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Editorial

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Dear readers:

IACSS and CACSS, the Croatian Association on Computer Science in Sport, organized the 5th International Symposium on *Computer Science in Sport* in Hvar, Croatia, between 25 and 28 May, 2005. Delegates from 18 nations participated in this successful and perfectly organized event.

11 invited keynote and plenary lectures were presented, 33 oral presentations were given and 10 posters were displayed.

Keynote speakers were Larry Katz (University of Calgary), Tom Reilly (Liverpool John Moores University), Boris Sakac (Head of the Olympic Results and Information System), Wolfgang Schöllhorn (University of Münster) and Otto Spaniol (RWTH Aachen University).

Plenary talks were given by Jürgen Perl, Alain Poncet, Martin Lames and Arnold Baca.

Four full papers and one abstract of invited keynote and plenary speakers are included in this special issue of IJCSS.

Larry Katz, James Parker, Hugh Tyreman, Gail Kopp, Richard Levy and Ernie Chang discuss the potential of virtual reality with regard to sport and wellness. They explore its promise, the value of virtual environment and examples of existing applications. A vision for the future is also provided.

In order to highlight the impact of computer use Thomas Reilly presents selected applications in the sport of football. Examples regarding virtual reality, match analysis, monitoring physiological responses and eLearning are presented.

Arnold Baca and Jürgen Perl give an overview of the history of Computer Science in Sport, summarize main areas of research, give examples of current research activities and discuss future perspectives.

In the abstract by Martin Lames the potential support of Computer Science for coaching is discussed with regard to game sports. A full version of this paper will appear in an upcoming issue of this journal.

Good reading!

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VIRTUAL REALITY in SPORT and WELLNESS: PROMISE and REALITY

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Abstract

Virtual reality has been used to help land a person on the moon and to instruct astronauts on how to manipulate the space arm. The military uses virtual environments to prepare soldiers for combat and airlines use virtual reality simulators to train and qualify pilots. Increasingly, game manufacturers are utilizing virtual environments and haptic devices to capture the attention of their adherents. However, many questions remain to be answered. How does one define virtual reality and virtual environments? How can virtual reality environments and simulations be used effectively in sport and wellness situations? Will coaches, athletes, and wellness specialists utilize the tools? What has been accomplished so far and what promises have been made? Do the benefits justify the costs? The reality maybe short of the promise, but can the gap be closed – virtually? This paper explores the promise of virtual reality, the nature of virtual reality environments, examples of existing applications, and a discussion of the research to date. It also provides a vision for the future.

KEY WORDS: VIRTUAL REALITY, VIRTUAL ENVIRONMENTS, SPORT, WELLNESS, VISUALIZATION

Introduction

The phrase “virtual reality” (VR) conjures up many different visions depending on ones background and experience. Defining the term is difficult as there are hundreds of versions. Using the Metacrawler search engine (www.metacrawler.com) the first “hit” was identified with three other search engines (Google, Yahoo, and Ask Jeeves) and describes VR as
“An interactive computer-generated simulated environment with which users can interact using specialized peripherals such as data gloves and head-mounted computer-graphic displays.”

Webopedia (www.webopedia.com) defines VR as:
“An artificial environment created with computer hardware and software, and presented to the user in such a way that it appears and feels like a real environment. To "enter" a virtual reality, a user dons special gloves, earphones, and goggles, all of which receive their input from the computer system. In this way, at least three of the five senses are controlled by the computer. In addition to feeding sensory input to the user, the devices also monitor the user's actions. The goggles, for example, track how the eyes move and respond accordingly by sending new video input. … The term virtual reality is sometimes used more generally to

refer to any virtual world represented in a computer, even if it's just a text-based or graphical representation."

According to Chen, Toh, and Fauzy (2004), VR is "Cutting-Edge Technology that allows the learner to step through the computer screen into a three-dimensional interactive environment either immersive or non immersive" (p. 147).

In essence, people who develop VR systems are using technology to create environments that allow the user to actively participate and navigate in events or worlds that engage the mind and body, whether emulating real worlds or defining imaginary worlds. The degree to which the senses are engaged (e.g., whether 3D or 2D, immersive or non immersive, surround sound or no sound) is directly related to the considerations of design, costs of development, costs of equipment, and the imagination of the user (see Figure 1).

The big players in the VR business are the military, airline industry, space agencies, and game manufacturers.

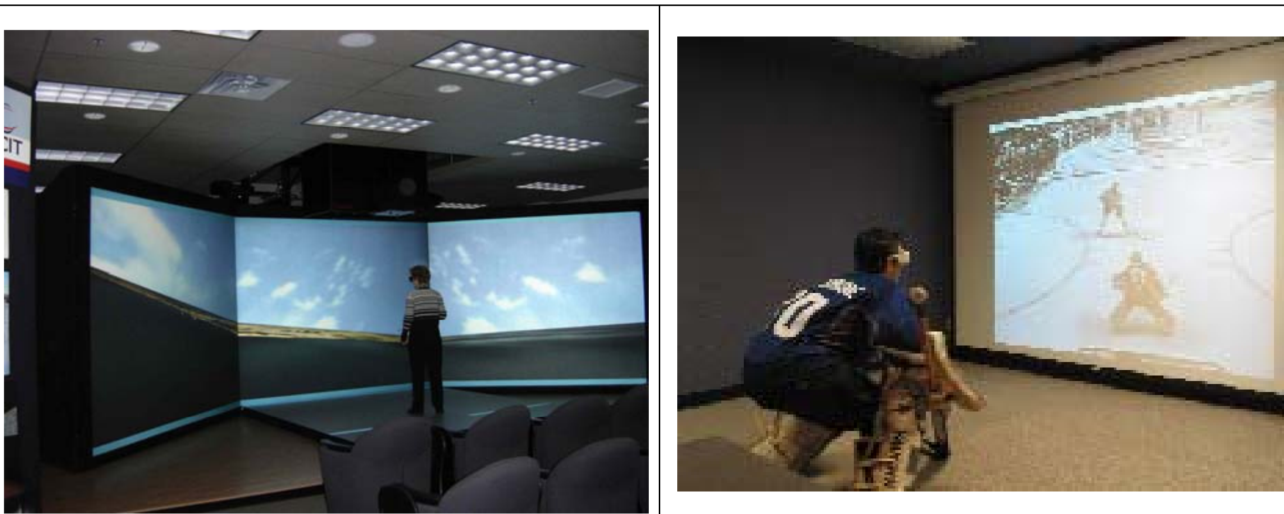

Figure 1. Four screen and one screen 3D virtual environments at the University of Calgary.

The first three groups are heavily involved in VR because of the high costs of making mistakes in the "real world." Good simulations allow military personnel, pilots, and astronauts to learn skills, study the impact of their errors, and learn good decision-making strategies. On the other hand, game manufacturers see great potential in creating environments that engage the minds and money of their target markets. Ironically, the game industry may be the most relevant with respect to the use of technology in sport and wellness because the "volume-to-cost" ratio could make the technology more accessible to coaches, athletes, and therapists.

This paper is concerned with the potential for VR as a vehicle for coaching, training, fitness, and rehabilitation. The critical factors are the availability of the technology, the effectiveness of the resources, and the willingness of coaches, athletes, and therapists to use them.

As a coaching and training tool, VR can allow one to watch, repeat, emulate, deviate, and speculate. Prior to the development of video technology, athletes watched their coaches perform the task; then they attempted to emulate the action. After success or variations of failure, the athlete would receive feedback from the coach. With the use of video, it became possible to capture the action and review it repeatedly while receiving extensive feedback. As computer technology advanced and biomechanical analysis became possible, the process became even more sophisticated. This process has expanded, and learning and decision-making, especially at the elite athlete level, can now involve massive amounts of data from a variety of sources such as video motion capture, pressure sensors, and positioning systems. New tools are available which would enable coaches to create Virtual Environments for skill acquisition, training, fitness and rehabilitation. The next logical step would be to construct VR environments that allow the athlete to vary situations and strategies, including the use of sound, and see the impact of their actions in "real-time." Very few sophisticated VR systems exist in the area of sport and wellness, and those that are being developed are primarily limited to research laboratories. The question is "What is the potential?"

The Promise

The ultimate promise of VR is to create an environment such as envisioned on the TV series Star Trek where the "Holodeck" is so sophisticated that one cannot tell the difference between reality and the virtual environment. Learner-centered Effective Virtual Environments (EVE) can provide experiences that would engage, provoke, cause reflection, challenge conceptions, develop skills, and change the way people understand themselves and their environment. Properly designed, these EVE's could enhance learning through applying the concept of "Flow - the psychology of optimal experience" (Csikszentmihalyi, 1982). According to Csikszentmihalyi (1982), Flow is a state of concentration so focused that it amounts to absolute absorption in an activity. Anyone watching a child fully engaged in a video game would understand this concept (see Figure 2). Such VR or effective virtual environments have the potential to significantly impact performance, but there are major problems.

Figure 2. Children engaged in a two person interactive video game using a Nintendo "Power Pad" haptic device.

The Power Pad haptic device was designed to allow children to play video games and exercise at the same time (see Figure 2). Those who played the game were excited, but only a few game modules were designed for the unit. It never did "catch on," and the Power Pad was discontinued after only a few years (www.gamersgraveyard.com). It is still unclear what went wrong with the Power Pad, but knowing this could help future designers avoid the same fate.

The Challenge

In order to develop successful virtual environments, there are five main questions to address:

1. What are the hardware and operating system needs?
2. How do you design effective virtual environments?
3. Can VR environments improve performance in sport and wellness?
4. Are VR environments in sport and wellness cost effective?
5. Will coaches, athletes and rehabilitation specialist use the VR technology?

What are the hardware and operating system needs?

According to Kondruk (2005) from the hardware and operating system perspective, it must be possible to deliver the ultimate in interactive, cost effective tools in order to support innovation, collaboration, discovery in visualization, and VR. This requires sophisticated architecture, including multiprocessor systems, 3D texturing and shading, volume rendering, dynamic video resolution, extreme scaling, sophisticated speakers, haptic interfaces, wireless and "networkable" capability, and the capacity to manage individual as well as multi-user interactions.

Creating effective virtual environments requires collaboration amongst engineers and scientists from an array of fields including manufacturing, media, and operating system development. Issues such as geographical distribution of data, accessibility, and data security also need to be addressed. Grid computing (the use of multiple high-end machines working together from potentially, widely ranging locations) can help with the distributed workload, but bandwidth constraints are still a problem, as is high performance online storage of data. Researchers are also demanding real-time remote collaboration. Kondruk (2005) further suggests that real-time processing will require multi-dimensional, multi-attribute, as well as spatial and nonspatial data fusion. To do this successfully, it may be necessary to reengineer existing data management strategies. Of course, over time, the problems seem to get more complex.

How do you design effective virtual environments?

Creating environments that are indistinguishable from the real world and/or creating environments that allow the users to experience prebuilt worlds and visualize three-dimensional representations of a problem, are amongst the most complex design endeavors. Some factors that influence software design for VR environments include: understanding the user perspective; appropriately applying the enabling technologies (e.g., audio, haptic devices); and, facilitating the vision of the designer. Systems need to be developed that engage the user/learner, facilitate the user/learner's opportunities to be effective in solving the problem, and create an environment where the user/learner can be efficient in achieving the objectives. Not only must the system be responsive to input from the user, but also the space in which the activity is performed requires manipulation. All these activities are happening in real time and need to be interactive. The actions can be independent or multiplayer, collaborative or competitive (between the user and the system and/or between the user and other users) and may be independent of time or distance. In all cases, the user enters the situation (VR environment) and must be provided with the contextual factors (e.g., physical environment, social cues, tools) to function effectively.

In order to teach new skill related tasks such as those in sports, it may be necessary to "layer the complexity" of the problem through problem identification, problem representation, and proper manipulation of space. This layering of the problem complexity has been applied to the creation of VR skill-training environments at the Canadian Space Agency (Kopp, 2000). Understanding the perspective of participants in VR environments and game simulations is a crucial consideration for enhancing the user experience. Sweetser and Johnson (2005) studied five areas of importance: consistency, intuitiveness, freedom of expression, level of immersion, and the physics of the environment as they relate to game type preference and game-playing experience. For example, they state that: "… interactions with the game environment and objects in the game environment should be intuitive and meet player expectations. People who are less experienced game players can be baffled by the physics of the game world and often need to relearn how to interact with the world like a child." (p. 321).

Self-control of the learning situation also appears to influence both attitude and performance of the user (Bund & Wiemeyer, 2004). Using table tennis videos of skilled professionals and allowing athletes to have control of practice scheduling for viewing of the videos, Bund and Wiemeyer (2004) showed that participants had higher self-efficacy scores and improved movement over yoked controls.

Wages, Grunvogel and Grutzmacher (2004) argue that realism and believability may not be positively correlated, and that striving for higher realism results in more technical problems and potentially greater awareness by the user of the artificiality of the environment.

Frames of reference are important in terms of the physical dimensions (e.g., size and location), psychological perspectives (e.g., walking in another person's shoes), and self-monitoring (e.g., see ourselves as others see us). For example, at the Canadian Space Agency, astronauts' performances can be recorded as they manipulate the space arm. The astronauts can then go into the virtual environment and observe their performance as though they were a third person monitoring the activity. Alternatively, virtual reality with the use of haptic devices, can allow a participant to replay, observe, and even experience the performance of another person such as an expert.

Enabling technologies such as haptic devices are supposed to create a feeling of touch, sight, or movement (Salisbury, Brock, Massie, Swarup, & Zilles, 1995). They provide basic impacts, pushes, and pulls that are associated with object manipulation, and this must happen with realistic force. Sliding a coffee cup across a table should require about 300 g of force, not 10 or 5000. It is this sense that allows the remote manipulation of objects. Presently, a lot of work is being conducted in the area of remote control surgery (Sutherland, 2005) and, without a very accurate sense of the forces being applied, the results could be catastrophic. The other aspect of haptic devices is touch and texture. Most people can slide a finger across a surface and obtain useful information such as smoothness, bumpiness, or stickiness. Touch is used for many control tasks including grasping and catching.

In general, texture is more difficult to replicate than force, and requires devices of greater complexity. Touch transmitters are often placed in gloves worn by users that impart multiple, small touch sensations to the hands. Touch can be enhanced by sound; for example, a suctioning noise during surgery may have a characteristic sound that hearing it, together with “feeling” the pressure, may impart vital information to the surgeon.

Audio, another enabling technology, is a critical aspect of the emotional impact of most environments but is frequently neglected in the development of games and virtual environments (Parker, 2005). Sound is a key indicator of motion, activity, and affective content. A fundamental aspect of sound is that one can both hear and feel it, especially at very low frequencies.

Computer games and virtual reality systems use sound for three basic things:

1. Music, which provides a great deal of emotional content.
2. Sound effects, including ambient sound (e.g., car crashes, audience reactions, running water, surf, wind, skate blades on ice).
3. Speech. Many games tell a story by allowing one to listen to conversations, or even participate in them. However, there are problems with speech recognition and speech understanding that need to be addressed.

In general, sounds reflect the environment (e.g., echoes are expected in large buildings but not in woods). Location is important, as sounds should appear to originate from particular points in space, particularly if the source of the sound is visible. All of these characteristics of sounds must be represented in virtual environments if they are to be convincing representations of real ones. Unless a very large set of audio data is available, synthesis may be the only way to display realistic sounds for VR purposes. In the real world, very few events create exactly the same sound twice. Every bounce of a basketball sounds just a bit different from the previous one, and the slapshot from the blue line in ice hockey has a sound that varies depending on the stick, player, swing, ice temperature, and precise distance from the net. Since the traditional way to use sound in a VR system is to play a recorded file, the user quickly becomes familiar with the files that are available. Furthermore, they may not be the correct sounds for the situation. Sound-based tracking technology that is robust and inexpensive is needed for sports environments (Ishii, Wisneski, Orbanes, Chun, & Paradiso, 1999). Correct positional audio is essential to provide accurate audio feedback. Most real sounds appear to have a specific source and, in some cases, this can be critical for decision-making. For example, when playing a game, it may be important to identify accurately sources of “yells” in order to receive passes or avoid collisions.

Other enabling technologies such as gesture recognition (using two or more cameras to track body position in 3D), eye tracking, and voice recognition have been used with varying degrees of success.

The designer has to be able to visualize abstract concepts including: dynamic relationships in the system; visualize and quantify multiple viewpoints in the environment; understand the interactions with potential events that may be unavailable or impractical due to distance, time, or safety; and, organize all the related objects. For example, trees and rocks, which are obstacles to motion in a skiing simulation, can be manipulated and have an effect on other objects in the virtual world.

Examples of graphic environments that apply some of these principles include Distributed Interactive Virtual Environments (DIVE) and Massively Multiplayer Online Role Playing Games (MMORPG). DIVE is an internet-based multi-user VR system where participants navigate in 3D space and see, meet, and interact with other users and applications. The first DIVE version appeared in 1991 (www.sics.se/dive). MMORPG’s are massive multiplayer online role-playing games. In a MMORPG, thousands of players are able to play in an evolving virtual world simultaneously over the Internet (www.answers.com/topic/mmorpg). The users are represented within this environment by a graphical entity (their avatar), they can manipulate objects though the avatar, and they can communicate with other participants. Interactive scripting for nonplayer characters are referred to as mobile objects (MOBS) and there are even aspects of artificial intelligence with players and environments (e.g., calling for help). These systems operate 24 hours a day, 365 days a year, with some games having over 20 million players with multiple languages and cultures. The systems allow for teamwork, problem solving, and the development of friendships. Many players invest considerable effort in creating avatars and their actions. Their identities are symbolized by their avatar. The simulated, or virtual, environment is represented in 3D with high quality positional sound, and players must keep track of multiple factors in real time. Both MMORPG and DIVE programs have found wide international followings. Ironically, in the World of Warcraft MMORPG, a recent, mysterious, unplanned, program-induced plague accidentally caused many thousands of the virtual players to die (Strohmeyer, 2005).

Some of the design principles from these programs are applicable to sport and fitness oriented VR programs even though design considerations in sport are potentially more complex. When working with athletes, the geometry of the graphical presentation must be accurate. Many times a judgment is made based on the apparent speed and relative position of the user. For instance, in a baseball simulation the velocity of the ball must not appear to change after the pitch is made. In addition, the trajectory must be realistic. In order for these things to be true, there must be an accurate model of the physics of the real world underlying the graphics software.

Can VR environments improve performance in sport and wellness?

Ijsselsteijn, de Kort, Westerink, de Jager and Bonants (2004) used exercise bikes in a virtual home video computer environment to demonstrate the impact of the immersion level and the advice of a virtual coach. The researchers were interested in participant motivation, biofeedback (heart rate and velocity), and the sense of presence or immersion (i.e., of being in the environment). Results indicated that: "…a more immersive environment in which the user feels present heightens the fun the user is having, and thus has a beneficial effect on the user's motivation. In the highly immersive environment, where the presence experience was stronger, participants reported more interest and enjoyment, more perceived competence and control and … they cycled faster!" (p. 56). While the virtual coach seemed to lower perceived pressure and tension, the virtual coach did not influence cycling speed.

Comparing virtual handball throwers with real handball throwers, Bideau, Kulpa, Ménardais, Fradet, Multon, Delamarche, and Arnaldi B. (2003) and Bideau, Multon, Kulpa, Fradet, and Arnaldi (2004) found that goalkeepers react similarly to both types of throwers. The motions of the real throwers were captured in order to create avatars for the virtual environment. Goalkeeper gestures were consistent with both throwers. The researchers concluded that the virtual environment offered sufficient realism to elicit natural gestures, and there was a high level of interest in further participation by the goalkeepers.

Over 500 people participated in a virtual swimming interface created by Fels, Yohanan, Takahashi, Kinoshita, Funahashi, Takama, and Tzu-Pei Chen (2005). The authors suspended participants by harnesses in the air using pulleys and swimming apparatus (headgear) with computer controlled visuals and sound. Issues of user size, experience, and swimmer control revolved around the fidelity of the environment and the "one-size-fits-all" harness. Since the program was part of an open exhibit, the roles of the audiences were also addressed. Almost all participants enjoyed the experience and were able to "swim" using simple strokes or by simply floating.

Yang and Jounghyun Kim (2002) created a virtual reality motion training system that produced a first-person viewpoint "ghost" martial arts trainer that the trainee could follow as closely as possible in order to learn a motion sequence. The graphic ghost master was superimposed onto the user's body so that it appeared that he was emerging from it thus, giving the user a first-person or egocentric view. To achieve this effect, a head-mounted display was required. The trainee then emulated the movements of the master. Technical issues with regard to the speed of movement, degree of freedom, and impact of the head-mounted display were discussed. However, results suggested that the participants in the VR environment followed the motions at least as well as those learning in a real environment and, in some cases, better, especially in the X, Z axis.

Virtual reality games have been designed to provide interactions in various environments such as snowboarding (www.irexonline.com/software.htm). These programs can build a player's range of motion, balance, mobility, stepping, and ambulation skills. You, Jang, Kim, Hallett, Ahn, Kwon, Kim, and Lee (2005) used some of these virtual games with stroke patients to see if the patients could improve motor recovery. The preliminary results with 10 stroke patients were very promising with significant recovery of locomotor functioning when compared to control patients.

At the Sport Technology Research Laboratory at the University of Calgary, the authors have experimented with virtual environments using 2D versus 3D images, interactivity with small screen versus large screens, and visualization as a means of preparing athletes for competition (Morey Sorrentino, Levy, Katz, & Peng, 2005). The results, like those of the studies described above, are promising, but fidelity and equipment issues are still being addressed and sample sizes remain relatively small. Further investigations need to be undertaken before firm conclusions can be reached.

Are VR environments in sport and wellness cost effective?

Virtual reality is here to stay. Simple systems already exist and experienced consumers at a games arcade can attest to the sophistication of many of the interactive systems that test their ability to fight, dance, or snowboard. However, these systems are limited with regard to their potential impact on sport and wellness. Developing specialized systems that can make a meaningful difference in performance or enhancement of skills is still very expensive, especially if intricate haptic devices are required, and so, researchers continue to apply for grants to explore their visions and theories. Finding that elusive, revolutionary application for virtual reality in sport and wellness is key. Until then, costs will still be prohibitive for practical purposes.

Will coaches, athletes and rehabilitation specialist use the VR technology?

Developments in digital technology makes it possible for coaches and athletes to gather information efficiently and effectively, analyze and integrate it, and apply resources in order to improve teaching and training. As technology evolves, it offers new and creative applications. However, in order for technological innovations to be used by coaches, the latter need the technological background and appropriate attitude towards technology. In many cases, however, there is a wide gap between changes and innovations that technology brings and the human capacity to adapt to it (Katz, 2001).

Today, computer-based technology influences many sport-related areas such as equipment design, performance evaluation, game statistics, measurements, and computerized training. While coaches report using computer tools such as word processors and the Internet, few report actively using technology that has been specially designed to enhance the training experience (Liebermann, Katz, & Morey Sorrentino, 2005). The adoption and implementation of an innovation is a multifaceted process that is affected by many factors. A complex interaction of social, economic, organizational, and individual factors can influence the adoption of a technology, as well as the way a technology is used after adoption (Park, 2003).

Raz-Liebermann (2005) studied the impact of a new coaching tool introduced to veteran coaches in a series of workshops. All the coaches reported being highly impressed by the technology and its ease-of-use, and almost all of them indicated that they would use the software (which was provided gratis to each participant) as part of their coaching routine. However, when the researcher followed up with the coaches months later, only a few of the coaches had used the program. Raz-Liebermann (2005) analyzed the factors influencing the intention to adopt a technology and identified self-efficacy, previous experience with technology, and personal and professional innovativeness as key factors. Interestingly, the more experienced coaches were less likely to consider adopting new technological approaches.

Thus, it would appear that even if sophisticated VR systems were developed and shown to be effective and cost efficient, persuading coaches, athletes, and rehabilitation specialists to use the systems may require a concerted effort.

The Vision

For human performance in sports and wellness, the vision is to create environments that are so compelling, enjoyable, transparent, and easy to engage others, that athletes at all levels will use them to improve their skills and participation in sports. Moreover, exercise and fitness will increase in the general community, resulting in higher levels of population wellness, with benefits in health, productivity, and the economy.

Figure 3 provides a visual representation of the program envisioned by the authors. In order to be successful, the program requires commitment from academic, industrial and sport/performance resources funded through the private sector, and government agencies. If effective, these initiatives should generate major business opportunities.

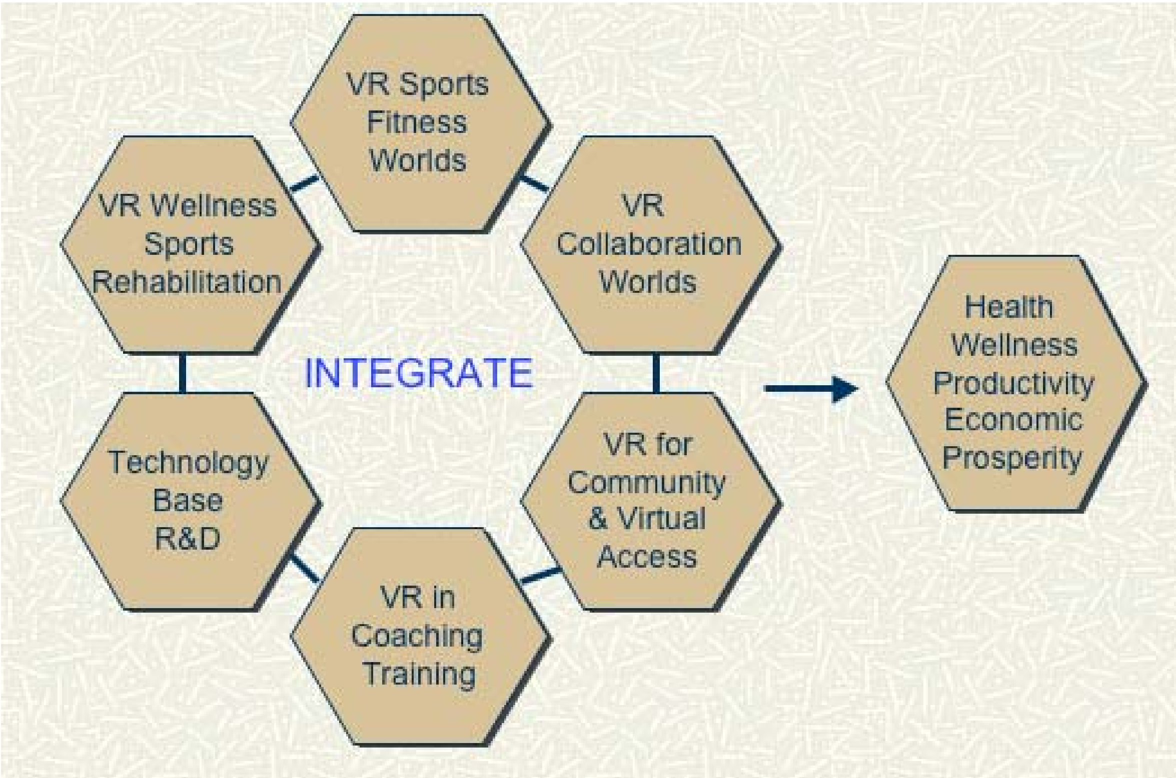

Figure 3. An integrated program for VR in Sport and Wellness.

The technology exists to create innovative 3D environments and preliminary research shows that EVE's are highly effective. While developing truly immersive experiences requires expensive, highly trained, multidisciplinary professionals with sophisticated equipment, ultimately the technology will be accessible, cost effective, and readily available to end-users. The idea is to create artificial realities in which rendering, perception, immersion, presence, feedback, visualization, and interaction with others are combined to give the user experiences that approximate and go beyond what is physically possible.

The vision has two major objectives:

1. Development of enabling technologies – hardware and software necessary to create representative, realistic virtual environments.
2. Creation of applications to accelerate learning, training, and ultimately, performance through use of collaborative virtual environments.

Research Goals

The research goals of the authors are to develop collaborative virtual worlds, explore virtual worlds in sport, fitness and rehabilitation, and study their effectiveness. These worlds would provide adaptive feedback and have scalability for many skill levels. Skills learned in these environments would be transferable to real-life situations and could be distributable over distance. Interactions and learning could be individual or collaborative (see Figure 4). The specific areas of interest include mental preparation, decision-training, improved reaction time, performance enhancement, and rehabilitation.

Final Thoughts

The technology required to create effective virtual environments is complex and requires distinct methods for each human sense. Most systems employ graphics for the visual sense and audio for the sense of hearing. Haptic or touch technology is less well advanced, and research into systems for emulating smell, even less so. It appears that no attempt has yet been made to represent taste. Balance and proprioception are important considerations in sports, rehabilitation, and fitness. Unfortunately, issues such as motion sickness and disorientation have still not been successfully addressed, and research and development in these areas lags behind the vision. Simple, effective virtual environments exist and can be developed for commercial and educational benefit, but elaborate, multidimensional systems are still either imaginary or restricted to elite users and researchers. Design considerations are extensive and costs for the more elaborate environments remain prohibitive. Yet, the technology offers the opportunity to individualize learning, apply cutting-edge learning principles, maximize performance, mimic intricate patterns, and create realistic and convincing environments that can be collaborative and interactive. For the moment, the commercial arena has been left to the users who are prepared to pay for “suspect” thrills such as hunting (www.live-shot.com) and virtual video games. Ultimately, the users will decide what survives.

Figure 4. Research Goals for Effective Virtual Environments.

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SELECTED IMPACTS of COMPUTERS in the SPORTS SCIENCES

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Abstract

The use of computers in the sport and exercise sciences is now unquestioned. They are employed in the functioning of laboratory facilities, data collection, data handling and prediction of forthcoming outcomes. The organisation of databases is more manageable and comprehensive. Routine activities in experimental and field-based work have been devolved to computers. In order to highlight the impact of computer use, applications in the sport of football are selected.

Firstly the design and control of virtual reality environments has extended the possibilities for studying motor behaviour and learning. This facility has added to talent development studies by considering how young subjects respond to challenging scenarios. Secondly, match analysis has become increasingly intricate, with details of player performance available to coaches the morning after play. Thirdly, in sports science support work the regular monitoring of physiological responses allow for evaluation of training sessions. The exercise intensity can be regulated, for example by means of heart rate response, rather than merely monitored. Fourthly, information on injuries incurred has been gathered electronically from the major European football clubs. Web-based surveys enable prospective epidemiological studies to be conducted cost-effectively. Finally, a burgeoning web-based use of sports- science support is provided for continuous professional development of coaches. This e-learning programme may be most effective when combined with multi-mode learning media. The same principle is used by textbook publishers who add further resources to support student learning. In these ways computer science has revolutionised sports science support and research work and professional development: sports scientists have a responsibility to apply the technology to suit the user.

KEY WORDS: EPIDEMIOLOGY, HEART RATE, MATCH ANALYSIS, MAXIMAL OXYGEN UPTAKE

Introduction

The brief in this review is to consider the use of computers in sports science. The emphasis is placed on applications, with examples selected mainly from the sport of association football. The pervasive use of computers in applied sports science is now accepted, even expected. In its training base prior to the Summer Olympic Games in Sydney 2000, the British Olympic Association had a specialist responsible for information technology. Computers were used in practically all aspects of activities. These included internet connections for athletes and coaches, news updates for all staff, communication within sports for administrative purposes, sports science monitoring, records of medical and physiotherapy treatments. There was also a multi-media facility mimicking the environment in the Olympic village, so that athletes could be prepared mentally for exposure to its features in advance.

In this review, five separate aspects are highlighted to illustrate computer uses. These are in the areas of performance analysis, sports science support work, laboratory activities, sports epidemiology and e-learning and education.

Performance analysis

Motion analysis provides a means of collecting data on movement of athletes which may be given a physiological interpretation. The principle is that covering a set distance requires a given energy expenditure. The technique was initially applied to football (soccer)- by using a coded commentary on individual players, detailing the intensity and distance of different categories of activity (Reilly and Thomas, 1976). The data in Table 1 underline that the activity is largely aerobic and that as little as 2 % of total distance is covered in possession of the ball. Nevertheless, the crucial events in the game when possession of the ball is vigorously contested depend on anaerobic efforts.

Table 1. Relative engagement of different categories of activity during soccer match-play (Reilly and Thomas, 1976). Values are expressed as a percent of total distance covered.

Activity	% of total distance
Walk	24
Jog	20
Back	7
Cruise	20
Sprint	11
With ball	2

The overall work-rate shows positional differences, the midfield players typically covering the greatest distance whereas the least distance is covered by the central defenders. The overall figures are highly correlated with aerobic fitness, expressed as maximal oxygen uptake (O2 max). Fatigue is evident towards the end of a game, the smallest fall-off in work-rate being evident among those with high aerobic fitness. The work-rate profile of the goalkeeper is distinct from that of outfield players.

The use of multi-camera systems to evaluate performance has revolutionised the process of data capture during match-play. The cameras are placed at strategic locations on each side and overlooking the playing pitch. All players may be analysed once the cameras are synchronised. Another benefit of the system is that motion analysis is combined with notation analysis whereby all actions of each player are recorded including game-related events. The output shows a breakdown for each player for both halves of the game. Performance may be compared between players and from game to game.

The various applications of computer-aided match analysis are listed in Table 2. Multi-camera systems are currently employed by the major clubs in La Liga (Spain), Premier League (England), in Italy and in France. The analysis is provided as a service, is expensive and therefore accessible only to those clubs rich enough to afford it. A downside is that the quantity of information available may daunt the coach so that responsibility for interpretation may fall on the trainer or sports scientist. For young players, events may be highlighted for video-feedback to illustrate coaching points.

Table 2. Main uses of computer-aided match-analysis.

Individual player evaluation
Evaluation of opponents
Feedback to players
Sports science support work
Talent development

Sports science support

One of the main areas in which sports science support personnel offer input to the preparation of players for competition is the training context. The type of exercise or component of the training programme can be recorded on computer. The important dimensions of the training sessions then are its intensity and its duration.

The heart rate has long been regarded as a valid means of indicating physiological strain, even during intermittent activity such as occurs in soccer (Reilly, 1979; Bangsbo, 1994). Traditionally long-range radio telemetry provided a way of measuring heart rate in field conditions. Athletes could be monitored at a distance up to 800 m. A receiver on the sideline picked up a signal worn by the athlete and could be connected to an ECG monitor. The heart rate could be displayed on a digital meter. Alternatively the audio signal could be used alongside a Heuer stopwatch to record heart rate at about 5-6 samples per minute.

The instrumentation was relatively cumbersome and was superceded when short-range telemetry of heart rate was developed in 1981. It took some years for the system to be utilised in a soccer training context. Meanwhile product development enabled data to be downloaded onto a computer and more recently for multiple recordings at one time without interference with individual transmissions. Besides, data are collected into percentage of time spent at different heart rate zones, indicative of different training intensities. The data may be viewed along a time-line and divided according to the relevant components of the training session. The overall output may be colour coded to signify intensity zones for each component and expressed as the relative amount of time spent in each intensity zone.

The comprehensive facilities may be utilised for quasi-experimental purposes in the field. Sassi et al. (2005) compared classical interval running with different soccer-training drills involving small group sizes. The heart rate data were supplemented with measurements of blood lactate. It was concluded that small-group work with the ball can present physiological training stimuli comparable with and sometimes exceeding interval running without the ball e.g. 4 x 1000 m runs. In contrast, technical-tactical training presents a moderate challenge to the circulatory system, more comparable with maintenance programmes or recovery on days following competitive engagements (see Table 3).

Table 3. Mean heart rate (± SD) in beats.min^{-1} and blood lactate (mmol.1^{-1}) during different training drills.

	4 x 1000 m	**4 vs 4**		**8 vs 8** (1/2 pitch)		**Technical-tactical drills**
		Without Goalkeeper	With Goalkeeper	Free touch	Free touch (Pressing)	
Heart Rate	167 ± 4	178 ± 7	174 ± 7	160 ± 3	175 ± 4	140 ± 5
Blood Lactate*	7.9 ± 3.4	6.4 ± 2.7	6.2 ± 1.4	3.3 ± 1.2	-	2.9 ± 0.8

*****Blood lactate is not from the same players

Heart rate was used initially to monitor physiological responses to training. The next step was to use the data to regulate the training intensity, for example heart rate values of approximately 125 beats.min-1 are compatible with recovery training, values of around 160 beats.min-1 are associated with aerobic training (e.g. 7 versus 7) whilst anaerobic metabolism is implicated in drills such as 2 vs 2 with 1 min exercise and 1 min rest. In such repeated bouts the mean heart rate can exceed 170 beats.min-1.

A project in underage soccer exemplifies the combination of heart rate monitoring, motion analysis and notation analysis. The aim was to compare 3 vs 3 and 5 vs 5 in terms of physiological load and behavioural measures. Motion analysis disclosed that the 3 vs 3 version was the more intense, with more distance being covered at high intensity than in the 5 vs 5 model. These observations were supported by the heart rate recordings, values being higher all through the game for 3 vs 3. Additionally, in the 3 vs 3 small-sided games, players had more touches of the ball, had more tackles and passes than in a 5-a-side (Platt et al., 2001). For the pitch area specified, the 3 vs 3 version induced a higher training stimulus and provided a better learning experience than 5 vs 5.

Experimental aspects

Problems identified in field conditions may be isolated for study in a laboratory situation where extraneous variables may be controlled. On-line systems for respiratory gas analysis have replaced the classical Douglas bag approach beginning in the late 1970s. In a study of circadian variation in responses to exercise, Reilly and Brooks (1982) at the University of California, Berkeley employed computer-based monitoring of both inspired and expired ventilation to ensure quality control of data. Over the last quarter of a century the major developments have been in improved breath-by-breath analysis and availability of software for re-breathing manouvres and integration of blood pressure data to measure maximal cardiac output and maximal power output of the heart.

Reilly and Ball (1984) demonstrated how dribbling in soccer could be studied by getting subjects to run on a motor-driven treadmill. The ball was returned to the player by a rebound board in the dribbling condition. Energy expenditure and blood lactate were elevated when dribbling at each of the four speeds that were studied. It was concluded that for a given speed a superior training stimulus was presented when activity was performed with the ball.

The intermittent pattern of exercise that is observed in a soccer match may be represented in a treadmill protocol that induces equivalent physiological responses. Drust et al. (2000) have used such a protocol for experimental purposes. The motor-driven treadmill may be programmed so that the necessary changes in velocity occur automatically. On a person-propelled treadmill, the cues to change speed of running may be presented to the subject by means of a computerised display. Power output can be recorded by means of a simultaneous measurement of treadmill belt speed and force production, the latter being registered by tethering the subject to a force transducer mounted on a wall at the rear of the treadmill (see Figure 1).

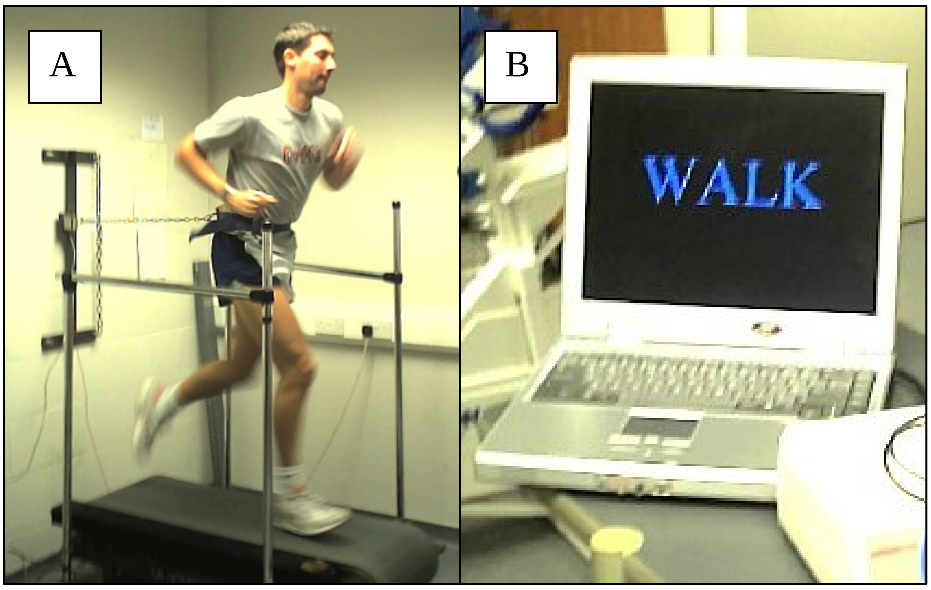

Figure 1. (A) Non-motorised treadmill and (B) the subject's view of visual cues (Clarke et al., 2004)

Virtual reality provides an alternative means of simulation for studies in sports psychology. Challenging situations may be presented on large displays in which the subject is experimentally engaged. Reactions, eye movements and decision making can be monitored. Such set-ups have been useful in identifying anticipation as a key factor in talented young players and in some characteristics of 'game intelligence' (Williams, 2000).

A more sophisticated system may be employed in simulation. The CAREN system is a rotating platform whose movements in six degrees of freedom are controlled by computer (see Figure 2). The subject may be presented with a real-life situation such as motion of a boat on water and balance reactions monitored. Motions may be recorded by means of 3-D analysis. Whilst the technique is in its infancy, employment of the CAREN system has many applications other than clinical conditions. Hence it is useful in retraining of movement patterns following injury, stroke, surgery and amputation. It has relevance for study of movement disorders which occur with Parkinson's disease, ageing, rheumatism and neurological impairments. Its uses in ergonomics, learning of sports skills, musculoskeletal studies and sport and exercise sciences have yet to be realised.

Figure 2. Computer control of rotatable platform in virtual reality environment of the CAREN system.

Epidemiology

Recruitment of subjects for surveys and experimental investigations is now feasible through e-mail and web-based contact. Since ethical issues are involved, procedures and expression of expectations are normally approved by the appropriate local Human Ethics Committee. This form of recruitment has influenced the design of studies by ruling bodies in soccer, notably UEFA and FIFA. The investigators may also use computers to facilitate data collection into a central co-ordination point.

An example of how injuries occurring in different countries may be collected into a single study was provided by Ekstrand et al. (2004). Fourteen of the top European clubs were selected by UEFA and invited to take part. Each club had a contact person responsible for inputting data on a common basis explained to each participatory club. Data were extracted for those players who later played in the World Cup finals in Japan and Korea. This format was used to explore reasons for underperformance of some teams at the 2002 World Cup.

The use of e-mail for collecting injury statistics allows for regular routine input. The central co-ordinator may send reminders when data input is delayed or any features are missing. A potential weakness is that trust is placed entirely on each reporter.

Rahnama et al. (2002) utilised a critical incident technique to study precursors of injury in soccer. They designed a novel computerised notation and analysis system for assessment of injury potential associated with a variety of game-related actions. Tackling and charging posed the highest risk among the 18000 events analysed. The critical periods of the game were the first 15 min and the last 15 min as these displayed the greatest number of actions with high injury potential.

e -Learning and Continuous Education

Electronic means are increasingly used as educational tools. Continuous professional development programmes have benefited from integrating e-learning modes with other media. An example is provided by the development of learning material for soccer coaches.

The FA Coaches Association Journal (Insight) was published first in 1997. Its contents included an equal contribution of scientific and coaching articles with a close correspondence between the two. From 2005, its four publications in hard copy are replaced by an equal split of hard copy and electronic publication. Members are encouraged in the hard copy to become engaged in on-line activities. Further benefits advocated include support from qualified tutors, participation in discussion fora, access to library resources and worldwide-web links. Members may also complete modules in sports psychology leading to a qualification endorsed by the Association.

Commercial publishers also support electronic means of learning though largely to supplement text books. Further resources include videos and tapes, so-called ‘masterclasses’ by experts, tutorial help and structured questions and answers for material in each chapter.

Electronic learning media are useful in distance learning, in continuous professional development, in coach education and in part-time academic programmes. Nevertheless, the benefits of personal access to tutor or lecturer cannot be overstated.

Overview

Users’ reactions to computers have changed and may change again in future. Previously there has been confusion among potential new users whereas others have been motivated by technological challenges. Currently there is general acceptance of their pervasive use, particularly as a professional aid. The danger is that in the future there will be a total reliance on computers, most evident when they break down.

Their pervasive use leads to responsibilities for software designers. The technology should suit the user according to ergonomic principles. Computers serve best when specific questions are addressed as otherwise they may inundate the user with superfluous information. Applications need to be evaluated continually for best results to be achieved.

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COMPUTER SCIENCE in SPORT: An OVERVIEW of HISTORY, PRESENT FIELDS and FUTURE APPLICATIONS (Part I)

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Abstract

30 years ago, in 1975, an international congress entitled "Kreative Sportinformatik" (Creative *Sports Informatics*) was organized in Graz, Austria. At this time, and in particular in the framework of the congress, *Sports Informatics* mainly meant *Sports Information* with special emphasis on activities in documentation and dissemination of information. Throughout the last 30 years *Sports Informatics* or *Computer Science in Sport* has become a scientific discipline in a more general meaning of *informatics/computer science*. Working areas have evolved, national and international associations have been founded, journals are published and congresses are organized regularly to present research activities. The paper gives an overview of the history of the first 30 years of *Computer Science in Sport*, of the development of its research areas and its integration into university education.

KEYWORDS: HISTORICAL SURVEY, SPORTS INFORMATICS, IACSS, COSISP

Introduction

Lees (1985, 3) reports first applications of computers in sport in the mid of the 1960s. Concepts and experimental methods applied in other scientific disciplines were adopted. Statistical analyses and numerical calculations of biomechanical investigations were performed with the mainframe computers available at that time. The computer programs developed by Plagenhoef (1969) published in the very first edition of the Journal of Biomechanics may serve as an example. In the biomechanical literature numerous examples can be found propagating the use of computers since then (cf. Lees, 1985, 4). Measuring devices acquiring biomechanical data (reaction forces, EMG data, etc.) using analog-digital converters and opto-electronic systems (cf. Furneé, 1989) for human motion analysis have been developed for decades. Moreover, modern computer technology was of crucial importance for solving numerical problems in biomechanical modelling and simulation (cf. Hatze, 1980 and 1983).

Another early use of computers in sport can be found in the context of notational analysis. Hughes and Franks quote the publication by Fullerton (1912), which investigated combinations of baseball players batting, pitching and fielding and the probabilities of success, as earliest publication in this area (Hughes & Franks, 1997, 37-38; see Figure 1). Downey (1973) presented a complex notational system for lawn tennis matches. The objective method of game analysis in squash proposed by Sanderson & Way (1977) was basis for a computerised system developed by Hughes (1985).

Pioneering work in this area was also done by Miethling & Perl (1981; see Figure 1). Their concepts for modelling sport games process oriented date back to the early 1980s.

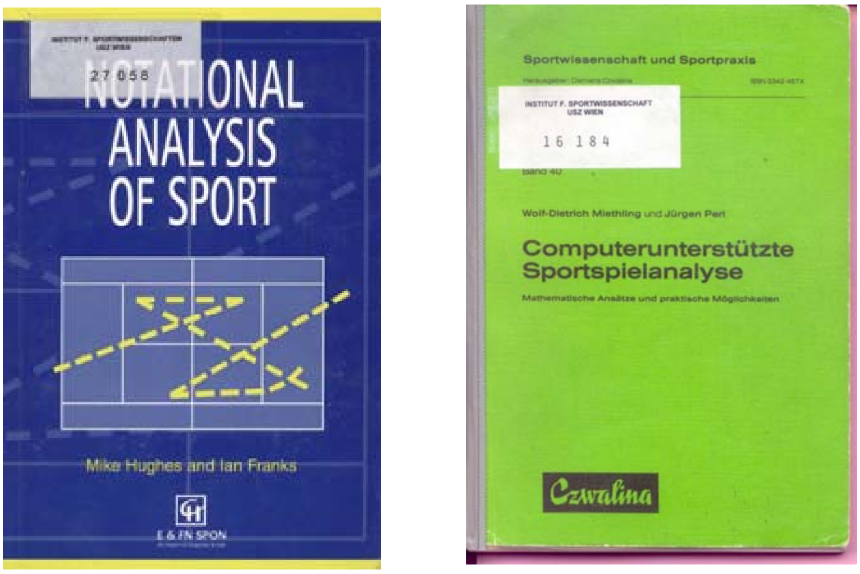


Figure 1. Pioneering books in game analysis. Left: Hughes & Franks (1997) containing a comprehensive survey; Right: Miethling & Perl (1981).

Computers in sport have also long been in use for information and documentation purposes. A historical survey of the International Association of Sports Information (IASI, 1994) reports 1967 as the year, where an automatic processing of sports documentation was first demonstrated at an IBM computer in Graz, Austria.

Applications of computer technology in Physical Education are documented since the mid of the ’80s (Sharp & Paliczka, 1984; Donnelly, 1987; Skinsley, 1987; Sharp, 1988). On the one hand, it was sought to integrate the computer into lessons (Skinsley, 1986), on the other hand learning software (“computer aided instruction”) was developed. In combination with modern multimedia technology such software has nowadays obtained a quality, which was not foreseen at that time.

Sports Information – Sports Informatics

Until the mid 1970s no differentiation between *sports information* and *sports informatics* can be noticed. Up to this time only *sport information* can be found as discipline of sport science. The central focus is put on documentation and information activities for physical education and sport. Data bases are set up and updated in order to collect and disseminate information on publications related to sport science of any form (paper, audio-visual, electronic, …).

An international organization was founded in 1960 to stimulate and support activities in the field of documentation, and to promote the dissemination of information to physical educators, sport scientists, documentalists and sport researchers. In 1974 the Name IASI (International Association for Sports Information) was introduced for this organization. In 1975, a Jubilee Congress entitled "Kreative Sportinformatik" (Creative Sports Informatics, see Figure 2) was organized in Graz, Austria. At this time, and in particular in the framework of the congress, Sports Informatics still was a synonym for Sports Information and focused on activities in documentation and dissemination of information.

Figure 2. Proceedings of Congress on "Creative Sports Informatics", Graz, 1975.

Since the mid 1970s a growing differentiation between *Sports Information* on the one hand and *Sports Informatics* or *Computer Science in Sport* on the other hand can be observed. Sports Information still mainly deals with aspects of documentation. Its activities are coordinated by IASI, the International Association of Sports Information. Computer Science in Sport has, however, become a scientific discipline in the actual meaning of informatics/computer science: “Science, technique and application of systematic, mostly computer assisted processing and transmission of information” (Informatics, 1998). IACSS, the International Association on Computer Science in Sport, has been founded in 2003 to improve the international cooperation in research and education.

Scientific development

During the last decades, Computer Science has become an important interdisciplinary partner for Sport Science. This is due to the fact that the use of data and media, the design of models, the analysis of systems etc. increasingly require the support of suitable tools and concepts which are developed and available in Computer Science. It is therefore not surprising that the scientific discipline *Computer Science in Sport* shows a prosperous evolution. National and international congresses were organized to provide platforms to exchange the latest experiences and ideas regarding the use of Computer Science in supporting the development of theory and practice in sport.

In Germany, for example, 9 biennial workshops were organized since 1989. In 1995 *Computer Science in Sport* was established as section of the *German Association for Sport Science* representing 900 sport scientists working in research and/or education. The phrase

sports informatics/computer science in sport has been included in the sport-scientific encyclopedia (Röthig & Prohl, 2004).
Australia and New Zealand shall serve as second example. The MathSport Group, which consists of a loose forum for Australian and New Zealand sports scientists, holds biennial meetings entitled *Mathematics and Computers in Sport Conferences.* Seven conferences have been held so far, the first in 1992.

International Symposia

In 1997 (June 12-14) an International Symposium *Computer Science in Sport* was organized in Cologne, Germany by Joachim Mester. Delegates from 17 nations participated. Arnold Baca organized the 2nd International Symposium (September 15-17) in Vienna, Austria. Scientists from 17 nations attended the conference. This conference was the starting point for a regular biennial organization of a symposium series. Mike Hughes welcomed participants from 14 nations at the 3rd International Symposium in Cardiff, Wales (June 26-29, 2001). Natalia Balagué organized the 4th International Symposium in Barcelona, Spain (May 14-17, 2003, 21 nations). Participants from 18 nations took part at the 5th International Symposium in Hvar, Croatia (May 25-28, 2005), which was organized by Leo Pavičić. The logos for the 2nd to the 5th conference are shown in Figure 3.

Larry Katz will arrange the 6th Symposium in Calgary, Canada.

Vienna Cardiff

Barcelona Hvar

Figure 3. Logos for 2nd-5th International Symposium on Computer Science in Sport

The 2nd International Symposium (Vienna) included a discussion session on internationalization. Possibilities and procedures for an improvement of the international co-operation within the area of the application of computer science in sport were discussed. It was expected that this would be advantageous for the acquisition and realization of common research projects. As a concrete result the International Working group "Computer Science in Sport" (COSISP) was founded (see Figure 4). The first co-ordinating steps were taken over by the organizing committee of the Viennese Symposium. Since February 2001, electronic newsletters are produced and distributed to interested subscribers. The cover sheet of the first edition is shown in Figure 5.

During the 3rd International Symposium in Cardiff it was decided to publish an eJournal (*International Journal of Computer Science in Sport*) and to prepare the foundation of an International Association on Computer Science in Sport (IACSS). The first issue of the eJournal was published in December 2002, IACSS was founded during the 4th International Symposium "Computer Science in Sport" in Barcelona (Figure 6).

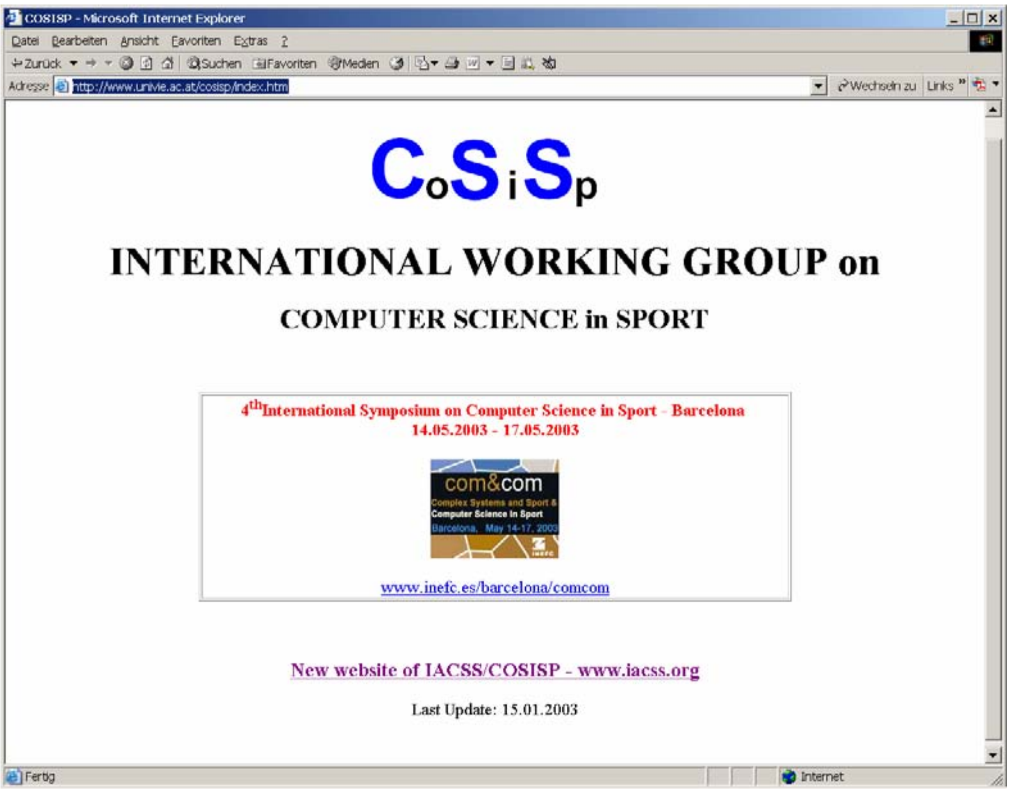
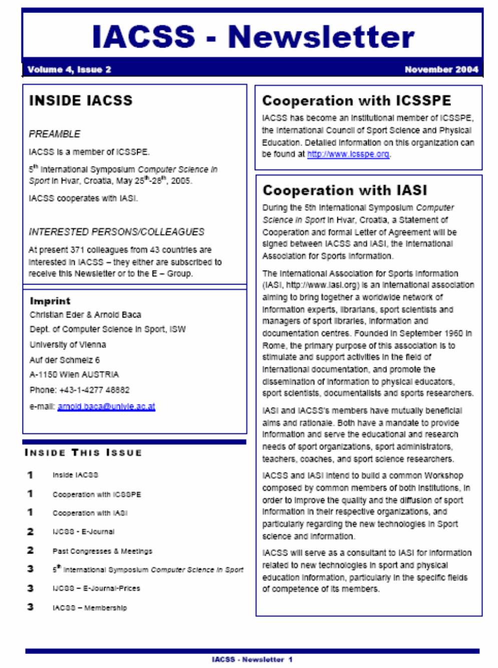


Figure 4. Homepage of the International Working Group on Computer Science in Sport (COSISP).

For a scientific discipline to be internationally recognized, certain criteria have to be fulfilled. During the 6th German national workshop on Computer Science in Sport in Konstanz, 1998, such criteria were specified for *Computer Science in Sport* (Haag, 1998, 58):

- Foundation of an international organization stimulating and supporting activities in Computer Science in Sport. This organization should become a member of ICSSPE (International Council of Sport Science and Physical Education), which serves as an international "umbrella" organisation concerned with the promotion and dissemination of results and findings in the field of sport science and their practical application in cultural and educational contexts (ICSSPE, 2005).
- Regular (biennial) organization of international symposia.
- Presentation of *Computer Science in Sport* as scientific discipline in the course of a Preolympic Congress.
- Publication of an international journal.

All these postulations have been fulfilled in the meantime. IACSS has been founded in 2003, international symposia are organized regularly since 1997, representatives of IACSS organized a workshop on *Computer Science in Sport* in the course of the Preolympic Congress in Thessaloniki in August, 2004, an international reviewed eJournal (IJCSS) is published since December, 2002.



IACSS - Newsletter

Volume 4, Issue 2 — November 2004

INSIDE IACSS

PREAMBLE

IACSS is a member of ICSSPE.

5th International Symposium *Computer Science in Sport* in Hvar, Croatia, May 25th-28th, 2005.

IACSS cooperates with IASI.

INTERESTED PERSONS/COLLEAGUES

At present 371 colleagues from 43 countries are interested in IACSS – they either are subscribed to receive this Newsletter or to the E – Group.

Imprint

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Cooperation with ICSSPE

IACSS has become an institutional member of ICSSPE, the International Council of Sport Science and Physical Education. Detailed information on this organization can be found at http://www.icsspe.org.

Cooperation with IASI

During the 5th International Symposium *Computer Science in Sport* in Hvar, Croatia, a Statement of Cooperation and formal Letter of Agreement will be signed between IACSS and IASI, the International Association for Sports Information.

The International Association for Sports Information (IASI, http://www.iasi.org) is an international association aiming to bring together a worldwide network of information experts, librarians, sport scientists and managers of sport libraries, information and documentation centres. Founded in September 1960 in Rome, the primary purpose of this association is to stimulate and support activities in the field of international documentation, and promote the dissemination of information to physical educators, sport scientists, documentalists and sports researchers.

IASI and IACSS's members have mutually beneficial aims and rationale. Both have a mandate to provide information and serve the educational and research needs of sport organizations, sport administrators, teachers, coaches, and sport science researchers.

IACSS and IASI intend to build a common Workshop composed by common members of both institutions, in order to improve the quality and the diffusion of sport information in their respective organizations, and particularly regarding the new technologies in Sport science and information.

IACSS will serve as a consultant to IASI for information related to new technologies in sport and physical education information, particularly in the specific fields of competence of its members.

IACSS - Newsletter 1

Figure 5. First issue of COSISP/IACSS newsletter, February, 2001.

Figure 6. Founding session of IACSS, May 16th, 2003, INEFC Barcelona.

Research activities

Research activities in computer science in sport are strongly affected by actual developments in computer science (Perl, within this issue):

- Hardware: processor speed, storage capacity, communication technology
- Software: tools
- Information management: data bases, data mining
- Media: internet, eLearning, multimedia

Currently, the following main areas of research can be distinguished:

- Data acquisition, processing and analysis; IT and communication
- Modelling
- Data bases and expert systems
- Multimedia and presentation

Most current research activities can be assigned to one of the following topics:

- Motion analysis
- Game and competition analysis
- Training and performance analysis
- Pattern recognition
- Complex systems
- Pervasive Computing
- Instruction, training, Virtual Reality

Selected examples are presented in the contribution by Jürgen Perl within this issue.

A strict assignment of each topic to one of the research areas mentioned above is not always possible. In motion analysis, for example, sophisticated systems are developed to acquire motion data. On the other hand, neural network models are applied to find out peculiarities in the data captured.

Nevertheless, an attempt has been undertaken to assign each oral presentation given at the international symposiums (1st to 5th) to one of the areas of research listed above. With few exceptions, a best matching field of research could be identified. Although this assignment is rather subjective, it should give a certain idea of actual research activities. An overview of all oral presentations is shown in Figure 7. The distribution for all symposia separately is presented in Figure 8.

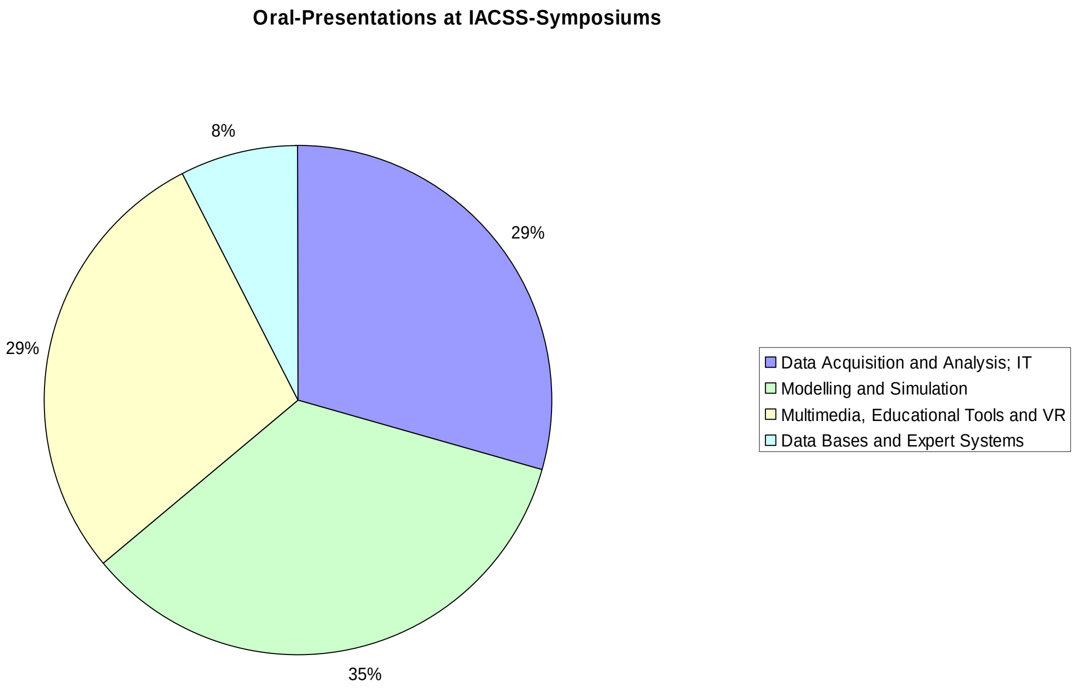

Figure 7. Oral presentations at IACSS symposia assigned to main fields of research – all symposia.

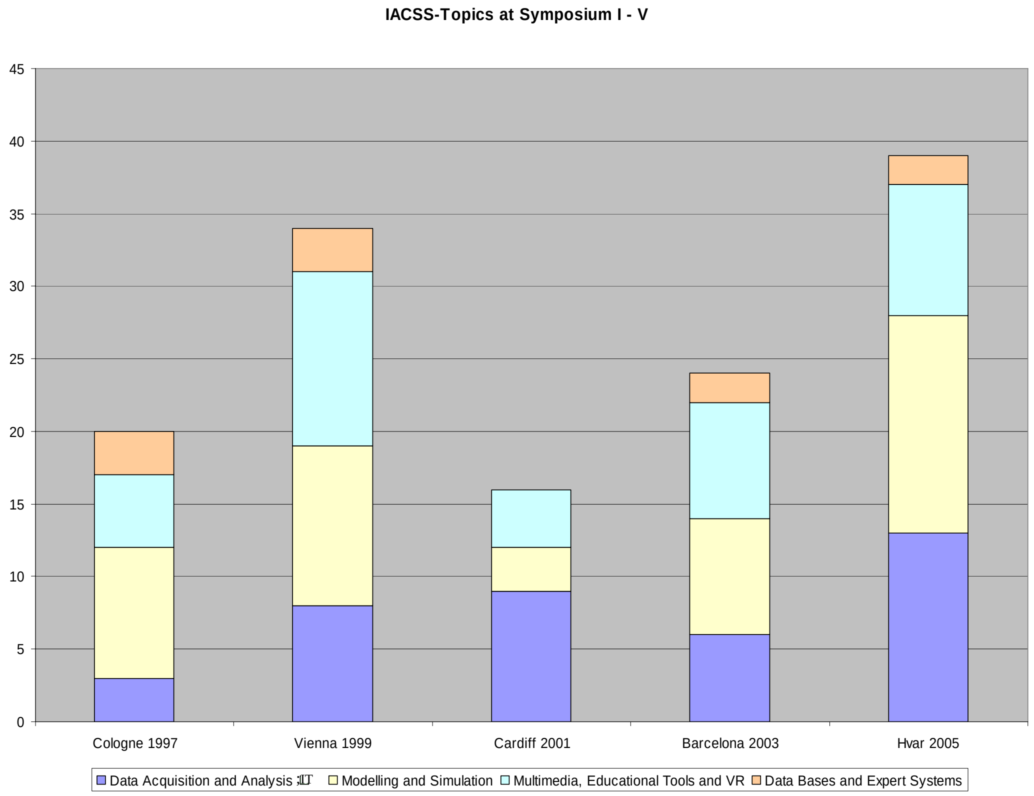

Figure 8. Oral presentations at IACSS symposia assigned to main fields of research – symposia 1-5.

Education

The development of *computer science in sport* and the increasing importance of knowledge in information and communication technologies and computer skills for career perspectives of students of sport science show consequences in curricula. Lectures not only on basic tools of informatics but more and more also on complex tools, concepts and advanced methods are integrated into education programs (Wiemeyer & Baca, 2001).

In addition, several universities have started to offer specific course programs related to computer science in sport. Two approaches can be distinguished. Course programs are either conceived supplementary to studies of sport science (e.g. Technical University Darmstadt, Germany) or supplementary to studies of computer science (e.g. Technical University Compiègne, France).

Courses related to computer science in sport appear to be well suitable to be integrated into a modular course system following the Bologna model (CRE, 2000).

Throughout the last years increasing efforts in developing multimedia based courses and materials can be observed in sport science (Katz, 2003; Sorrentino, 2001; Igel & Daugs, 2005; Wiksten, Spanjer & LaMaster, 2002). Multimedia eLearning will facilitate distance learning and the international exchange of study modules. It is expected that (national) master programs will be increasingly offered in the very near future. The master program (MSc Performance Analysis) established at the University of Wales (MSc Performance Analysis, 2005) may serve as an example. Currently (2006) the core modules are as follows:

- Dissertation Project
- Research Issues in Sports Studies
- Research Methods in S*ports*, E*xercise* & C*omputer* S*cience*
- Coaching Process
- Performance Analysis
- Modelling, Performance Profiling and Statistical Analysis
- Computerised Performance Analysis
- Qualitative Biomechanics of movement in performance

In addition to national master programs the evolution of international master programme (e. g. European Master) is expected.

Summary

An impressive development of computer science in sport/sports informatics throughout the last 30 years could be pointed out. Fields of research have evolved, regular congresses are organized, and an international journal is published. Because of these advances consequences in education can be observed, which in their turn will show catalytic effects on the scientific and organizational progress.

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A COMPUTER SCIENCE in SPORT: An OVERVIEW of PRESENT FIELDS and FUTURE APPLICATIONS (Part II)

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Abstract

During the last about 15 years, the spectrum of Computer Science in Sport has changed a lot. Due to the development of computers and information technology as well as of scientific concepts and methods new working areas have been developed. Meanwhile, the field of research and applications stretches from data bases to artificial intelligence. Traditional areas like game analysis and theory of training are involved as well as technologically innovative areas like internet-based coaching and e-learning.
Future development of rapidly changing fields like Computer Science in Sport is difficult to predict. There are, however, two major aspects that in general seem to increase its importance continuously. On the one hand, the amount of available data increases permanently and makes it more and more difficult to extract the useful information. On the other hand, the role of world wide communication becomes increasingly important and needs improved information technology. Both trends not only require more powerful computers but in particular better concepts and techniques in order to handle problems in a fruitful and interdisciplinary way.

KEY WORDS: COMPUTER SCIENCE, SPORT SCIENCE, DEVELOPMENT, NEW PARADIGMS, INTERDISCIPLINARITY

Introduction

The story starts in 1976, when Herbert Haag, a well-known German sport scientist, first mentions the term "Sportinformatik" – which in English is "Computer Science in Sport" but at that time means "Sport Information". IASI, the International Association of Sport Information, has successfully been dealing in this area over decades now. In contrast, Computer Science in Sport needed much more time for developing. One reason for the delay is that the hardware and software tools that had been necessary to get to work new ideas in that field were available only much later. As soon as personal computers became powerful enough for the analysis of complex interactive systems like sport games, i.e. at about the mid-eighties, the interest in using computers in Sport Science grew rapidly. Since the mid-nineties, computers, computer-oriented concepts, and computer-based analysis methods form a basis for the still increasing field of Computer Science in Sport. (For more details of this historical development see the contribution of Arnold Baca within this issue.)

In the following first section the development of Computer Science during the last 10 years is briefly sketched. The second section deals with those particular areas of Sport Science which in a specific way were responsible for the fast development of interdisciplinary cooperation in Computer Science in Sport. In the third section typical problems are discussed which, however, are not specific for Computer Science in Sport but appear always when huge amounts of data or models of complex systems are dealt with.

Development of Computer Science

The development of Computer Science during the last ten years of course is influenced and characterized by new areas of demand and corresponding research – like internet technology, computer graphics and animation techniques, and e-learning concepts. The precondition, however, for getting all those new ideas to work was that surprising improvement of computer hardware: It was only in the last ten years that the personal computer's processor speed increased from about 100 MHz to more than 3000 MHz, which means a factor of 30. And even more, namely by a factor of 50, increased the available main storage capacity from about 20 MB to more then 1000 MB. An increase of such a size is more than just an increase of quantities. In practice, it meant a change of quality that has strongly been influencing software performance, tool interfaces and handling, and in particular information transfer of any kind. Ten years ago, for example, a software tool consisted of about 60% high speed algorithmic programs, and 20% of low speed user interface and data background organization, each. Today, the absolute size of the algorithmic kernel is still the same. But interface and data organization have increased tremendously and now make up about 80% of a software tool. Nevertheless, the tools run even faster.

The advantages of that development are obvious: The user gets fast response, pretty presentations, suggestive information transfer; the visual user interfaces support an easy tool handling; and last but not least the tool development is supported by visual development kits.
There are, however, disadvantages as well: One problem is that the tools become more and more complex, and therefore the processes that are run in a tool's software are difficult to understand. Another problem is that we can transfer huge amounts of data to or from the computer, but in turn it becomes more and more difficult to get the real information from the data. This means a second change from quantity to quality, which is contra-productive to that of hardware development mentioned above. In particular in the area of information management, we meanwhile have a lot of well-based concepts for organizing and retrieving data. But, as is well-known from internet search, it is still rather difficult to select exactly that information from all the data which is particularly needed or interesting.

Finally, the development of multimedia should be mentioned: Only ten years ago it was still a challenge to transfer analogue video frames from a camcorder to a personal computer for digitizing and analysis. Today, digital picture data can be transferred between arbitrary devices like laptops, camcorders, cameras, cellular phones, palms, beamers, printers, or television sets. This development not least helps Sport Science for much better and easier recording, handling, and online-analysis of visual data in research as well as in training and competition.

Computer-based development in Sport Science

According to the development of Computer Science, Sport Science can take advantages in recording, analysing, and handling data. Again, the improvement does not just mean "more" and "faster". The improved quality of data handling also and in particular allows for

overtaking or developing new concepts and methods – as e.g. are process orientation or soft computing:
Process orientation means that not just one isolated activity causes an isolated change of a state, but sequences of activities or events cause sequences of states, where in particular buffers and transfers play an important role for delayed effects. It is of particular importance that such delay effects are driven by internal system dynamics and therefore very often can not properly be measured by statistical methods like cross-correlation. This is quite obvious in cases like game analysis or rehabilitation but holds also for motor analysis and training- and performance-analysis.

In Figure 1 an example is given dealing with original load input (red dotted line) and performance output (green dotted line), where the time unit is "1 day". The left graphic shows the original values, the cross correlation analysis of which results in a delay of 3 days. This indeed fits with experiences from practice. However, a shift of the load input 3 steps to the left as is done in the right graphic obviously does not really improve the understanding of the interaction process between load input and performance output. The reason is that such an interaction is much more complex than a 3-step-shift, and its understanding needs a deeper insight in the internal dynamics of organic buffers and material production and transport.

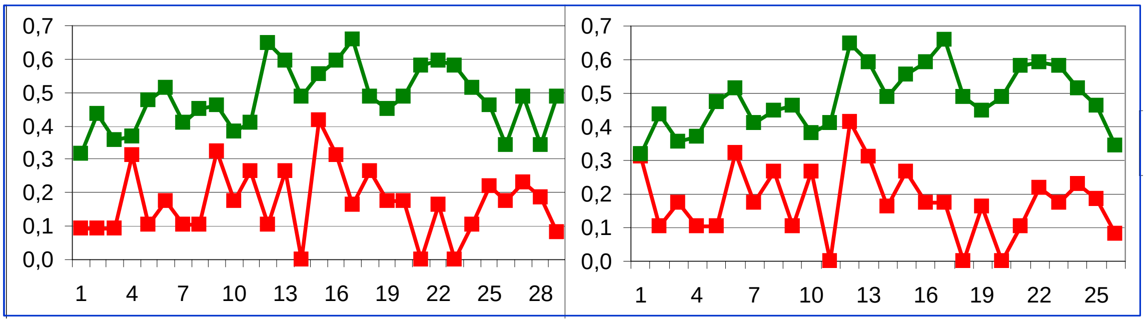

Figure 1. Interaction of load input (red line) and performance output (green line). Left graphic: originaldata; right graphic: load data shifted 3 steps to the left.

The improved technical and conceptual offers of Computer Science can help for improving such analyses – e.g. by means of system dynamics modelling, as is currently done in a number of projects.

An important new area of Computer Science dealing with new approaches and concepts is soft computing – which means a change of paradigms as is sketched in Figure 2. The motivation on the hand is that the complexity of natural systems can hardly be mapped to data in a mathematical understanding of precision. On the other hand soft natural methods like selective trial and error have proven to be useful in solving complex problems.

This way patterns of motions or tactical patterns in games can be analysed and compared more easily by means of artificial neural networks; interaction and communication in games can better be described by means of fuzzy modelling; solutions in high-dimensional problem spaces like optimal tracks of motions or optimal designs of sports equipment can be find much faster by means of genetic algorithms.

conventional	**new**
mathematics	biology
determinism	randomness
precision	fuzziness
completeness	flexibility

Figure 2. Examples of changes of paradigms for modelling complex systems.

Not least, soft computing and new paradigms allow for a more holistic view and understanding of complex systems and therefore avoid cutting systems into wrong and too small pieces and neglecting important connections and interactions.

Finally, computer- and net-base communication should be mentioned, which supports data processing and transfer in intranets as well as in the internet. The development in this area is just at the beginning. Two examples may make plane how powerful the approach is:
Computer-based education or e-learning is a well-known and common area of net-based communication. It helps for multiplying capacities, increasing flexibility of demands and offers and improving quality and relevance of contents and presentation. In particular in Sport Science it improves or only enables the transfer of information from research to students.

Internet-based training works in the same way and offers the same advantages as net-based education does. Moreover, it enables online-analysis of training or competition data at the original place without the need of transporting expensive and extensive devices and numerous staff members. This not only can safe a lot of money but really enable a scientific support even in cases of long distances between the place of competition and the research home base. First approaches have been tested and work satisfyingly.

Working areas and current activities

In the following some of the current working areas of Computer Science in Sport will be briefly introduced.

Modelling is one of the most basic working areas, not only in Computer Science and Sport Science. Whenever complex system behaviour has to be analysed – in case of technical systems as well as in case of biological systems – the main problem is that of modelling its structure and the interaction of its components. As has been mentioned above, a reduction on just comparing input data to output data is not sufficient neither for qualitative nor for quantitative analyses. Only if the system's dynamics is transparent and well-understood there is a chance of predict the future system behaviour based on its present state and the planed activities. Figure 3 shows what the main steps and advantages are: If the model maps the system's dynamics in an adequate way, the model can be simulated iteratively. By comparing simulated and real data the model can be calibrated – i.e. adapted to the modelled system, which can be repeated for a continuous improvement of the model. Such a model and its simulation not only help for a better understanding of system behaviour in general but also allows for finding and optimizing schedules or strategies without stressing the athlete.

As just one example, Biomechanics has been demonstrating during more than 30 years how fruitful proper modelling, simulation and presentation can be.

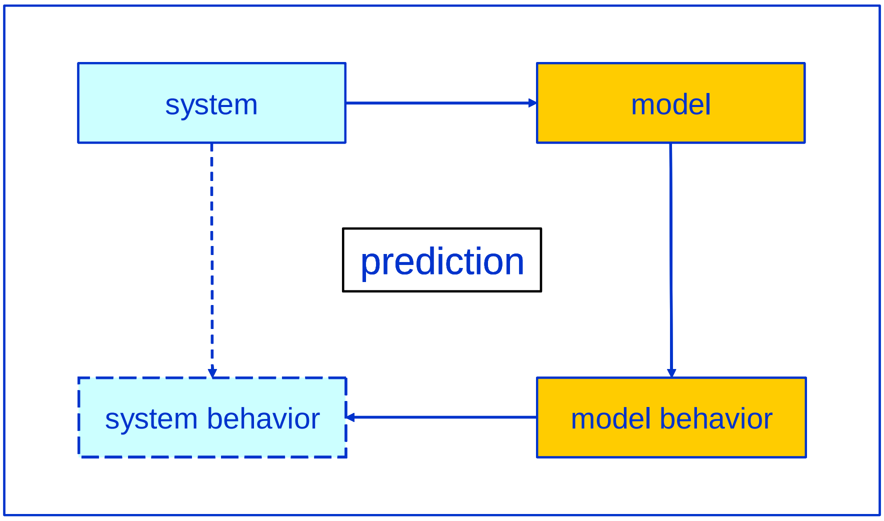

Figure 3. The system is modelled; the model behaviour is calculated and so simulates the system behaviour. If the model is correct and calibrated to the system the simulated system behaviour fits the real system behaviour and therefore can be taken for prediction.

An important application in area of modelling in Computer Science as well as in particular in Sport Science is pattern recognition. Patterns in sport can be taken as tactical patterns from a game, as motor patterns from movements, as training or performance patterns in training analysis and so on. As is demonstrated in the following examples, such patterns reduce the complex real information onto the most relevant parts – e.g. trajectories of a time-dependent process – and so help for easier analyses.

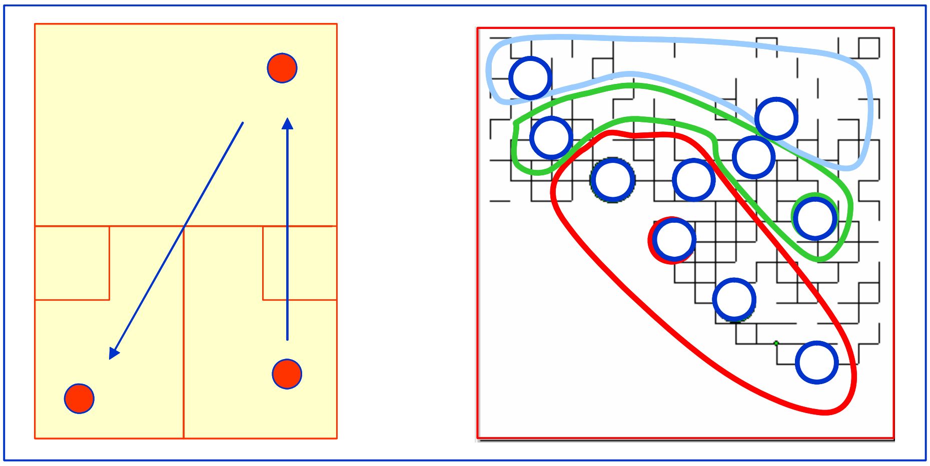

Figure 4. Left graphic: a sequence of striking positions. Right graphic: A neural network with some of its neurons marked by blue circles, which represent characteristic rallies of squash. Areas of major types of rallies like "long line" or "cross" are marked by coloured lines.

Figure 4 shows a model-based approach for the analysis of tactical behaviour in squash by means of artificial neural networks. The left graphic represents the information taken from the game – namely the sequences of striking positions of each of the players. The right graphic represents an artificial neural network that has learned what the characteristic types of rallies are (blue circles) and what major types of rallies have to be distinct (blue, green and red marked areas). The tactical behaviour of the players is reflected by the frequencies of the characteristic rallies, which form player-specific patterns that can be compared and analysed. The main advantage of neural networks (compared to statistical method) is that they are able to reduce the huge space of all possible rallies to a small set of characteristic ones on their own, i.e. without any additional input.

In the same way movements can be classified and represented by trajectories, as is demonstrated in Figure 5, where the trajectories of rower A and rower B can be compared under the aspect of intra-individual stability or inter-individual similarity. It can easily be seen, that all the trajectories are rather similar to each other, but the rowing of A is more stable than that of B. A closer look, however, shows that there are specific differences in some parts of the trajectories, which can be reason for a deeper analysis of the corresponding video frames.

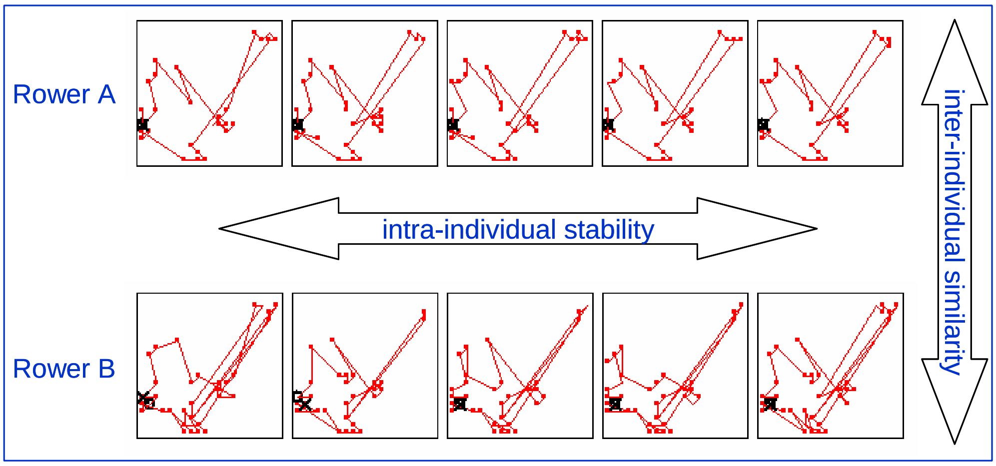

Figure 5. Net-based trajectories of ergometer rowing: Each node represents the 2-dimensional mapping of the corresponding high-dimensional vector of biomechanical attribute values like articulation position, angle, speed, or force at one point in time. Each trajectory represents the same part of the rowing motion at different times. Particular parts of the trajectories correspond to regarding phases of the movement.

In an analogous way trajectories can be used for making tactical behaviour more transparent, as is demonstrated in Figure 6 (see legend there):

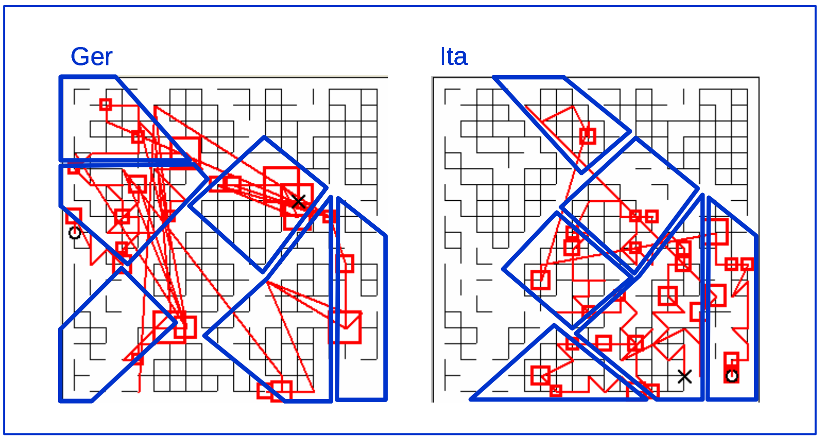

Figure 6. Net-based trajectories of defence activities in volleyball (women, Germany vs. Italy): The high-dimensional team constellations (i.e. positions of the player at one point in time) are represented by 2-dimensional nodes, marked by red squares the diameters of which represent their frequencies. Blue marked are the areas of similar types of constellations.

As can be seen from the trajectories, the behaviour of the German team (Ger) and the Italian team (Ita) are quite different, with regard to the main types of constellations (blue marked areas) as well as with regard to the frequencies of changing those constellations. The German team moves in a somewhat nervous way frequently between different defence constellation types in order to find the final one, while the Italian team finds very fast its final constellation type and then just adapts in small steps.

The last example of modelling and dynamic patterns deals with the problem of scheduling appropriate training plans: As has been discussed above (see Figure 1), scheduling needs prediction of behaviour and therefore requires an understanding of the dynamics of the complex system "athlete" under the view of load-performance-interaction. If at least the trends of that interaction can be simulated (as is demonstrated in Figure 7), this helps a lot for scheduling better training planes, avoiding too much overload and contra-productive training units.

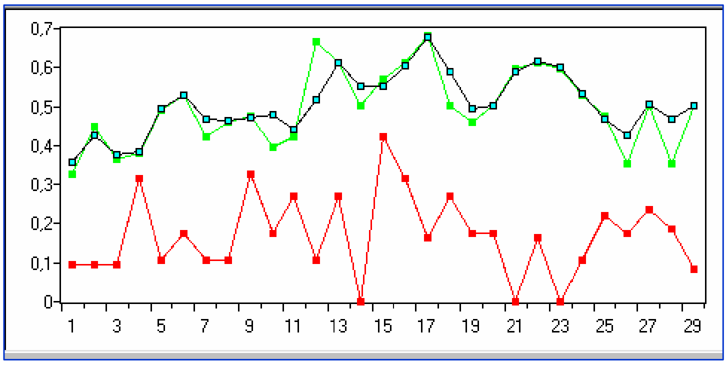

Figure 7. Example of dynamic simulation of load-performance-interaction: Training load per day (red dotted line: hours of training) results in a delayed performance output (green dotted line: haemoglobin concentration). The interaction of load and performance depends on a complex internal dynamic, which can be simulated by means of an antagonistic model (black dotted line: simulated performance output).

For more details in particular regarding prediction of performance and scheduling of load see the contribution of the author in issue 4 (2) of this journal (Perl, 2005).

Of course, such simulations not only need models but also require lots of data that have to be organized using appropriate tools like data bases, information systems, retrieval systems, or expert systems. In turn, if once organized that way data are available not only for particular simulations in training but also for education, administration and communication.

The up to date-technologies of data organization offer a wide range of data recording, data handling, data analysis, and data retrieval. The main problem, however, are data format standards, without which no data transfer and communication is possible. But even if those standards could technically be defined to enable data exchange: coaches, teams, clubs or other institutions not always like that data transfer – in particular not if they are expected to make their own data transparent and available.

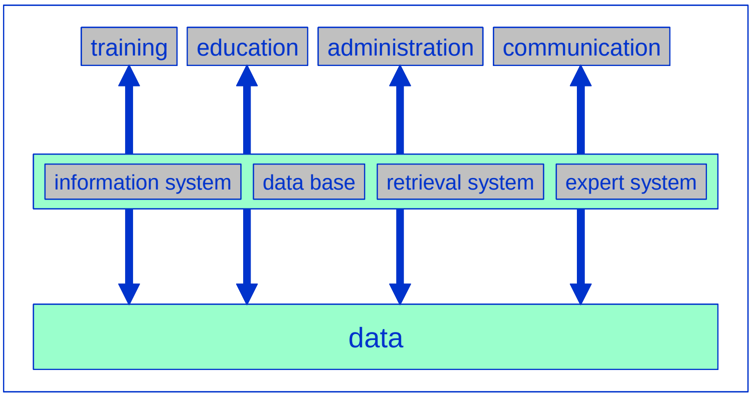

Figure 8. Data organization: Tools and fields of application.

This problem makes plane that very often not only innovative technology but also social and political agreements are necessary for future-oriented development.

If in turn the technologic capabilities are taken and combined in a proper way, the results can really be surprising and convincing, as has been demonstrated in the case of interned-based training (Link & Lames, 2005). As mentioned above, the remote training activities or events can be observed, analysed and coached by only a very small staff, supported by electronic devices that communicate with a well-prepared base station at the research institute. This way, resources can be saved without getting a lack of support or information.

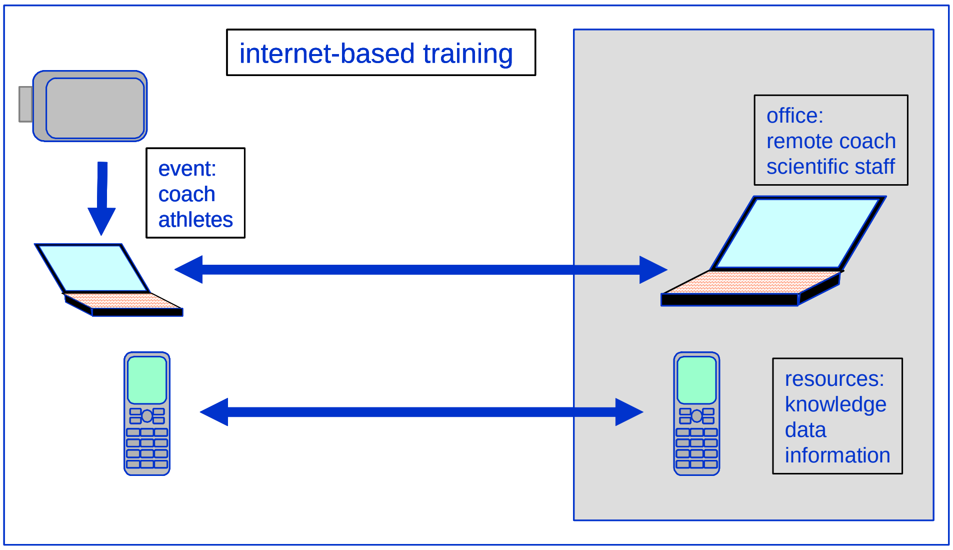

Figure . Communication and data transfer between event and research institute via internet and satellite.

The last example of computer-based future oriented developments deals with animation. As mentioned above, animation is an important factor in the area of biomechanics as it is helpful for offline-analysing movements as well as for online-controlling movements.

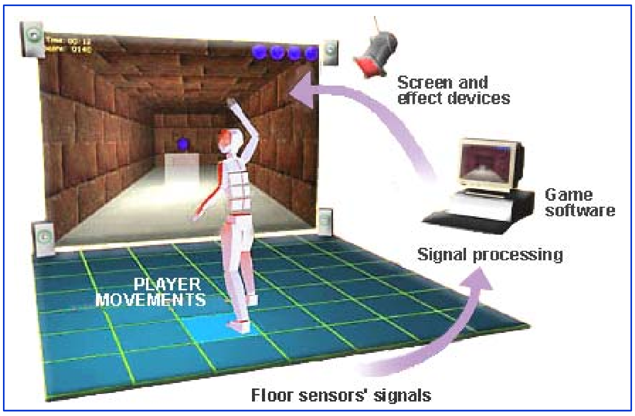

Figure 10. Computer-based movement simulation and animation.

Moreover, the meanwhile available technology allows for simulating and animating virtual movements, as is sketched in Figure 10 (for more and detailed information see the contribution of Larry Katz within this issue). The aim is to give the athlete a fast feedback and a better understanding of his movements in order to improve them.

Bottlenecks and other problems

Although the computer-based technological development in Sport Science is really surprising, there are some problems left – or only now become visible – that make clear that processor speed and storage capacity is necessary but not sufficient. In particular the problem of handling huge amounts of data is not solved by increasing storage capacity. Instead, there are two major transfer problems:

How can data be obtained from the system's information? A system's dynamic offers a lot of information, which a human observer can easily recognize and process mentally. If recorded to digital frames for computer-based analysis, the information is still available, but technically hidden in a large set of pixels, from which the relevant data have to be recognized and extracted automatically. Therefore, as is well-known for example from computer-based game analysis, the bottleneck of data recording has two aspects: Either it is done manually – it then works but needs a lot of effort, which normally is not available. Or it should be done automatically – it then needs very clever tools, which normally are also not available or are much too expensive.

But even assumed that sufficient data have been obtained, e.g. from sensor-based measuring, and analysed – then the question arises: How can the relevant information be obtained from the analysed data and transferred to the user. If there are millions of data for instance from a movement it is comparably easy to calculate quantitative statistical information. But it is rather difficult to answer qualitative questions like that regarding to stability, similarity, or optimality. The above described methods are steps in the right direction, but just first steps. A lot of work remains to be done.

Finally, and this seems to be the crucial point, all modelling and calculation does not help anything if the basing understanding of the system, its structure and its dynamics, is poor. Even the best model cannot be better than the corresponding system understanding. From this point of view the interdisciplinary development of Computer Science in the field of Sport

Science on the one hand can help to solve problems and on the other hand can make clear what the actual problems beyond computers and technology are.

Conclusion and outlook

In 1989, on the occasion of the first German Workshop of Computer Science in Sport, Günter Hagedorn, a well-known German Sport Scientist, asked in his contribution: "Computer Science and Sport: A reasonable marriage?" The answer – based on bold expectations as well as on critical doubts – was "yes".

16 years later many of the old expectations have been met, and new challenges have arisen.

And the answer is still "yes", as Arnold Baca points out in his contribution within this issue.

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Coaching and Computer Science

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Abstract

Coaching comprehends all activities in training that are related to a special competition. It can be divided in activities prior, during, and after competition which one may call preparation for competition, control of competition, and competition debriefing (Hohmann, Lames & Letzelter, 2001). Computer Science provides support in all these phases of coaching, but there are quite different demands and restrictions leading to very different solutions. In the remainder of this contribution, the potential support of Computer Science for Coaching is discussed with regard to game sports.

The ultimate aim in preparation for a competition is the development and implementation of a winning strategy. In order to develop a strategy we have to assess or estimate the potential and capabilities of our own team and of the opponent. And, most important, we have to speculate on the result of the interaction between the two teams: how will my defender perform against their attacker? Strategy development requires comprehensive estimations based on interpretations of facts and the coaches' philosophy of the game. The technological support available so far consists of observational systems that that are in general made up by a database with video clips of the analysed scenes. This allows easy, flexible, and spontaneous retrieval of information and makes strategy development as comfortable as possible (Hansen & Lames, 2001). However, the core of strategy development has not been tackled by computer science so far. The implementation of the rules governing strategy development remains a challenge for a future expert system.

During a game the coach tries to influence the outcome by changing or stabilizing competition tactics. Control of Competition is made possible by the rules of a game which specify certain intervention periods such as half-times or time-outs or measures such as the change of players a coach may take. This results in strict limitations for the support computer science can give to coaching during a match. Since we want to analyse the ongoing match, there has to be a real-time assessment. Information relevant for competition tactics have to be ready for use at the intervention points.

Recently, there has been much progress in RTPA (real-time position analysis). There are several automatic and half-automatic systems under development using a variety of technologies, such as GPS, micro-waves, radar, and image processing. In the near future it seems possible to track the positions of players and ball in the field continuously, thus providing continuous streams of positional raw data. What has not been appreciated enough so far is the fact that the positional data alone do not support the coach during the game. Analyses on different levels of abstraction have to be completed in order to obtain valuable information for this purpose (Beetz, Stammeier & Flossmann, 2004). On the lowest level positions and movements are transformed into heat maps with the

spatial distribution of activities for each player, but we also want to have action profiles of the players, chains of actions leading to scoring opportunities have to be detected and, above all, the strong points and weaknesses of the opponent have to be assessed in order to select appropriate counter-measures. The combination of acquiring positional data and reconstructing intentional behaviour in multi-agent systems will be one of the most exciting challenges for computer science in sports in the future.

Competition debriefing after a match is a frequently neglected activity which is nevertheless of central importance in order to improve training. It provides feedback for the athletes, for the training process, and – mostly underestimated – for the coaches capability in strategy development. Technologically very much the same features may be used as in the preparation for competition, the difference is only the game analysed.

As a conclusion it may be pointed out that there is much support for coaching by computer sciences right now but there are even bigger promises for the future.

KEY WORDS: COMPUTER SCIENCE, SPORT SCIENCE, DEVELOPMENT, NEW PARADIGMS, INTERDISCIPLINARITY

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