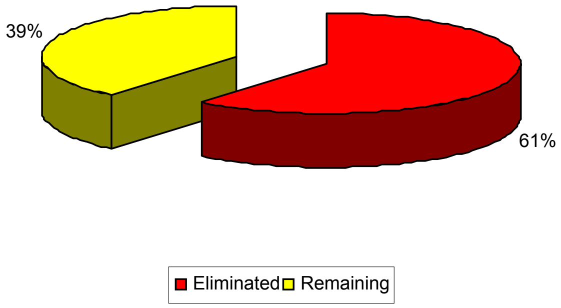
From the beginning, it can be said that such diversity clearly reflects the fact that e-Learning technologies are of big interest not only for the higher education but for free-market education as well. Following to that, I found it difficult to select the suitable e-Learning platform. It was in fact easy to realize that, although it might be difficult to accomplish such a task, its importance is uncontestable. That is why I developed a reasonable selection algorithm that helped me to sort out the best suitable e-Learning platform for the NaturNet-Redime project. In the e-Learning platform algorithm selection schema, three intensity levels were identified: low, medium and high intensity selection level.

4.1.5.1 Low intensity selection level

The low intensity selection level method was the most simple of the three. Having to choose from a rather large range of e-Learning platforms, the first to be expelled from the list were the expensive software solutions. The motivation for this decision is directly connected to the project proposal conceived by NaturNet-Redime. Since the idea of this project was to offer free content and software solutions to the regular European citizen, the cost for purchasing one of the commercial software solutions would have been simply unacceptable.

The second condition for the elimination of candidates at this point was a very poor documentation of the e-Learning platform, beginning with the web page design and finishing with the actual documentation about internal functionalities. It must be said here that platforms that had a poor presence on the Internet were not even selected for the first 36 e-Learning platform samples. This raw selection eliminated a large number of the listed software. In other words, it means, in numbers, that from the entire sum of 36 (see Annex I) only 14 (see Annex II) were considered eligible for the next level. Only 39% of the platforms existing in Annex I fulfill this first criteria-bundle. 17 platforms have either poor documentation or no information on the standardization characterizing the platforms in point of content management and other functionalities. Expressing the phenomenon in percentages, it means that 47% of the selected platforms have either poor documentation or no information on the e-Learning standardization.

Figure 19. Graphical representation of the low intensity selection process



4.1.5.2 Medium intensity selection level

After eliminating 61% of the original e-Learning software collection, a second step was made: the selection algorithm had to be developed in such way that even very similar software solutions can be differentiated. Strictly speaking, the following criteria were included in the selection algorithm: e-Learning standard, license type, documentation, development language, database type, multilingualism, special functions and distribution. For each of these eight criteria, correspondent percentual *degrees of importance* (DIm) were assigned. These percentages were designated in close correlation with the software needs, terms and conditions applied in the NaturNet-Redime Project.

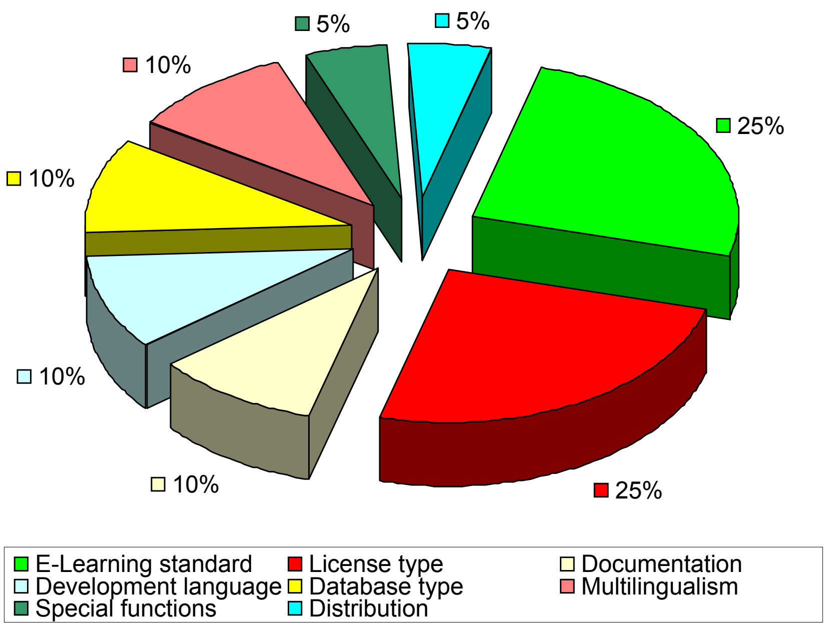
Table 18. The selection criteria matrix (values a_i)

Nr	Criteria	Degree of importance	Observations
1	E-Learning standardization	5	Knockout criterion
2	License type	5	Knockout criterion
3	Documentation	2	Important for software development
4	Development language	2	Important for software development
5	Database type	2	Important for software development
6	Multilingualism	2	Number of languages supported
7	Special functions	1	Forum, chat
8	Distribution	1	Community dimensions

As indicated above, the *degrees of importance* inside the matrix were assigned according to the level of importance of each criterion involved in the selection process. The value five of the *degree of importance* was assigned to the standardization and license type, which can also be considered knockout criteria. The *degree of importance* value two was conferred to the criteria related to software development, which have to fulfill certain conditions in order to enable customization for the e-Learning platform of NaturNet-Redime Project. *Documentation, development language* and *database type* have also played a great role in the selection. Some guidelines were set so that the technical team of the project should be able to customize the platform in an easy and quick way. At last, the value one of the *degree of importance* was conferred to the criteria which do not directly influence the development process, but which can facilitate work by bringing extra information accumulated through the users' previous experience with other platforms.

Why in this order? The answer is simple: as already shown in Chapter 2, *e-Learning standardization* is the most important element in the development of new e-Learning software In fact, the reutilization of already existing learning materials from different sources is only possible if specific standardization is followed. *License type* proved to be another very important aspect related to the selection of the platform: from the total number of 36 platforms that were investigated, 22 were commercial, with prices within a large spectrum of variation, whereas 14 were open source e-Learning platforms corresponding to a GNU General Public License.

Figure 20. Criteria importance in the e-Learning platform selection process



Documentation refers to the existence of information that can be useful to the other (seven) criteria of selection. In this respect, even if documentation of how to use the software was easy to find in all platforms, the majority of the commercial e-Learning platforms were not sufficiently documented. This can be explained through the fact that the scientific background of the software was also included in this category. This also justifies the necessity of adding a gradient (how well-documented a platform is: values from 1-the-highest-level-of-documentation to 5-the-lowest-level-of-documentation) to the initial hierarchy. *Development programming language* is the programming language in which the e-Learning platform was conceived. This is an important point in the selection, because later modification in the software could be needed if the initial language is not appropriate. *Database type* is also an important aspect in the selection of the e-Learning platform. A SQL database was preferred because of the large experience of the NaturNet-Redime project members with this type of database. The *multilingualism* functionality of an e-Learning platform was very important for the NaturNet-Redime project. The entire project is aiming at Sustainable Development issues at an European level and, accordingly, the platform should be able to provide the information in as many languages as possible. *Special functionalities*, like forum, chat of internal mailing, were also an important issue in the selection of the software. Its principle can be explained as follows: more functionality equals more time spent using the e-Learning platform, and more interest means finding out what the content is all about. *Distribution* refers to the frequency of usage of a specific e-Learning platform, i.e. the more installations, the more users have used the platform. A widespread utilization means for us a successful candidate in the selection process.

Furthermore, each of the selection categories expressed in Table 18 was divided into subcategories with the purpose of creating an even better and smoother selection. In this way, the selection process would be a result of the analysis and evaluation/counting not only categories but also of the subcategories. Because of the different number of subcategories, whenever categories have less than four subcategories, the missing subcategories will be replaced with zero values.

Table 19. Degree of importance selection matrix (values b_j)

	Criterion	Weight
Standard	SCORM Certified IMS and SCORM compliant Other standard No standard	3 2 1 0
License	GNU-GPL: Open source Non Open source	1 0
Documentation	Very good Good Bad	2 1 0
Development language	PHP No PHP	1 0
Database	MySQL PostgreSQL Not specified or no SQL	2 1 0
Multilingualism	Yes No	1 0
Special functionalities	Yes No	1 0
Distribution	More than 10 installations Less than 10 installations	1 0

The selection Matrix [A] was created in order to eliminate platforms that are not suitable for further work that had to be done within the project framework. As you can see in the Formula 1, the matrix is the result of the multiplication of a vector represented by the values **“a”** inside the matrix and a matrix represented by the values **“b”** from the resulting Matrix [A]**.** These values represent the categories and the subcategories of the selection criteria.

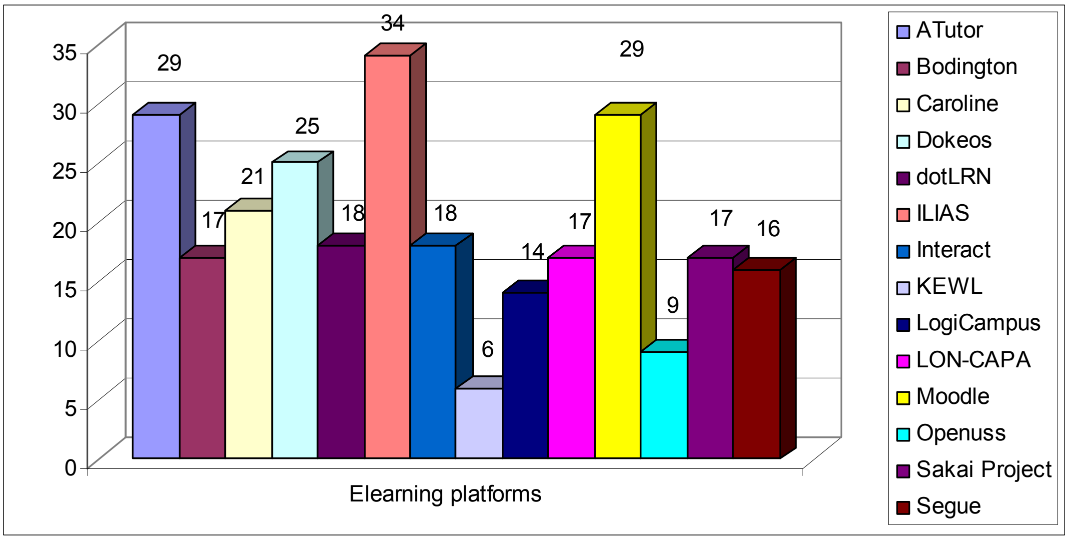
Formula 1. The e-Learning platform selection matrix

$$\text{Matrix A} = \begin{pmatrix} a11*b11 & a21*b21 & a31*b31 & a41*b41 & a51*b51 & a61*b61 & a71*b71 & a81*b81 \\ a12*b12 & a22*b22 & a32*b32 & a42*b42 & a52*b52 & a62*b62 & a72*b72 & a82*b82 \\ a13*b13 & 0 & a33*b33 & 0 & a53*b53 & 0 & 0 & 0 \\ a14*b14 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

The values in Matrix [A] are the result of a multiplication between of the value of the *degree of importance* of a category and the individual value of each subcategory *weights*. By doing so, the selection process reaches a second level, the so called detailed-analysis level, guaranteeing a better precision in selecting the best e-Learning platform for NaturNet-Redime.

When performing the selection according to Matrix [A], the 14 analyzed e-Learning platforms become marks. The scores obtained for each platform during the selection are graphically presented in Figure 21. Most of the platforms that were analyzed by the means of the selection matrix had a score under 20 points. Only 5 of them obtained a score over 20 %. The best score was received by ILIAS, which summed 34 points, followed by ATutor and Moodle, both receiving the same score of 29 points.

Figure 21. The medium selection results

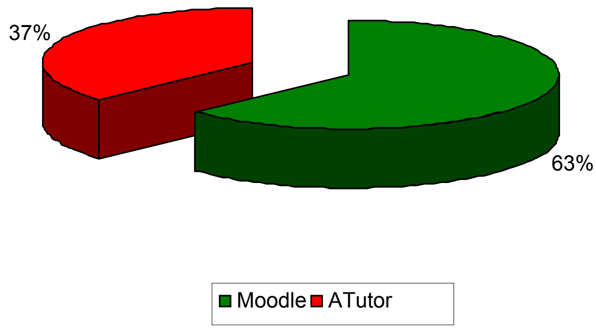


It was rather hard to decide which platform will occupy the second position, because both platforms occupying the next two positions fulfill the conditions of the selection matrix in the same way. Since the selection criteria presented in the selection matrix were not sufficient for a clear evaluation of the best platforms – planned to be analyzed in detail in a third selection level – an extra selection criterion was necessary: the ultimate criterion of selection referred to the number of users and their distribution on the globe.

Recent statistics[33] made by the platform developers themselves, revealed the Moodle was installed on 33977 servers (majority of 63%) whereas ATutor was present on only 19917 servers.

33 The statistics dates from 15.10.2007 (source: www.Moodle.org & www.ATutor.ca).

Figure 22. Comparing installment frequency between Moodle and ATutor



In this extra selection step, it was Moodle which was the winner because of the almost double number of installations and the huge number of community members.

4.1.6 ILIAS versus MOODLE or the High Intensity Selection Level

The comparison of those two e-Learning platforms has to be looked at from three different perspectives. Among these, the most important perspective[34] is the one which relies on the opinion of the Information Technology (IT) expert: he/she will be able to give an objective response to the most important technical issues regarding a series of factors that have to be taken into consideration when selecting an e-Learning platform. The most relevant such factors influencing the selection of the platform used in the NaturNet-Redime project are tabled in Annex II. These factors have also been used in the second selection phase of the e-Learning platform. Based on that, the IT expert has to decide which standardization model will lie at the basis of the e-Learning platform that will be eventually used for the e-Learning modules present in the NaturNet-Redime Project. Without a proper standardization model of the e-Learning platform, which will allow the interchange of e-Learning modules with other similar projects, the success of the projects will be at risk.

The second perspective refers to the content editor's perspective or the teacher's perspective. This perspective is of great importance too because the teacher is the resource editor,

34 The definitory criterion is set from a strictly comparison-based point of view.

administrator and mediator of the learning process. The teacher has to be able to create, edit or import content in a relative short period of time with a minimum effort. For this condition to be fulfilled it is necessary that the platform interface is clearly laid out, intuitive and self-explanatory. The teacher is often confronted with terms that are synonyms but define two different functionalities. Although the teacher is not necessarily a computer specialist, the content editing process has to be similar to document editing.

The third perspective is the learner's perspective, which has the lowest level of importance in this comparison. Nevertheless, the learner's perspective is the user's perspective on the software used and not on the content presented through the means of these e-Learning platforms. This perspective is seen as having a lower level of importance since the majority of the e-Learning platforms have similar learner-user interfaces and the differences that could influence the selection process are minor. However, the learner is the subject of the e-Learning course-ware and the selection process has to take into account learners' needs. The target group described in Subchapter 4.2.4 also influences the comparison, because some users are able to easily adapt to new challenging web sites or e-Learning platforms while others are not.

4.1.6.1 Introducing ILIAS

ILIAS is an online Learning Management System (LMS) which was initially developed as part of the VIRTUS Project (Donati et al 2004) at the University of Cologne in Germany. ILIAS is capable of publishing learning content within an integrated system thought any web browser. During the publishing process, the user is able to create and edit content by using both online and offline tools. ILIAS enables the users to communicate and cooperate through tools like forum, chat and e-mailing.

In addition, ILIAS is an open source software under the GNU General Public License (GNU-GPL), meaning that all source codes of ILIAS are free to use and upgrade. This was a very important aspect for the NaturNet-Redime Project, because ILIAS had to be integrated and made accessible from inside the NNR portal.

ILIAS guarantees the e-Learning content reuse by being compliant with the SCORM 1.2 standard at the LMS-RTE3 Level. ILIAS was the first open source LMS that is compliant with the SCORM 1.2 standard. Organized in a modular format and being programmed in a object-oriented programming software, ILIAS enables customizing for different needs and purposes.

4.1.6.2 Introducing MOODLE

Moodle is an acronym for Modular Object Oriented Dynamic Learning Environment. It was developed at the Curtis University in Australia by Martin Dougiamas and the first version was released in 2002. Moodle is a free software under the GNU Public License. Theoretically, this e-Learning platform is based upon “a corroboration of systematic communications theory and a constructivistic pedagogy” (Gertsch 2006). Together with the first version of the software, a whole user-community arose around it and now users can find technical solutions by simply entering on www.Moodle.org in the forum section. Important steps have been taken in the direction of standardization, from Moodle also, i.e. the SCORM standard as we have seen in Subchapter 4.1.3.3 of this dissertation thesis.

MOODLE developers see in the software a “separate and connected” e-Learning platform:

Separate behavior is when someone tries to remain 'objective' and 'factual', and tends to defend their own ideas using logic to find holes in their opponent's ideas. Connected behavior is a more empathic approach that accepts subjectivity, trying to listen and ask questions in an effort to understand the other point of view. Constructed behavior is when a person is sensitive to both of these approaches and is able to choose either of them as appropriate to the current situation[35].

4.1.6.3 ILIAS versus MOODLE from the expert perspective

The NaturNet-Redime project was eventually provided with an appropriate e-Learning standardization analysis, which has been done in the framework of the present thesis. Based on this analysis, a report was elaborated and presented for debate to the NaturNet-Redime consortium. After presenting this report on e-Learning standardization – the result of analyzing a large spectrum of e-Learning standards[36] – the technical group members of the NaturNet-Redime project were invited to take part at the Internal Technical Workshop (ITW)

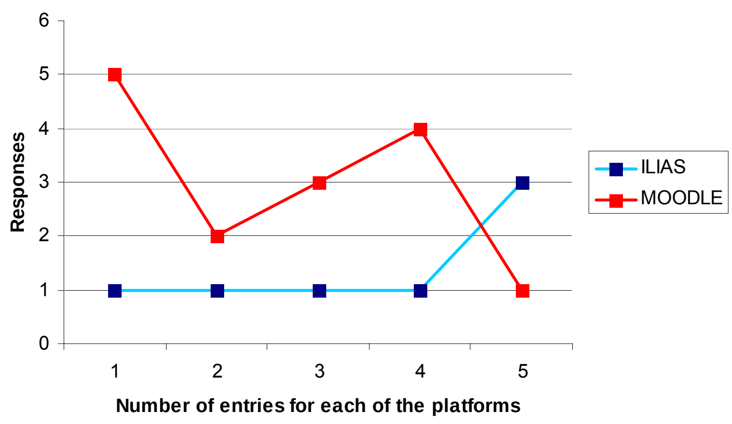
35 Source : www.Moodle.org

in Freiburg. On this occasion, a second report was elaborated, presenting the selection process of the most appropriate e-Learning platform(s) that should/would have been integrated in the NaturNet-Redime portal together with other software tools. The second NNR internal report was based on the low and medium intensity selection processes previously described in the chapter.

The comparison of the two most appropriate platforms (ILIAS 3.3 and Moodle 1.5) was made mainly during the July 2005 Technical Meeting of the NaturNet-Redime computer specialists (July 2005). The members of the team were Karel Charvát Sr. (CCSS), Karel Charvát Jr. (CCSS), Octavian Iercan (FELIS), Markus Jochum (FELIS), Christian Schill (FELIS) and Marek Šplichal (CCSS). In the first part of the meeting, the results of my report were discussed and it was unanimously agreed that SCORM would be the best standard for the future NaturNet-Redime e-Learning project.

In order to provide the report with effective data, an expert interview was organized during the ITW in Freiburg. Details upon this procedure will be presented in Subchapter 4.1.4 of the dissertation. The comparison between ILIAS and MOODLE was partially based upon the expert interview methodology (see Subchapter 4.1.4) whose results are presented below:

Figure 23. Expert interview ILIAS vs. MOODLE results



In Figure 23, the results of the expert interview (details in Annex III) are presented in graphical form. On the Y axis, the categories are represented: numbers stand for the level of agreement with the statement in the interview. On the X axis, the expert interview questions are notated but, since the same question was asked both for ILIAS and MOODLE, the number

36 As presented in section 2.2.3 under E-Learning standardization.

of 10 questions was reduced to 5. For clarification, Table 20 decodes the significations of the Y axis in the Expert interview diagram above:

Table 20. Response coding of the expert interview questionnaire

Response	Code
Strongly agree	1
Somewhat agree	2
Neither agree or disagree	3
Disagree	4
Strongly disagree	5

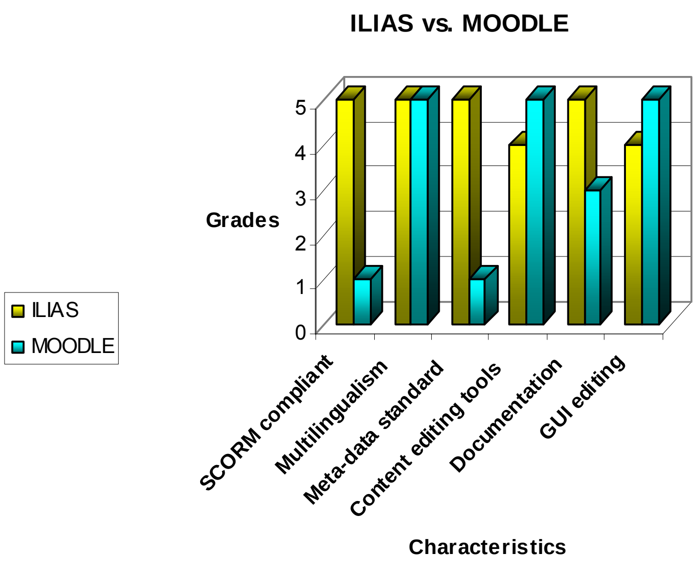
After completing the expert interview, the experts were also asked to give grades from 1 to 5 (1 being the lowest grade and 5 the highest) to the characteristics expressed in the table below.

Table 21. Analysis results of the expert interview July 2005

Criteria	ILIAS	MOODLE
SCORM compliant	5	1
Multilingualism	5	5
Meta-data description standard	5	1
Content editing tools	4	5
Documentation	5	3
GUI editing	4	5
Average	4.666	3,333

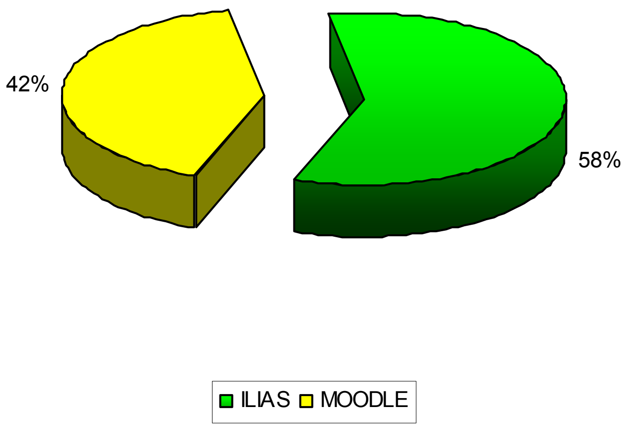
This quantitative system used for the evaluation of the two platforms was only realized in order to give a better graphical overview of the results obtained through the expert interview and to control, if possible, these results.

Figure 24. Characteristically comparison between ILIAS and MOODLE



Summing up the values given to different criteria on which the selection process was based, the best suited e-Learning platform for the NaturNet-Redime project is ILIAS. In the figure below (Figure 25) we can easily see that ILIAS leads in the selection process with 16% ahead of MOODLE.

Figure 25. Concluding comparison results



However, the NaturNet-Redime project partners laid emphasis first on the facility with which content can be manipulated and edited and, second, on the way the graphical interface (e.g. of MOODLE) looks, than on all the other criteria that were presented in this chapter. That is why, in the following two subchapters, two other comparisons regarding the way the two platforms behave in praxis will be presented: (i) how efficient the two are and (ii) how easy it is for teachers and students to use them. Since at the end of the expert interview ILIAS proved to be the winner of the first comparison methodology, it will therefore be the favorite in the final selection too.

4.1.6.4 ILIAS versus MOODLE from the content editor perspective

In the previous subchapter, ILIAS and MOODLE were analyzed from the expert point of view. The experts were mainly concerned the technical aspects of the e-Learning platforms that have been analyzed. The standardization of the processes that a platform has to fulfill was the most important criterion on which the decision on the best e-Learning platform will be based.

This chapter focuses on what the regular users, such as content editors or better said lecturers, find as important and useful. Here the standardization of each platform plays no role and the analysis of the platforms is made at the visual and functional level. The visual level refers especially to the Graphical User Interface (GUI) of each of the analyzed e-Learning platforms. The platform that looks more familiar and has more intuitive commands will probably be preferred by the users. Graphical interfaces of e-Learning platforms should therefore focus on "providing a clear idea of the content organization and the system functionalities, besides offering a simple navigation" (Ardito 2004).

As already pointed out, when the two finalists of the prior e-Learning platform selection were presented at the NaturNet Workshop in Vysocina (Czech Republic), the project members found MOODLE as the best solution for the NaturNet-Redime e-Learning platform. This can only by explained through the familiar GUI of MOODLE, the quick orientation in the platform and the functionalities that are accessible even from the main page of each module. The functionalities of the two platforms are in fact almost identical, as it will be seen in the following, but the modality of presenting these functionalities is the one that influenced the project partners in selecting MOODLE instead of ILIAS.

Each of the following subchapters will analyze the characteristics of both e-Learning platforms focusing on different points of interest: they will receive a *Plus* (+) for the better qualified platform and a *Minus* (-) for the less qualified platform.

4.1.6.4.1 The Personal-Desktop comparison

Both platforms dispose of a well-organized learner or content editor personal desktop. Both have the possibility of: checking emails, monitoring the online users, visualizing news inside the learning platform, using a calendar and input appointments, editing one's personal profile, writing notes, setting bookmarks or checking the learning progress. The big difference between ILIAS and MOODLE at this point is the accessibility of these tools. While ILIAS offers the possibility of accessing all these functionalities from the Personal Desktop window, by clicking on the correspondent button of each of these functionalities and access them one after another, MOODLE offers the possibility of using all the functionalities in the same Personal Desktop window by organizing the functions as widget on the left and right side of the window. As a result of the Personal-Desktop comparison, MOODLE receives a *Plus* (+)

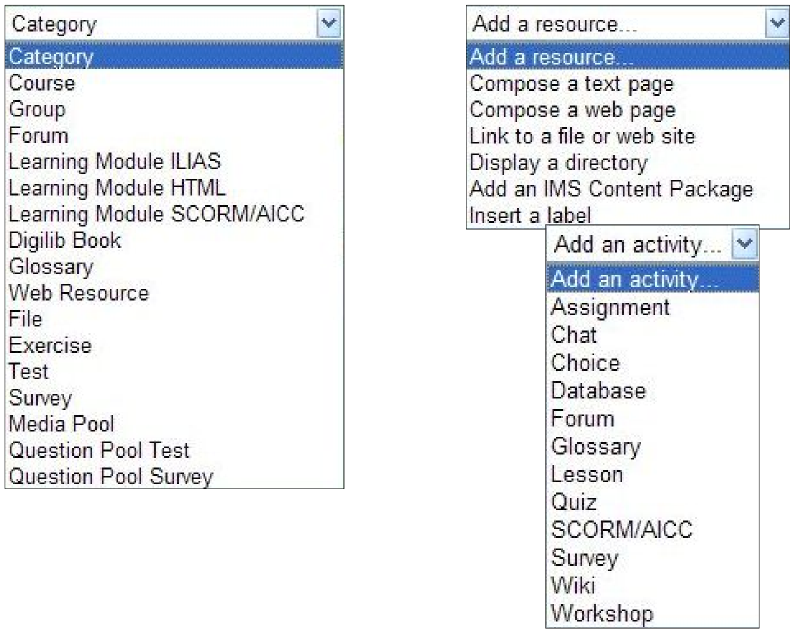
and ILIAS a *Minus* (-) not because of the lack of functionalities but because of accessibility reasons.

4.1.6.4.2 Content organizing and packaging functionalities

Both compared platforms are able to satisfy a series of "standard" requirements for content editing and manipulation: the image below is a screenshot of the possibilities offered by the platforms in this respect. All functionalities of ILIAS and Moodle have been simultaneously tested in order to find out which of them are described by a different terminology.

Figure 26. ILIAS and Moodle platform functionalities

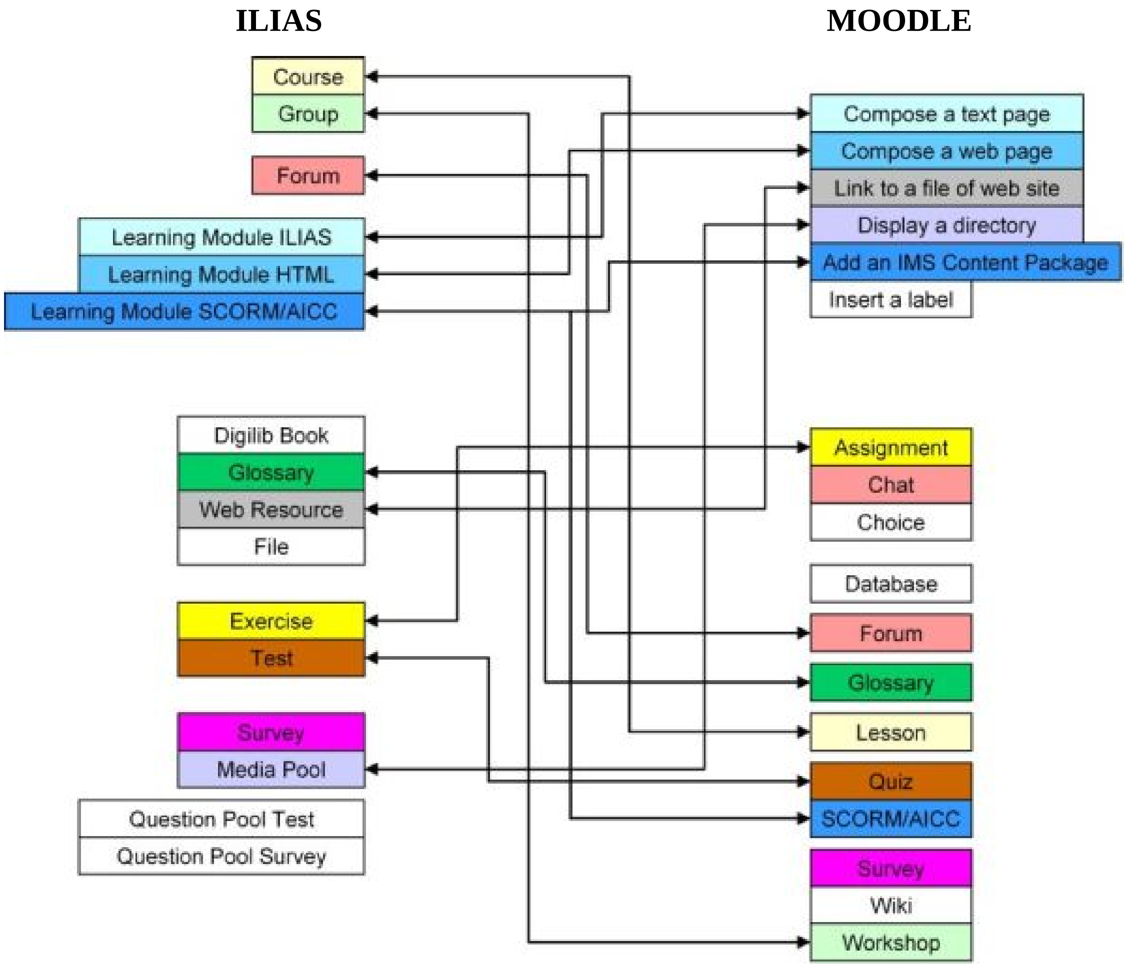
ILIAS ***MOODLE***



The functionalities provided by the two platforms are similar and cover the entire spectrum of tools which are rather common in any e-Learning platform. As it can be noticed in the image below (see figure 27), the functionalities have different names but the actions that can be performed are similar. For example, "course" in ILIAS is "lesson" in MOODLE; another eloquent example would be the "Web Resource" in ILIAS and "Link to a file" or a "web site" in MOODLE.

In the following scheme (see Figure 27) the direct connections between the functionalities of the two platforms are presented; the editorial functionalities of ILIAS (left) and MOODLE (right) are also presented. The functions that describe the same actions inside the e-Learning platforms are colored in the same color and targeted with a connector line. The uncolored boxes are the ones that have no correspondent in the other platform. It is important to remark that the essential functionalities of each platform have a correspondent into the other, such as courses, forums, glossary, etc. From the same comparative picture, an important characteristic of the concept of the platform can be emphasized, namely the order of the functionalities in the content editing section. In ILIAS the structure is based upon the work-steps order, meaning the order in which the functionalities are used for the successful elaboration of e-Learning content. In Moodle, the functionalities are organized alphabetically and not following the systematic content elaboration steps.

Figure 27. Detailed functionalities: ILIAS vs. MOODLE



In this subchapter, ILIAS becomes *a Plus* (+) and Moodle a *Minus* (-) because of the following three reasons: (a) in ILIAS a SCORM Learning Module can be created, (b) in ILIAS it is possible to realize a survey with a single edited question, (c) in ILIAS there is a question pool in which survey and quiz questions can be saved and afterwards used for new surveys or quizzes. All the previously mentioned features are not possible in Moodle.

4.1.6.4.3 Comparison of content editor utilities

As the content editors of both platforms are very different, a series of advantages and disadvantages can be spotted. For example, MOODLE uses the WYSIWYG HTML editor that allows for an easy and real-time content editing as well as for image loading, website linkage and other features enclosed in the WYSIWYG HTML editor. This editor is fully integrated in the Moodle platform and because of that there is no need for an extra software installation.

ILIAS, on the other hand, uses a macro function designed for the open source content office tool Open Office. This means that, for editing content in ILIAS, two other software packages have to be installed, meaning Open Office and ILEX (the newer version is called eLAIX). There is also another possibility of editing content in ILIAS, by using an internal content editor that has no extra features and works exactly as Windows Notepad. Linking other websites or media files with the ILIAS content through this internal text editor is only possible through hard-coding. That is why the hard-coding process was tested when building the GIS courses. The results proved that editing through this viewer is, although very time consuming, very useful when editing content that has already been processed in ILEX. ILEX – or now eLAIX – can import file types such as the ones presented in the following image (see Figure 28).

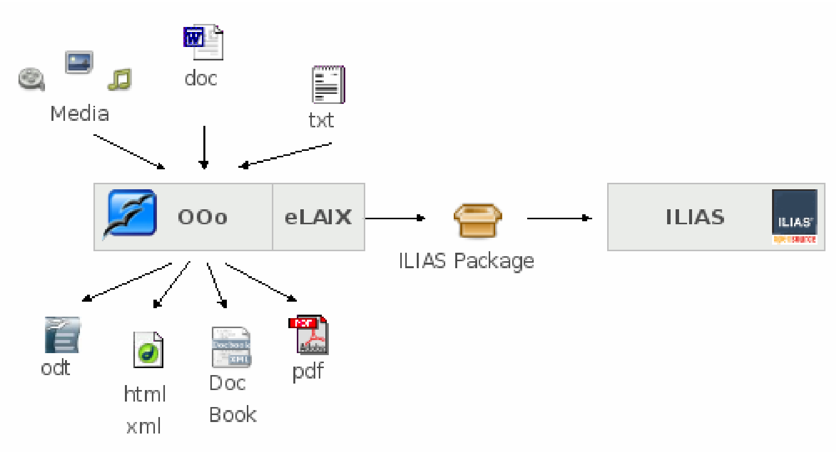


Figure 28. eLAIX[37]

37 Source: http://www.boldt-media.de/concept.html

The present dissertation makes a comparison of the editing tools, by taking into account their stage of development in June 2005:

- ILEX generated problems and erroneous content mostly when multimedia files and tables were uploaded and converted. More exactly, it often happened that the spaces between paragraphs were multiplied or that tables and multimedia objects were over-dimensioned. The formatting problems had to be solved in the ILIAS internal editor. Recent tests, based on the newer version, eLAIX, revealed that the error frequency drastically dropped and almost no intervention with the ILIAS internal editor is needed.

- The WYSIWYG HTML Moodle editor is not able to convert file types like *.pdf or *.html into e-Learning contents, as iLEX or eLAIX do. Instead, Moodle created a special function that will automatically convert these file types into e-Learning content without having to import the information into an editor.

That is why, at this stage of the comparison, Moodle received a *Plus* (+) and ILIAS a *Minus* (-), because of the extra work that a teacher needs to do before being actually able to design a lesson.

4.1.6.4.4 The SCORM content export functionality

As both platforms are compliant respectively certified, it became necessary to test these features. First the exporting function for ILIAS was tested. In order to do that, Lesson one of the GIS e-Learning group (see Table 3) was selected. At a general level, results showed that the export was easy to conduct in ILIAS, the same happening with the importing of the SCORM content. The imported lesson was actually tested for integrity of the functionalities existing in the module. There were two points where the SCORM content packages did not represent 100% the original ILIAS modules. The first one refers to the integration of the media presented in the media display sector 2 (see Figure 39). When the SCORM module was created, the external file was not integrated into the export file, and, because of this, the modules are not fully operational. The second point of divergence from the original is the lack of editing abilities for these modules. On the other hand, tests with modules that have one frame display and not three, proved that the problem is not related to the import-export functions but to the displays of the three-frame layout of ILIAS.

Because MOODLE versions analyzed in 2005 were not capable of importing SCORM content, the analysis was performed again in September 2007, when the platform was already certified. The same problems that were initially spotted at ILIAS were also discovered at MOODLE. The problems were again generated by the three-frame layout of ILIAS, not by the import-export functionalities, as already explained, and it is therefore reasonable to say that both platforms are compliant respectively certified ADL SCORM 2004. However, since MOODLE does not generate SCORM content, ILIAS and Moodle are still different, and therefore ILIAS receives a *Plus* (+) and Moodle a *Minus* (-).

4.1.6.5 The learner perspective

Considering the IT-oriented decisions that were taken by the NaturNet-Redime technical team during the ITW in Freiburg, the FELIS members responsible for the NNR project decided to present/test both e-Learning platforms during a workshop in Vysočina - Czech Republic. Presentations were realized in both e-Learning platforms, ILIAS and MOODLE, so that the user can get more familiar with the GUI's of the two platforms. The presentation of ILIAS was realized by me and the MOODLE presentation by my team college Markus Jochum. Each of the presentations took half an hour and was followed by one hour meant as testing time.

After the presentations and their testing time, an Explorative Expert Interview followed. This time the expert interview was performed by the means of voluntaristic experts (see Chapter 4.1.2) that reconstruct subjective representations (cf. Kruse 2006: 141). The interview was meant to reveal, through a subjective perspective of things, which is the most interesting e-Learning platform, in future users' view. I adopted the position of the interview co-expert and participated in the interview. The procedure of the interview involved a voting process in which the experts had to express themselves in favor of one or the other platform. The interview members were instructed to focus on the Graphical User Interface of the platforms, their functionalities (like forum, chat, calendar), on message and content editing and the user-friendliness of the platform. The sum of these characteristics should help them in designating the preferred e-Learning platform. In order to help experts in understanding the elements that had to be taken into consideration in this interview, a questionnaire (see Annex IV) was presented.

The majority of votes were expressed in favor of Moodle whereas only few voted in favor of ILIAS. That is why Moodle was designated as the NNR project e-Learning platform.

4.2 Development methodology of the e-Learning Models

4.2.1 The NaturNet Redime Project

The NaturNet-Redime Project (NNR) is a combined project of two initial project proposals submitted to the European Union Frame Program 6 (EU-FP6). Being composed of two initially distinct project proposals (NaturNet and Redime), the NNR project will fulfill the following rather different tasks:

1. The NaturNet part of the project focuses on building an Interoperable Internet Architecture, through which users can access and visualize much of the currently existing data on sustainable development.

2. The REDIME part of the project focuses on learning through modeling and simulation in order to develop tools for the public that would allow them to learn about sustainable development. Enhancing Qualitative Reasoning (QR) modeling tools which make them easy and interesting for everybody to use is certainly of highest importance to NNR project.

The merger of the two technological and methodological solutions, K-Learning and Qualitative Reasoning, was intended to make the users understand and learn more about sustainable development at European level. Both technical and methodological solutions are accessible in the NNR web portal.

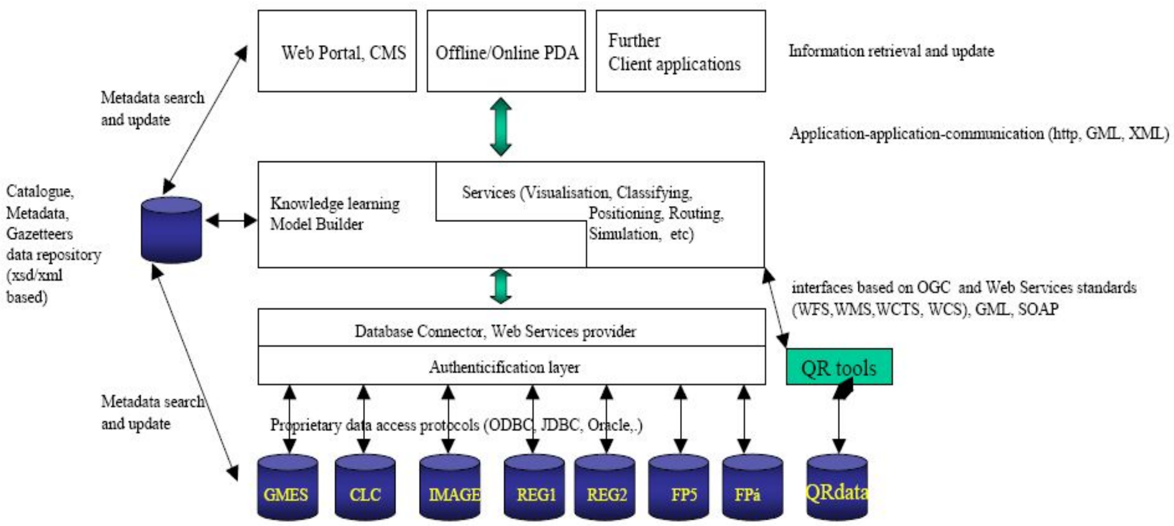
4.2.2 The goals of the NNR project

NNR ground objectives are described as follows:

Improvement of knowledge and the provision of education concerning all aspects of Sustainable Development. The project will thus develop and demonstrate prototype technology and educational programs towards implementing the European Union's Strategy for Sustainable Development (SSD). Extensive stakeholder understanding of the various factors and tools that affect sustainable development is one of the main goals of the NNR project. The content will focus on and integrate ecological, economic, social and technological factors and will prepare training facilities for Strategic Impact Assessment (SIA)[38].

The NNR project's most interesting research area for the present dissertation concerns the "k-learning approach", which refers directly to the knowledge management-based learning system in which the e-Learning platform is also integrated. Figure 29 presents the components of the Knowledge Management Based Learning System (KMBLS):

Figure 29. The NNR Knowledge Management Based Learning System



(cf. *NaturNet-Redime Consortium Agreement* 2004)

The learning activity is created on the bases of the NNR project e-Learning platform, or the Knowledge Learning Model Builder, as it has been named in the above image. The usages of the other tools described in the image were also part of the e-Learning modules created in ILIAS and Moodle. It is important to emphasize that, even if only Moodle was designated as

38 Source: http://www.naturnet.org/index.php?mid=1&smid=1&lng=en

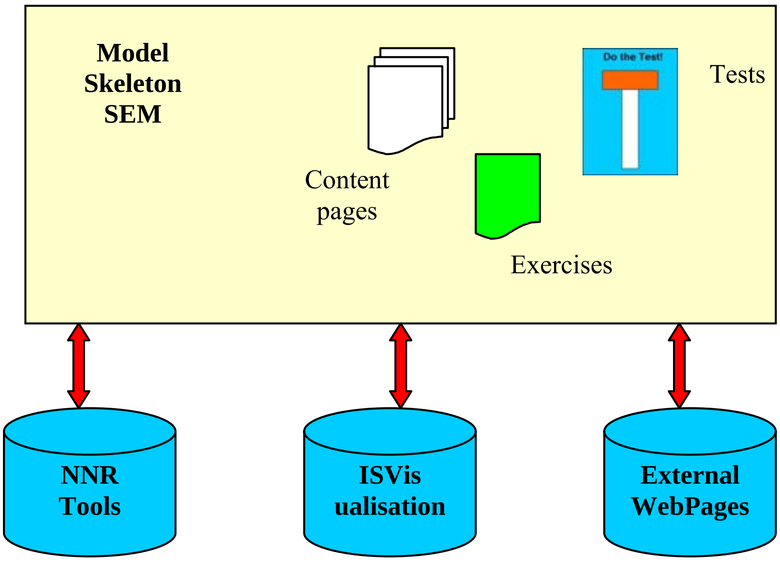
the NNR e-Learning platform, ILIAS, being used for the present dissertation, was also connected with part of the NNR tools present in KMBLS.

4.2.3 The concept of the content generation

The didactical methodology adopted for the realization of the e-Learning content used in the present dissertation thesis follows the already described didactical concept in Chapter 2.3. The principle described in the above-mentioned chapter is based on the work of Clark and Mayer (2002). The developed e-Learning modules were realized through two different e-Learning platforms, which have been also compared earlier. Thus, the two selected platforms, ILIAS and MOODLE, and the e-Learning content included in them follow Clark and Mayer's (2002) didactical methodology.

The technological methodology is however different. This happens because of the constructional differences existing between the two platforms. Still, the technical development methodology had no impact on the preservation of the didactical methodological scheme. In the following, a basic technological description of the content development will be presented. The *skeleton of each e-Learning module* (SEM) was built from independent or connected web pages which are in the end followed by a set of questions grouped in a test. The test was intended for the fixation of the received information. This basic SEM was further developed into a so called *bodied e-Learning module* (BEM) by creating external exercises and connecting the content to several applications already existing in the NNR project.

Figure 30. The e-Learning Content Module Body (BEM)



In the image above (Figure 30), the term NNR tools designates all the software solutions that are free accessible on the NaturNet-Redime webpage. The BEM contains not only the internal contents of the e-Learning platform but also information and content from other sources. The NaturNet-Redime project focused on distributed data and information that were made available for the users through the means of the NNR portal. The BEM tries to connect, as much as possible, various amounts of tools that are able to intensify the interactivity of the users with the e-Learning platform and the NNR portal.

4.2.3.1 Simulations as part of the SEM

Simulations in Geoinformatics education represent a new learning trend. They contain information that a learner would only receive in workshops or exercise-oriented classes. They are therefore essential for e-Learning in the Geoinformatics field. This work uses two types of simulations: *presentational* and *interactive*.

The first type of simulation is called presentational because the learner assists in the presentation of elements which simulate a certain process without having to interfere. This type of simulations also has a slight interactive character by incorporating a control bar, which allows the user to navigate between simulation pages and elements. Some of the presentational simulations include an audio stream which explains the content of the images in words and, at the same time, they create a greater information exchange rate between the computer and the learner.

The interactive simulation is based on the "learning by doing" principle, meaning that the simulation only sets forward when the learner executes the next correct step in the development of the simulated process. By using this kind of simulations, the interactivity between the learner and the learning environment is maximized. The simulated processes are able to indicate the learner the exact steps necessary for a successful realization of proposed problems. Exemplifications of both simulation types are presented in Chapter 6 (Subchapter 6.3.2) of this work.

4.2.3.2 Real-time interactivity in the BEM

The term r*eal-time interactivity* suggests that something must be done instantly, i.e. in direct connection with the user's actions, and through interaction with one or the other software. In the BEM structure of the e-Learning modules, two components are able to create real-time interactions.

One is the ISVisualisation software (see Subchapter 4.3.3) which allows the user to actively visualize different types of data: (a) raw LIDAR data; (b) already processed data in form of 3D models and (c) 3D models through Web Services. The existence of this type of tool enables the learner to visualize various abstract notions related with the 3D model, such as: the three dimensions and the relation with longitude and latitude, position of the isolines, altitude gradient (RGB color map) etc. The learner is then able to connect to servers containing large quantities of three-dimensional data and visualize these data.

The second component is related to the tools (accessible trough ILIAS e-Learning platform) developed in NaturNet-Redime and present online on the project portal: MAPMAN, MAPOBSERV, VIS3D. They can enlarge the possibilities of better understanding already taught notions which are explained in detail in the e-Learning modules.

4.2.4 The target group

The target group consists of: students of the University of Freiburg that attend the courses of the Department for Remote Sensing and Landscape Information Systems (FeLIS), long-life learners, decision makers, etc.

The GIS and the Remote Sensing courses belong to the extra qualification offer students of the University of Freiburg benefit from. This means that the GIS content of the courses addresses beginners as well as students that already have GIS knowledge. As learning strategy, students will be mainly confronted with studying through the traditional face-to-face approach. In this scenario, the GIS modules are constructed in such way that they can be used as an extra source of information for the courses that are thought in the traditional way at the FeLIS. Thus, students have the possibility of giving/receiving feedback regarding the level of knowledge that they have reached at the end of the course. Moreover, they can use these modules as extracurricular information that brightens their horizon in the LIDAR technology. The LIDAR technology begins to be used not only in research but also in business areas such as tourism, cartography or local administration.

For other types of users, GIS courses are a good opportunity of learning a new technology by the means of e-Learning. With the help of the GIS modules, the user has the possibility of experimenting online the features of the GIS software, by connecting the modules to the NaturNet-Redime GIS tools existing on the project portal. For example, the target group of the Remote Sensing modules that present the Waldkirch Scenario is represented by users that already have knowledge of Remote Sensing and who will be able to use the modules in finding a solution for a similar case study.

4.3 3D Models and 3D visualization through ISVisualisation software

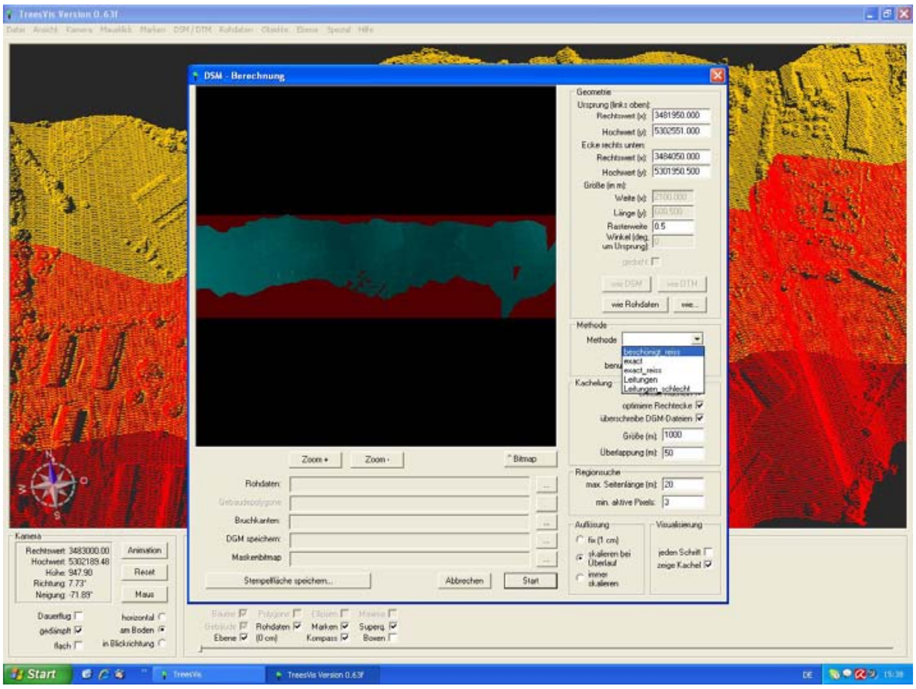
4.3.1 3D model generation

The 3D models used for the development of the e-Learning content are generally based on LIDAR data. Some other, already existing, 3D models realized from other type of datasets, such as satellite data, were also used in simulations for the GIS e-Learning courses. The majority of the 3D models used in the e-Learning modules were developed with TreesVis and its internal mathematical algorithms. These 3D models were used in the Remote Sensing e-Learning module development and as basis for the ISVisualisation software. Other 3D models, that did not use ISVisualisation, produced simulations like *3D Viewshed Simulation*, where the DEM was used as a basis for the 3D visualization of vector data by the means of ArcScene. From the 3D analysis tools in ArcInfo, the Viewshed functionality is used for determining the viewable and invisible areas of a terrain from a given location. Height values of the DEM are classified to a *vector layer* which will indicate the visible and non-visible areas of the DEM from the specified point.

As already presented in Chapter 3, the LIDAR data from the Waldkirch region have been collected by two institutions, the LV-BW and IGI, the former using the ALTM 1225 laser scanner providing pulsed data (First-Last pulse), and the latter using LiteMapper 5600 providing full-wave data. Parts of the two datasets have been loaded into TreesVis and, by using the internal algorithms for DSM calculation, several DSM have been generated.

The DSM generation is based on the following three original methods developed at FeLIS: *Beschönigt Reiss*, *Exact* and *Exact Reiss*. These three methods are actually different sets of parameters that are then adopted by the surface calculator algorithm. Every parameter sets content parameters like the following: *break, gravitation, magnetic force, iteration number, pace size*, etc; but each of these parameters takes other values according to different methods. The more precise a method is the larger the number of parameters that has to be determined in order to get a good result. For example, the *Beschönigt Reiss* method contains a sum of 25 parameters and the *Exact* method only 8 parameters. The parameter set *Beschönigt Reiss* generates a varnished surface by eliminating small surface variations. Instead of generating a surface that connects all points in the dataset, this method tries to approximate a surface that will cover more than one point. The *Exact* set of parameters, on the other hand, integrates all points even if then the DSM surface has a much more irregular surface. The *Exact Reiss* method contains a larger set of parameters than the *Exact* method and it will therefore filter point data differently. If a point in the dataset is positioned far away from other points in the dataset, this point will not be taken into consideration when determining the surface of the DSM.

Figure 31. DSM generation using TreesVis



Inside the DSM calculation method, other parameters can be determined, such as point density, meaning the resolution of the resulted DSM; dimension of the DSM can also be defined by manual input of the geometry (coordinates for the 4 corners of the selected region) or by selecting the region of interest in a bitmap pictogram. All the calculated DSMs were then compressed in a TIFF format in order to import these models into the ISVisualisation of Macromedia Captivate.

4.3.2 The VisAD Library and its role in the development of ISVisualisation

VisAD is a Java-based library and its name is an acronym for Visualization for Algorithm Development. The development of this library was carried out at the University of Wisconsin by Prof. Hibbard et al. (2005) and it is considered as: „combining a flexible data model and distributed objects", which support "the sharing of data, visualizations, and user interfaces among multiple data sources, computers, and scientific disciplines "(Hibbard 2005).

The exchange of data and information over the Internet is a modern reality. In the future, anyway, it will be possible to work in networks in order to perform computational activities, to view and collaborate with other users in an ongoing project. VisAD developers are determined to realize, at least as far as VisAD concerns, such a system. VisAD offers the possibility of creating software that:

i. excludes the fixed hardware (i.e. a specific computer unit or resources on an intranet server) from the programming problematic,
ii. restricts data analysis at a reduced number of data structures
iii. allows for course software component reusability which will permit users to combine already developed programs, or parts of these (objects), for their own needs (Hibbard 2005).

The data that can be used with VisAD is implemented through abstract data models. Using data models, numerical and other data-types can be used in connection with VisAD, such as coordinates, grids, time series, etc. The data can be computed through an API written by the developer. Displaying data follows an "abstract display model" (Hibbard 2005) than makes the process possible by mapping primitive data to primitive displays. The display component of the API (Application Programming Interface) is based on Java 3D or Java 2D, depending on the dimension in which the data has to be presented.

The software based upon VisAD uses the Java Remote Method Invocation (RMI) that allows work over networks. Displays and computation processes can be connected to one or more that one dataset and one dataset can be connected to more than one display at a time. These functionalities can be used for realizing collaboration on the network, once that a change has occurred in the main program, the contents of the displays change instantly and more users benefit from this real-time collaboration.

4.3.3 ISVisualisation: A Web-Based Visualization Software for Airborne Laser Scanning Data

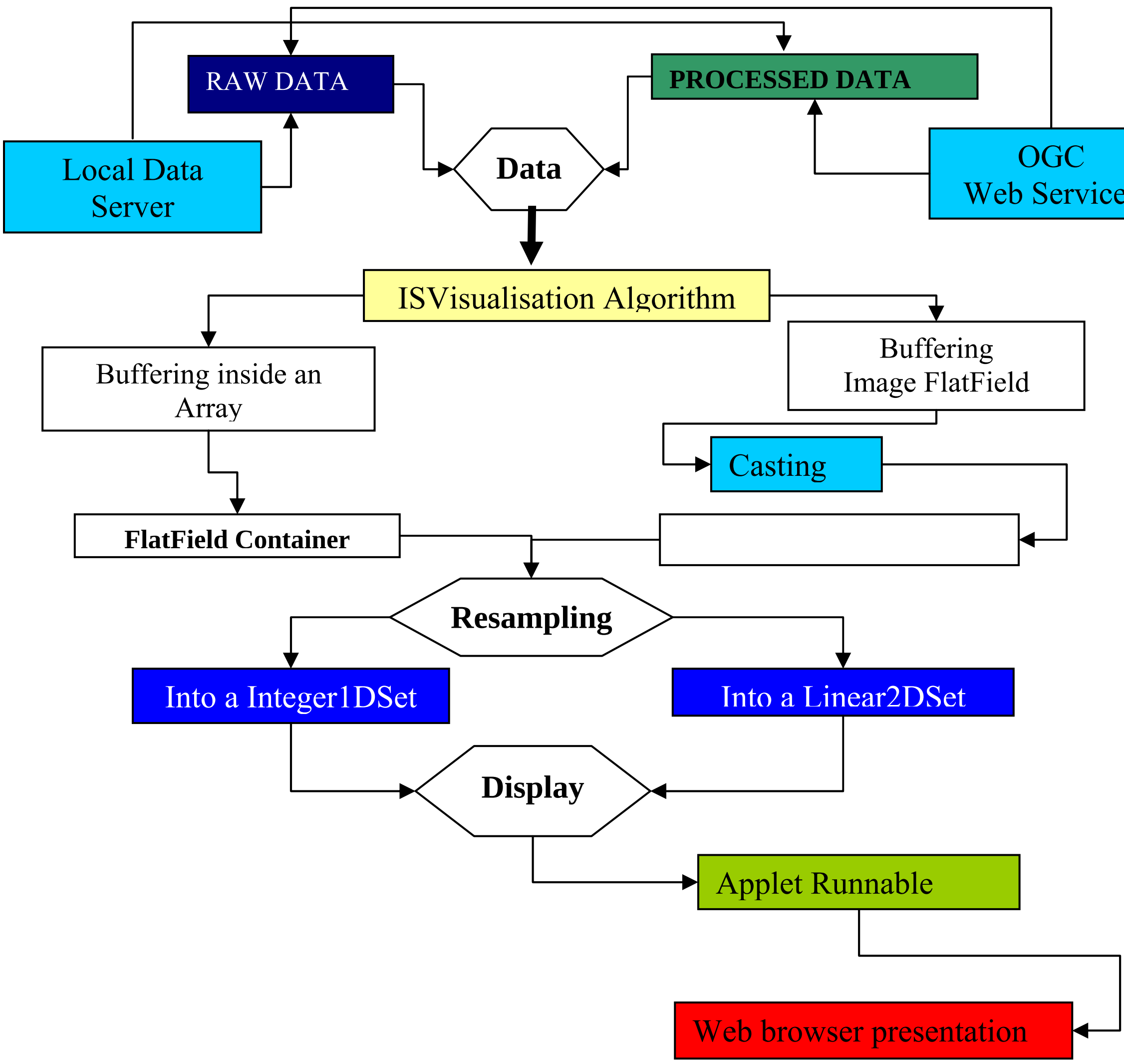
4.3.3.1 Introduction

The interest in the LIDAR technology manifested by scientists and decision makers all over Europe is growing and the need of software tools which can manipulate LIDAR data follows the same exponential curve. Visualization and modeling software solutions have been developed for the manipulation of such data, but most of them perform the above-mentioned tasks offline because of the important hardware resources needed during processing. Visualizing LIDAR data in Internet, over a web browser, is a challenge to which the ISVisualisation software responds (Iercan et al. 2007).

ISVisualisation is directly connected to my PhD research project. The software is based upon the Java technology and has been developed for the detailed study of LIDAR raw and already processed data inside e-Learning modules. The aim of this visualization software is to help visualize LIDAR data and acquire a better understanding of the geographical site situation. A combination between the Java programming language and Java3D and VisAD (Visualization for Algorithm development), both Java extension libraries, has been used for the ISVisualisation software development. The purpose of this chapter is to present the possibilities and boundaries of web-based visualization software such as ISVisualisation for the analysis of ALS (Airborne Laser Scanning) data.

The data types that can be visualized with this software are: (1) ALS raw data in the *.asc data format and (2) already existing DEMs (Digital Elevation Models) in *.tif data format. The access to the data sources is made possible by using OGS Web Services and locally existing data. The generation of visualization displays for the different data types is based upon VisAD specification classes. Once that the file has been read and buffered, the data can be further resampled for different functionalities and a display can be generated. The display can contain either surface elements that will render Earth's surface in a realistic way, or other displays that show isolines and/or the collection of ALS data point clouds. The distances between isolines can be modified, in real-time, in the user interface of the ISVisualisation software. The utilization of different displays for the visualization of three-dimensional terrain shapes is thought to be useful to the users for a better understanding of the landscape situation. This visualization software can also be used for other datasets than LIDAR, as far as data is present in the same formats as the ones described before.

Figure 32. ISVisualisation's Mathematical model



In Figure 32, the entire methodological concept of the ISVisualisation software is depicted. Raw data, processed data existing on local servers or local hard-drives, and data provided through web services are collected and run through the *ISVisualisation Algorithm*. At the beginning, the algorithm will sort data and proceed as each data type requires. If data is already processed, it probably exists in *.tif format and will be first loaded in a specific image data container called *Image FlatField*. Other data formats can also be handled but the usual data type for LIDAR processed data is *.tif because DEMs are usually saved in this file format. The information contained in the Image FlatField is afterwards cast into a FlatField[39] that will allow for data resampling. The raw data, on the other hand, are buffered in an array and, only after that, transferred to a FlatField container. Data are resampled depending on the number of dimensions in which the data has to be rendered. After the resampling, the Sets are sent to displays which will paint the data into the GUI (Graphical User Interface). For all this to be available on the web, ISVisualisation was connected to an applet and presented over a regular web browser to the public.

In the following, the three methodological steps adopted during the software development process are presented.

4.3.3.1 VisAD point cloud display methodology

Before processing (see Chapter 3.2), LIDAR data is a point cloud in which a point has no connection to its neighbors. The first challenge for the development of ISVisualisation is the display of these original points. A mathematical model had to be created for the visualization of the points, so that data can be loaded inside the computer memory. The most serious problems appearing at this stage are related to the VisAD mathematical model which should be used for determining the right type of VisAD object[40]. The following VisAD mathematical was thus considered to offer the possibility of coming up with a proper definition of the data loading process.

$$(\text{longitude, altitude}) \rightarrow \text{index}$$

Formula 2. Data loading mathematical model

39 FlatField is the VisAD class for finite samplings of functions whose range type and range coordinate systems are simple enough to allow efficient representation (http://www.ssec.wisc.edu)

40 See Subchapter 3.3.7 for further details.

The VisAD mathematical model creates a matrix with a variable domain and range. The domain and range are represented by the VisAD data-objects of the Tuple type. They are data objects based on scalars of the Real type, but semantically grouped so that they form complex data objects. This matrix is just a collection of three dimensional Cartesian coordinates that follow a specific pattern indicated by an index variable, which was used as a "range" for the "Tuple domain". The "Tuple domain" consists of three elements: latitude, longitude and altitude. The "range" is represented by the "index variable" that results after reading the file and it represents the number of points contained in the file. Given the above-mentioned terms, we can easily infer that the three dimensional "Tuple domain" (x, y, z) is in fact used together with "range" for the construction of a function that takes values from R^3 to R, where "R" represents the set of all real rational numbers, and "R^{3}" consists of three real numbers and specifies a location in the three-dimensional space. In other words, LIDAR data are displayed as a point cloud structured by latitude, longitude and altitude. No relationship was developed between the points inside a point cloud, but they were all referenced to the system origin.

This transcribes itself in the VisAD language as an Integer1DSet whose parameters are the index values of the different Cartesian coordinate Tuples and the number of samples that are to be displayed (see Formula 3). The Integer1DSet is a numerical description of a Tuple or a Scalar. The description refers to the data type of the measures and the geometrical from of the data objects. The data type is in this case *integer* and the geometry is only one dimensional because a point has one single geometrical dimension.

```
index_set = new Integer1DSet (index, number_of_samples)
```

Formula 3. Point clod visualization data model

The mathematical model which backgrounds the programming of the three dimensional visualization of the point cloud is a collateral algorithm. This algorithm was developed as an intermediate development phase with the intention of creating an algorithm for surface rendering. Even though this algorithm is not the one intended to be developed first, it has proved itself very important for showing the properties and consistency of the data.

After converting the data in a VisAD 1DSet, it has to be loaded inside a container. This data container is a FlatField. As shown in the beginning of this chapter, a FlatField is capable of storing data and it provides, at the same time, the possibility of manipulating data. After loading data to a FlatField, they can be accessed through functions and functionalities such as displays. However, in order to be available to a large number of functionalities, the data has to be referenced through the means of a DataReferenceImpl, which connects names to variables and, in our case, data to displays.

4.3.3.2 Visualizing rendered surfaces

The generating of visualization displays produced for the different data types is based upon VisAD specification classes. Once a file has been read and buffered, the data can be further resampled for different functionalities. These functionalities will be available in displays, which contain either surface elements that will render Earth's surface in a realistic way or displays that present contour lines or both. The distances between contour lines can be modified in real-time from the user interface of the ISVisualisation software. The utilization of different displays for the visualization of three-dimensional terrain shapes is meant to facilitate the user's understanding of the landscape reality. The self-developed visualization software can be also used for other datasets than LIDAR as far as data is present in the same formats known by ISVisualisation.

The visualization of terrain models inside displays is only possible if the correct VisAD data model is created. As previously shown (Subchapter 4.3.3.1), the visualization of LASER data as an ASCII file raises some implementation problems that have to be solved in a different way than the GRID file visualization. The data encoding in a GRID dataset makes the reading process for the VisAD-based software easier. The VisAD library contains a special class that handles GRID data. This class is called TiffForm and it is a child class of Form, which is "a leaf-node in the data form hierarchy for the storage of persistent data objects"[41]. This can justify the decision of visualizing three dimensional GRID data in *.tif format. Using this type of data implies a totally different approach to data-handling. An ASCII file can be read with a String Reader and afterwards sorted using a text File Parser. For the *.tif files, a combination of TiffForm with a FlatField and a GriddedSet is used, because, in this way, the *.tif data format, which is specifically addressed by the VisAD classes, can be directly loaded without the need of extra buffering. The read information by the means of the already mentioned VisAD classes is then stored in a FlatField container (a VisAD-specific data container).

41 Source: VisAD Java Documentation (http://www.ssec.wisc.edu/~dglo/docs/index.html)

The VisAD mathematical model "is the most important step in designing a VisAD application"[42] because it determinates the data structure that will be used for the development of the application. For this reason, the determination of the domain and the range of the functions that handle data in the ISVisualisation viewer will follow Formula 4:

$$(\text{latitude}, \text{longitude}) \rightarrow \text{altitude}$$

Formula 4. Domain and range determination

The second step after determining the mathematical model is the determination of the VisAD data objects domain and range. In the case of ISVisualisation, these objects are Real Tuples. The range is determined by dependent variables and the domain is determined by independent variables that are varying with the dependent variables. For the realization of the VisAD mathematical model first the independent variables have to be created, then the dependent variables and only afterwards an object has to be used for establishing a mathematical function between them. After specifying the mathematical model and its function of determination, the program is ready for loading the data. Consequently, the FlatField container has to be created and adjusted according to the function already existing by parameterizing the function to the FlatField definition. Then the scalars (the domain and range) are determined and the dimensions of the GriddedSet are assigned.

Visualizing Isolines and the real-time conversion of grayscale GRIDs to RGB are also problems whose methodological background is presented in the viewer development section. Visualizing ISO-lines supposes the simplification of data from surfaces to contours (i.e. lines), which are still three dimensional. The first step is to simplify data by converting the GriddedSet into a Linear2DSet. At this point, a new function has to be defined. Even though the function follows the same mathematical model, it will handle the data in a different way than in the case of surface visualization. The parameters of the function respect the domain of the prior function but they also add a new range to this. The new function is used for the definition of a new FlatField that will contain the ISO-lines data. This new field needs to be calibrated by resampling it to fit a smaller number of samples corresponding to the lower level of data. After creating and resampling the FlatField, scalar maps, based on the two FlatFields, are created. The scalar maps are used for the graphical representation of the data inside a

42 Source: the VisAD Tutorial Documentation (http://www.ssec.wisc.edu/~billh/tutorial/s1/Section1.html)

display. More about displays and extra features accessed through widgets is presented in this chapter in Section 4.3.4.4.

4.3.3.3 Visualization of images from ISVisualisation through OGC WMS

The visualization of locally stored data has already been presented whereas their methodological functions will be later described in Chapter 5. The data is stored on the same server with the ISVisualisation source-code and that is why the access to data does not imply any authorization. The same should be the case for data existing on other servers. This leads to the conclusion that the simplest way of accessing data, without having to authorize on each server, is the utilization of OGC Web Mapping Services.

The OGC WMS offer the possibility of accessing data by sending a copy of the original file, in the encoding format ordered, to the client (in this case ISVisualisation). The connection between ISVisualisation and OGC WMS was made possible through the usage of the Jump[43] Java library. The JUMP library is part of the JUMP Unified Markup Platform, which is a software tool developed for the visualization and processing of spatial data. Inside ISVisualisation, JUMP is used, first, for the connection between maps or for map creation and, second, for capabilities requests to the WMS. The ISVisualisation class OGC WMS, which is responsible for the connection to the WMS, creates and initializes a connection to the server, after which a map request is sent to the server. The server’s response is saved in an array list. From this list, available data can be selected and displayed in ISVisualisation. Once the layer is selected, the image is automatically sent to the display refresher (details in the following subchapter) and then made available in the GUI of ISVisualisation.

4.3.3.4 GUI programming and display functionalities

The GUI of the ISVisualisation software has been developed in Java. The structure is based on a Javax.swing[44] and is composed of a JFrame, a JPanel and several buttons with diverse functionalities. The JPanel is occupied by the VisAD displays and it will be refreshed or, better said, repainted every time when a new function or button will be activated. All these

43 Source: the JUMP Project homepage (http://www.vividsolutions.com/projects.asp?catg=spageo&code=jump)

44 Source: Java library for GUI programming (http://www.dpunkt.de/Java/Referenz/Das_Paket_Javax.swing/1.html)

components are organized by using a GridBagLayout[45]. The GridBagLayout allows for a better organization of the interface and, in the case of ISVisualisation, where the display needs the largest part of the JFrame, it preserves the best proportion between the larger and smaller components. The GUI is integrated in an Applet, which offers the possibility of online usage. The online availability is also a complicated problem, because of the applet authorization, which has to be made by an accredited institution and is not free of charge. To avoid the applet authorizing process, the ISVisualisation applet as well as the data that the software visualizes will be made available on the same server as the original software.

In the upper right corner of the GUI, a couple of widgets offer the possibility of real-time editing of characteristics. The first widget is the LabeledColorWidget, which maps the altitude in a color table. The colors can also be manipulated by resetting them to the gray color or even by dragging the color lines with the mouse. The resetting to the grayscale will modify the appearance of the 3D model and will cause the appearance of the Isolines in altitude related color scheme. In this way the Isolines are visible and easy to place in terrain. The second widget is the GMCWidget, which turns the mapping texture on and off, enabling the scale and point mode visualization of the data. The third widget is the ContourWidget and it permits the display of labels, intervals and filling effects between isolines.

45 Source: Java GUI layout manager (http://Java.sowas.com/awt/gridbaglayout.php)

5 Results of ISVisualisation programming

5.1 Point cloud display

The point cloud display is designed especially for the visualization of LIDAR data in raw ASCII format. Because LIDAR data in ASCII format occupies a computer memory larger than the LAS data type (see Subchapter 3.3.2), the visualization of this type of data can be easier performed when the computer hardware has a large RAM memory. The memory heap space is a well-known problem with large data packages in Java, but the display of data with a size under 100Mb should not be a problem for ISVisualisation.

At the beginning of the programming period, I started to generate a 3D model, under the form of a surface, directly from LIDAR points. This programming process has been later divided into two separate processes, one that will visualize the point cloud without rendering any surface, and a second process that will render images present in a *.tif form. The LIDAR point clouds could be uploaded and displayed successfully even if the data volume had been bigger than 50 megabytes of memory.

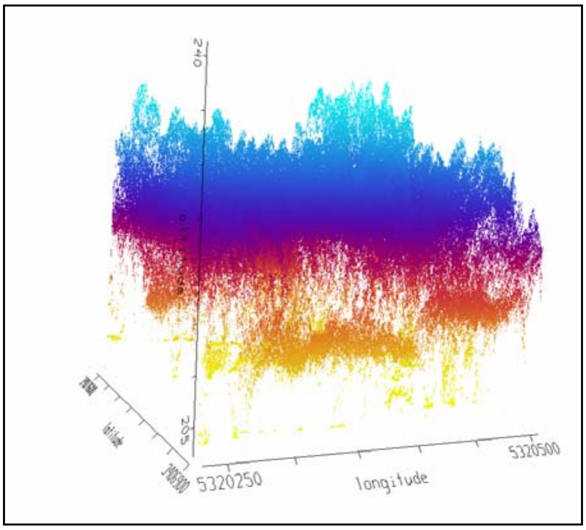


Figure 33. Point cloud display

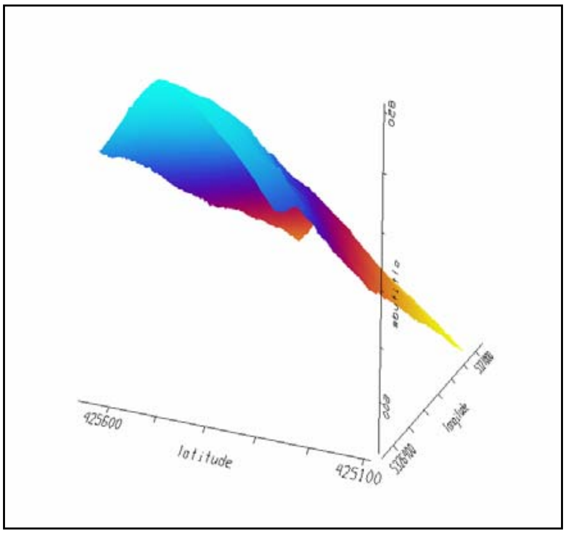


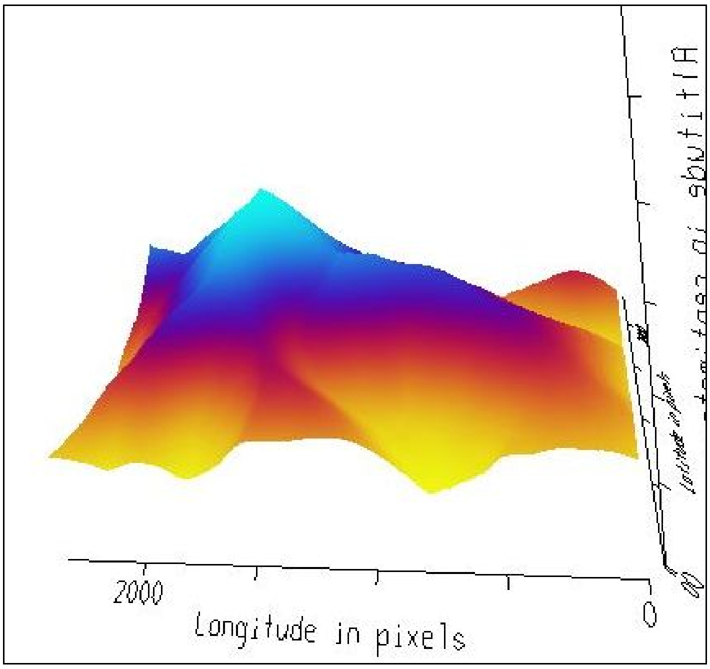
Figure 34. High-density point cloud surface

The results, as you can see in Figures 33 and 34, are displayed in RGB, based on the altitude-function criterion, from blue-high to yellow-low. I chose the color inversion for a better visualization of the results. Even though my initial intention was to obtain a surface (as in Figure 34) that interpolates the points in order to create a surface, this result is very important because of the presence of singular points that carry three-dimensional information. Using this possibility of visualizing raw information, errors can be detected before engaging in complicated and time-consuming filtering processes.

5.2 Visualizing rendered surfaces

The initial task of the programming algorithm enclosed in ISVisualisation was, as already mentioned, the rendering of the 3D models as surfaces. According to the methodological flow presented in Chapter 4, the 3D model visualization proved to be a success (see Figure 35). Not only that a model could be visualized but, along with it, a series of special widgets were also available in the viewer.

Figure 35. 3D model in RGB negative



The visualization of 3D models with ISVisualisation does not only focus on the visualization of the actual model but also on the visualization of isolines and of altitude differentiation, respectively of isolines intervals, through the colors used for the 3D model. When using the LabeledColorWidget, the 3D model can be visualized in grayscale (see Figure 36) and in this way the isolines, having confounded themselves with the background before, come visibly forward. There were two main modalities by which the intervals between isolines could be colored, based on a combination between the colors of the two delineating isolines (see Figure 37):

a. extension of the existing presets for the visualization of isolines;
b. introduction of GMCWidget, by eliminating the texture mapping and using the fill option from GMCWidget.

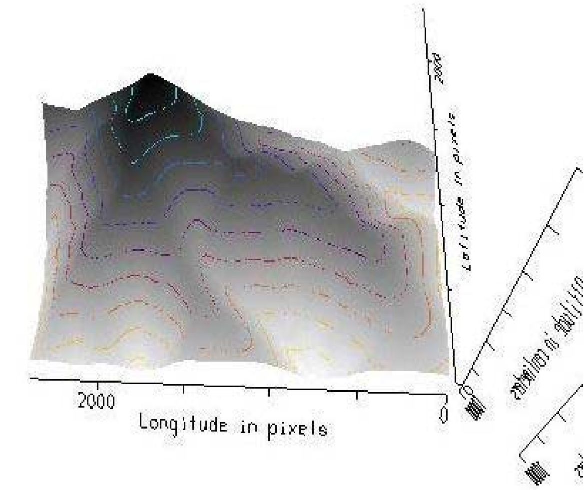


Figure 36. 3D model in grayscale with superimposed isolines

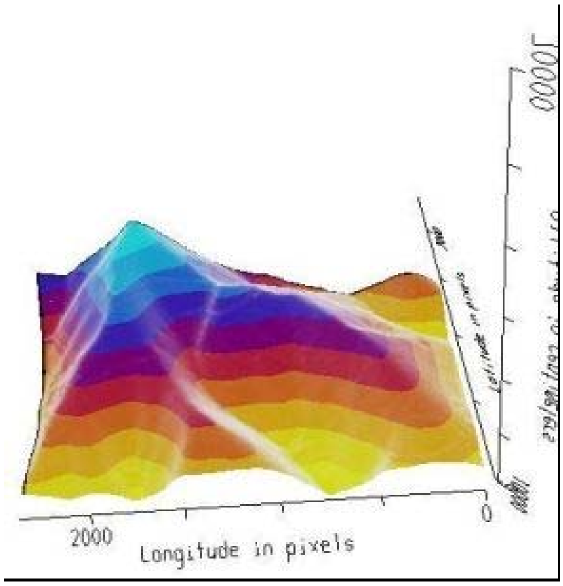


Figure 37. 3D model in RGB differentiation between isolines intervals

5.3 Visualization of images through OGC WMS[46]

The visualization of images on a server through Web Services proved itself to be a harder mission as previously anticipated. The connection with the server was realized using the specifications for Web Mapping Services of the Jump[47] libraries. In this way, after addressing the *Get Possibilities* query to the WMS server, a set of information will be received. The answer contains available images and some of their characteristics. A noticeable problem appeared when trying to load data into ISVisualisation: the server returned data in RGB format through three information channels or, better said, three layers of reflectance (24bit) whereas ISVisualisation, based on the VisAD data structure, needed grayscale data (32 bit) constructed only on one layer of reflectance. VisAD has no class that can manage to convert three-channel RGB images into one-layer grayscale images or to directly load RGB. On the other side, the Apache server where the WMS is present, can not convert data images (ex: jpg,

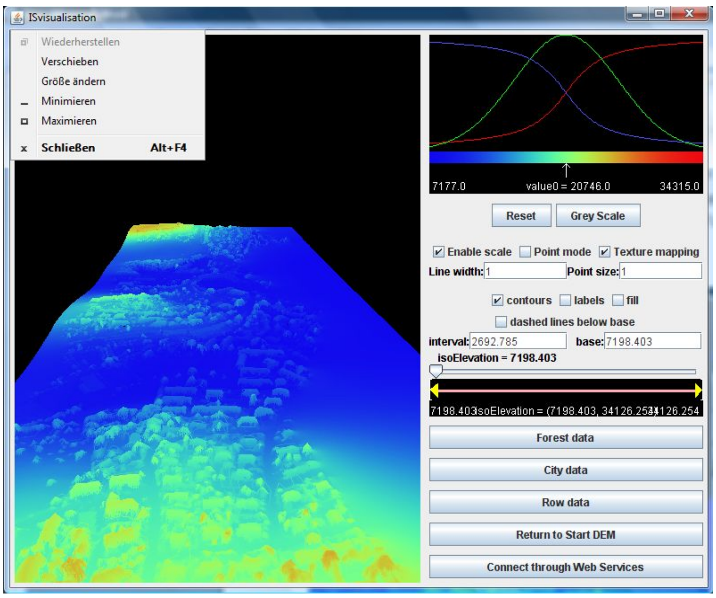
46 OGC WMS – Open Geospatial Consortium Web Mapping Services (http://www.opengeospatial.org)
47 Source: the JUMP Project homepage (http://www.vividsolutions.com/jump)

gif, img, etc.) to *.tif since it has no functionality for doing this kind of transformation. Because of the impossibility of converting the received image on-the-fly, a buffering of the image sent by the server was needed. Once the buffering made, the conversion of the image to gray values could be realized and the visualization of a 3D model through WMS in ISVisualisation was made possible.

5.4 GUI programming and display functionalities

For the visualization of the Java classes implemented with VisAD, a GUI was created. The GUI is split into two parts, a Panel surface where the VisAD displays can be shown and another surface with buttons, check boxes and an interactive LabeledColorWidget. On the left side of the GUI, data can be visualized on the display surface. As you can see in the image below (see Figure 38), GUI displays the 3D models on the left side of the JFrame and the handling widgets are placed on the right side of the frame. All the features already presented in the methodological chapter (Subchapter 4.3.2.4) function very well, but the application velocity depends on the type of functionality put to work. When a change of color is asked, the system needs more time than when the density of the isolines is changed. The longest time for a system refresh is allocated to the data loader. This happens because the new data has to be run through the entire program and then put into the display. Just as an example, in order to load data with the size of 50Mbytes, ISVisualisation needs 10 seconds.

Figure 38. ISVisualisation applet



6 Exemplification of e-Learning content generation and design

The teaching of GIS and Remote Sensing is nowadays strictly connected to GIS and Remote Sensing software. Teaching these disciplines only in a traditional way will eventually lead to the lack of understanding between teacher and learner. Acknowledging this, the Department for Remote Sensing and Landscape Information Systems (FeLIS) of the University of Freiburg promotes teaching performed in computer pools where students have direct access to GIS and Remote Sensing software. The software used in the classrooms in usually not free of charge and students can not afford to buy it. In this way, e-Learning is the best solution for teaching these disciplines, as it can be accessed anytime, anywhere and students can take lessons whenever they have time to do so. The e-Learning modules are not meant as a substitution for the courses already being taught at FeLIS, but as an additional form of education which is available for all students registered at the University of Freiburg.

6.3 The GIS e-Learning modules on ILIAS

There are fourteen GIS e-Learning modules (see Table 3) produced in ILIAS and they are placed on the ILIAS e-Learning platform[48] of the NNR project. Twelve of them are lessons (numbered from one to twelve) and contain information on GIS, ranging from the simplest issues in GIS to the complicated components of the high-end GIS software. Along with these lessons, two other learning entities are present: an exercise, which is connected to lesson no. three ("Earth's Geographic Coordinate System") and an extra lesson called "Spatial Analyst", which focuses especially on the Spatial Analyst Tool of the ESRI ArcGIS software.

The first four lessons are introductive and are meant to help the student understand GIS basics and to prepare him/her for the lesson(s) to come. This first group of lessons is compulsory for beginners and also recommended to non-beginners. Lessons five to eight concern the concepts of the GIS data and database models and are strong connected to each other. For the best performance to be achieved, it is recommended to attend the whole group of lessons before going to the following group. The third group of lessons contains the lessons nine to eleven and, additionally, an extra lesson called "Spatial Analyst". This group refers to data analyses

48 Source: http://ILIAS.naturnet.org/

and each lesson can be handled as it were a single entity, except the two lessons dedicated to the same topic, “Data Evaluation”.

Most of the lessons (nine of them) are followed by tests and two of them end with an exercise. The exercises should be solved at home and the results are to be sent back to the examiner together with a short explanation. Each of the nine tests includes five questions directly related to the content previously presented in each lesson.

A glossary and extra web-resources are also available in the ILIAS GIS lesson modules. The glossary contains only the terms that needed explanations during the lessons, while links to other glossaries are present in case the student needs to find some more information on terms that are not present in the e-Learning modules.

6.4 The Remote Sensing e-Learning modules on Moodle

The Remote Sensing e-Learning modules are grouped in a chapter called “Combating Floods using LIDAR data – A case study in Waldkirch/Germany” on the MOODLE e-Learning platform[49] of the NaturNet-Redime project. The ten modules (see Table 4) were designed as a case study for the region of Waldkirch. They are meant to help the learner understand the Remote Sensing methodology and technical details when wanting to solve a flooding control problem. These eleven e-Learning modules are, from the beginning, content-specific and have less introductory elements than the GIS learning modules on ILIAS.

The e-Learning content of the eleven above-mentioned e-Learning modules starts with information on the location of the town of Waldkirch, the problematic of the situation and a UML schematization of the steps to follow in order to solve the problem. The second module presents the specialized firms which will manage the flight planning and data analysis. This section reveals the importance of selecting the proper aircraft for data acquisition. The third module introduces the existing LIDAR hardware, mentioning their usability in different situations. After presenting the existing hardware in module three, module four gives further details on the utility of each of them, pointing out advantages and/or disadvantages and presenting, at the same time, possible applications and concrete utilization problems. Module five offers further information on the technical background of the LIDAR technology by discussing flight stripes, meteorological conditions during flight, system calibration, and LIDAR data formats. Module six is a continuation of module five and its content refers to point determination, orientation data, orientation accuracy, digital airborne cameras and their calibration.

After the data acquisition stage described above, data processing comes into discussion in module seven. The biggest problem occurring in data processing is the strip adjustment problem. In module seven several data processing algorithms are presented and exemplified. Module eight presents errors that may occur in positioning and distance measuring or beam related errors. Modules nine and ten are related: they both present filtering algorithms for the LIDAR data. A series of well known algorithms is therefore presented in detail. The eleventh module is the last one and contains information upon LIDAR data visualization possibilities:

- locally, in real-time, on a local computer using the TreesVis (see Subchapter 3.4.5) software solution;
- online, also real-time, through a server, using the ISVisualisation software (see Subchapter 6.2).

The learning modules for the case study Waldkirch have to be seen as a whole and can not be separated, as in the case of the GIS modules. The learner has to follow the indicated sequence of content units in order to succeed in understanding the problems and the solutions to the problems offered by the course. At the end of the last module, the software that can be used for such data is presented and an online utilization of ISVisualisation is also demonstrated, so that the learner may have the possibility to understand how LIDAR data can be used in spatial planning decisions.

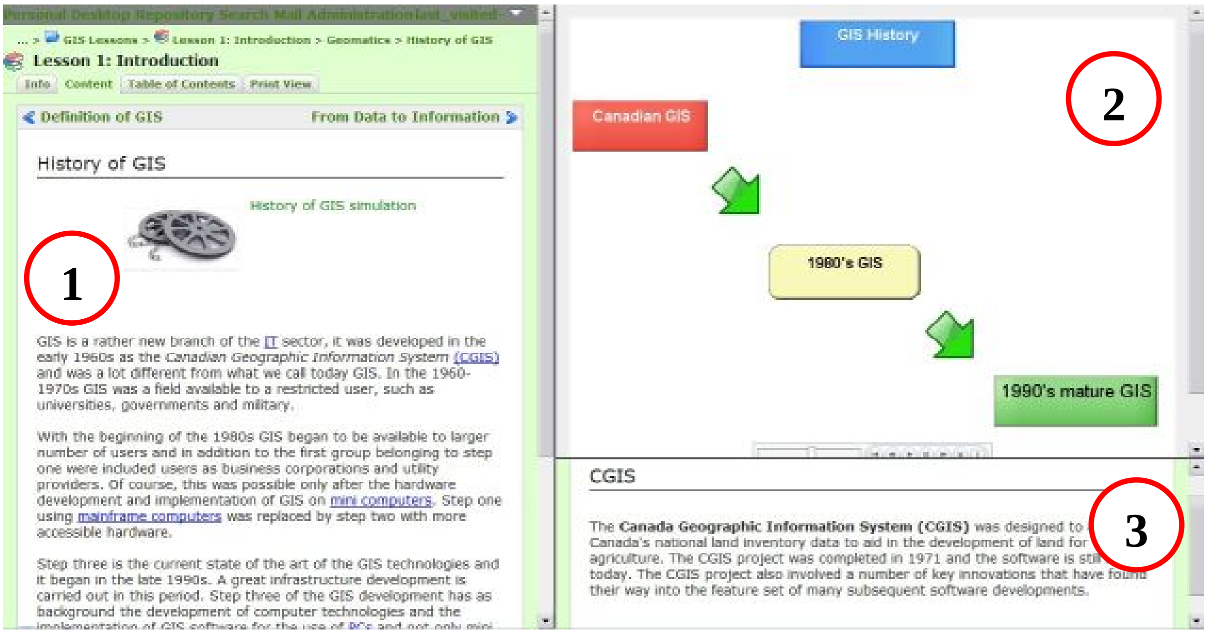
49 Source: the NaturNet-Redime portal homepage (http://portal.naturnet.org)

6.5 Media design of the e-Learning modules

6.5.1 Display windows of ILIAS used for the GIS modules

ILIAS offers the possibility of selecting from a range of five display types. For the development of the specific GIS e-Learning modules, a display composed of three zones was selected. The three display zones are the *regular content zone* (Zone 1 in Figure 39) where text, images and media can also be embedded, the *media zone* (Zone 2 in Figure 39) where flash simulations can be visualized and the *glossary zone* (Zone 3 in Figure 39) where the glossary entries are viewable. This type of display was selected because of its multifunctional zones and because the media present either in the content or in the media zone can be zoomed in and reopened in an extra window.

Figure 39. Example of e-Learning module in ILIAS

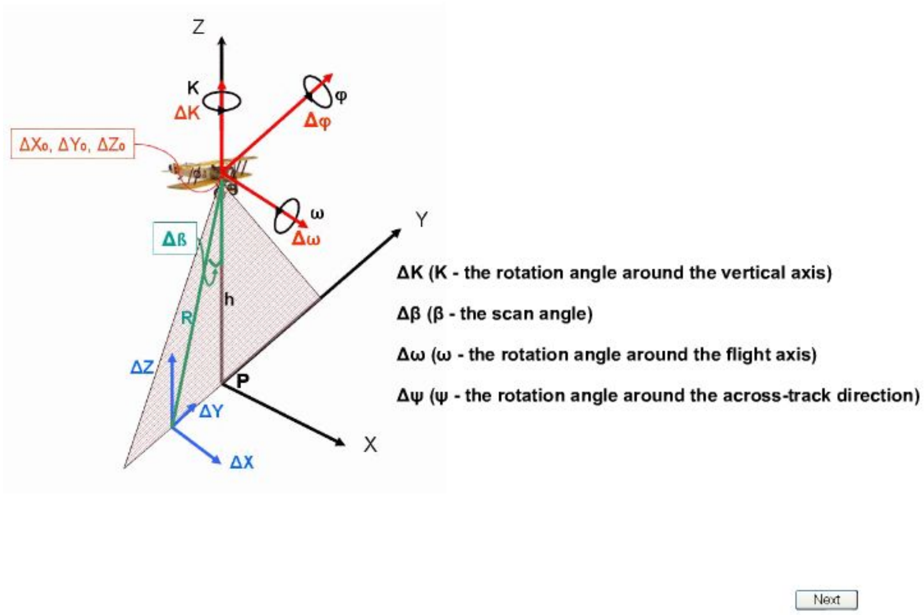


Using this type of page layout, content and media can be simultaneously followed by the learner. Moreover, definitions of technical terms can also be read without having to change window in order to look inside a glossary. The dimensions of the three-display zone can be modified in such a way that one window could occupy the entire screen when needed. In this way, the learner can focus on the window whose information is most needed at a specific time during the learning process.

6.5.2 Simulations and interactivity

Simulations in this chapter have to be understood as flows of graphics that simulate a process. The simulations present in all the e-Learning modules were realized with the help of Macromedia Captivate (see Subchapter 3.4.7). These simulations have both a presentational and an interactive character. In fact, even simulations with a presentational character offer slight interaction with the learner by giving him/her the possibility of shifting between pages. Moreover, both the presentational and the interactive simulations have a control line which allows the user to navigate between pages inside a simulation. Presentational simulations partially contain an audio background so that the viewer, at the end of the simulation, can get a very good idea of the depicted contents. An interesting subtype of presentational simulation is the error compensation simulation (see Figure 40) which is a part of the Remote Sensing e-Learning modules in Moodle and encapsulates graphics of the possible error sources and the error calculation table for an error affected data set. The error deviation determination is based on formulas that are present in the e-Learning module.

Figure 40. Presentational simulation example –Error compensation for LIDAR data

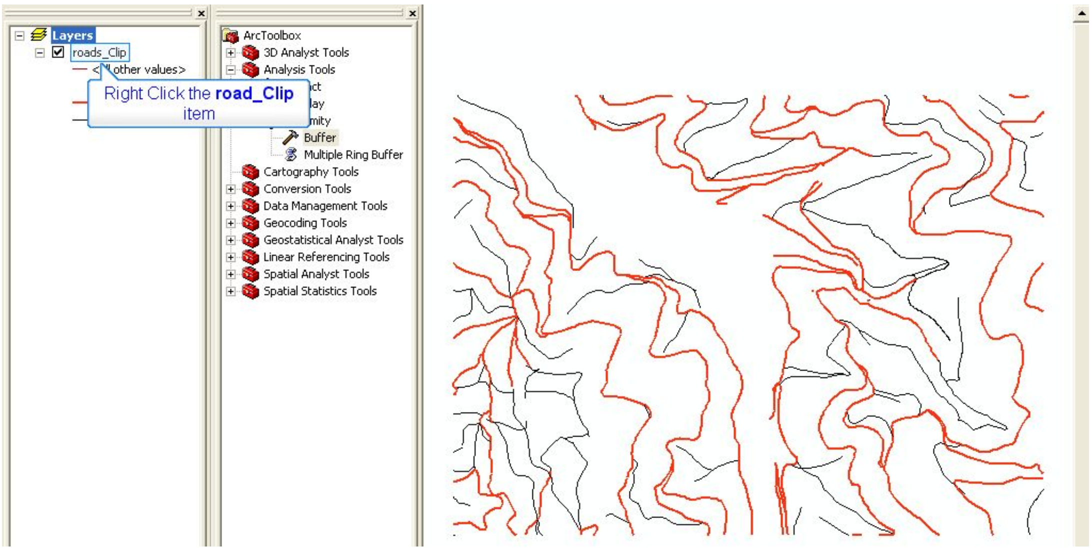


The interactive simulations are based on the “learning by doing” principle. This type of simulations proceeds with learning activities only when the learner follows the right procedural steps. An interactive simulation, like the proximity filter simulation (see Figure 41), allows the learner to understand the principle and the workflow which determine the filtering possibilities for GIS applications. This simulation can be explained as follows:

Having the road net, which includes two different classes, of a region and knowing that a road with the index 92 (large road) brings on a distance of 7,5m from the axis in both sides a high pollution level, create a buffer that will help us determine unpolluted zones.

The user is confronted in this case with a concrete problem and the simulation gives him the possibility to solve it and to learn, at the same time, the various procedural steps to the solution.

Figure 41. Interactive simulation



6.5.3 Waldkirch model visualization

The visualization of Remote Sensing data in real time was made possible through the use of the ISVisualisation software (see Chapter 6.2), which was especially developed for this dissertation thesis.

6.5.3.1 Visualization vs. interaction

Visualization and interaction are two concepts that go very well together but which are also often misunderstood because no distinction between them is clearly made. Interactional visualizations, as the already presented simulations developed in Macromedia Captivate, are the best examples able to lead to the differentiation between the concepts. Through these visualizations, the learner interacts with the computer by simply following the workflow within a simulation. When thinking that an interaction needs some kind of input from the learner's side, we can stipulate that this is the breakpoint between the two notions.

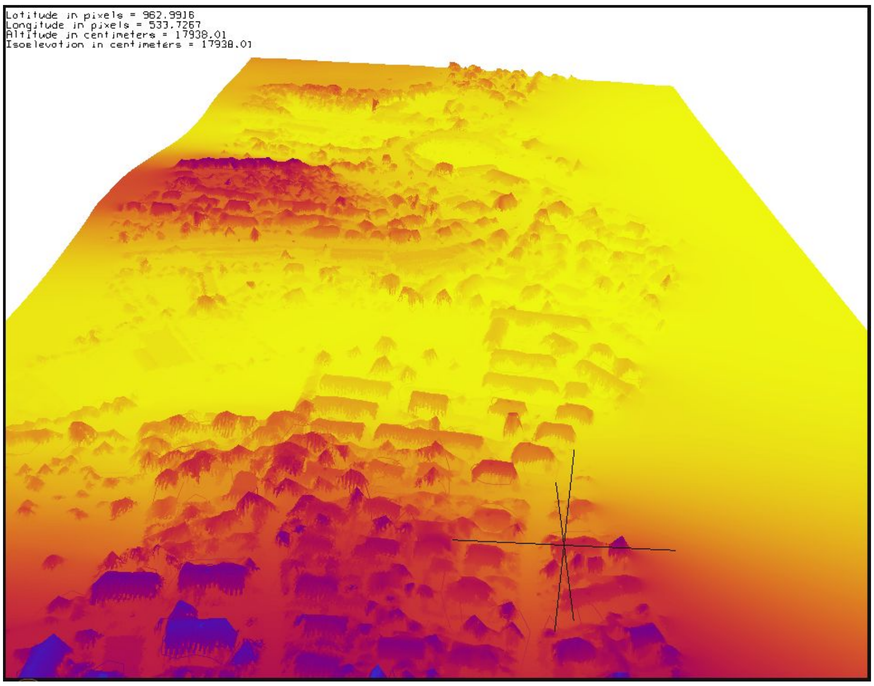
6.5.3.2 Real-time visualization

Real-time visualization is a concept that goes even further than the interactive simulation; it allows the user such a great field of possibilities that, when speaking about 3D models of the real world, the learning process is actually an endeavor of data and geographical locations made in real-time. ISVisualisation offers this possibility to learners by actively involving them in visualizing 3D models in different ways. 3D models can be visualized in RGB, where the colors are changing with the altitude, or they can be visualized in grayscale, where special features like Isolines are clearly visible and 3D models can be visualized only as isolines. The intervals between the Isolines can be interpolated in the color of the two isolines delimitating the interval. The coordinates of the points constituting the 3D models are also viewable by the means of a coordinate system and by using a specific keyboard/mouse combination. Coordinates and altitude are displayed in the upper left corner of the viewer's display window. Connecting the ISVisualisation to web services gives the learner the possibility of visualizing images freely available on the web.

6.5.3.3 The Waldkirch model

In Figure 42, a 3D model of Waldkirch is visualized, in which buildings and vegetation are easy to recognize.

Figure 42. 3D model of Town Waldkirch in RGB negative



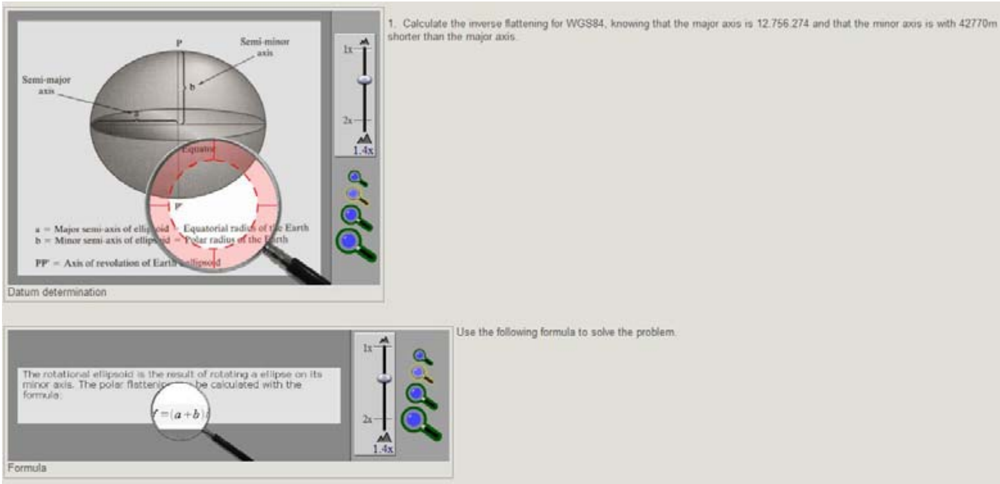
The ISVisualisation software offers the possibility to handle data by zooming into it as well as to determine the coordinates of a point by positioning the *cursor cross* on the point to be determined. Zooming is possible by holding the shift key and simultaneously moving the mouse: up for zooming in and down for zooming out. In order to determine a point, one has to hold pressed the middle button, also called the *scroll* button, or hold both of the lateral buttons of the mouse. When doing so, information on latitude/longitude and positioning of isolines appears in the upper left corner of the viewer's window. Moving around the entire 3D model is also possible by holding pressed the left mouse key and drag the mouse in the intended rotation direction.

6.5.4 Feedback through tests and exercises

At the end of each GIS e-Learning module, an exercise-test will help the learner to fixate information and verify the correctitude of the knowledge acquired. The tests are One-Choice and Multiple-Choice, each of the tests containing five questions based on the already taught course. The evaluation of the questions comes at the end of each test, where the learner has the possibility of restarting the test and discovering his/her mistakes. The learning control is a very important function of e-Learning modules, because it allows the students to concentrate on the most important issues in a lesson.

Along with tests, exercises are also part of the evaluation procedures in an e-Learning environment. They are meant to give the learner the opportunity of actively solving various GIS specific problems. The exercise "Earth's flattening calculation", realized with the help of the SCORM compliant content generator software called *eXe*, challenges the student to understand the approximation of the rotational ellipsoid which mathematically corresponds to the shape of the planet. In other words, the determination of the WGS84 datum represents in fact the determination of the approximation of the rotational ellipsoid which will better assess Earth's surface through the use of a mathematical model.

Figure 43. Earth's flattening exercise calculation



Performing the calculations for the inverse flattening of the Earth, by knowing the major and the minor axis, brings the learner to understand the practical aspects of the Earth' approximation models.

Exercises are used in e-Learning models in order to activate learners (cf. Stümpel 2005). This means that a learner who studies the content of a lesson in depth because he/she has to solve a specific problem raised by an exercise or a questionnaire, will definitely focus on that content so much that and the risk of treating the lesson superficially will be avoided.

7 Discussion and future work

This chapter will discuss, in turns, the development of the e-Learning modules as part of the NaturNet-Redime project, the selection and analysis of the existing e-Learning standardization and software, and the technical and methodological challenges of the ISVisualisation software development. The whole analysis will be treated from a critical perspective, by taking a bird-eye's view on the existing literature on each of the enumerated discussion subjects. The central scientific questions of the present thesis will be given elaborate answers, insisting on the 3D modeling usage in the field of GIS and Remote Sensing e-Learning models.

7.1 Discussion upon the e-Learning standard selection and analysis procedures

The standardization of the e-Learning software and the existing e-Learning platforms are two problems that have been treated, from the beginning, as ground milestones both for the present thesis and for further research in the domain of e-Learning.

In the first chapter of the thesis, seven research questions were raised, meant to serve as reference points and guiding hypotheses throughout the research process triggered by the investigated scientific area. The first two questions refer to the e-Learning content standardization and e-Learning in general but they also refer to the existing e-Learning software which can match both the purposes of the NaturNet-Redime project and those of the thesis.

E-Learning standardization is a current and very important issue, which is directly correlated to the follow-up development of an e-Learning concept as a cooperative and source-distributed information resource. Discussions on "how much standardization does e-Learning need" have been a burning theme in the last years at the European level and worldwide (Wierzbicki & Wankelmuth 2003). Most standardization models have been developed independently from the others and therefore incompatibility problems have appeared. The biggest problem of e-Learning standardization setting is not the inexistence of the standardization but the misunderstanding, from the developer's and user's point of view, of the expression “conform to e-Learning industry standards” (Masie 2002). That is why the culling of the perfect e-Learning standardization was essential for the selection of an appropriate e-Learning platform. Questions on the necessity of using e-Learning standards, and especially of using SCORM as a standard, are very frequent in the e-Learning development community. A straightforward answer given by a well-known e-Learning specialist was: „SCORM is as close as you get to Mandatory in the world of e-Learning”[50] (Karrer 2006). Indeed, in the last years, SCORM has reached a *de facto* status among other e-Learning standardization models because it “is a fairly easy standard to deal with” (Karrer 2006) and because of its bundled structure.

The selection of SCORM as the most suitable standard for the NaturNet-Redime e-Learning platform was the result of a selection process which is largely explained in Subchapter 4.1.1. Before presenting the selection of standardization models, an overview of the potential e-Learning platforms was provided (see Annex I): an enumeration of 36 platforms with different standardization models. A percentage of 44% of the open-source e-Learning platforms and 27% of the commercial platforms are SCORM compliant, whereas 64% of the commercial platforms give no information upon the standardization used in their development. In both cases, SCORM had the highest percentage of all present standards. This entitled me to study SCORM into detail and compare it with the other standards also present in the e-Learning platforms enumerated in Annex 1. Not only that the literature points out SCORM as the most complete e-Learning standard but, at the first Technical Meeting of the NNR Project, the NNR specialists agreed with my decision in having SCORM as selection criterion/pattern for the future e-Learning platform.

As already presented in Subchapter 4.1.1 and graphically depicted in Figure 6, SCORM standardization is a bundle of standards, being the fruit of the joined efforts of several specialized institutions enumerated in Table 11. In this work, it has already been acknowledged that SCORM, being the result of such a sustained effort of so many specialized institutions, is, at the moment, the best standardization possibility for e-Learning software. This is directly reflected in its ability to encapsulate valuable components from already tested and utilized standards.

50 Source: the web blog of Tony Karrer (an e-Learning “Guru”): http://elearningtech.blogspot.com/2006_09_01_archive.html

At the European level, as shown in Subchapter 4.1.1.2, the interest in the standardization of e-Leaning platforms has more to do with technology than with content. In Figure 7, it is shown how the central e-Learning topics are distributed in diverse projects: 75% is technology-oriented and only 14% focuses on Learning Objects, which represent the content.

E-Learning standardization is much more important in the open source e-Learning platform design sector that in the private one since the majority of the open source e-Learning software developers are connected to universities. In order to support this statement, Chapter 4 provides an overview of the standardization models valid for open source and commercial e-Learning platforms. Their standardization status is also analyzed: 75% of the Open Source e-Learning platforms are conform to a standardization model (of which 44% is SCORM compliant); on the other hand, among the commercial platforms, only 36% follow existing standards (of which 27% is attributed to SCORM and 9% to IMS). This situation was probably caused by the competition between the e-Learning developing companies and the need of securing models from further unauthorized utilization. At the opposite pole, there are the open source developers that feel the urge of interchanging information, such as universities or governments, which are interested in offering information to the broad public.

All these SCORM-related percentages are based on partially-complete information because of the lack of details regarding standardization provided by different e-Learning developers.

7.2 Discussion upon the e-Learning platform selection and analysis procedures

Research question: *To what conclusions brings us the ILIAS Moodle comparison?*

Comparisons between e-Learning platforms have already been made, but most of them only treat a low number of platforms, such as in the works of Donati et al. (2004) and CatalystIT (2004). In the two publications, ATutor, ILIAS and Moodle platforms are compared from the multimedia and software functionality point of view. However, the comparisons do not define a complex matrix, such as the one used in the present work, and they are not therefore able either to cover the entire spectrum of factors contributing to good applications, such as the present work encloses.

Winter (2006) draws a parallel between Blackboard, Moodle and Interact and specifically "addresses the use of LMSs to support workplace learning and professional development", but this publication, again, mostly presents the results of some interviews which summarize personal experiences of the interviewed subjects and it does not present any strategy of selecting the best possible e-Learning platform.

Other comparisons, like the ones performed at the University of Granada in Spain (Itmazi & Megias 2005) are mainly oriented towards the technical aspects of the implementation of platforms, towards the frequency of utilization and they also include commercial software in their selection. Itmazi and Megias (2005) generally compare studies that recommend one or the other e-Learning platform. Moreover, standardization does not play an important role but, as usual in the e-Learning world, multimedia and software functionalities are preferred to any content or functionality standardization models.

The present work is therefore useful, in that it introduces a methodology of selecting the appropriate e-Learning not only from the software development perspective but also from the point of view of the content standardization, runtime functionalities and multimedia integration; bringing all these parameters to the same level will be able to create an equilibrium state indispensable to a sound exchange of e-Learning content between existing and follow-up e-Learning installations. Other authors like Karrer[51] (2007), being a CEO of an important e-Learning software development firm, will only focus on the business-related input such as stakeholder definitions, agreeing with the stakeholders on proceeding, defining a business strategy, etc., which totally underestimate the need of standard-orientation in the e-Learning selection process.

The e-Learning platform selection process explained in Chapter 4 extends over two subchapters, Subchapter 4.1.5, where the low- and medium-intensity selection levels are detailedly presented, and Subchapter 4.1.6, where the high intensity selection level is explained. The first selection step was the simplest to perform, where the open source and the commercial e-Learning platforms were separated. The most important arguments in favor of selecting an open source e-Learning platform were the fact that the NaturNet-Redime could not afford buying a commercial software solution and because the open source platforms also

51 Source: the web blog of Tony Karrer (an e-Learning "Guru"): http://elearningtech.blogspot.com/2007/10/lms-selection-process.html

provide source codes which could be modified according to the projects' needs. Even though the low-intensity selection of the platform was based on only one criterion, only 39% of the initially selected platforms were eligible for the medium-intensity selection level.

It has to be emphasized at this stage that eliminating commercial e-Learning platforms from the medium intensity selection level meant, at the same time, the exclusion of high-quality platforms which could have occupied the top positions otherwise.

The medium-intensity selection methodology implied the introduction of a larger number of selection criteria. Eight selection criteria were therefore designated and, in order to eliminate all undesired platforms, each of them received *weights* which emphasize the features wanted for an e-Learning platform. By using the eight criteria and their *weights*, a selection matrix was generated (see Formula 1): among these eight selection criteria, two, the e-Learning standardization and the license type, were designated as knock-out criteria. After performing the selection by using the selection matrix, three platforms detached from the majority (see Figure 20). The top platform, which obtained most points through the selection matrix, was ILIAS and the following two were MOODLE and ATutor. As the following two platforms had equal scores, an extra selection criterion had to be included, such as the number of instances installed on each of the two platforms. The platform having the biggest number of installed instances was Moodle, with almost twice more instances than ATutor (see Figure 21). In this way, Moodle joined ILIAS in the last and most accurate selection level also called the "ILIAS versus Moodle Selection Level".

The high intensity selection level was conceived in order to accurately delineate the differences between ILIAS and Moodle and to designate the best platform for the NaturNet-Redime Project. At this point, the selection process was considered from three perspectives: the expert's, the content editor's and the learner's perspective.

The expert's perspective on the selection process between the two e-Learning platforms is largely explained in Chapter 4 (see Subchapter 4.1.6.3) and consists of an enunciation of the six selection criteria and the assessment of these criteria by the means of an expert interview (see Chapter 4.1.4 and Annex III). From the expert's perspective, two methodologies were used for the platform selection: the expert interview and the direct voting based on a scheme presented in Chapter 4 (see Subchapter 4.1.6.3). Both selection methodologies have indicated ILIAS as the best suitable e-Learning platform for the NNR project.

Going further to the content editor comparison perspective, the platforms were compared by using criteria such as: personal desktop quality, content organizing and packing functionalities, content editor utility, SCORM exportability. All these criteria are organized in subchapters and at the end of each subchapter a *Plus/Minus* estimation was made. The conclusion of the content editor's perspective was that the two platforms are equal in this respect, both summing two pluses and two minuses in the comparison process.

The third comparison perspective is the learner's perspective, for which a second expert interview was realized (see Annex IV). The interview revealed that the users were more interested in using Moodle than ILIAS, even though they knew that Moodle did not respect the standardization model selected for the NNR project. This can be explained trough the fact that the majority of the members in the consortium are middle-life adults to seniors and only a small part of them are less than 35 years old. In is explainable then that, because of the strong resemblance to a website, Moodle won the selection process in the NaturNet workshops. Moodle has a user interface that is very much alike with a normal website whereas ILIAS, on the contrary, is a completely new platform with new navigation buttons and terms used for content resources. Theoretical studies state that "websites tend to be produced by young designers, who often assume that all users have perfect vision and motor control, and know everything about the Web" (cf. Nielsen 2002) and that is why younger users considered Moodle and ILIAS not so different from the learner point of view. The theory was confirmed by a group of younger users, representing the *Gymnazium Bozeny Nemcove* from the Czech Republic, who considered ILIAS more interesting than Moodle. These young users based their decision mostly on the functionalities that both platforms were able to offer.

Based on the results reached in the present dissertation, it can be stated that standardization is one of the most important aspects of e-Learning software and content development and, even if the software providers are not interested in doing so, the e-Learning community is longing for standardization in this field. In the future, it is expected that large open source e-Learning software developers may introduce standardization and possibly SCORM, exactly as the commercial e-Learning software providers WebCT and Blackboard already did. This is a tendency that has to be argued for, especially in higher education.

7.3 Discussion upon the e-Learning modules

This section of the discussion tries to answer to research questions enunciated at the beginning of the thesis: *What possibilities offers e-Learning for Geoinformatics education?* and *What possibilities offer e-Learning platforms for the designing Geoinformatics content*?

Geoinformatics is a domain where learning supposes a constant interaction with computers and new software. That is why, in order to increase efficiency in education, universities and other institutions specialized in Geoinformatics are interested in collaborating for e-Learning content interchange (Mäs & Reinhardt 2007).

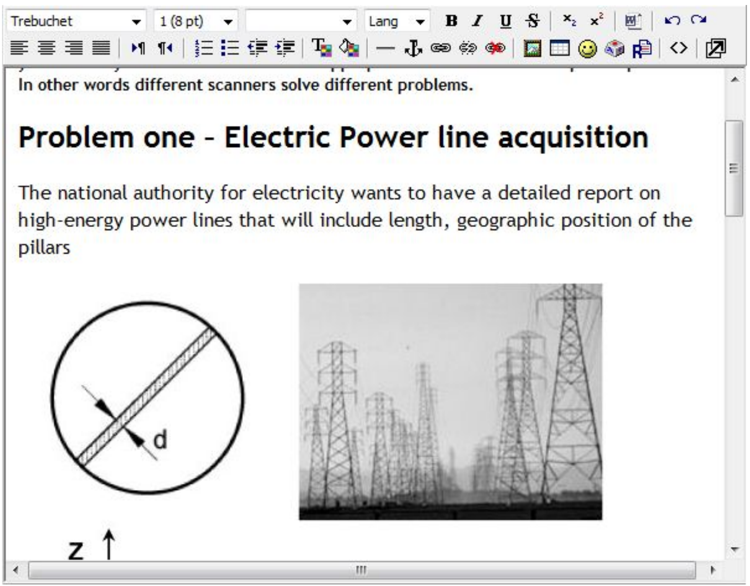
The e-Learning modules designed for this doctoral thesis are differentiated into two classes, depending on the development motivation and background. Being developed for two different groups of users, as shown in Chapter 4 (see Subchapter 4.2.4), the models can be also differentiated from each other on the basis of the e-Learning platform on which the content was inserted. The e-Learning modules especially generated for the FeLIS Institute's students aim at achieving a learning process which includes compulsory examination and evaluation processes. The modules developed for the NNR users have no mandatory fields but they still have the possibility, at a reduced scale, of examination and evaluation meant to help learners to understand the content and control the information acquisition.

Even if the e-Learning content elaboration followed similar methodology and didactical concepts (see Subchapter 2.3), some differences appeared based on the technical differences in the infrastructure of the e-Learning software. For media file visualization (ex: *.swf, *.avi, etc.), ILIAS provides a media window where the media can be played without interfering with the content visualization present on the same page. Moodle is incapable of doing so and, in general, the content editor has to generate a new window for the visualization of media files outside content. In other words, Moodle does not offer the optimal solution in media visualization.

When generating a course in Moodle, the content editor has the impression of writing inside a webpage and not in a separate module destined for e-Learning. The connection to pages in a module is easy to realize but it still creates confusion between editors because they have to connecting pages from a popup list. This problem does not exist in ILIAS, where different pages are placed in folders and the order in the module is determined by the order in the containing folder. Pages are successively loaded in the order of their presence in the containing folder and the buttons which are used during navigation inside the modules are automatically named as *the following page*. The structure of ILIAS is much more organized than Moodle's and that is why jumping from the last to the first page is not possible. In this matter, Moodle demonstrates an incredible flexibility which in ILIAS could only be done by creating internal links inside the content.

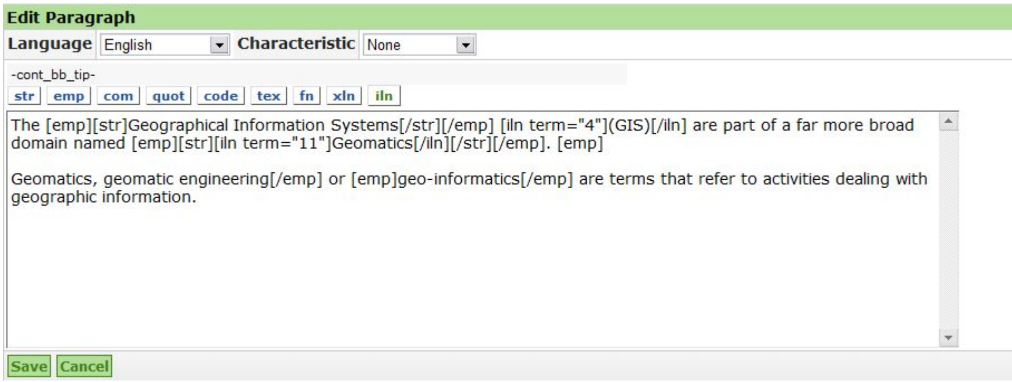
When thinking at text editing and media file uploading inside the two platforms, Moodle is the detached winner, because of its quick and easy editing features due to the integration of a WYSIWYG HTML editor. This editor allows the content editor to write, copy, and paste formatted text, link WebPages, create table as easy as in a specialized Office package.

Figure 44. WYSIWYG HTML editor implementation for Moodle



Creating content directly in the e-Learning platform is very simple in Moodle and image uploading can also function by using the editor. ILIAS is in this respect a more poorly equipped software, because, even if we consider that iLEX is a perfect tool for generating e-Learning content, the editing has to be done in the ILIAS default editor (see Figure 45).

Figure 45. ILIAS default text editor



No doubt that editing in this type of editor is very time consuming and inefficient. Because of this, it is probably easier to edit text in Open Office in ILIAS and, only when having finished, to use iLEX for the content upload. Even so loading data like simulations and videos will have to be done in ILIAS and not directly using the editor, like Moodle's WYSIWYG HTML editor. After uploading the media file in the media pool of ILIAS, a link has to be established by using the ILIAS default editor. This is ILIAS' weakest point in editing and, at the same time, its biggest problem in general. Editing in this way needs time, not only for editing itself but also for instructing editors in how to use this default editing tool.

Another problem spotted while exploiting ILIAS and Moodle was the content interchange when using SCORM modules. ILIAS is an ADL certified e-Learning platform, which means that it can generate as well as import SCORM content. Testing this functionality of ILIAS was easy to realize: the import-export functionalities are easy to find when editing a model and selecting the Export tab, i.e. you can select between XML, HTML or SCORM packaging. Importing data in ILIAS does not raise any problems either. Moodle stated that their platform is SCORM compliant, thus being able to import SCORM modules. However, many times when trying to import SCORM packages exported from ILIAS, an error message was returned. By loading SCORM modules, the structure is a bit modified, background color is usually changed to gray or media is not available any more. For other modules, the index is changed by introducing an extra chapter under which the module can be found; hence the module has to be clicked twice in order to view the contents.

As a conclusion, it can be said that, when choosing between ILIAS and Moodle or any other e-Learning platforms with similar properties, one has to take into account the activation area and the scope of the learning process. If interested in e-Learning in higher-education, ILIAS is the platform that assures the best set of possibilities for future development and growth. It is the best choice in educational institutions, where a specific learning structure has to be followed. When thinking about public education, i.e. long life learning, as in informing citizens on a specific topic, Moodle is the platform that would best serve the needs of the municipality. It seems better for the education of the large public, where the learning activity does not need an extremely rigorous evaluation determining the structure of the e-Learning modules. At a more specific level, connected to the learning process at FeLIS, ILIAS is the best suitable solution, first because of the already existing ILIAS installment at the other departments of the Faculty of Forestry and Environmental Sciences and, second, because of the arguments presented in this work in Chapter 4, where the e-Learning platform selection pointed it out as the best suitable e-Learning platform.

7.4 Discussion upon the development and the integration of ISVisualisation in the e-Learning platforms

Research question: *Is it possible to develop a 3D Viewer based on Java 3D and VisAD for the visualization of LIDAR data and 3D models online?*

The decision of developing the ISVisualisation software was taken based on the necessity of having a flexible real-time visualization tool that is able to load and present both raw LIDAR data and 3D models, which are obtained either from LIDAR data, satellite data or from aerial photographs. As Sheppard & Salter (2004: 485) emphasized in their publication, there is still much need for further development and understanding in order to integrate the visualization methods into practice.

The ISVisualisation software based on VisAD and Java3D provides students the means of using in practice a brand new software development, by connecting ISVisualisation to the learning process. In literature, there are a few publications related to the usage of VisAD for 3D models, but absolutely nothing could be found on the usage of VisAD library for the visualization of LIDAR raw data, LIDAR processed data as well as the visualization based on VisAD and Java3D of images received from a server through Web Services.

Restrictions on the data type are only related to the data format in which the 3D models and LIDAR raw data can be visualized. LIDAR raw data can only be visualized in *.asc data format (ASCI) and 3D models can only be loaded and visualized if they are compressed in a *.tif data format (TIFF). Over the years, a large number of 3D viewers have been developed, that can visualize 3D models inside a browser. Such a viewer is the Cortona[52] 3D viewer, which can be used in order to visualize different types of data, including VRML. The majority of these viewers focus on visualizing small-dimension 3D models, which can be easily loaded over the web in a web browser, but they are not able to load large amounts of data such the ones used inside ISVisualisation. Moreover, ISVisualisation is based on the VisAD library, which is a special Java library for numerical data, such as raw LIDAR data or raster data of the 3D models. Using VisAD and its special data containers, the loaded data is cached in a FlatField data container which gives the programmer a multitude of further processing possibilities, which the regular data buffering of the generical data viewers is not able to provide. Another great advantage of ISVisualisation is that it has been enclosed in a Java Applet and that it can be run on practically any computer connected to the Internet without having to download or install any other feature or program. ISVisualisation is constructed exclusively on open source libraries and therefore there are absolutely no restrictions in using it or for further development. Continuing the idea of open source software, ISVisualisation is also free of charge, which the majority of the web 3D viewers are not.

When starting programming ISVisualisation, the biggest problems encountered were caused by the difficulty of understanding the VisAD principles. Data management classes enclosed in VisAD are fully new definitions that have absolutely nothing to do with other Java libraries and therefore the effort of learning this “new language” was great and time consuming. The literature on VisAD is rather scarce and insufficient, while the majority of people developing VisAD and working with it are somehow rather associated only with the University of Madison-Wisconsin/USA. A VisAD community and as well as an efficient mailing list exist indeed, but the velocity of the information exchange was rather low and insufficient in order to be able to understand “what’s VisAD all about” in a short period of time. On the other hand, documentation on VisAD Java classes is well organized and satisfactory; a tutorial developed by Ugo Taddei from University of Jena, as well as numerous projects being developed on the base of VisAD, also exists on VisAD’s homepage.

VisAD library provides methods to cash and process LIDAR point cloud data. Already having a background in C programming, I automatically thought about loading LIDAR point cloud

52 Source: cortona 3D Viewer (http://www.parallelgraphics.com/products/cortona)

data into an array and from there sending it to a function that will eventually paint the points into a display. VisAD has no array definition but uses “Functions anywhere you can use arrays, but Functions also allow you to express some very complex operations simply”[53]. With the help of these functions, numerical data can be very easily cashed and loaded into a FlatField container in order to have then the possibility of painting it into a display. The development of this class was in fact an “accident”, because the intension was to directly read raw data in ISVisualisation and then generate a 3D surface from this data set without having to generate a DEM. Only after I saw the first data displayed, I realized that the generation of such a surface would be practically impossible because of the hardware resources which this algorithm would need in order to generate and keep refreshing the 3D surface. We should not forget that ISVisualisation had to be integrated into an applet and it was meant to work online, where large processing times are not wanted. Because of this, DEMs were generated and, with the use of another class, put into the ISVisualisation GUI.

Raw data presented in ISVisualisation had at least 50Mb memory size and the viewer did not show the data at the beginning. In NetBeans IDE, an error message indicated the memory allocation problem *Java.lang.OutOfMemoryError: Java heap space*. This happened when the JVM (Java Virtual Machine) ran out of available memory during processing. The solution was to increase the value of the available memory by using the following syntax inside NetBeans IDE under Project Properties/Run/VM Options: -Xms96M -Xmx512M. In this way, defining the minimum memory size to 96 Megabytes and the maximum to 512 Megabytes would change the default settings of the JVM and eliminate the lack of memory resources. The same problem appeared when loading 3D models in the form of processed DEMs, even if the data size was not greater than 10Mb. This happened because the memory allocated for the variables remained the same for small and large datasets.

Displaying 3D models residing from DEMs proved to be a better and quicker way than the initially intended data visualization and processing of raw data. This is because VisAD library contains a special class called TiffForm which is designed especially for reading data coded in *.tif. After reading the data using TiffForm, the data is loaded into a FlatField container (see Chapter 4.3.3). The problems encountered in the period when the DEM viewer had been designed were strictly related to the problems of system understanding which have been solved without big efforts.

53 Source: VisAD Java Component Library Developers Guide.

7.5 Future work

In the present thesis, new e-Learning standardization and e-Learning platform selection strategies as well as e-Learning model development examples have been proposed. The visualizations, and especially those performed through ISVisualisation, were realized in order to add the “third dimension” to the e-Learning models. Because of time constrains, e-Learning model evaluations were not realized, and the features of the 3D visualization software ISVisualisation were not finished or extended.

Thorough testing and evaluation of each student were not realized either, because of technical limitations within the NNR project. In other words, the testing and model evaluation can only be realized if the platform login is able to give students the opportunity to use their identification as students at the University of Freiburg by the means of a LDAP function. In this ideal way, every student would automatically get a personal account in the e-Learning platform and the evaluation processes would be relevant, without having to manually create account for every student. The module evaluation would only be relevant when the number of users were statistically relevant.

As presented in Figure 30, the e-Learning modules realized within the present work could integrate other features than the ones already developed within NNR. One of the extra features that could be added to these modules is a sort of E2E-Comunication (e-Learning Platform to e-Learning Platform Communication). E2E-Comunication could favor learning objects (i.e. Sharable Content Objects) interchange through the use of WebLearningObjectServices (Web Services that are able to retrieve SCOs). Efforts in this direction have already been made and some authors already offer schemes of possible system architectures (see Qiu & Jooloor 2004 and Pankratius et al. 2004).

More than that, ISVisualisation software itself has to be further developed in order to be able to visualize data in its own coordinate system, saved in the GeoTiff format of every 3D model. The VisAD library also needs to be upgraded in order to facilitate geo-referenced data visualization, or an extra library, like JGrass, should be used, where geo-data reference definition has already been integrated. The Web Mapping Services connection for ISVisualisation also needs further development; at the moment, a “Get Capabilities” query is started when a button is pressed but the data accessing is made using hardcode. Instead of this a selection windows could be generated in order to have the possibility of selecting all available data on a connected server. In the future, a Web Feature Services connection could be developed, that will combine the visualization of 3D terrain models with feature layers containing significant information for a specific region.

7.6 Final remarks

As clearly stated in the introductory chapter, the main objective of the present PhD thesis focused on the realization of standardized e-Learning modules for the Geoinformatics education. The overall success rate of such an objective can only be assessed through the evaluation of the intermediary research stages leading to practical outcomes i.e. e-Learning modules. That is why, in the following concluding lines, I will refer to the subordinated objectives of the paper and their degree of realization, in the light of the above-mentioned positive aspects (see *Discussions*) respectively still-to-be-solved problems (see *Future work*).

One of the first and most theoretically demanding tasks of the paper involved the process of determining a standardization model for the platform selection. Considering that the reached result (i.e. SCORM) confirmed the general tendencies on the e-Learning market, it can be said that the criteria chosen for selection and the corresponding selection stages represent an objective and reliable selection algorithm which can be reiterated in similar conditions. In the same way, the platform selection led to an interesting new conclusion, namely that ILIAS is more adequate for teaching at the university level whereas Moodle better suits the needs of lifelong learners.

Another very challenging objective consisted in the conceiving and programming of a software programme which should serve the purposes of 3D visualization in the frame of preselected e-Learning modules. This software is ISVisualisation and it is an accomplishment in itself: despite the few inadvertencies (see above), its usage matches the demands of the e-Learning modules design, proving the success of the programme.

The realization of the e-Learning modules was again an endeavour. The strong interdisciplinary character of the paper became, at his stage, perfectly visible: e-Learning theories combined with e-Learning applications (standardization and platform selection), using knowledge from informatics (programming of ISVisualisation; 3D software analyses) and GIS/Remote sensing ("Introduction to GIS"/" Combating Floods using LIDAR data in Waldkirch") and referring to pedagogy (design and structure of the e-Learning modules) and sociology (expert interview). In the light of these remarks, it should be concluded that, all in all, the thesis' objectives have been reached, paving the road, at the same time, for new and challenging investigations in any of the already mentioned domains.

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9 Annex

9.1 Annex I - List of e-Learning platforms

Nr.	Open Source	Links	Standard
1	ATutor	http://www.ATutor.ca	SCORM
2	Bodington	http://www.bodington.org	IMS
3	Caroline	http://www.claroline.net	SCORM
4	Dokeos	http://www.dokeos.com	SCORM
5	dotLRN	http://dotlrn.org	SCORM
6	ILIAS	http://www.ILIAS.de/ios	SCORM
7	Interact	http://www.interactlms.org	SCORM
8	KEWL	http://kewl.uwc.ac.za	?
9	LogiCampus	http://logicampus.sourceforge.net	?
10	LON-CAPA	http://www.lon-capa.org	IMS
11	Moodle	http://www.Moodle.org/	IMS
12	Openuss	http://openuss.sourceforge.net/openuss/index.html	?
13	Sakai Project	http://www.sakaiproject.org/	OKI
14	Segue	http://segue.middlebury.edu	OKI
	Commercial		
1	123Doc Medical Education	www.123doc.com	?
2	ANGEL Learning	www.angellearning.com	SCORM
3	Authorware	http://www.webucator.com	?
4	Blackboard	http://www.blackboard.com	SCORM, IMS
5	Brihaspati	http://home.iitk.ac.in/~ynsingh/tool/brihaspati.shtml	SCORM
6	IETAV System	http://www.concursosecursos.com.br/cursos_centro.html	?
7	Desire2Learn	http://www.desire2learn.com	SCORM, AICC
8	Eduadi	http://www.eduadi.com.br	?
9	Edumate	http://edumate.excido.com	?
10	FirstClass	http://www.firstclass.com	?
11	Knowledge Forum	http://www.knowledgeforum.com	?
12	Litmos	http://www.litmos.com	?
13	Scholar360	http://scholar360.com	?
14	SimplyDigi.Com Inc	http://www.simplydigi.com	SCORM
15	Studywiz	http://www.studywiz.com	SCORM
16	TeN Acado	http://www.transversalnet.com/products/acado.htm	?
17	Thinking Cap	http://www.thinkingcap.info	SCORM
18	TrainCaster	http://www.traincaster.com	?
19	TutorVista	http://www.tutorvista.com	?
20	WebCT	http://www.webct.com	SCORM, IMS
21	Xmind	http://www.xmind.org	?
22	ziizoo	http://www.ziizoo.com	?

9.2 Annex II - List of e-Learning platforms for the second selection process

E-Learning Platforms		
ILIAS		
Criteria	Characteristics	Developer Observations
Standard	SCORM 2004	Personal desktop for each user with information about last visited courses, new mail or forum entries. SCORM 2004 and AICC compliance Course management system Communication features like mail system, forums and chat Group system for collaborative work and organizing users and resources Integrated authoring environment (Editor) to create courses even without any HTML knowledge Support of metadata for all levels of learning objects Context-sensitive help system for learners and authors http://www.ILIAS.de/ios/index.html
License type	GNU-GPL: Open Source	
Documentation	1	
Development language	PHP	
Database type	MySQL	
Multilingualism	Yes	
Special functions	Forum and Chat	
Country of origin	Germany	
Distribution	More than 10	
MOODLE		
Criteria	Characteristics	Developer Observations
Standard	IMS,	Course management system (CMS). Open Source software package It can scale from a single-teacher site to a 40,000-student University. http://Moodle.org/
License type	GNU-GPL: Open Source	
Documentation	2	
Development language	PHP	
Database type	MySQL, Postgre-SQL	
Multilingualism	Yes	
Special functions	Forum	
Country of origin	Australia	
Distribution	Less than 10	
.LRN		
Criteria	Characteristics	Developer Observations
Standard	SCORM, IMS	Open source enterprise e-Learning platform. .LRN is used by higher education institutions, as well as K-12, government, and non-profit organizations. .LRN also provides a total cost of ownership significantly lower than custom or commercial solutions. http://dotlrn.org/
License type	GNU-GPL: Open Source	
Documentation	4	
Development language	?	
Database type	?	
Multilingualism	Yes	
Special functions	Forum	
Country of origin	USA	
Distribution	More than 10	
SEGUE		
Criteria	Characteristics	Developer Observations
Standard	OKI	Open source content management system When integrated into an institution's administrative systems, it can become a portal providing access to an individual user's course and personal websites. http://segue.middlebury.edu
License type	GNU-GPL: Open Source	
Documentation	5	
Development language	PHP	
Database type	SQL	
Multilingualism	No	
Special functions	?	
Country of origin	USA	
Distribution	Less than 10	
CLAROLINE		
Criteria	Characteristics	Developer Observations
Standard	Wiki	Publish documents in any format (PDF, HTML, Office, Video...).
License type	GNU-GPL: Open Source	

Documentation	3	Run public or private discussion forums. Manage a list of links. Create student groups. Compose exercises. Structure an agenda with tasks and deadlines. Make announcements (also via email). Have students submit papers. http://www.claroline.net
Development language	PHP	
Database type	MySQL	
Multilingualism	Forum	
Special functions	Yes	
Country of origin	Belgium	
Distribution	More than 10	
DOKEOS		
Criteria	Characteristics	Developer Observations
Standard	SCORM	Course management web application. Free software released under the GNU GPL OSI certified and can be used as a content management system for education and educators. Very user-friendly and flexible system with an easy to use interface. http://www.dokeos.com/
License type	GNU-GPL: Open Source	
Documentation	4	
Development language	PHP	
Database type	MySQL	
Multilingualism	XML, CSV file Import	
Special functions	Yes (31)	
Country of origin	Belgium	
Distribution	More than 10	
ATUTOR		
Criteria	Characteristics	Developer Observations
Standard	IMS + SCORM 1.2	Open Source Web-based Learning Content Management System (LCMS) designed with accessibility and adaptability in mind. Administrators can install or update ATutor in minutes, and develop custom templates to give ATutor a new look. Educators can quickly assemble, package, and redistribute Web-based instructional content, easily retrieve and import pre-packaged content, and conduct their courses online. Students learn in an adaptive learning environment. http://www.ATutor.ca/
License type	GNU-GPL: Open Source	
Documentation	2	
Development language	PHP	
Database type	MySQL	
Multilingualism	Forum, XML, Apache server	
Special functions	Yes	
Country of origin	Canada	
Distribution	?	
INTERACT		
Criteria	Characteristics	Developer Observations
Standard	IMS	Online Learning and Collaboration platform Open source CMS, LMS designed with the intention of making it easy for students and lecturers to interact online, based around constructivist and vygotskian views of teaching and learning. The initial system concept was based on the LearnLoop online learning system, but Interact has a completely different code base, although we have borrowed some of the LearnLoop icons with the permission of the LearnLoop development team. http://www.interactlms.org
License type	GNU-GPL: Open Source	
Documentation	5	
Development language	PHP	
Database type	MySQL	
Multilingualism	Apache Server	
Special functions	Yes	
Country of origin	New Zeeland	
Distribution	?	
OPENUSS		
Criteria	Characteristics	Developer Observations
Standard	???	We don't want to reinvent the wheel two times!! http://openuss.sourceforge.net/openuss/index.html
License type	GNU-GPL: Open Source	
Documentation	4	
Development language	Java	
Database type	?	
Multilingualism	Forum	
Special functions	Yes	

Country of origin	Germany	
Distribution	More than 10	
SAKAI		
Criteria	Characteristics	Developer Observations
Standard	OKI	A new Collaboration and Learning Environment (CLE) for higher education. The Project began in January, 2004. Goals The Sakai Project's primary goal is to deliver the Sakai application framework and associated CMS tools and components that are designed to work together. These components are for course management, and, as an augmentation of the original CMS model, they also support research collaboration. The software is being designed to be competitive with the best CMSs available. http://www.sakaiproject.org/
License type	GNU-GPL: Open Source	
Documentation	2	
Development language	?	
Database type	?	
Multilingualism	Yes	
Special functions	?	
Country of origin	USA	
Distribution	More than 10	
LON-CAPA		
Criteria	Characteristics	Developer Observations
Standard	IMS	Full-featured, web-based course management system. It is similar to commercial systems Open-source freeware system Distributed networked system Highly scalable and offers load balancing between servers Platform runs on a dedicated Linux server http://www.lon-capa.org/
License type	GNU-GPL: Open Source	
Documentation	4	
Development language	?	
Database type	?	
Multilingualism	Chat, Email, Forum	
Special functions	Yes	
Country of origin	USA	
Distribution	?	
BODINGTON		
Criteria	Characteristics	Developer Observations
Standard	IMS	
License type	Apache 2.0: Open Source	
Documentation	5	
Development language	Java	
Database type	MySQL	
Multilingualism	No	
Special functions		
Country of origin	UK	
Distribution	Less than 10	
LogiCampus		
Criteria	Characteristics	Developer Observations
Standard	?	
License type	GNU-GPL: Open Source	
Documentation	3	
Development language	PHP	
Database type	MySQL	
Multilingualism	No	
Special functions	Yes	
Country of origin	?	
Distribution	Less than 10	

KEWL		
Criteria	Characteristics	Developer Observations
Standard	?	
License type	GNU-GPL: Open Source	
Documentation	5	
Development language	?	
Database type	?	
Multilingualism	?	
Special functions	?	
Country of origin	New Zeeland	
Distribution	Less than 10	

9.3 Annex III - Interview Nr. 1

List of participants

Nr	Name	Current occupation	Affiliation
1	Karel Charvát Sr.	Project manager	CCSS
2	Karel Charvát Jr.	Student	CCSS
3	Octavian Iercan	Researcher	FeLIS
4	Markus Jochum	Researcher	FeLIS
5	Christian Schill	Researcher	FeLIS
6	Marek Šplichal	IT- Expert	CCSS

The purpose of this questionnaire is to identify the most suitable e-Learning platform for the NaturNet Redime Project. The raw selection of the platform has already been done and the finalists are ILIAS and MOODLE. Fill in the questionnaire and let us find out your opinion!

1. The e-Learning platform ILIAS considers that SCORM compliance is a mandatory characteristic

   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither agree or disagree
   - ☐ Somewhat agree
   - ☐ Strongly agree

2. The e-Learning platform MOODLE considers that SCORM compliance is a mandatory characteristic

   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither agree or disagree
   - ☐ Somewhat agree
   - ☐ Strongly agree

3. NaturNet Redime Project considers multilingualism a basic feature for the ILIAS e-Learning platform

   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither agree or disagree
   - ☐ Somewhat agree
   - ☐ Strongly agree

4. NaturNet Redime Project considers multilingualism a basic feature for the MOODLE e-Learning platform

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree or disagree
- ☐ Somewhat agree
- ☐ Strongly agree

5. Meta-data description standardization is a indispensable element for the NaturNet Redime e-Learning platform ILIAS

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree or disagree
- ☐ Somewhat agree
- ☐ Strongly agree

6. Meta-data description standardization is a indispensable element for the NaturNet Redime e-Learning platform MOODLE

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree or disagree
- ☐ Somewhat agree
- ☐ Strongly agree

7. The level of existing documentation on ILIAS is very high

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree or disagree
- ☐ Somewhat agree
- ☐ Strongly agree

8. The level of existing documentation on MOODLE is very high

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree or disagree
- ☐ Somewhat agree
- ☐ Strongly agree

9. ILIAS's text editing tool is easy to handle and a intuitive tool

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree or disagree
- ☐ Somewhat agree
- ☐ Strongly agree

10. MOODLE's text editor tool is easy to handle and a intuitive tool

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree or disagree
- ☐ Somewhat agree
- ☐ Strongly agree

9.4 Annex IV - Interview Nr. 2

List of participants

Nr	Name	Current Occupation	Affiliation
1	Petr Horák	Project Management	CCSS
2	Štěpán Kafka	Project Management	CCSS
3	Marek Šplíchal	IT department	CCSS
4	Markus Jochum	Researcher	Felis
5	Octavian Iercan	Researcher	Felis
6	Nino Paternó	Project Management	Sicily
7	Jerome Granados	Project Management	Corsica
8	Peteris Bruns	IT department	Krimulda
9	Una Bike	Project Management	Krimulda
10	Frank Hoffmann	Project Management	IGN
11	Jan Štěrba	Teacher	GYBON
12	Milena Hálková	Teacher	GYBON
13	Anonymous	Student	GYBON
14	Anonymous	Student	GYBON
15	Anonymous	Student	GYBON
16	Anonymous	Student	GYBON
17	Jiri Hiess	IT, GIS development	Vysocina

The purpose of this voting is to identify the most suitable e-Learning platform for the NaturNet-Redime Project. The raw selection of the platform has already been done and the finalists are ILIAS and MOODLE that were previously presented to you. Follow the following structure and let us find out your opinion!

2. The e-Learning platform with a better organization (structure, symmetry, accessibility of tools) of the homepage is:

   - ☐ ILIAS
   - ☐ Moodle

3. The e-Learning platform having the best offer on functionalities like forum, chat, calendar, appointment generator, etc. is:

   - ☐ ILIAS
   - ☐ Moodle

4. The e-Learning platform having the easiest and quickest way of content editing is:

   - ☐ ILIAS
   - ☐ Moodle

5. The e-Learning platform with the easies way of handling already existing content, by this was meant copying, cutting, renaming pages, chapters, etc. inside models is:

    - ☐ ILIAS
    - ☐ Moodle

6. The e-Learning platform that needs less computer resources when used for content development and navigation is:

    - ☐ ILIAS
    - ☐ Moodle

7. The e-Learning platform that loads and presents media content such as images, movies and flash elements in a shorter time period, is:

    - ☐ ILIAS
    - ☐ Moodle

8. The e-Learning platform that is exporting functional content to other e-Learning platforms is:

    - ☐ ILIAS
    - ☐ Moodle

9.5 Annex V - List of abbreviations

Term	Explanation
3D	Three Dimensions
ADL	Advanced Distributed Learning
ASCII	American Standard Code for Information Interchange
ASPRS	American Society for Photogrammetry and Remote Sensing
AXIS	Apache Extensible Interaction System
BEM	Bodied E-Learning Module
CAM	Content Aggregation Model
CBL	Computer Based Learning
CEO	Chief Executive Office
cf.	confer = "bring together"
CMI	Computer Managed Instruction
CSF	Content Structure Format
DEM	Digital Elevation Model
DIAL	Differential Absorption LIDAR
DMS	Data Management System
EOI	Element of Interest
FeLIS	Abteilung für Fernerkundung und Landschaftsinformationssysteme
GeoTIFF	Geoinformation embedded in a TIFF file
GIS	Geographical Information Systems
GPS	Global Positioning System
GUI	Graphical User Interface
i.e.	illud est = "that is"
ibid.	ibidem = "in the same place"
IDE	Integrated Development Environment
IEEE	Institute of Electrical and Electronics Engineers
IFETS	International Forum of Educational Technology & Society
ISPRS	International Society for Photogrammetry and Remote Sensing
JVM	Java Virtual Machine
KMBLS	Knowledge Management Based Learning System
LDAP	Lightweight Directory Access Protocol
LIDAR	Light Detection And Ranging
LMS	Learning Management System
NNR	NaturNet-Redime Project
OGC	Open Geospatial Consortium
OOP	Object Oriented Programming
QR	Qualitative Reasoning
RADAR	Radio Detection and Ranging
RAM	Random Access Memory
RDF	Resource Description Framework
RGB	Red Green Blue
RTE	Run-Time Environment
SCO	Sharable Content Objects
SCORM	Sharable Content Object Reference Model
SEM	Skeleton E-Learning Module
SN	Sequencing and Navigation
UML	Unified Modelling Language
URI	Uniform Resource Identifier
VisAD	Visualisation for Algorithm Development
VRML	Virtual Reality Modeling Language
WGS84	World Geodetic System 1984
WMS	Web Map Service
WWW	World Wide Web
XML	Extended Markup Language