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Mobile Coaching

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FAKULTÄT FÜR !INFORMATIK

Mobile Coaching

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Zusammenfassung

Der Anwendungsbereich des mobilen Trainings zählt zu den relativ jüngen und aufstrebenden Methoden in der Welt der Sportinformatik. Dessen Hauptziel ist es, Sportler sowie deren Betreuer durch das Einbinden von leicht anwendbaren bzw. mobilen Hilfsmitteln bei der Durchführung ihrer Sporteinheiten zu unterstützen. Solch eine Mobilisierung wird in erster Linie durch die Verwendung von Handheld-PCs wie z.B. PDAs erreicht. Die meisten Geräte dieser Art können sich mittlerweile drahtlos mit dem Internet und anderen Rechnernetzen verbinden, was ihre Anwendung an nahezu beliebigen Orten möglich macht. Auf diese Art und Weise kann eine beständige Verbindung sowie eine stabile Datenübertragung sehr einfach realisiert werden.

Diese Arbeit präsentiert eine konkrete Implementierung eines mobilen Trainingssystems, welches im Stande ist, all diese Vorteile zu nutzen. Ein PDA dient dabei als Speicher- und Synchroniesierungseinheit für verschiedene Arten von Informationen, wie z.B. biomechanische Daten, während eine Serverkomponente die abgeglichenen Werte verarbeitet, um diese später in Form eines Diagramms für den Endbenutzer abrufbar zu machen.

Abstract

Mobile Coaching is a recently upcoming method of the rather newly established area of Computer Science in Sport. It's main goal is to enable mobile and handy to use training support for sport-related people like athletes and coaches. This mobilization is achieved, primarily, by the integration of modern handhelds such as PDAs. Meanwhile, most of these devices have the ability to connect wirelessly to the Internet and different other computer networks, providing effective mobile coaching opportunities at the place of training. In this way, a reliable connection and hence a stable transfer of data can be easily realized.

This thesis presents a mobile coaching system that is able to make use of all these benefits. It includes a PDA, which is primarily responsible for the storage and synchronization of different kinds of information, for instance biomechanical values, and a server component, where the synchronized data is processed in order to give a diagramed feedback to the end-user.

Acknowledgements

I am grateful towards my supervisor Prof. Baca for offering me the chance to work on a topic in the field of Computer Science in Sport, which is not only related to my studies but also is an area of personal interest. Moreover, I am particularly indebted to my mentor Dipl.-Ing. (FH) Kornfeind, who has been of great assistance and a valuable partner in the realization of the mobile coaching system.

I would like to acknowledge my parents for providing me with good educational opportunities. Moreover, I want to thank my entire family for the general support given as well as for motivating and encouraging me all through my studies and especially while working on my master thesis. Special thanks to my father and sister, who were willing to critically read my work.

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1. Introduction

The fields of computer science and particularly the branches of communication and information technologies have made a huge progress during the past decades, as the following well-known examples show (compare also Figure 1.1, source from [7]):

1. The Internet and more precisely the World Wide Web become more and more widespread, counting billions of users nowadays.

2. Mobile devices like cell phones and PDAs were invented and are used these days not only as telephones or organizers, but also for many additional purposes like capturing pictures or listening to music, just to mention few.

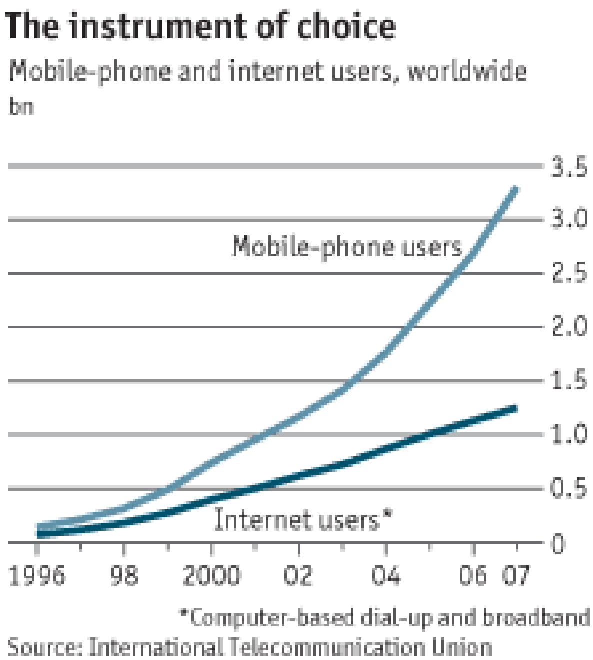

Figure 1.1.: Mobile-phone vs. Internet users

And although this was not conceivable 20 years ago, the above listed inventions are not only well-established in our scientific world, but have also become part of modern life style today.

1.1. Motivation

Consequently, the specified technologies - namely Internet and mobile devices - have been integrated in many different information technology areas as well. Computer Science in Sport, a still new and not very common field of informatics, is one example for this trend. As stated in [13], at the beginning of this discipline the primary objectives were the documentation and dissemination of information with a rather theoretical focus. But over the years the technical advances in the field of computer science changed the research possibilities and hence also the activities in the area of Computer Science in Sport. Meanwhile, this discipline and moreover its practical use are becoming more prevalent and developed. In [29], for example, the author writes about some innovative approaches, thereby mentioning the recently upcoming fields of Internet-based training and coaching, which is a main subject of this work.

1.2. Aim and Structure of the Thesis

This thesis presents a mobile coaching application that should support athletes, coaches and other specialists in their training and coaching programs.

Before doing so, some fundamental backgrounds are discussed in Chapter 2. This includes, on one hand, an introduction into the area of Computer Science in Sport, thereby describing in more detail the history and research development of this area. Additionally, information on mobile devices and on some relevant communication technologies is given. Furthermore, the progress and importance of the disciplines of computer-based training and particularly mobile coaching are pointed out. The chapter concludes with a description of the software package IBM™ Lotus Expeditor[1], which is the basis for the actual software development.

[1]IBM Lotus Expeditor and all other initially labeled IBM products are trademarks of IBM corporation.

Hence, Chapter 3 is devoted entirely to the developed application, more precisely to its architecture, hardware, software and implementation. Finally, some comments on the actual scope of use are suggested too.

The thesis continues with a discussion including a final outlook and closes with a conclusion, thereby analyzing the presented mobile coaching system.

2. Fundamentals

Before going over to the details of the developed application and furthermore its implementation, a couple of fundamentals should be taken into account in order to discuss some basic knowledge and understanding of the background theory. First of all, a brief introduction into the field of Computer Science in Sport is given, which includes some theoretical, historical but also practical information on this area. The latter is, as one can imagine, a key point of this thesis and thus explained in an individual section, thereby specifying different terms like computer-based training in general and mobile coaching in particular. For these purposes, the reader is provided beforehand with a couple of facts on mobile devices, including available operating systems and also on some of the most common communication technologies. The end of the chapter introduces the used software product IBM Lotus Expeditor.

2.1. Computer Science in Sport

The development of computer science during the past decades has had an increasing influence on the progress of science and research. Computers as well as applied informatics have been introduced in many new research areas, in which they are by now well-established. A concrete example for this tendency is, amongst many others, sports science [36, 37] - a discipline where the advantages of informatics are meanwhile integrated to the full extent.

2.1.1. Historical Background

Going back in history, computers in sports were used for the first time in the 60s, when the main purpose was to accumulate sports information. Databases were created and expanded in order to launch documentation and dissemination of publications like articles or books that contain any kind of knowledge related to sports science. Until the mid 70s also the first organization in this area called IASI (International Association for Sports Information) was formally established. Congresses and meetings were organized more often with the aim of standardization and rationalization of sports documentation. Since at that time this area was obviously less computer-oriented, it is not surprising that specialists talk about sports information rather than sports informatics when mentioning the beginning of this field of science.

However, with the invention of microprocessors [24] and thus the creation of more powerful computers and scientific methods in the 70s also the real history of Computer Science in Sport began. This was as well the first time when this term was officially used and the initiation of a very important evolution in sports science.

In the early stages of this area statistics on biomechanical data, like different kinds of forces or rates, played a major role. Scientists started to analyze sports games by collecting and looking at such values and features in order to interpret them. Later on, with the improvement of computer hardware - in particular microprocessor speed - many new scientific and computing paradigms were introduced, which were also integrated in Computer Science in Sport. Examples worth mentioning are modelling, pattern design and recognition as well as simulation [30, 38]. These methods are mainly applied in ball games like soccer, basketball, table tennis, squash or volleyball [25], but also in water sports such as swimming [31] and rowing [12].

Additional information on this topic and in particular on computer-based training including some practical applications can be found in Section 2.4.

Present Issues

Despite of the continuous progress, today, some issues in the field of Computer Science in Sport remain to be analyzed and improved, too. Since the above mentioned techniques produce a huge amount of data, it is evident that databases and information or expert systems have become more and more important. The storage and even more the analysis of such data sets are therefore crucial points in the area of Computer Science in Sport, but also in informatics in general. The main problem is, however, how to handle such big quantities of data in a way so that the most relevant parts are filtered out. And although many suggestions were made and implemented, this question is nontrivial and there is still a lot of research needed in oder to find more effective solutions and hence to push further development methods.

2.1.2. Research Communities

A clear demonstration for the evolution and propagation towards computer science in sports is also the fact that nowadays people do research in this area all over the world. In Australia and New Zealand, for instance, scientists have built up the MathSport group of ANZIAM (Australia and New Zealand Industrial Applied Mathematics), which since 1992 organizes biennial meetings under the name Mathematics and Computers in Sport Conferences. Main topics are mathematical models and computer applications in sports, as well as coaching and teaching methods based on informatics.

The European community was also among the leading motors of the emergence of the field. Some workshops on this topic were successfully organized in Germany since the late 80s. In 1997 the first international meeting on Computer Science in Sport was held in Cologne. The main aim was to spread out and share applications, ideas and concepts of the use of computers in sports, which should also make a contribution to the creation of internationalization and thus to boost research work in this area.

Since then, such international symposia took place every 2 years all over Europe. As the first conferences were a raving success, it was decided to go even further and the foundation of an organization was the logical consequence. This step was accomplished in 2003, when the International Association on Computer Science in Sport (IACSS) was established during the 4th international symposium in Barcelona, when Prof. Jürgen Perl was also chosen as the first president. Almost at the same time, the first international e-journal on this topic (International Journal of Computer Science in Sport) was released too. The internationalization is confirmed moreover by the fact that the last conference took place in Calgary (Canada) and thus outside of Europe. During this symposia additionally the president position changed - it has been assigned to Prof. Arnold Baca.

As another result of this development, the term 'Computer Science in Sport' has been added in the encyclopedia of sports science in 2004 [33]. For more information on this topic like relevant organizations, congresses, conferences and journals, please refer to the appendix topic Computer Science in Sport. It also includes a listing of some of the most relevant geographical regions in which Computer Science in Sport is applied, as well as important contact persons and their research activities.

2.2. Mobile Devices

Mobile devices have become very popular in the past decade. Evidently, such handhelds have started to establish themselves in everyday life, being in use for many different purposes. Today, mobile phones, for example, don't serve as phones only, but also fulfill other roles like capturing pictures, listening to music or just saving data.

Here, for understanding purposes, a distinction between a couple of types of mobile devices should be made. Smartphones, on the one hand, are sometimes seen as mobile phones with more advanced functionalities, while PDAs, on the other hand, are defined as small computers. More details on this topic are presented in Subsection 2.2.2.

2.2.1. Operating Systems

For mobile devices, just like normal desktop PCs, an operating system (OS) is the essential software component. Some of the most common OS for handhelds are amongst others:

- Windows Mobile
- Symbian OS
- iPhone OS
- BlackBerry OS
- Android

Being dominant in the desktop market, Windows is also one of the leading OS concerning mobile devices. Originally developed for PDAs, the so-called Windows Mobile

OS meanwhile runs on smartphones too. Symbian OS, mainly made for Nokia devices (especially in the US), has the largest share in the market of the more sophisticated phones. Worth mentioning is also the currently upcoming iPhone OS, which is simply an adjusted version of Apple's Mac OS X system. BlackBerry OS, designed by the Canadian company Research In Motion (RIM), is another common OS for handhelds and regarded as one of the most stable OS in the sector of mobile devices. Finally, Android, recently released by Google, is a promising new OS for smartphones.

2.2.2. Functionalities

When comparing the currently available handhelds with the first devices of that type, the strengths of the modern attachments lie definitely in their small and handy design as well as the build-in functionalities. This is mainly due to the capability of developing smaller hardware parts on the one hand and the increase of memory capacity and processor power on the other hand. Consequently, such attachments are meanwhile also used in many research areas, including Computer Science in Sport.

A nowadays more and more indispensable feature of mobile devices is certainly their ability to be connected to different kinds of networks such as the Internet and providing services like for example the World Wide Web, which enables, amongst others, an easy transfer and exchange of data. Therefore, some of the most advanced communication technologies and protocols are described in the following section.

2.3. Internet and Communication Technologies

The appearance and the progress of the Internet and the therewith connected invention of new communication technologies have contributed to the development of Computer Science in Sport [20]. This is specifically demonstrated by the already existent spread of sport-relevant information via the World Wide Web on the one hand, which consequently involves a very mobile and prompt access of research results on the other hand.

However, when talking about the Internet and modern communication technologies, it is important to point out more precisely their functionalities. For these purposes, some examples are illustrated below [32]:

1. Bluetooth is a protocol that is primarily in use in personal area networks (PANs) and enables the communication between different devices. Since no wires or cables but radio frequencies are used for the connection, Bluetooth is referred to as a wireless protocol.

2. Another wireless technology is Wi-Fi, which particularly supports connectivity to the Internet (more precisely to WLANs) via devices.

3. GPRS (General Packet Radio Service) is a so-called 2G (second-generation) wireless service that in contrast to the 1G (first-generation) telephone system uses digital instead of analog signals for the data transfer.

4. An expansion with higher data speed transfer is the 3G (third-generation) technology UMTS (Universal Mobile Telecommunications Service), which was initially implemented for mobile phones, but is meanwhile also in use in the modern handhelds due to its ability to connect to the Internet.

5. While 3G has just proven one's worth, meanwhile experts already talk about the implementation of fully IP- and packet-based 4G (fourth-generation) systems and predict their establishment for 2012.

Nowadays, most of the above listed protocols are a standard for many mobile devices. Although speed limit is indeed an issue, it is still remarkable how efficient and convenient these hardware tools are today. Meanwhile, with the advancement of connectivity techniques, completely new fields within Computer Science in Sport itself are evolving and computer-based training methods such as mobile coaching exemplify this in particular.

2.4. Computer-based Training

In professional sport, both, competition and high performance play an important role. The basis of reaching one's physical best and hence success is still a well-timed and proper training. And while in former times professionals depended mainly on themselves and different coaching methods only, recently, due to ambitious research in Computer Science in Sport, also technological progress started to influence their achievements.

2.4.1. Definition of Coaching

But first of all, let's pose the question what coaching actually is and give an exact description from the literature. Coaching is related to training, more precisely it is sometimes identified as a subset (together with other actions like tactics) of the training process [18]. Furthermore, Lames defines in [22, 21] the term coaching as a complex activity, thereby splitting it up in the following 3 phases:

1. Preparation of competition
2. Control of competition
3. Competition debriefing

Stage one describes the situation before the actual competition. Coaches decide on a specific strategy that has to be followed by the athletes. During the second phase the aim is to find out if the strategy is applied in reality and if it leads to a winning situation or not. Obviously, in case that there is time available during the competition - for example by the possibility of using time-outs in some sports like basketball - decisions on a possible change of the tactics can be made, while in other sports like swimming this is almost impossible. The last stage has the purpose of analyzing the strategy and performance in such a way that an improvement can be made while the next cycle is performed. Worth mentioning is also that meanwhile research on tracking and analyzing the behavior of coaches is done too, more precisely by using a so-called Split Screen Video [16].

However, after clarifying what the terms training and coaching roughly cover, it is now time to focus on some practical applications. In the last years many new training methods and systems were developed with the goal to assist sportsmen in their workout, some of them are illustrated in the following subsections.

2.4.2. Feedback Systems

Nowadays professional sport is so highly competitive that at the end very small "fractions of a percentage point decide on success or failure"[14]. Hence, the immediate return of feedback information during or just after training and competition is of great relevance for athletes and coaches. In the referenced paper from above, Baca highlights the high importance of such systems and also gives some concrete uses.

Feedback systems should serve as a support for sportsmen, aiming the achievement of better performance results. For this purpose, in general, the data of the users (for example the applied forces) are firstly measured, then collected, thereupon processed and finally presented in a certain way. The complexity lies definitely in the issues of when and how feedback can be given most effectively. It has been proven that a possibly rapid return of the results is one significant improvement factor [22, 26]. This implies also the integration of mobile devices, since they can be applied very easily at almost any place of training. Additionally, due to time restrictions, it is important to be aware that such feedback systems should be designed in an user-friendly way in order to allow an easy use. Eventually, a clear presentation tool should be included as well, preferably in form of a graphical visualization like for instance a diagram.

In [17] the authors propose a system for the sport rowing, which should provide transfer of biomechanical data from a boat over a wireless network using laptops. The concept sounds plausible, though, such transmissions are hard to realize on-water. This raises the idea of moving those measurements on-land by introducing rowing ergometers [28]. A couple of different dynamometers (e.g. one for the measurement of the feet's reaction force and another one for the measurement of the hands' pulling force), which can be fixed onto such an ergometer as well as on a boat, are presented in [15]. The measured data are transmitted to a PDA, thereupon processed and visualized. Advantages of the use of an ergometer instead of a boat are that the results are even shown concurrently to the actual performance and are visible to the athlete too.

2.4.3. Mobile Coaching

Mobile coaching is a quite new approach in the area of Computer Science in Sport that is currently trying to establish itself. Especially the appearance and the continual improvement of mobile devices has awaken interest in the use of such hardware for hobby as well as elite sports.

In general, the definition of mobile involves the capability of moving or being moved very easily. In the context here, the mobilization factors comes from the use of mobile devices and their ability to be applied at almost any place. In order to provide the reader with a more illustrative description, some samples are exemplified below.

The probably most popular mobile system in this area is the so-called heart rate monitor - usually a wireless equipment, which, in its simplest design, is able to carry out real-time measurements of one's heart rate. A chest strap is serving as a radio transmitter by sending radio signals to the receiver (in most cases a watch or another type of mini computer), where the heart rate is displayed. An extension of the heart rate monitor is presented in [19] under the name MarathonNet. The goal of the developers was to implement an equipment that is not fixed to an individual athlete only, but should preferably involve all parties of a sporting event - in this case a marathon. Therefore, additionally to the heart rate measurement function, many additional components were introduced, some of them are described below:

1. Since a huge amount of people is participating in such marathons and professionals are usually routed by their running partners, MarathonNet provides runners with the opportunity to be in contact with these escorts.

2. Furthermore, it is possible to adjust a "virtual escort" in order to pursue predefined goals more closely.

As stated in [31], there are also many other coaching systems, which are mainly based on video analysis. Such applications are in use in different sports like soccer or swimming. The main purpose is to support coaches and athletes in their training methods by looking at and analyzing video data sets.

In [23], for instance, a video and Internet-based coaching system for the ball game beach volleyball is demonstrated. The application enables a direct connection between coaches and athletes through the World Wide Web. In this way, in sports like beach volleyball where budgets are limited and hence coaches are not always able to arrive with the players to the competitions, it is possible to imitate real training or match situations. One alternative is, for instance, to select video data sets regarding a concrete event and analyze as well as discuss them between the interconnected participants. For this purpose, the implementation offers special features like chat, video-conference and tactic board functions. The authors also propose in their outlook the usage of a GPRS- or UMTS-enabled handheld, which could be used directly on the beach volleyball courts and hence would mobilize the system.

The implemented mobile coacher, which is presented in detail in the following chapter, allows such an innovative approach by integrating a web-enabled PDA in the development. In this way, a greatly enhanced mobilization is achieved.

2.5. IBM Lotus Expeditor

IBM's Lotus Expeditor framework [5] is a quite powerful software package, that provides its users with the ability to create applications for desktops but also mobile devices. Included in the current version are, amongst others, a client and server installation package as well as a toolkit for the development of client applications.

Lotus Expeditor can serve as a pretty efficient instrument since it is built on top of the Free and Open Source Software (shortly called FOSS or FLOSS) [34, 35] Eclipse™ platform[2] [3], but at the same time offers many additional extensions, which can be integrated very easily in the development environment [39].

The Lotus Expeditor Toolkit allows programmers to develop different kinds of client applications, including:

- Eclipse Rich Client Platform (RCP) applications (desktop client only)
- Eclipse embedded RCP applications
- Web applications
- Embedded transaction applications
- Portlet applications (desktop client only)
- Database applications
- Messaging applications
- Web services applications

As it can be concluded from the list above, there are software products designed for

[2]Eclipse is a trademark of Eclipse Foundation, Inc.

desktops as well as for mobile devices. In order to be able to run and assemble applications for such hardware, it is required to set up those installation packages for desktops and/or devices depending on the needs. Moreover, for development, deployment and testing purposes the installation of the Lotus Expeditor Toolkit is essential. This can be done very easily by migrating it using Eclipse's Software Updates function.

Implemented and compiled programs can be deployed thereafter by creating additionally a feature and update site project in Eclipse, which can be then transferred and installed on the mobile device. Another relevant advantage of the software package is that client applications don't need the Expeditor Server (which is basically managing the client components) for running and hence can act as standalone programs.

The next chapter deals with the system development of the mobile coaching system. As described in Section 3.4, IBM Lotus Expeditor is also in use for the implementation of the application on the mobile device and the server part of the coaching system. Since the software framework includes many different components, just the parts related to the implementation are exemplified.

3. System Development

After pointing out the basic theoretical aspects, which are essential for the understanding of the coaching equipment, it is now time to concentrate on its actual development. Therefore, this chapter presents the most important realization factors, including, amongst others, facts about the architecture, the used hardware, the installed software and the implementation of the mobile coaching system. Moreover, the definition of the user scope is given.

3.1. Architecture

The developed system is built up according to a typical client-server model, where client and server are separated from each other and thus work independently. At the same time, it is relevant to notice that the two parts are able to collaborate with each other in order to allow an effective interaction of the system. In addition, the use of modern handhelds - namely a PDA - provides athletes and coaches with very efficient mobile coaching opportunities. The following section describes in more detail the construction and design of the so-called client-server architecture in the case of the implemented system.

3.1.1. Client-Server Architecture

As illustrated in the basic scheme of Figure 3.1 the assembly is split up into 2 major parts - client and server. Moreover, on the client side there are 2 significant components, which require closer inspection and are described below, while details on the server are given right afterwards.

Client Side

The first relevant attachment is an electronic device, which includes a so-called ToothPIC module and is basically an analog-to-digital converter (ADC). Consequently, during their training, athletes are cabled to a sensor system for the purpose of carrying out different kinds of measurements (e.g. of biomechanical values). In this way, at the same time while sportsmen are performing their workout, a permanent production and registration of analog signals is initiated. Those inputs are transmitted through the ADC equipment and converted into digital data. It is important to keep in mind that there are different channels for each base as well as individual sensors. Specific examples therefore are force sensors, accelerometers, potentiometers or strain gage sensors.

Once the data is digitized, it is sent via a Bluetooth connection to a PDA, which is at the same time the second important component on the client side. Hereby a distinction has to be made between 2 cases: online and offline configuration of the device. As a start, in either circumstances the received data is saved in a local database. Here is also the point where the initially configured server comes into play.

Server Side

If, in addition, the mobile device is connected to the Internet - for example through a GPRS or Wi-Fi connection - the data is sent to the running server, where the information is stored permanently. This process is called synchronization and is described in detail in Subsection 3.4.1. Consequently, the server part is responsible for the administration, organization, management control and storage of a big amount of data.

Furthermore, the server side includes the implementation of web applications, giving athletes and coaches the chance to look at the achievements and also analyze them in order to improve the training results. This feedback information is realized in form of graphical diagrams, which can be viewed after a proper login. More details on this implementation part are discussed in Subsection 3.4.3.

The following section goes deeper into the description of the actual hardware characteristics.

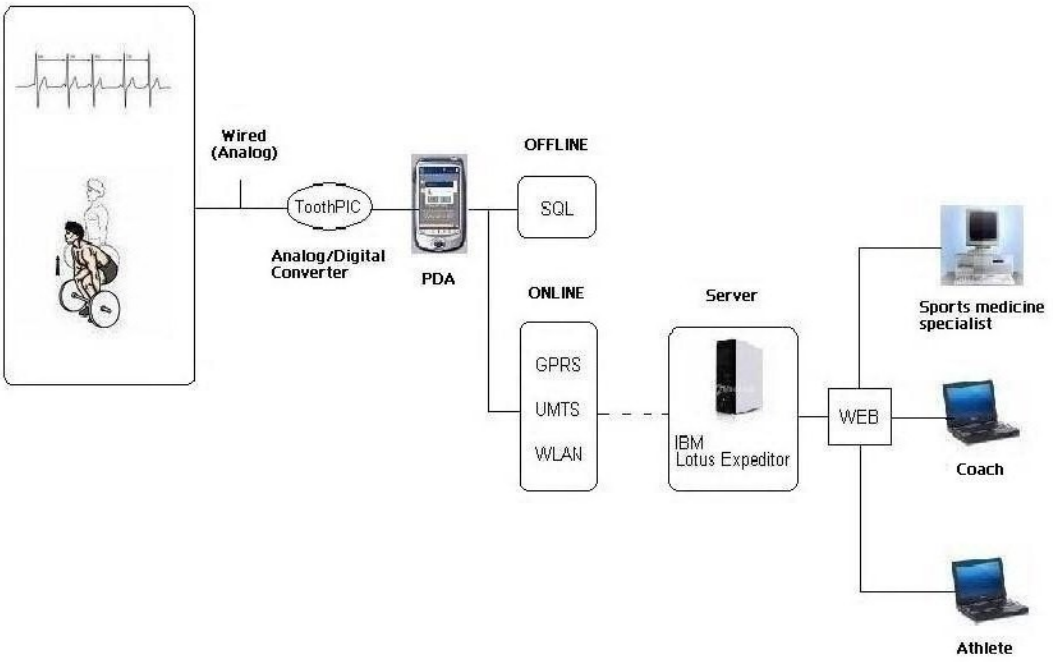

Figure 3.1.: Client-Server Architecture

3.2. Hardware

This section is entirely dedicated to the features of the hardware of the mobile coaching system. This is done again in such a way, so that an exact distinction between client and server components is made.

3.2.1. Client

As already mentioned in the previous section, the following two hardware tools are of practical importance on the client side:

1. ADC device
2. PDA

In the case of the coaching system a Fujitsu Siemens LOOX T830 (see Figure 3.2) is in use as a mobile device and features the following technical details:

Description	Feature
Operating System	Windows Mobile 6 Professional
Wireless LAN	802.11b/g
3G	Yes
GSM/GPRS	Tri-Band 900/1800/1900 MHz
Integrated GPS	Yes
Integrated Keyboard	QWERTY
Bluetooth	2.0
Camera	2 Megapixels
Memory Slot	MMC/SD(IO) slot

Table 3.1.: PDA Features

Figure 3.2.: Fujitsu Siemens Pocket LOOX T830

3.2.2. Server

The server part runs on Windows™ Server 2003[3] Standard Edition Service Pack 2 and has an integrated Intel Xeon 2.40 GHz CPU and 3.71 GB RAM.

[3]Windows Server 2003 is a trademark of Microsoft Corporation.

3.3. Development Tools and Configuration

In order to be able to implement and run the client program, it is required to install and configure some essential development tools, which are presented below. For the purpose of obtaining a better overview, again, this is done separately for client and server.

3.3.1. Client-Side Software

The following table represents the software components that are used for the development of the client application.

Description	**Development Tool**
Development Environment	Eclipse 3.2.2 IDE
Bundle Developer Kit	IBM Lotus Expeditor Toolkit
Supported Client Runtimes	j9/jclDesktop, j9/jclDevice
Database Development	IBM DB2
Programming Language	Java (Java2 Micro Edition)

Table 3.2.: Development Tools

IBM Lotus Expeditor and Eclipse

From the table above, it can be concluded that the development is based mainly on some of IBM's software products (a couple of them were already presented in Chapter 2), which consequently play a major role in the implementation. Due to the convenience and easy integration facilities of IBM Lotus Expeditor, the development environment chosen is Eclipse 3.2.2 IDE (Integrated Development Environment).

As already mentioned in section 2.5, the installation of the IBM Lotus Expeditor Toolkit is required for the development of mobile - namely embedded Rich Client Platform (eRCP) - applications. The eRCP is a subset of the RCP, offering the possibility to implement and deploy programs not only on desktops, but also on mobile devices. The migration of the toolkit can be done via Eclipse's Software Updates function.

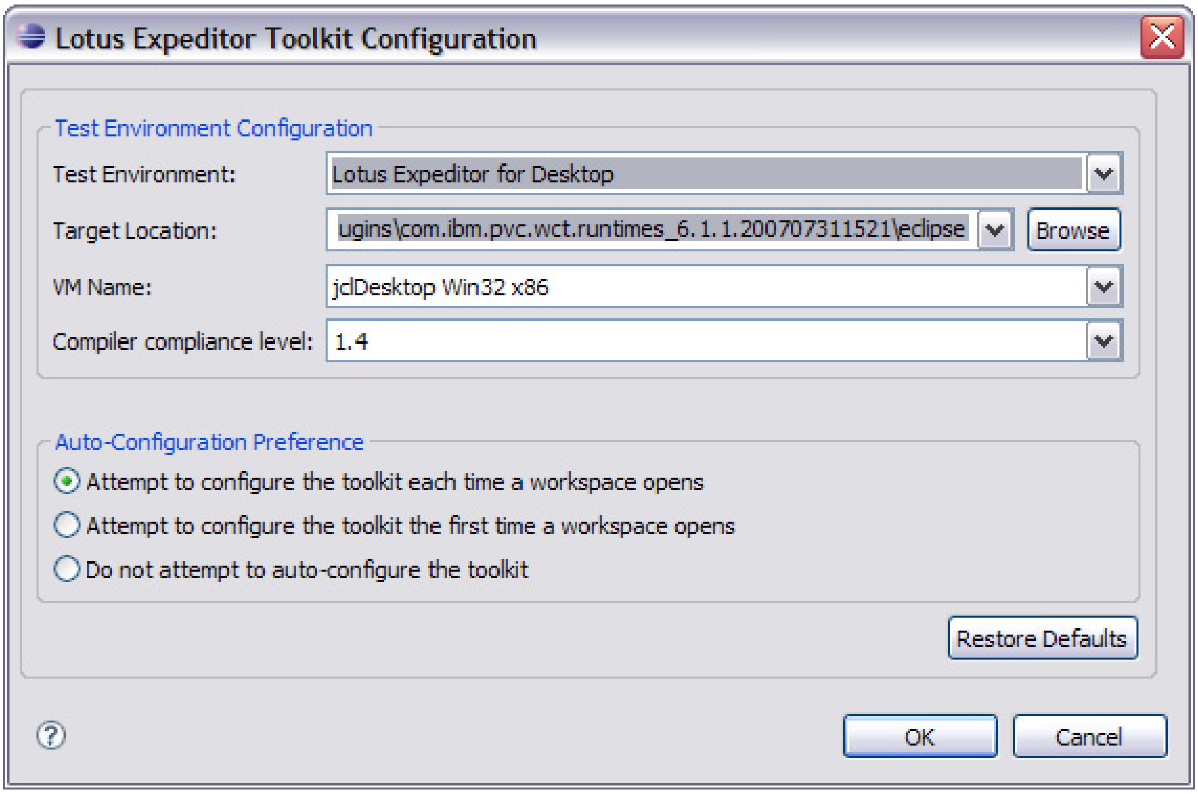

Figure 3.3.: Lotus Expeditor Toolkit Configuration

Once installed, after a restart of Eclipse, a configuration window will appear (see Figure 3.3), providing its users with the opportunity of configuring the test environment, including the environment itself, the target location, the VM name and the compiler compliance level.

After choosing the appropriate configuration, the selected test development is loaded. Additionally, it is important to always check that the right test environment is in use. This is, amongst others, due to the issue that the plug-ins and features for the device environment are limited compared to those of the desktop version.

The client's runtime used for the PDA is Lotus Expeditor's test environment j9/jclDevice, which is basically a Java ME (Micro Edition) virtual machine. Moreover, it can be seen as a kind of simulator of the device's real runtime, having the same look and feel and thus offering developers the chance to run and debug their applications before transferring them onto the PDA. The program (to be discussed later on) is implemented in Java, more precisely in J2ME (Java™ 2 Platform, Micro Edition)[4], including a subset of libraries, which were particularly designed for the development of applications on mobile devices.

Running Operation - Requisites

In order to be able to run the implemented source code, it is required to set up and configure the Lotus Expeditor client package, which was already presented in Subsection 3.3.1, on the appropriate device. Moreover, developers have to be aware that if some additional features, like for instance synchronization or database utilities, are in use, versions of these components (also part of this package and specially designed for devices), have to be deployed on the device too.

Database System

For both, the client's and server's data acquisition (including e.g. the storage of the measured values), the relational database system IBM™ DB2 is used. On the mobile device the data is saved in a local DB2 database, which is represented by a file database,

[4] J2ME is a trademark of Sun Microsystems.

while on the server the DB2 Enterprise Server Edition is set up and configured. In the next subsection the reader is given with more details on the server itself.

3.3.2. Server-Side Software

On the server the following essential software components are in use:

- IBM Lotus Expeditor Server
  - DB2 Everyplace Synch
- IBM DB2 Server
- IBM HTTP Server 6.0
- IBM WebSphere Application Server 6
- IBM WebSphere MQ Everyplace
- PHP 5

As already mentioned, synchronization is a key issue of the developed coaching system and thus a closer look on this topic needs to be taken too. Concretely, in this case, synchronization means the ability to synchronize relational data between client and server. Here again, IBM's Lotus Expeditor along with the DB2 component offer a package called DB2 Everyplace Synch Server [1], which is an important part of the Lotus Expeditor Server. It allows - together with the DB2 Everyplace Synch Client (has to be set up on the PDA) - the almost automatic synchronization of relational data between server and client.

A big advantage of the software is that information can be transferred not only in one direction but bi-directionally, meaning that after an appropriate configuration, data can be sent from the client to the server as well as the other way round. Furthermore, one can choose between the supported Open Database Connectivity (ODBC) and (the chosen) Java Database Connectivity (JDBC) data sources.

Mobile Device Administration Center

However, in order to be able to make use of the convenience of easy replication, it is necessary to set up and enable such a connection first. For this purpose, a program named Mobile Device Administration Center, which is part of the just explained Synch package, has to be started on the server.

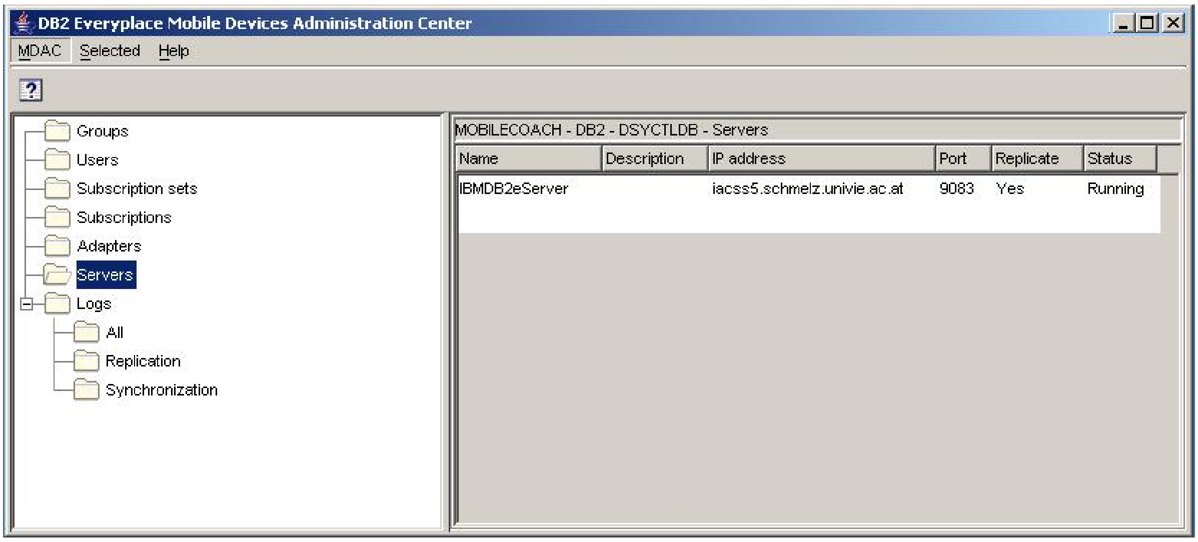

Figure 3.4.: Mobile Device Administration Center

Figure 3.4 illustrates the interface of this application. As shown, there are a couple of so-called 'synchronization objects', which, together with their functional utilities, are presented in the following table:

Synch. Object	Description
Group	Group of users
User	User identification
Server	Running host and used port
Subscription	Type of information to be replicated
Subscription set	Collection of subscriptions
Adapter	Synchronization and communication purposes

Table 3.3.: Synchronization Objects

"A synchronization object contains information about aspects of the synchronization process" [10]. A group contains users, who have related synchronization properties.

Users and groups can be added, edited and deleted over a web interface, which can be usually found by loading the server address with a 'user-management'-tag added after it (in case of the coaching server it is identified by http://iacss5.schmelz.univie.ac.at/user-management). Subscriptions define the type of information that has to be replicated between client and server. In general, one can differentiate between a file and a table subscription, which is moreover subdivided in an upload and a JDBC subscription. In addition, the already established target and source databases (the next subsection offers more information on this topic) have to be chosen using the Mobile Device Administration Center.

As illustrated in Figure 3.5, this would mean that on the PDA of the mobile system there is a target database set up called VAL (which stands for value), from where the relational data is synchronized with the equally named source database on the server.

The other synchronization objects are aggregations of single subscriptions called subscription sets on the one hand and adapters, designed mainly for communication and synchronization purposes, on the other hand.

An important function of the program is also the log tab, offering developers the possibility to see what kinds of log entries are made and thus the chance to fix problematical synchronization issues. Furthermore, in the server tab, the host address plus its listening port can be viewed.

Control Center

Another relevant program of the server package is the so-called Control Center, having its main scope in managing the whole database system. It is possible to interrogate, create, update, edit and delete a lot of information as well as modify predefined system data. Here, for example, there is the option to change the value AllowMultipleDevicesPerUser of the control database DSY.PROPERTIES from the default setting false to true. This would allow users with the same identification name and password to synchronize data with different devices.

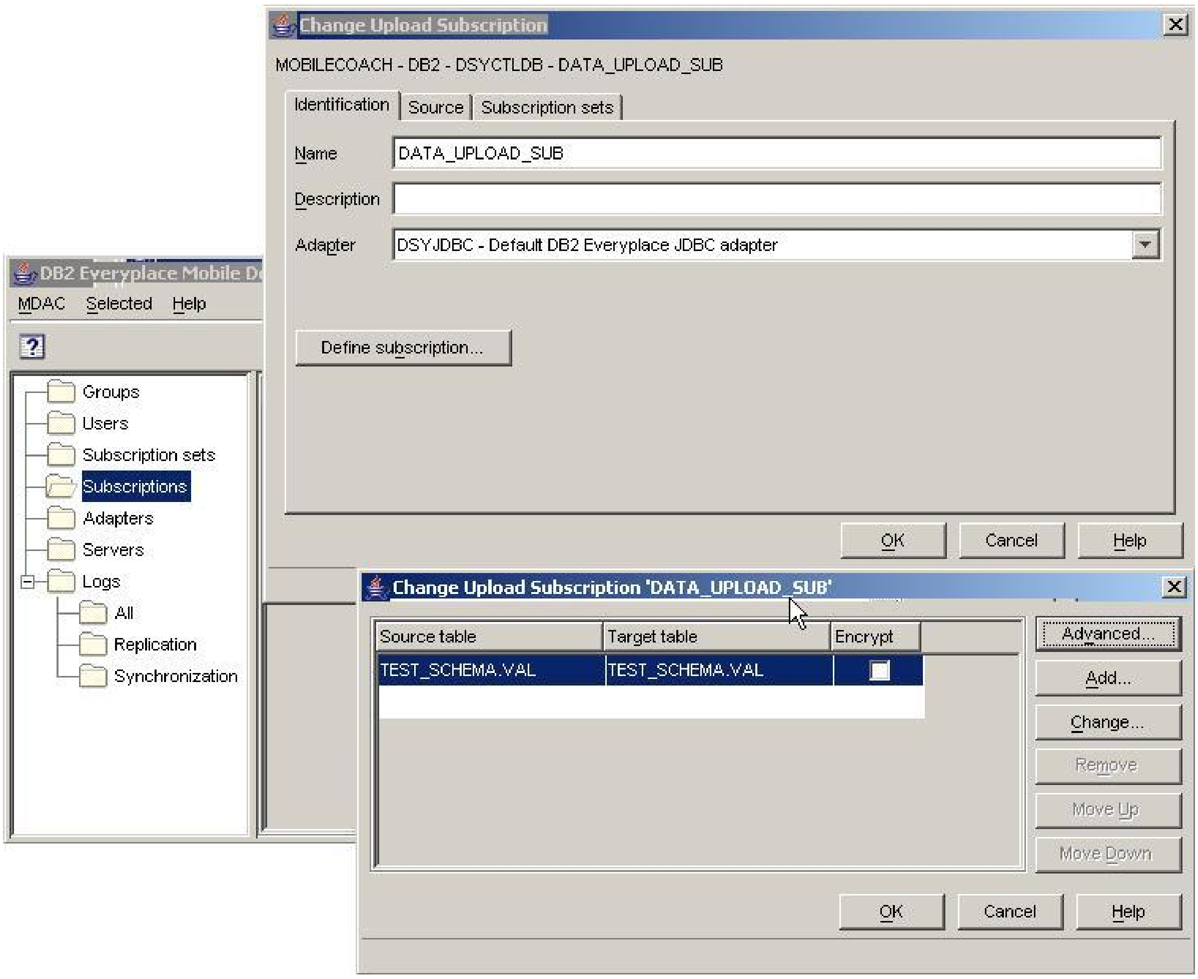

Figure 3.5.: Subscriptions

Other Components

An also essential product is the IBM^{TM} HTTP Server, which is basically based on the Apache web server - one of the most popular web servers, serving almost every second web page worldwide [6]. It forms, together with the installed PHP^{TM} 5 package[5] [9], the basis for the development of the feedback component of the mobile coaching system. Consequently, being among one of the most relevant parts, it is presented along with other implementation details below.

3.4. Implementation

This section covers the most crucial facts on the actual software implementation of the PDA as well as the feedback module. In order to do so, a closer look is made at the mobile application including its running operation, functionality, deployment and the visualization method used.

3.4.1. Mobile Application

After setting up the server and the client components, it is of great importance to test their functionalities, like for instance the synchronization process. For such testing purposes, a simple application is developed and thereafter deployed on the PDA. The simplicity is confirmed moreover by the fact that the tests are carried out by processing precast instead of real-time values. Therefore, some already available training data from the sport rowing are used.

Figure 3.6 (on the next page) illustrates an overall class diagram of the mobile application. As shown, there is an Activator class that, as prescribed, extends the org.eclipse.ui. plugin.AbstractUIPlugin class. "This provides the base functionality for starting and stopping the application within the OSGi framework" [2]. Open Service Gateway Initiative is a dynamic and component-oriented service platform, which is based on Java and has the main aim to enable the installation, update and uninstallation of software components without restarting the actual system [8].

[5]PHP 5 is a trademark of The PHP group.

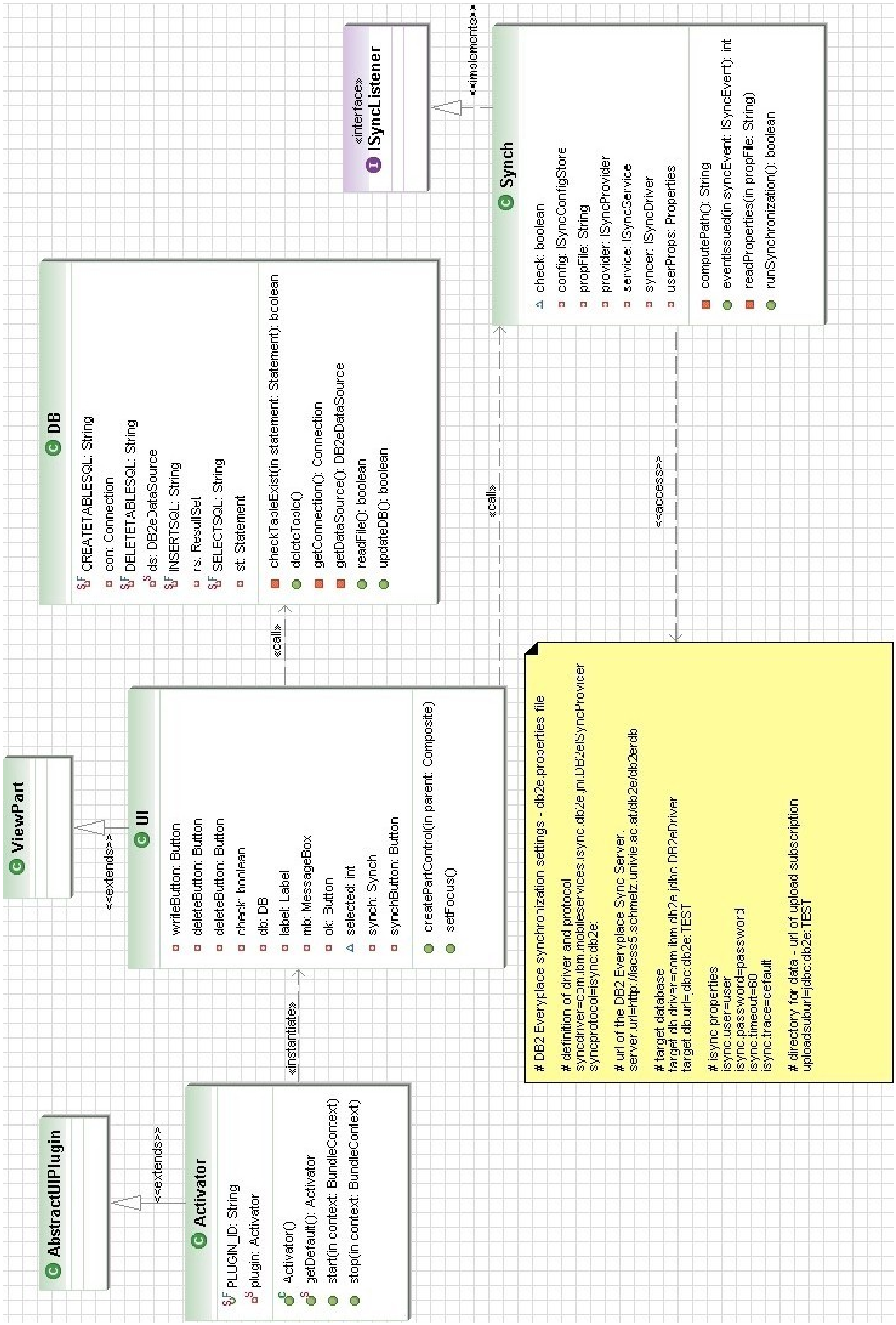

Figure 3.6.: Class Diagram

The user interface is implemented in the class called UI, which is a subclass of the org.eclipse.ui.part.ViewPart class. This is required in order to be able to define one or more views of the application. A view represents in general the final look of the user interface. For example, one can choose between the so-called "normal", "large" or "status" view, depending on the screen size of the device. These settings are usually defined in a XML (Extensible Markup Language) [11] file by markups like the ones in the following code:

```
<extension
       point="org.eclipse.ui.views">
   <view
         category="org.eclipse.ercp.category.normal"
         class="mobile.coaching.UI"
         id="mobile.coaching.view1"
         name="mobile.coaching.view"/>
</extension>
```

Moreover, the UI class has to implement the following 2 methods:

- public void createPartControl(Composite parent)
- public void setFocus()

Typically, createPartControl defines the user interface of the application, while setFocus plays a role in accepting focus when needed. In summary, a simplified source code of the class would look similar to the successive one:

```
public class UI extends ViewPart {

       private Label label;
       ...

       public void createPartControl(Composite parent) {
              parent.setLayout(new GridLayout(1,false));
              label = new Label(parent, SWT.NONE);
              label.setText("Welcome to the Mobile Coacher");
```

```
            ...
        }
        public void setFocus() {}

    }
```

In the createPartControl method, after defining the layout (in this case a so-called GridLayout is specified), one can start with the implementation of the user interface. The setFocus method is left empty for simplicity and also because giving focus is not essential for the mobile application.

The Synch class, holding the most important synchronization tasks, is also worth mentioning. Therefore, it has to implement the ISynchListener interface, which enables the interception and control of all possible synchronizations events.

For these purposes, the db2e.properties file contains some crucial synchronization properties and is, hence, accessed by the Synch class. Included are, amongst others, the URL of the DB2 Synch Server, the target database and directory for the upload subscription as well as some necessary synchronization properties like driver, protocol and user login information. Finally, the class holding the name DB is forming the database management of the application. As already mentioned in Subsection 3.3.1, the data acquisition is realized as a file database and thus in a couple of single files. The UI class interacts with the DB and Synch class by calling some of the implemented methods via the user interface, for example through the defined buttons.

Running Operation

It is important to notice that, in order to be identified as such, eRCP programs have to be defined and (if correctly compiled) started as so-called Client Services. In Eclipse, this can be done simply by selecting and creating a new type of application in the run option. After typing in the name, it is relevant to check if all options are set correctly. This includes the path directory, the already described JRE and moreover the use of the right plug-ins.

When completed, clicking on the run button should evoke the startup of the Lotus Expeditor eWorkbench (Figure 3.7) and the appearance of the mobile application in the list of the running environment. A double click on the program runs it and hence shows the outcome of the user interface.

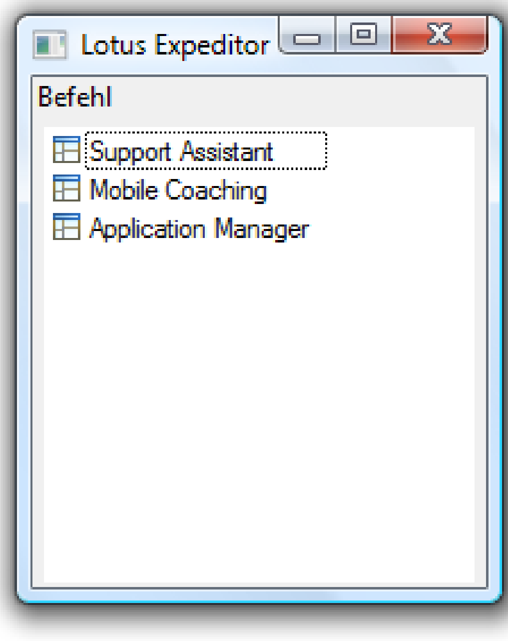

Figure 3.7.: eWorkbench

Basic Functionality

Figure 3.8 illustrates the basic look of the application and thus its main functionalities. As already mentioned, some previously measured data from the sport rowing are used for testing purposes. They are usually represented by floating-point numbers and initially saved in a file, from where they are read through by the program. Clicking the button Write Data invokes saving of the values in the local database.

In order to delete the created table automatically and not manually by just deleting the files from the database directory, a button for such purposes is specified too. Since it is one of the most crucial components of the application, the realization of the synchronization method is described below.

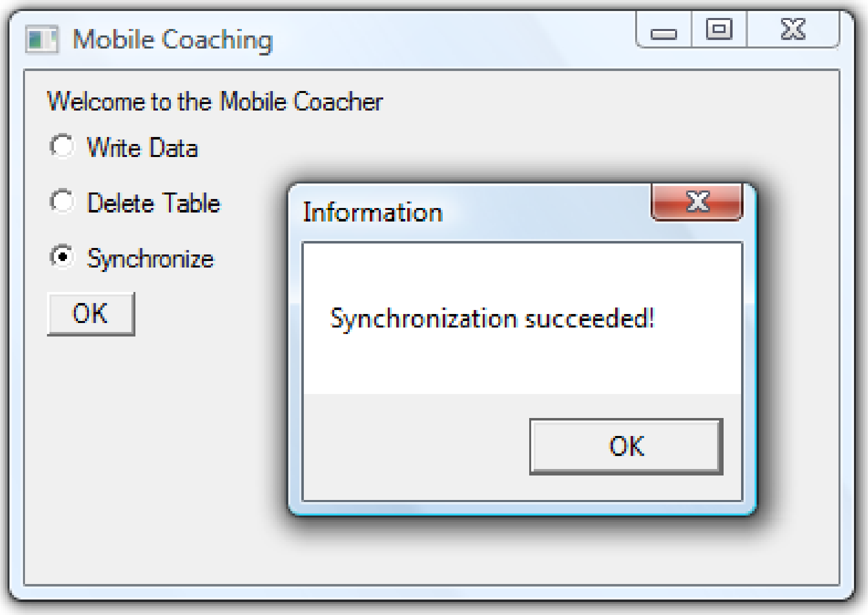

Figure 3.8.: Mobile Coaching Application

Synchronization

The button named Synchronize offers users the opportunity to synchronize the initially written data with the server. This can only be carried out if the PDA is connected to the Internet. Therefore, as already mentioned in Subsection 3.1.1, it is important to distinguish between the following 2 setups:

1. Online configuration
2. Offline configuration

The used PDA supports not only a Bluetooth but also a GPRS and a Wi-Fi technology, both of them enabling access to the Internet. If one of these connections is activated, the received data can be forwarded immediately to the server. Otherwise the training results are saved in the local database only and a synchronization with the server is carried out once the device is connected to the Internet.

Consequently, if the PDA is in an offline configuration and an attempt to synchronize is made, the message "Synchronization failed!" is popped up. This is also the case if some other error appears, like, for example, if another connection problem occurs or the wrong user ID is in use. Codes and information regarding errors and bugs can be viewed in the log file on the PDA or checked in the log entries (of the already in Subsection 3.3.1 presented) Mobile Device Administration Center. Otherwise, if the PDA is in an online mode, the data is sent to the server and a message box with the text "Synchronization succeeded!" is shown.

3.4.2. Deployment on the PDA

In order to test and experiment with the mobile application under a real environment on the device (and not under the simulating conditions in Eclipse), it is necessary to package it in two relevant projects [27]:

1. Feature
2. Update Site

Both projects can be inserted individually by pressing Eclipse's menu item File, followed by New and later on Project, thereafter choosing the appropriate one under Plug-in Development.

Features, on the one hand, are used for assembling all the required RCP plug-ins. For this purpose, it is important to add the initially created plug-in of the application (here mobile.coaching) to this feature, either in the available feature.xml file or using the equivalent but user-friendlier Plug-ins tab.

The Update Site project, on the other hand, is responsible for packaging the features as well as their actual installation. It is also defined by a XML file, which should look similar to the following one:

```
<site
       type="org.eclipse.ercp.update.http">
   <feature url= "features/Mobile_Coaching_Feature_1.0.0.jar"
         id="Mobile_Coaching_Feature" version="1.0.0">
       <category name="Mobile_Coaching_Category"/>
   </feature>
   <category-def name="Mobile_Coaching_Category"
```

```
            label="Mobile_Coaching_Category"/>
    </site>
```

As can be seen, the site type is set to org.eclipse.ercp.update.http, which is of great importance since thereby the feature is defined as device specific. The remaining definitions like feature url and category definition have to be fixed too.

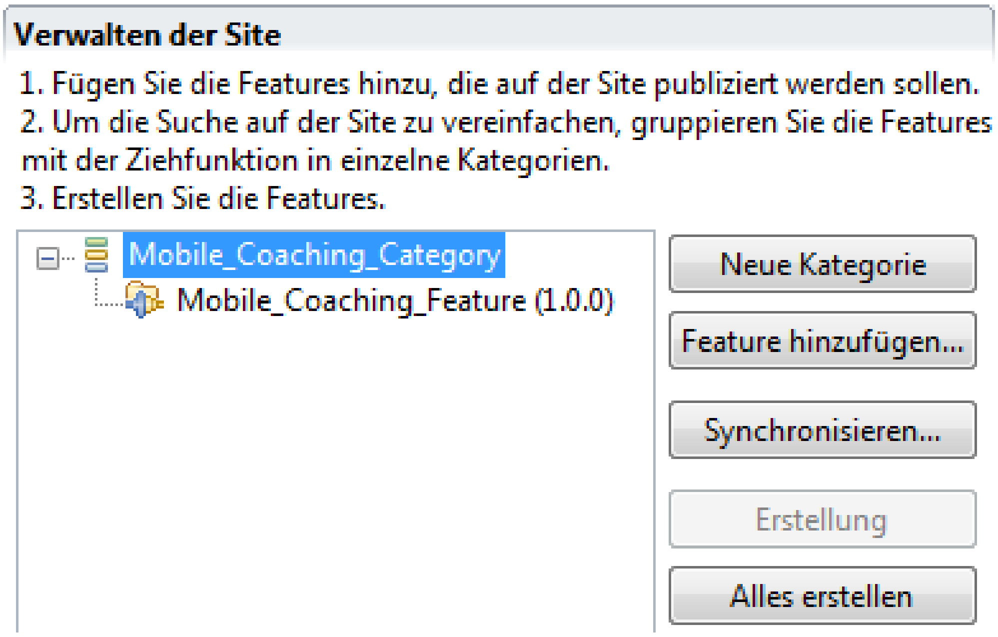

Figure 3.9.: Update Site Map

The graphical representation of the so-called Update Site Map is illustrated in Figure 3.9.

After defining a category, adding the feature to it and building all the modules, the deployment on the PDA can be carried out. For this purpose the Update Site project has to be exported (the easiest way to do this in Eclipse is as a so-called File System) and thereafter transferred to the device by using USB or a flash card. On the PDA, in the Lotus Expeditor client, one can choose the Install New Applications/Features option in order to install the mobile application. After restarting Lotus Expeditor, the coaching program should be loaded and listed in the eWorkbench. For further information on the user interface and functionality, please go back to the details already explained in Subsection 3.4.1.

3.4.3. Visual Feedback

The return of visually assisted feedback is definitely a key feature of the mobile coaching system. As already discussed in Subsection 3.4.2, once some training data is available, it is of great importance for coaches and athletes to have a look at the actual results. A graphical presentation of the aggregate values is probably the easiest and most demonstrative way of having a quick view on the achievements. For this purpose, the system provides their users with the ability of logging in via a web interface and then with the opportunity to look at the training performance via a diagram.

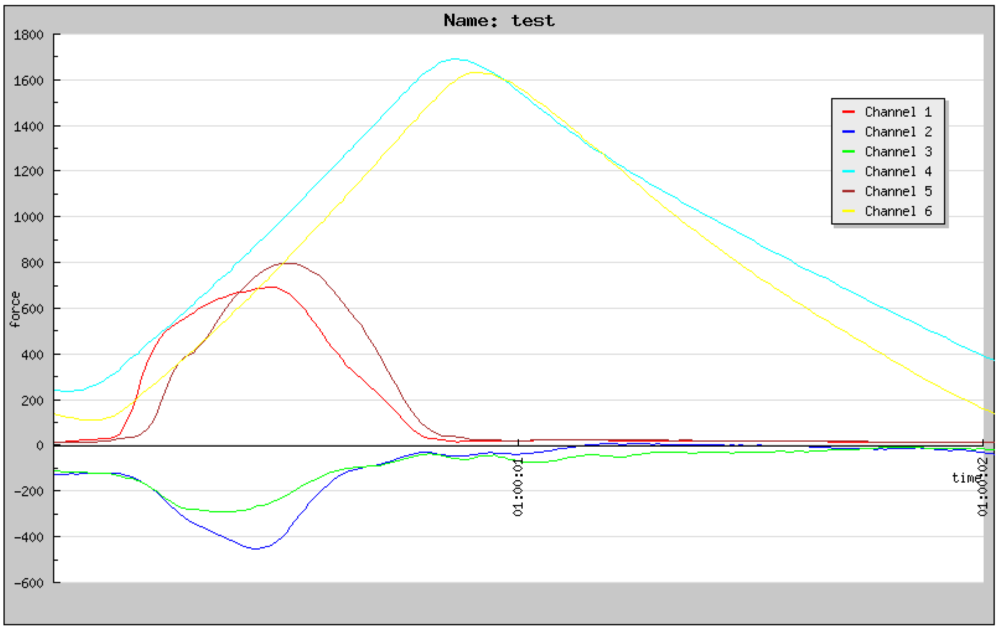

Figure 3.10.: Visualization

The chart in Figure 3.10 gives an example for a visualization alternative. It illustrates the measured biomechanical data during a stroke for the sport discipline rowing. As shown, 6 different channels are visualized, each of them representing a specific force factor. The X-axis specifies the time duration in seconds, while the Y-axis shows the concrete force values in newton (N). Obviously, an entire stroke takes a bit longer than two seconds, while the force values vary depending on the momentum and the used power.

For the representation of the graphics the open source code library GD (originally standing for "GIF Draw", informally for "Graphics Draw") is in use [4]. It enables the dynamic creation of different kinds of images and is moreover easy to integrate and use under PHP.

Single users are added via the already explained Control Center (Subsection 3.3.2) by inserting them into the according database - usually the one that is also used for synchronization purposes.

3.5. Scope of Use

The current section briefly surveys the relevant user groups of the mobile coaching system as well as sports in which it can be actually applied.

3.5.1. User Scope

As the name of the system - Mobile Coaching - already indicates, its main user scope includes sport-related people. The major users can be subdivided into the following three groups:

1. Sportsmen
2. Coaches
3. Experts

In the first place, the system is evidently designed for sportsmen with the purpose to improve their training and competition results. Additionally, it should also serve as an assistance for coaches who are tracking strictly their athletes' training performances. Finally, the consultation with experts, like for instance sports medicine specialists or biomechanics, can be essential in order to be able to make the right interpretation of the data.

3.5.2. Applied Sports

The system doesn't have the focus on one specific sport, but is meant to be generic. Though, due to current technical limitations and possibilities, the sport rowing is chosen for the purpose of testing the application. Even so, it should be clear that the presented method should be applicable in every sport, where opportunities for measuring force or any kind of other values are given. Here it should be also taken into consideration that equipments like the used sensors are not appropriate in every sport, since they can lead to disturbance or interference of the athlete's motion [14].

4. Discussion

The initially introduced literature, including the sports-related research projects and innovations, show clearly that the applied field of Computer Science in Sport and the surveyed system in particular are definitely concepts of great present demand. Furthermore, based on the previous discussions, it can be inferred that methods for improving training and competition performances of sportsmen have evolved a lot in the last couple of years and are of great importance today.

The specific set-up created by Baca and Kornfeind [15] as well as the system developed by Collins and Anderson - both applied in the sport rowing - can be seen as ancestors of the mobile coacher. Moreover, also the system of Link and Lames [23] for the ball game beach volleyball is closely related to the approach of this thesis, since they additionally propose the deployment of mobilization tools in form of a PDA for their technical procedure.

However, the overall concept of the illustrated coaching technique suggests something novel and innovative in that it offers great mobilizing possibilities by involving a web-enabled smartphone in the development. Such mobile devices do not only have the opportunity to connect to the Internet at almost any place, but also have the advantage of being small-sized and handy to use. This brings the great benefits for athletes and coaches to check training results just after workout or even concurrently. Hence, users can analyze very specific training data - like for instance the achieved force values - in a very expeditious way and without the need to leave their training place for the purpose of looking at their performance outcome.

In addition, it is important to notice that nowadays, due to the extremely high competition in professional sport, immediate feedback approaches are of great relevance for the field of sports science. In times, where sportsmen are pushing themselves to their limits and beyond, such methods are considered as very significant in order to achieve predefined goals.

4.1. Final Comments and Outlook

While the presented mobile coaching system does offer a very promising pioneering method, further investigations have to be undertaken in order to ensure the further progress.

One important issue is the still limited connection bandwidth for mobile devices, which restricts the possibility of transferring lots of training data, especially when this is required at once. To ensure a sustainable development of the mobile coacher, it is essential to deploy and introduce cutting-edge technologies as soon as they become available. Particularly, the early incorporation of modern transfer methodologies and hardware components is a prerequisite for the development of better and timely mobile coaching solutions.

Furthermore, for simplicity and technical reasons some already measured biomechanical values are taken for testing purposes instead of using an ADC device. Therefore, for fulfilling the initial goal, it is relevant to include such a converting equipment in the mobile coaching system.

5. Conclusion

In this thesis the implementation of a training system is presented, which has the ability to support athletes and coaches in their workout process. On the one hand, this is achieved by applying sensors on the bodies of the athletes and in this way measuring different kinds of biomechanical values.

On the other hand though, the important issue of the method is definitely the use of an applied mobilization technology, which is accomplished by the implementation of a PDA. Such hardware devices provide their users with the opportunities to be online at almost any place and any time. Thus they enable very handy application methods for mobile training purposes by being able to collect, save and resend the measured data to a server. There the information can be processed, for example in order to give feedback in form of a visualization tool.

All in all, it can be concluded that the presented mobile coaching system builds a very future-oriented basis for athletes and coaches in means of assistance and support. Nevertheless, further research and the final completion of the entire system should be carried out for the purpose of the establishment of continuatively effective training opportunities for sportsmen.

A. Computer Science in Sport

A.1. Organizations

The most relevant organizations that deal with the topic of computer science in sports are presented in the following table. Moreover, their foundation date and web address are mentioned too.

Name	Foundation	Web Address
IASI (International Association for Sports Information)	1960, Rome	www.iasi.org
MathSport Group	1992, Gold Coast	www.anziam.org.au
ECSS (European College of Sport Science)	1995, Cologne	www.ecss.de (rudimental)
ISEA (International Sports Engineering Association)	1998, Sheffield	www.sportsengineering.co.uk
COSISP (Computer Science in Sport)	1999, Vienna	www.univie.ac.at/cosisp
IACSS (International Association of Computer Science in Sport)	2003, Vienna	www.iacss.org/cms

Table A.1.: Organizations

A.2. Geographical Distribution

The tables below show the geographical distribution of several relevant regions in which Computer Science in Sport is applied. Some contact persons and their research activities are also listed.

Country: Germany

Contact: Jürgen Perl
Web Address: http://www.informatik.uni-mainz.de/566.php
Research: Tennis Simulation (TeSSy), Adaptation, Performance Potential Model (PerPot), Dynamically Controlled Network (DyCoN), Modeling

Contact: Martin Lames
Web Address: http://www.sport.uni-augsburg.de/mitarbeiter/05lames
Research: Game Analysis, Model Building and Simulation in Sports, Dynamic Systems Modeling in Sports, Genesis of Goals in Soccer

Contact: Josef Wiemeyer
Web Address: http://www.ifs-tud.de/ifs/Arbeitsbereiche/Bewegungswissenschaft/Wiemeyer/profil
Research: Movement Science, Modeling, Sports Performance, Simulations, Multimedia and Teaching

Contact: Wolfgang Schöllhorn
Web Address: http://www.sport.uni-mainz.de/Sport/416.php
Research: Movement Learning/Teaching, Recognition, Feedback Training, Pattern Analysis

Tabelle A.2.: Research in Germany

Country: Wales

Contact: Mike Hughes
Web Address: http://www2.uwic.ac.uk/UWIC/schools/sport/StaffProfiles/academicstaff/performanceProfMikeHughes.htm
Research: Analysis and modelling of sports performance, Analysis of coaching behaviour

Contact: Peter O'Donoghue
Web Address: http://www2.uwic.ac.uk/UWIC/schools/sport/StaffProfiles/academicstaff/performance/DrPeterODonoghue.htm
Research: Sports Performance, Tournament Design, Time Motion Analysis of Field Games, Simulation

Tabelle A.3.: Research in Wales

Country: Austria

Contact: Arnold Baca **Web Address**: http://public.univie.ac.at/index.php?id=9034 **Research**: Multimedia Systems, Education, Game Analysis, Information and Feedback Systems in Sports

Tabelle A.4.: Research in Austria

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From http://www.eclipse.org/

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