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Interactive M(obile)-Learning with UbiLearn 0.2[2]

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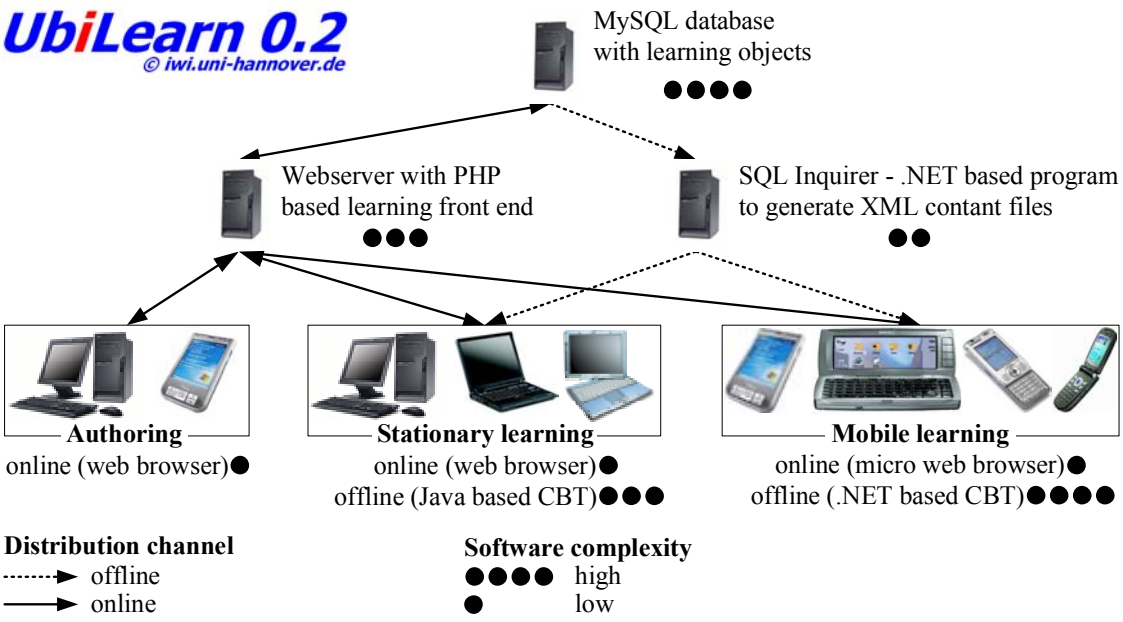

[1] Copies or a PDF-file are available upon request: Institut für Wirtschaftsinformatik, Universität Hannover, Königsworther Platz 1, 30167 Hannover (www.iwi.uni-hannover.de).

[2] This paper summarizes results of an ongoing research. An extended version will appear in Michael H. Breitner and Gabriela Hoppe (Eds.), "E-Learning: Einsatzkonzepte und Geschäftsmodelle"; Physica, Heidelberg, 2005.

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Interactive M(obile)-Learning with UbiLearn 0.2

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Abstract: Complex standard e-learning platforms and systems often suffer from inflexibility, an organizational overhead and high total costs of ownership. But customer and software quality orientation require individual solutions for some e-learning demands. This paper considers the design, development, operation and maintenance of an individual e-learning system called UbiLearn (Ubiquitous Learning System). UbiLearn's mobile module is focused. Release 0.2 supports blended learning with different types of exercises and tests, e. g. text based and multiple choice questions. Answers are evaluated automatically. Solutions can be presented as text, figures and slides, audio or video files. Typical learners are undergraduate or graduate students and readers of textbooks. Learners can use different front ends for desktops, laptops, personal digital assistants (PDAs) and Smartphones. Both online web based training (WBT) and offline computer based training (CBT) are implemented. The ubiquity approach of UbiLearn addresses various front ends and everywhere content availability. Reusability – better multi-usability – of software and content is exploited, e. g. in the CBT front ends for desktops/laptops on the one side and PDAs/Smartphones on the other side. Multi-usable content is provided by a uniform MySQL database using standardized learning objects.

1 Standard E-Learning Systems and the Individual E-Learning System UbiLearn

Learning which is supported and/or made possible by the use of information (and communication) technology (IT) is defined as e-learning. IT must not only be auxiliary but has to be obligatorily connected with the learning process [SBH01]. IT suitable for enabling or supporting e-learning is called e learning technology. Important parts of e-learning technology are e-learning applications or front ends, i. e. software applications which are suitable to support or enable e-learning on specific hardware. E-learning systems combine hardware, software and networks where required. E-learning scenarios include e-learning systems and users like learners, instructors, tutors and authors.

E-learning technology is object to fundamental and rapid technological changes. Fig. 1 gives an overview over important e-learning technologies and trends and shows important e-learning terms. Some of today's most important and interesting research fields are standardization, learning objects and multiusability, mobile-learning (m-learning) and peer-to-peer learning networks.

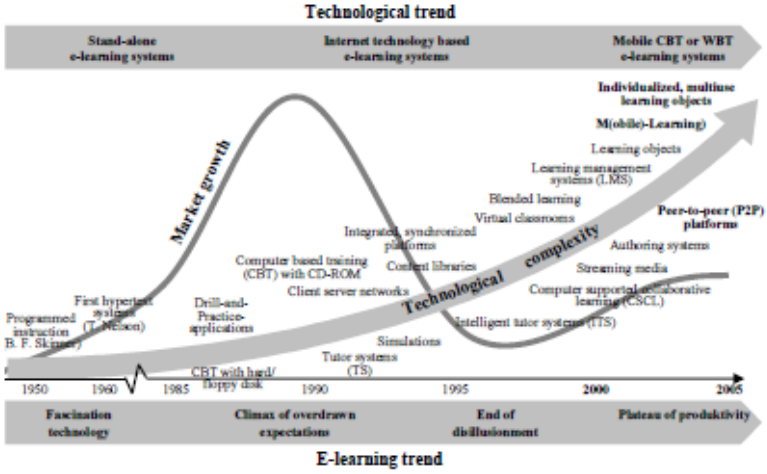

Fig. 1. E-learning development: Technologies and trends (based on [Za00]).

Depending on the usage of standard or wireless networks offline computer based training (CBT) and online web based training (WBT) are distinguished. Didactical, technological and functional options of WBT are usually more complex than those of CBT. For equivalent learning alternatives WBT applications usually are preferred both by learners and instructors. Here only e-learning applications for handheld devices, as personal digital assistants (PDAs) and Smartphones, are classified as m-learning. Note that often e-learning on notebooks is called m-learning, too. Nevertheless the used applications usually are identical with those for desktops computers.

Today most m-learning applications are CBT realizations since only a small minority of handheld devices has wireless network or telecommunication components. Wireless access via GSM, GPRS or UMTS is still very expensive. Only wireless LAN (WLAN) access is reasonably priced, but technical feasible WBT solutions are not yet exploited. WLAN hotspots are not very well distributed in Germany except at airports, some universities, train stations and few private houses and apartments. In two, three or at most five years permanent and cheap internet connections will be common not only for PCs and laptops, but also for handheld devices. By today's standards offline m-learning is favorable, but in the near future likely m-learning with a permanent online connection is likely to be the better choice.

Since fall 2002 the e-learning system UbiLearn is developed at the Institut für Wirtschaftsinformatik, Universität Hannover, by the authors and several graduated students, see [IWI04]. As yet it is a tutor system which accompanies lectures and textbooks in information systems research. UbiLearn enables students and textbook readers to memorize central topics and ideas in information systems research comfortably and successfully.

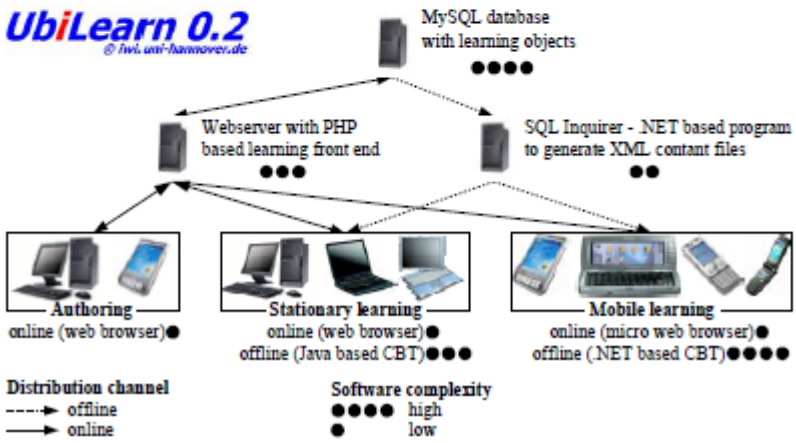

Fig. 2. UbiLearn concept: A synergetic e-learning system for ubiquitous learning.

UbiLearn's key features and qualities are, see Fig. 2:

1. Blended learning orientation: Exercises and solutions coming along with lectures or textbooks can be presented. Learner's answers are evaluated automatically and no tutor is necessary. Various types of multiple choice exercises are implemented. Text answers are parsed and compared to a text solution.
2. Flexibility and customer orientation: Learners learn the same content with different e-learning technologies, e. g. PCs, notebooks, PDAs and have convenient 24/7 access. Solutions are available as text, figures, audio and/or video files to exploit the different potentials of different e-learning technologies. Offline and online e-learning are supported. Adaptivity to learner's individual learning requirements can be realized by registering central learning data. Ubiquitous e-learning stands for seamless, unobtrusive, anytime and anywhere e-learning.
3. Reusability and multiusability orientation for content: Multiusable content is provided by a uniform MySQL database using standardized learning objects for all the e-learning technology supported.
4. Strict software quality orientation: Requirements for software quality and measurement of software quality are outlined in several international ISO (International Organization for Standardization) standards, e. g. ISO 9000/1/2/3/4

and ISO 8402, see also [H03] an [WM01]. Summarized quality software must have

- good functionality, i. e. suitability, correctness, interface connectivity and adequacy,
- high reliability, i. e. stability and error tolerance and easy restart ability,
- good user friendliness, i. e. low learning effort, good documentation and good ergonomics,
- good performance, i. e. high speed, low requirements for resources and good overall system behavior,
- easy maintainability, i. e. changeability, readability of code and testability, and
- easy portability to new hardware or new operating systems, i. e. easy installability, high compatibility and high convertibility.

Management of software quality is necessary during all stages of the software life-cycle, i. e. design, development, operating and maintenance of the UbiLearn e-learning system.

2 Interfaces and Standards

The mentioned requirements for software quality lead to certain interfaces and standards for UbiLearn.

Platform independency: Platform independency is required on the backend and on the user's side. Platform independency is important to allow as many potential users as possible to use the system. Especially for mobile learning there are currently no standards regarding operating systems and hardware architecture. Therefore, UbiLearn supports all major operating systems on client and server side. These are mainly Microsoft Windows, UNIX and Linux. The platform independent solution is achieved by using an online platform which is accessible via internet browser. This solution is called web based training (WBT). Users do not need special software to gain access. As internet browsers are available on nearly every computer, even most PDAs, UbiLearn can be accessed from all internet connected devices. This requires a permanent online access. WBT access is restricted to computers with online connection. In case there is no online connection available UbiLearn provides a special offline program for computer based training (CBT). This program contains the learning content, stored in a platform independent XML-File on the local harddrive. The offline application itself is currently available for Windows, Windows Mobile and Linux.

Cost efficiency: The more expensive a system is the harder it is to reach a crucial spread rate. This applies to users as well as to providers. Important costs are not only costs of purchase but all costs caused by using the system, the so called total costs ownership (TCO). Major components generating high costs of ownership are hardware and software. UbiLearn does not require uncommon hardware, neither on the client nor on the server. Software costs are categorized in fixed costs and running costs. Fixed costs are caused by licenses for operating systems

and applications. Running costs are caused by updated, either of the software or the content. Software costs are minimized by using only open source or public domain software on server and for client side programs. Software and content updates are available for free. No licenses are necessary.

Modularity: UbiLearn is designed towards modularity to increase maintainability. Major system components can be substituted by other components, e. g. if the system's performance needs to be upgraded or certain modules are already available. A modular architecture increases scalability and portability.

Reliability: Total reliability of a system bases on the reliability of the least reliable component. All used components are considered regarding to their reliability.

The mentioned requirements lead to a three layer architecture in which data application logic and the client program are separated in three layers [see Fig. 2]. The data layer requires a server where the learning objects are stored. Regarding the requirements of reliability, flexibility and portability the server should be executable on Linux, UNIX and Windows systems. A powerful database that complies with these requirements is MySQL. Application layer and client applications are separately considered for web based (online) and computer based access (offline). Together with the fact that only public domain or open source components should be used the classical LAMP[6] concept is considered best suitable for web based training. The LAMP concept combines Linux as operating system, Apache as webserver, MySQL as database and PHP as scripting language. This concept is known as very reliable and efficient. The fact that many companies and developers use the LAMP concept leads to a great knowledge base in the internet. This increases maintainability. For web based training only an internet browser is required on client computers, i. e. desktop computers, notebooks, PDAs and Smartphones. Using UbiLearn offline the programming logic is mainly located on the client computer. For computer based offline learning UbiLearn contains a Java based program for stationary computers and a .NET based program for mobile devices. Both are functionally identical with the web based training module.

3 Major Components of UbiLearn

3.1 Underlying Database

Learning content is stored as standardized learning objects in a MySQL database. MySQL is freely available and supports the GPL License model making it cost efficient. Nevertheless MySQL is as powerful as many commercial databases. UbiLearn's three layer architecture makes the content database independent from the applications logic. The learning content is accessed either by standardized database interfaces or XML files. In case the database's performance is not adequate

[6] LAMP = Linux, Apache Webserver, MySQL database and PHP scripting language.

any more or a new version is released it can easily be updated anytime. Alternatively it can be replaced by a database of another manufacturer.

All questions and answers are stored in the database. Both questions and answers contain multimedia content like audio or video files which are also stored within the database. This makes it easier to port the complete content to another server. The e-Learning content is stored in so called learning objects. Note that the term "learning object" is not defined consistently. Here learning objects are a bundle of related questions, their answers and additional information in form of multimedia files or illustrations. As additional information internet addresses, comments of other users and statistical information are stored. For offline usage content of requested learning objects is stored in an encrypted XML file by an additional program, i. e. a program called SQL Inquirer, see [Ma04]. Offline applications are independent from direct database access without enabling unauthorized access to the learning content.

3.2 Web-Based-Training Module

Web based training software makes e-learning available to many users without requiring additional software. UbiLearn offers an integrated web based training module. Flexibility, user friendliness, performance, cost efficiency and easy maintainability are ensured.

UbiLearn's WBT module was developed by A. Otmakhov until April 2004, see [Ot04]. Similar to other systems it is realized in PHP and pure HTML. The PHP scripting language is embedded in standard HTML files. These files are requested by users through web browsers. Requested pages are parsed by the server and thus PHP sections are executed. The result is a pure HTML file which is send back to the requesting browser. No additional plug-ins are required on the client's side ensuring support of all current browsers. Since JavaScript is deactivated for security reasons by some users and not supported by all browsers, especially on mobile devices, JavaScript is not used in UbiLearn.

The described technique is used by several other approaches. It enables embedding of multimedia content in an easy to access front-end which is accessible without any additional software (beside a web browser). As a browser is performance efficient no high end devices are required on the user's side. Therefore, also small devices like PDAs or Smartphones can access the learning platform without the necessity of device specific software. A special feature which makes the difference between UbiLearn and most other approaches is that UbiLearn is strictly developed for multiusage purposes. Programming logic and front-end design are strictly separated using HTML templates. For each kind of device an own template is available. Strict separation of content and layout enables an individual layout adjustment to the given display resolution of the accessing device. This allows support for different display characteristics. Major varying display characteristics are size, resolution and number of supported colors. To increase compatibility no proprietary features or features that are not supported by common browsers are used.

3.3 Computer-Based-Training Module

WBT programs are executed on a web server. Without online connection the programming logic must be ported to the client computer. An Internet browser is not adequate as front end since a web browser just displays information without parsing. Converting the programming logic of PHP scripts in web browser interpreted languages like JavaScript is inefficient. Furthermore, most web browser interpreted languages are not very powerful. Installing a web server and the required PHP modules on every executing client computer is inefficient as well. Therefore UbiLearn contains an independent program that offers all features of the web-based module offline. Complexity is higher than in the web based module as the programming logic is completely included in the program and not on the server, see [Br04].

We consider Java to be the most suitable programming language. Major reason is the high platform independency compared to alternative languages, especially so as Microsoft .NET is only available for Windows systems. Java is available for all major operating systems on desktop computers and for PDAs. This enables efficient reusability of the underlying programming code. Only standard Java components where used. In the GUI-Layer Java's Swing is used as windowing toolkit. Swing components are completely platform independent. Other technologies like Java's Advanced Windowing Toolkit (AWT) differ in appearance dependent on the operating system and the used runtime environment. The second layer is completely independent from the GUI-layer and contains the programming logic. The separation of the program's interface and logic enables high reusability of the underlying logic analogous to the web based module. Exchanging the GUI-layer by a Java-Applet makes it possible to run the program in a web browser. No program installation would be required. The Java-Applet functionality is not implemented yet. The third layer is responsible for persistent data storage. User transactions are stored in XML-files for statistical analyses. Logic-layer and persistency-layer can be reused for mobile applications as Java is available for most PDA operating systems. On computers without a Java runtime environment a virtual machine has to be installed. Virtual machines are available for all major operating systems.

The desktop intended front-end supports all kinds of tasks that are stored in the database. These are currently questions with text answers, multiple choice tasks and closes. Learning content is distributed in encrypted XML files. XML content files are generated by a program called SQL Inquirer. It is completely compatible to the files used for the mobile module to increase reusability.

3.4 Mobile-Learning-Module

The UbiLearn mobile module is the latest UbiLearn enhancement and has to fit into the existing infrastructure. The resulting requirements are considered. Every application development considers general aspects, i. e. a specific goal definition, a suitable process model and a reliable validation process. Mobile applications do additionally require careful consideration of specific factors for success. The soft-

ware, the application itself, has to accomplish specific requirements for mobile systems, i. e. basically network abilities, limited memory and processing power. The client platform has to be chosen carefully as there are many different hardware platforms available which are usually not compatible or equally suitable for mobile learning. An application becomes mobile using wireless network technologies like WLAN, IRDA, UMTS, GPRS or HSCSD. Every network standard has its own advantages and/or weaknesses. E-learning software often contains content that is protected by copy rights. Therefore mobile applications have to be carefully secured because mobile devices are predestinated to be lost or stolen. General and specific factors for success of mobile applications are illustrated in Fig. 3. They are described in details in the following sub-sections.

3.4.1 Goal definition

Every application development starts a definition of the goals which are intended to be realized with a specific solution. A project's success is measured by the degree of achieved goals. Goals of mobile systems can be economies of costs or time, reduction of redundancy or functional enhancements of existing systems. Every goal definition has to be quantifiable and measurable to enable validation. Major goals have to be explicit and realizable – the fewer major goals are defined, the easier is the validation process. Secondary objectives can be realized in later development phases. Thus system complexity and realization time are reduced. Fuzzy objectives like "learning has to be made more comfortable and mobile accessible" ought to be avoided. Instead statements like "basic mobile learning application has to be accessible for at least one third of the relevant students" are advisable. This enables significant application validation.

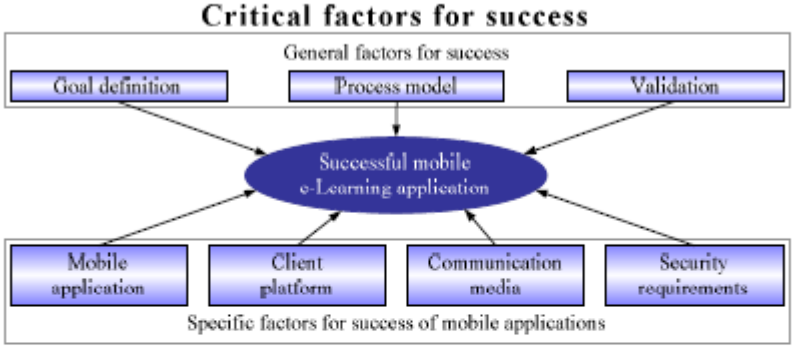

Fig. 3. Factors for success of mobile e-learning applications.

Major goals of the UbiLearn mobile module are:

- The prototype has to be compatible to the existing UbiLearn learning objects stored in a central database to enable maximum reusage of existing content.

- The prototype design has to be sustainable for further development, i. e. adaptivity to new hardware and content, e. g. multimedia video courses.
- The prototype has to be able to support all kinds of tasks of the UbiLearn system. These are mainly clozes, multiple and single choice tasks and free text questions.
- The mobile prototype should be able to reach a maximum number of students for a test run at the campus of Hannover University. Here, the relevant target group is specifically students of business information systems.

3.4.2 Process model

The process model for development and validation of the UbiLearn mobile module is the standard process model for software engineering. It contains four main phases: Analysis, concept design, implementation and system installation. Analysis, implementation and installation of a first prototype were realized in the diploma thesis of Philipp Maske during summer of 2004, see [Ma04].

In the analysis phase the existing environmental conditions are analyzed. Existing UbiLearn components are modeled and required interfaces are defined. All existing kinds of tasks and their functionality are listed to assure that the mobile version supports the same functional range as the existing components, i. e. CBT and WBT modules. From this list the technical requirements of hardware and software platform for the UbiLearn mobile module are derived. Hardware limitations constrain mobile functionality. Beside the existing system the current mobile device market and its development trends are analyzed. The gained information supports qualified decisions for optimal hardware, software design and connection media concerning sustainability. Major questions are:

- What hardware platforms exist and which one is powerful enough to accomplish the determined requirements?
- Is there a superior hardware platform?
- Which operating system has currently the highest market share – to maximize the number of reached students?
- Is there a superior operating system – to maximize the number of reached students?
- Which hardware and software combination has the best total cost of ownership?

An additional survey focuses on the pervasion of mobile devices and the target group's motivation for e-learning. The results facilitate a qualified decision for the optimal e-learning device. Main questions are:

- How many students of the target group, e. g. Business Administration students at Hannover University, own mobile devices like PDAs or Smartphones? Common mobile phones without multimedia abilities are not considered as they do not enable mobile e-learning.
- Which operating system has the highest market share among the interviewed students? In case this number significantly differs from the market average the reasons should be analyzed.

- How many students plan to purchase a mobile device in the next twelve months and which operating system do they prefer?

The concept design bases in the derived requirements and the survey results. It contains a schematic concept of the first prototype and is realizable on every hardware and software platform. The concrete realization in a specific programming language and development environment follows in the implementation phase. The finished prototype is installed on at two different devices and tested within the validation phase.

3.4.3 Validation

The validation phase should be as short as possible. Reasons for too long validations often are often too complex and imprecise goals that hamper early decisions. Too many involved people also retard decisions. Here, concrete objectives are determined and the validation group is staffed with three to four people only.

A first prototype for the UbiLearn mobile module is realized in September 2004, see [Ma04]. Minor validation steps with three testers lead to a final prototype in November 2004. The current version is fully operational. Further validation takes place from November 2004 to the end of the local winter semester in February 2005. Test subjects are the currently running graduate courses “information management” and "system development and softwareengineering".

3.4.4 Mobile application

Center of every mobile solution is the mobile application – the program itself. For optimal integration in the UbiLearn system the mobile e-learning application has to support all kinds of e-learning tasks the stationary applications are supporting, i. e. single- and multiple-choice-questions, free text questions and clozes. Multimedia attachments are supported as well. The goal of functional comparability to stationary systems makes software development a challenge. Hardware limitations constrain mobile functionality; especially processor performance, memory size, display resolution, graphical performance and network bandwidth. These constraints lead to special requirements concerning software ergonomics. They are considered by software architecture and screen design. All general requirements of high quality software are achieved.

Platform independency is more important than it is for stationary applications as more different and incompatible operating systems and hardware platforms are available. Here, Hewlett Packard's iPAQ with Microsoft PocketPC is considered superior to all considered alternatives. This decision is strongly related to the choice of a development environment. The general goal of cost efficiency leads to Java. Technical superiority of Microsoft's .NET outweighs this fact. The complete decision process for hardware platform, operating system and development environment is described in detail in the next section.

Processor speed and memory size are the most limiting characteristics for mobile application functionality. For many multimedia options available on desktop computers handheld devices have not enough processor power and/or memory.

Here, a modular concept is considered superior. Only basic functions are implemented to enable an e-learning application with adequate performance. The final prototype runs on systems with 166 MHz satisfactorily.

Basic requirement of high quality software is that applications are usable intuitively. The limited display resolution narrows the screen design on small displays. Here, a clear and efficient screen design is used that offers basic functionality to the user without wasting graphical performance to unnecessary three dimensional effects. All menus and windows are designed two dimensional. Advanced options are accessible by extra menus. Due to hardware limitations multimedia attachments are only displayed if requested by the user. The input options of small handheld devices offer the possibility to type text in a native style. Smartphones often use the telephone keys. On both cases the typing process is uncomfortable compared to normal computer keyboards. For mobile learning the ability to answer questions being on the move is critical. Single and multiple choice tasks optimally achieve this requirement. Especially for very small devices like Smartphones multiple and single choice questions are the best way to port e-learning to handheld devices and guaranteeing software ergonomics. UbiLearn mobile support all kinds of questions, e. g. text and single/multiple choice questions. The kind of questions can be filtered by the user. Both screen design and an exemplary lecture video are illustrated in Fig. 4.

free text question multiple choice question multimedia attachement

Fig. 4. Screenshots of the UbiLearn mobile module.

The available network bandwidth is critical for mobile learning. Network connections are needed for program and content updates. A program update function is currently not implemented. Program files are installed with an intuitively to use setup program. Content files, e. g. XML content files and multimedia attachments are distributed offline and online. For offline distribution different storage media

can be used, e. g. memory cards. For online distribution data can be downloaded either by a host computer and copied to the PDA or by the PDA itself. In both cases content files are stored on the handheld device. No permanent internet connection is required. Multimedia attachments usually require much memory. The smaller a multimedia file is, e. g. a video file of a lecture, the worse the video quality is. To spare network bandwidth videos are distributed together with XML content files. Recorded lectures of 90 minutes currently have a file size of about 100 megabyte each. For smaller devices with little memory videos can be streamed from an online source if an online connection is available. Currently videos are satisfactorily streamed with 150 kilobits per second. If the online connection does not offer such bandwidth the video compression is adjusted automatically to the available bandwidth.

Learning content often exists in many different formats. They are not inherently supported by the UbiLearn mobile module. For major formats additional programs exist which are either freely available or inherently implemented in Microsoft PocketPC, see Tab. 1. All major formats are usable with free software. This increases cost efficiency.

Tab. 1. Supported file formats and required programs.

File format	Application area	Required program	costs
PDF	Lecture slide shows and scripts	Adobe Reader for PocketPC	free
PowerPoint	lecture slide shows	Microsoft Pocket PowerPoint	included
Word documents	lecture scripts	Microsoft Pocket Word	included
Images	illustrations to clarify questions	Microsoft Pocket Excel	included
Sound files	questions can be read out and listened to by ear phones or internal speaker	Mobile Windows Media Player	included
Video files	Complete lectures can be distributed as video files	Mobile Windows Media Player	included

Mobile devices' life span is shorter than of desktop computers. Therefore sustainability and adaptability of mobile applications are very important. UbiLearn has a modular three layer architecture, i. e. graphic layer, logic layer and persistency layer. Every layer consists of program modules that can easily be replaced or adapted if single requirements change. E. g. in case graphical characteristics of the target device change graphic layer modules are replaced to support the new environment. The architecture is illustrated in Fig. 5.

3.4.5 Client platform

The consideration of a client platform starts with a survey of the target group. Here, these are the students at Hannover faculty of business administration, espe-

cially business information systems. Most important point is the availability of mobile devices, operating systems and the device's technical characteristics. The survey is conducted by Philipp Maske, see [Ma04]. Interviews with 60 students lead to significant results. About 20 % of all interviewed students have either a Smartphone or a PDA. Three-quarter of these students use Windows Mobile as operating system. About four fifth of the interviewed students are interested in mobile learning.

Further consideration of the client platform is divided into the consideration of the *hardware* and the *software* platform. Especially the hardware platform is important concerning sustainability as mobile hardware platforms usually do not support a change of the operating system. Only operating system updates are supported if at all. The market for desktop computers is currently homogeneous. Most desktop computers use processors of the x86-architecture and are widely compatible. In contradiction the market for small computers like Smartphones and PDAs is very heterogeneous. Different and incompatible architectures are used. This makes it impossible to achieve complete platform independency. UbiLearn was considered to be as platform independent as possible.

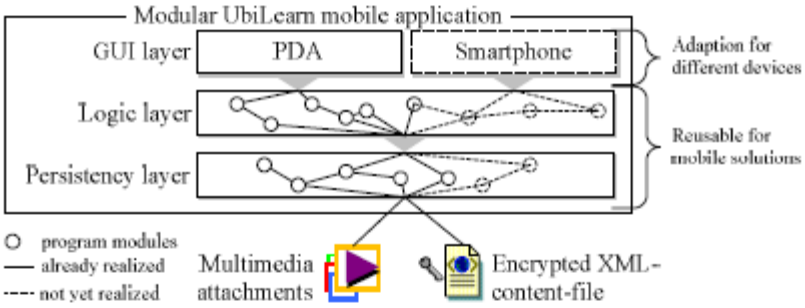

Fig. 5. Overview of the UbiLearn mobile architecture.

Basically there are two major device sizes, i. e. PDAs and Smartphones. Most current Smartphones are not powerful enough to support the mentioned kinds of applications, see [Ma04]. In the future Smartphones might be powerful enough to support e-learning applications. Therefore only PDAs are considered in detail. At the moment Symbian's operating system is most commonly used on Smartphones. The high market share bases on the high proportion of mobile cell phones with calendar, contact list and other functions that lead to calling them "smart" out of marketing reasons. Actually the market share of Windows Mobile for Smartphones is higher if only real Smartphones are considered. In addition Microsoft Windows Mobile for Smartphones is only available for a few months now. The market share is increasing constantly as more compatible hardware devices are developed. The actual market shares are illustrated in Fig. 6.

Fig. 6. Market shares of mobile operating systems.

Further consideration is restricted on PDAs. For PDAs two major operating systems exist, e. g. Palm OS and Microsoft Windows Mobile. Palm OS was originally developed for small devices with little processor power and memory as well as black and white displays. A long time Palm OS was the only available operating system for PDAs. Microsoft Windows Mobile was developed for handheld devices with color displays and multimedia capabilities. Its compatibility to the desktop operating system Windows is highly adequate. Major differences of the two operating systems Palm OS and Windows Mobile are illustrated in Tab. 2.

Tab. 2. Comparison of major mobile operating systems.

	Pocket PC	Palm
Performance (processor and memory)	++	•
Display quality (resolution and colors)	++	•
Multimedia support	++	-
Adequate input options	++	+
Market share and sustainability	++	+
Cost efficiency	+	++
Support of Java/.NET	+/++	+/-

Of the three major operating systems for handheld devices, i. e. Windows Mobile, Palm OS and Symbian, only Microsoft Windows Mobile is available for both PDAs and Smartphones. This enables a higher level of data compatibility which facilitates platform independency and the options to reuse programming code for a Smartphones version of UbiLearn mobile once Smartphones are powerful enough. On a long term basis it is reasonable to believe that Microsoft is going to dominate the market for mobile operating systems for PDAs and Smartphones. Therefore Microsoft Windows Mobile is considered superior here.

Due to the fact that reusability and sustainability are very important the used programming paradigm is object oriented. Therefore the used programming language is object oriented as well. Only few programming languages support Windows Mobile. i. e. SUN Java and Microsoft .NET. There is no optimal development environment or programming language. Java is advertised as fully platform independent and cost efficient because it is available for free and for nearly all

kinds of platforms, including Palm and Windows Mobile. Java is a mature technology and known as efficient. From this theoretical perspective Java seems superior to .NET. Practical research leads to the conclusion that .NET is more cost efficient as Java as the Java mobile runtime environment, which is necessary to run mobile Java applications, is very expensive and usually not available in small numbers of items, see [Ma04]. Furthermore every little change in the hardware configuration requires an adapted version of the Java runtime application. .NET only needs a development environment which is included in Microsoft Visual Studio .NET which can be used to develop all kinds of .NET applications. The runtime environment is inherently included in Windows Mobile. Furthermore the .NET architecture is especially adapted for Windows Mobile and is superior in graphical performance and functionality. Because of the increasing market share of Microsoft Windows Mobile and the current development of runtime environments for PalmOS .NET is considered most sustainable here.

The decision to use Windows Mobile as operating system restraints the choice of a possible hardware platform. Hewlett Packard's iPAQ series has the highest market share of all Windows Mobile based devices. Their market share is constant, the product family is continued and the devices are known as reliable. Therefore the iPAQ family is considered superior here. Nevertheless the UbiLearn mobile application runs on every device with Microsoft Windows Mobile and adequate performance.

3.4.6 Communication media

For mobile learning program and its content have to be transferred to the mobile device somehow. Currently devices with mobile network interfaces like wireless LAN (WLAN) or similar techniques are a minority. Further aspects are costs and availability of the competing network standards. Mobile cell phone networks have high availability but their usage usually is expensive. The cheapest option to realize online mobile learning is WLAN technology. WLAN is not highly available at present. Differences in transmission rate, cost per megabyte and network coverage are illustrated in Fig. 7. Due to the goal of highest possible mobility and cost efficiency UbiLearn mobile is realized as an offline solution. Only content updates can be downloaded with a mobile web browser or transferred by a memory card. Optional features that support online functionality like synchronization of separate online (WBT) and offline (MBT) learning sessions are added in the future.

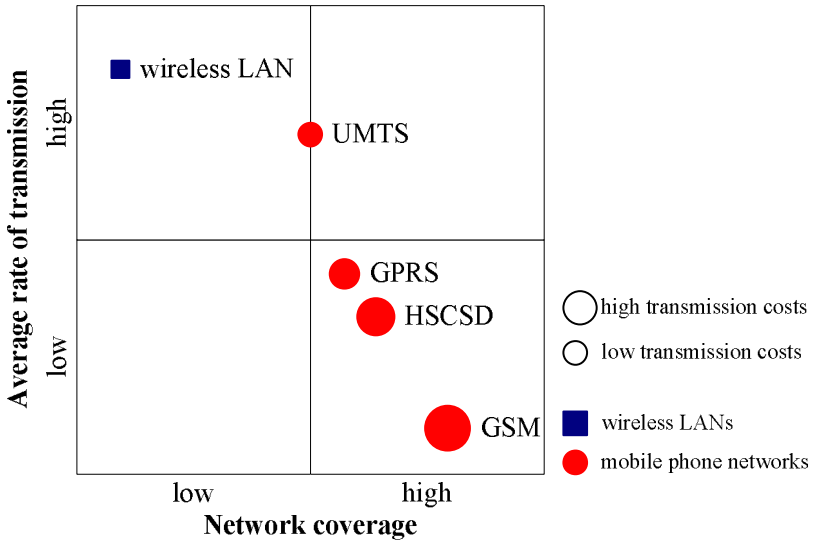

Fig. 7: Classification of mobile Internet connections.

3.4.7 Security requirements

There are no special needs concerning the security requirements as no security relevant systems are attached by UbiLearn. Only security aspect that has to be considered is the copyright aspect of used content. Once digital content is created special affords are necessary to avoid the content from being copied without permission. Microsoft .NET does not inherently support an encryption algorithm for mobile runtime environments. For UbiLearn mobile a proprietary encryption algorithm is realized, see [Ma04]. It is adapted to the limited hardware resources of an average target device. The encrypted learning content is completely stored in the handhelds memory, e. g. the RAM memory or a memory card. Loading the content it is decrypted in real time. The encryption process of a complete content file takes less than 1 minute which is the maximum duration a user is willing to accept.

4 Conclusions and Further Research

This paper presents the ubiquitous learning platform UbiLearn. UbiLearn is a flexible and reliable e-learning platform. It accomplishes all major aspects of software quality, i. e. good functionality, high reliability, user friendliness, good performance, easy maintainability and portability. Thereby UbiLearn generates low costs of ownership by using open source and public domain software, database and programming languages. Important feature of the UbiLearn system is

high content reusability as the learning content is stored in standardized learning objects in an independent database. All UbiLearn modules base on the same data base. Learning objects can easily be composed to new lectures. Once a learning object is created it is reused multiple times.

Learning software for stationary learning is at a mature stage of development. Most of them need either installations on a specific computer (CBT) or permanent online access (WBT). This makes learning either dependant from being at a specific place or having an online connection. Key element of ubiquitous learning is to bring learning to motion. UbiLearn mobile enables learning anytime and anywhere. Latest enhancement presented in this paper is the UbiLearn mobile prototype. UbiLearn mobile bases on a Hewlett Packard's iPAQ device family and Microsoft's .NET which enables a maximum number of supported devices within the target group. Here, target group are business administration students in Hannover. UbiLearn mobile makes learning independent from time, place and online connection. All major kinds of learning objects are available on the handheld device, including multimedia attachments like videos or animations. The system is flexible enough to be used in every handheld device with .NET runtime environment. In the near future UbiLearn Mobile will also be available for Windows Mobile for Smartphones.

Currently research at the Institut für Wirtschaftsinformatik concentrates on further development of UbiLearn, especially the mobile module. Currently UbiLearn is a tutorial e-learning system. All major kinds of learning tasks are supported, i. e. text answers, multiple choice questions and clozes. All kinds of tasks support multimedia content in questions and solutions. Mobile devices are continuously further developed. It is conceivable that in the future mobile phones will support speech recognition. The user listens to the questions and answers by speaking without any keyboard or pen. This will increase usability of mobile devices and especially e-learning. Another major goal is synchronization of learning content. A started learning session will be synchronized with the UbiLearn server to be resumed from another device. These affords are complemented by evaluating the usage of e-learning systems, see [BHB04]. The results are directly introduced into UbiLearn. Moreover applications of e-learning systems especially at universities are analyzed, see, e. g. [Ho05].

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