Innovations in Sport Technology: 
Implications for the Future

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Abstract

Coaches and athletes are always striving to reach peak performance. Modern electronic technology, particularly the Internet and high speed, multi-way digital communication, makes it possible for coaches and athletes to efficiently and effectively gather, analyze and integrate information and resources in order to improve training, decision making, and collaboration. These resources can be accessed in real time and changes implemented immediately, if necessary. New developments in the research laboratory permit athletes to experience simulations through the use of virtual reality and video game analysis, which may also significantly improve their performances. This paper will look at these innovations, and discuss the implication of these new forces of change from various perspectives including coaches, athletes, spectators, fans, parents, officials, media, industry, and the individuals who must organize and maintain the resources. Discussion will include the issues related to the background and training which will be required to employ these new tools.

1. Introduction

This paper will discuss the role of innovations in sport and technology and the implications of these innovations for the future. According to the Webster's New World Dictionary sport is defined as:

1) "Any activity or experience that gives enjoyment or recreation; pastime or diversion"; or

2) "Such an activity, especially when competitive, which requires more or less vigorous bodily exertion and carried on, sometimes as a profession, according to some traditional form or set of rules, whether outdoors (...) or indoors (...)".

Webster's, definitions for technology include "applied science" or "the system by which a society provides its members with those things needed or desired".

Given the broad context for the term technology, even as it applies to sport, the scope of the potential discussion is quite extensive. Therefore, this paper will focus on the use of technology in sport from the perspective of frequently asked questions (email requests for information received by the author); new innovations; and, the implications for these innovations for the future with reference to various target audiences (i.e., coaches, athletes, spectators, fans, parents, officials, media, industry, and support personnel).

The most frequently asked questions with regard to sport and technology include:

- Has science and technology improved sport ?
- How does the Internet impact sport ?
- How is technology used to aid decision making in sport ?

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- Will technology replace human judgements in sport: will we no longer need human referees and judges?
- What factors are influencing the development and use of technology in sport?
- What new research is being undertaken in sport technology?

2. Has science and technology improved sport and physical education?

Martens (1997) has suggested that kinesiologists and physical educators have been profoundly effected by technology which he states is: (...) “radically altering how we practice our professions and live our personal lives. This amazing world of technology is dramatically improving productivity and quality in the manufacturing of products and the delivery of goods and services. It reduces drudgery and, contrary to early concerns, often inspires greater creativity because of the elimination of tedious tasks.” (p 251)

The question that Martens asks his colleagues to address is "How do we avoid technology taking us for a wild ride in which we have no control or little influence, but instead determine how we may optimally put technology to use (...)." (p. 252)

In his book When Things Bite Back, Tenner (1997) describes how the introduction of safety features such as boxing gloves for boxers and protective headwear for football players has led to a greater incidence of injury. For example, the adoption of boxing gloves to make bare knuckled boxing safer made it possible for fighters to throw punches to the head without breaking their hands, with the result that there were more incidents of brain injury and death after the introduction of boxing gloves than before.

Malone (2001) likewise outlines the unexpected and unpredicted consequences of computer and Internet use on individuals and society at large. For instance, some researchers thought that the microprocessor would be an answer to the world's energy problems, since they used less energy than mainframe computers. Of course, at the time no one expected that there would be billions of processors and controllers in the world so that the microchip would become one of the biggest users of energy. Sophisticated and advanced technology may have benefits for society, but the unintended side effects can be quite devastating.

In reference to improving sport, the question can be viewed from at least two perspectives: competitors (i.e., the athletes) and non-competitors (i.e., everyone else).

Competitors

Certainly, as Katz and Green (1989) noted, by using techniques incorporating technology, it is possible to stretch the imagination and the abilities of the athlete. The natural ability of an athlete is being enhanced beyond what was once thought possible - the limits only end with the imagination.

Just prior to the Olympic Games in Sydney in the summer of 2000, Sullivan (2000) asked the rhetorical question, "Will technology take the gold?". In his article, Sullivan discusses the fact that: “The Olympics create a world where a fraction of a second can be the difference between obscurity and world fame. The margins are so thin, it's not enough to train hard and give 100 percent on competition day. You've got to wear a uniform with the least water resistance, or run in shoes outfitted with the latest gadgetry, and you must train against both fellow athletes and machines.” (p. 1)
In speed skating, it is impossible to win, or even place, without using the newest “clap skate” technology (May, 2000; Greenwald & Thibault, 2000). Clearly, from the perspective of the elite athlete, if the goal is to strive for the ultimate performance, break records, and increase performance efficiency, then technology is improving sport. If, however, "enjoyment" is a factor in defining improvement, the answer may not be so simple. Athletes are pushing the limits from the physical perspective, so much so that there has been a major increase in the frequency and severity of injuries (Greenwald & Thibault 2000). Moreover, athletes in less advanced environments are less able to compete, so that many sports become exclusionary. The constant necessity to develop equipment, facilities, and training techniques, which can mitigate against injury while at the same time improve performance, increases the costs of preparing an athlete and hence, further excludes those without access to substantial resources. Root, Domonkos, Granek, and Hustler (1998) and Froes (1997) provide interesting discussions of these points. According to an article in the Sporting Goods Manifacturing Association (2001) in households with incomes of less than USD 40,000 only 49% of children are engaged in sports; in households of USD 40,000-80,000, 63% are, and in households with more than USD 80,000, 73% participate.

The November 2000 issue of *Scientific American Magazine* is dedicated to "Building the Elite Athlete" with many stories highlighting the impact of technology on sport and performance. For example, May (2000) suggests that the advancements in equipment design may improve performance so much that it could even destroy the challenge in some sports. Technology has changed the focus of sport to the extent that Stix and Fischetti (2000) now define athletic performance as "a set of physical parameters (force vectors and acceleration), biological processes (pulse rate and maximum oxygen uptake), and mental states (psyched up or psyched out)". The physical and biological processes lend themselves to technological intervention, but now even the psychological training is becoming heavily influenced by technology (e.g., biofeedback, visualization and virtual reality training).

**Non-Competitors**

The discussion of non-competitors includes the diverse groups mentioned above (e.g., spectators, media personnel). From the viewpoint of the spectator or fan, the ability to see sports from many perspectives has great potential. Mester, Scifriz, Spitzenpfeil, and Spahr (2000) at the German Sport University in Cologne have worked with IBM and German Television ZDF to develop modern high-end visualization programs for the reproduction and display of complex models for alpine downhill skiing and tennis. The results of computer simulation and graphic reproduction are combined with video footage to offer the TV-viewer a familiar form of motion display while still providing scientific parameters and models of performance that help explain winning and losing.

The cost of producing these programs is passed on to the advertisers, and so the spectators have to deal with the increased number of commercial breaks in the sports coverage. Even spectators who frequent sporting events are required to wait while television commercials interrupt the ongoing action. This is especially true in North America where events as diverse as hockey, basketball, and figure skating, require extended breaks in action to facilitate commercial requirements.

Omega Networks has launched [www.ticket2sports.com](http://www.ticket2sports.com) a broadband, online sports resource providing fans with a virtual ticket to video-on-demand for amateur sports. To quote the website [www.Ticket2Sports.com](http://www.Ticket2Sports.com) : “Your Arena for video-on-demand of elite amateur sports competitions, clinics, instructional, and interviews. Sports you want - the way you want - when you want it”.

The English language notwithstanding, it is still necessary to have quite sophisticated equipment in order to access the site.
Another interesting opportunity for sports fans to indulge in vicarious participation is the concept of the virtual spectator. With satellite, cell phone, and geographical positioning systems (GPS) technology, sports spectators can now log in and track races (boats, motor cars, cross country bike racing) using real-time telemetry information. Technically, it is possible to look at a race from multiple positions and even participate through the addition of a computer-simulated boat/car/bike (Richardson, 2000).

Coaches are in a similar situation. It is now possible for a coach to access the latest training information, tools, and resources for their athletes. However, the coach must also have the technological background in order to make use of these technologically based assets, or at least a plethora of experts to collect, collate, and disseminate/provide access to these opportunities in a timely fashion. Since, both the equipment and expertise come at a substantial price, the specter of exclusion once again is omnipresent.

The currently available evidence would suggest that the use of technology makes it possible for coaches to provide their athletes with the best possible opportunities to achieve their maximal performances. However, the role of technology in coaching is still an emotionally charged issue. Liebermann, Katz and Morey Sorrentino (2000) looked at senior coaches’ attitudes toward technology. Despite the fact that the coaches surveyed were generally highly experienced, those with higher education backgrounds viewed technology more favorably, but those for whom coaching was their primary livelihood, did not view technology as a significant contributor to their success.

### 3. How does the Internet impact sports?

First of all, the Internet provides everyone with the opportunity for the proverbial 15 minutes of fame. No matter how obscure the notion, it is possible to publish an idea for worldwide consumption. The Internet allows individuals to communicate with others of like mind from around the world, where previously such individuals would be isolated because of the uniqueness/obscurity of their ideas. The technology and business of the Internet is so dynamic that a non-existent company 10 years ago, American Online (AOL) can buy Time Warner, one of the largest publisher/media companies in the world. At the same time, children as young as three years of age are accessing the Internet to look up the personnel details of their favorite athletes and sport teams. Intille (1996) provides a good overview of the use of the Internet in sports including implications and visions for the future.

During the Summer Olympic games in Sydney Australia in the fall of 2000, there were hundreds of Internet sites bringing sports fans, family members, reporters, and other interested individuals up to the minute details, including pictures, audio recordings and video clips of the action. Literally hundreds of millions of hits were recorded on these Internet sites over the course of the competitions. There are thousands of sport related sites on the Internet ranging from information sites (www.sportquest.com) and sport gambling (www.SportsBetting.com), to interactive sport games (www.alphasim.com). The Internet and the World Wide Web provide excellent opportunities to discover information that is timely and easy to access. There are two major problems. One problem is maintenance of the Websites (there are many links that are no longer valid, or are out of date). The second problem is determining the accuracy and reliability of the information provided, as there are currently no mechanisms for ensuring quality control of the content. Nevertheless, sites like Sports Technology Hotlist located at www.white.media.mit.edu/~intille/sports-technology.html, The Sports Information Resource Centre (SIRC) a virtual resource centre for sport information - www.SPORTQuest.com, and Scholarly sports sites for researchers, located at www.ucalgary.ca/library/ssportsite will provide interested surfers with copious amounts of information to sort through.
According to Sportsbusiness.net in its January 10, 2001 newsline, www.SportsLine.com, a Columbia Broadcasting Systems (CBS) website had page views in the fourth quarter of 2000, of approximately 2.8 billion, an average of 30.2 million daily page views. Sportsbusiness.net sends out a daily newsline to all its customers covering the business of sport and holds annual conferences on sports media, and sports business, including a recently held conference in December 2000 in conjunction with the International Olympic Committee (www.sportbusiness.com).

4. How is technology used to aid decision making in sport?

With online communication, coaches and athletes can keep in constant contact. Data can be recorded on performance, instructions can be transmitted, and detailed performance modifications can be made. Video conferencing and audio conferencing provide the coaches and athletes with close contact even at extreme distances. With the latest technology, athletes' performance monitoring can include heart rate and blood pressure. It is even possible to analyze waste materials collected directly from source, and send the results automatically to the coach/team doctor for changes in diet and nutrition. With recent sport video analysis systems, coaches can collect and code action data during the event and then show the athlete(s) where problems have arisen for instant corrections. Such programs already exist for most team sports. During intermissions, between heats, and during time outs, teams can watch selected events from the recent action, which can be instantly accessed, and changes can be made that can have a major impact on the outcome of a game.

In North America, instant replay judging is now a common practice in hockey and football. The head referee on the field can be over-ruled, by the instant replay judges who sit and watch the replay of the action to determine the accuracy of the on-field decision.

5. Will technology replace human judgements in sport? Will we need human referees and judges?

There are already technologies that assist umpires in sports like tennis with line calls (Miah, 2000), but it is not clear whether technology will evolve to eliminate referees altogether. As regards officiating in subjective sports such as gymnastics, figure skating, and diving, researchers are looking into new ways of training human judges to be more objective and consistent in their ratings. The idea is that computerized judging is not technically possible at the moment, nor is it necessarily desirable. What is probably more valuable, is the development of techniques which give judges opportunities to practice with the identification of relevant cues, to consider their physical view position and the ramifications of their location, and the ability to react and record their thoughts accurately and efficiently. This includes the development of simulations, which allow the judge to make and review their decisions, re-evaluate their decisions from different vantage points, and then evaluate their responses relative to other professionals. This could be accomplished through animation, three-dimensional modeling, and the use of actual competition footage using multiple camera angles. Also, there is a need to develop tools that judges can use to input their thoughts at the touch of a button or pen (e.g., using forms created for personal digital devices like a palm pilot) and be able to easily access their recorded thoughts as the competition unfolds.
6. What factors are influencing the development and use of technology in sport?

The most sophisticated use of technology in the world to date is being organized by the National Aeronautical Space Association (NASA), the European Space Agency (ESA), the Russian Space Agency (RSA), the Japanese Space Agency (NASDA), and the Canadian Space Agency (CSA). These agencies are responsible for the largest civilian project in history, the creation of the International Space Station (Kopp, 2000).

Astronauts are the ultimate athletes. They are involved in intensive training for performing in environments that are impossible to accurately simulate on earth. In order to perfect the performances of the astronauts (even the slightest error could result in death), the space agencies provide the most sophisticated training environments. Computer-based learning, computer simulators, and virtual reality environments are created to ensure mastery of material and technique. Problem-based analysis is used to identify errors and correct them. Tertiary backup systems are put into place and if problems occur, these problems are simulated on earth using exact replicas of the equipment in space. Mission controllers and the astronauts are engaged in real-time decision making in high-risk situations accessing the latest technology over amazing distances. These same models and tools will eventually find their way into the sports arena.

Similarly, the militaries of most western countries are probably the largest users of technology for training. The sophisticated weaponry in the hands of mostly volunteer armies requires proper training to avoid serious injuries and possible deaths. The spin off research and development that results from military research and training is finding its way into sport technology research and ultimately to the athletes.

Sports equipment and clothing manufactures are competing intensely with each other for the opportunity to sell their products to athletes and coaches. These manufacturer fund development activities are looking for the elusive edge over their competitors. The biggest problem for research scientists is to ensure that research into the effectiveness of the newest fad drives the decision-making and not the advertising that surrounds the distribution of the equipment or clothing. Since the Sporting Goods Manufacturing Association estimates advertising at 4.46 billion dollars in 2000 (www.sgma.com), there is a significant influence on the buying public.

Lastly, the multi-billion dollar video games industry has provided impetus for low-cost interfaces that can be used in sport research. The video games industry will have a significant influence on sport in many ways; firstly, because it provides low-cost, high quality processing power and, secondly, because children (athletes of the future) are much more willing to interact with technology.

"Players head into uncharted waters where perseverance, wit, luck, and interminable hours of practice count for everything (...) games are the great equalizer. The game gave kids the sort of power they couldn’t get anywhere else. It was safe to make mistakes while playing, because there was always another chance (...) they found an environment that they could beat the pants off their parents (...)" (Sheff, 1993, p. 4). The athletes and coaches of the future will be much more willing to utilize technology because children of the last decade have grown up in technology rich environments.
7. What new research is being undertaken in Sport Technology?

Katz (1992) predicted that coaches and athletes would be able to develop elaborate audiovisual databases of performances that would be instantly accessible and customizable for appropriate use. Katz also pointed out that: “Artificial or virtual reality enables participants to become part of an abstract environment where no physical machinery is required, yet one experiences the essence of time, space, and equipment.” (p. 31)

Today, these visions are becoming the reality.

McKethan and Turner (1999) have developed a multimedia system that helps analyze sports skills in children. Their system is designed to allow students to compare mature and immature execution of skills. Students can also use the program to examine cues for correct performance.

Katz, Kilb, and Liebermann (2001) have developed an interactive volleyball multimedia program for volleyball coaches that provides educational lessons on planning a practice, an interactive database of 400 full motion volleyball drills, and an integrated practice-planning tool which allows the coach to select the appropriate drills, customize a practice, and then print out the practice plan. If desired, coaches can even demonstrate the drills using a video projection system directly connected to the computerized practice plan. The program is based on a needs model that looks at the factors that should be considered when developing interactive tools for coaching or teaching sports games (Liebermann & Katz, 2001).

At the University of Nice, Garbarino and Billi E. (2000) have developed a sophisticated computerized modeling system that analyzes team play. The system captures graphic representations of every player and tracks their on-field activities. This system is being used with professional European Football (Soccer) clubs to evaluate on field activity and player performance.

According to Adelson (2000), new technologies are being developed which use transmitters on hockey players’ helmets. These transmitters provide sport fans with information on how fast a winger is skating, how hard a defenseman is checking, and even how long a shooter is actively participating. The transmitters, imbedded in players’ helmets, will relay information to receiver antennae in the glass and then on to the fans television or computer screen. The technology will allow an instant animated recreation of games. Technically, fans would be able to put themselves in the helmet of any player they chose.

Jenkins (2000) reported that Olympic sprinter Michael Johnson was wired up for a recent relay. Small sensors were taped to Johnson’s chest and leg to measure every stride and heartbeat during his portion of the 4 x 400 meter relay. Information about Johnson’s heart rate, speed, distance, acceleration, cadence, stride length, and energy burn rate were displayed in real time during the race. Both coaches and sports fans can have access to the database of information.

Concha (2000) explains how the Los Angeles Lakers basketball team uses wireless digital scouting tools. These handheld digital devices use color touch screens, voice recording, and web-based interfaces to collect, track, chart, query, and integrate information on each athlete. With millions of dollars riding on selecting the best players, tools like these will be essential for every professional sports team.

Using a virtual reality sailing simulator, Walls, Bertrand, Gale, and Saunders (1998) were able to demonstrate a high correlation between performance on the simulator and performance in a competitive sailing event. The simulator used a laser dinghy deck and high quality graphical representation of helming, sheeting, tacking, and boat trim. Sailing technique, fitness, and judgment of
boat position on course were measured and used as a method of ranking performance. Participants, high-competitive helmsmen, gave the virtual reality environment high ratings for overall feel and simulation of physical movement.

As technology evolves and people explore novel ideas, new and more creative applications are being developed. Yeadon (2000) is looking at the practical use of pinpoint accuracy models so that coaches can help their athletes “know where to look” when performing aerial maneuvers. Coaches can use simulation models to test their latest theories and then athletes can first experiment with the new maneuvers in a virtual environment that will allow for error without risk of injury.

8. Conclusion

There is a widening gap between the human capacity to adapt to change and the drastic changes which technology brings to the environment. In order to help those involved in sport to cope with innovation, researchers will have to develop smart sport communities. The objective of these smart sport communities would be to integrate technology into the environment using new and innovative approaches that would address the needs of the constituents (e.g., athletes, coaches, trainers, etc.) and empower them to take control of the situation. The criteria for success should include applications and resources which:

- are currently being used and for which there is clear evidence of success;
- address clearly defined and measurable needs;
- are interactive and responsive, in real time, to client needs;
- are transferable across sporting environments;
- provide interactive, networked, collaborative, and simulated learning opportunities over distance;
- results in positive changes which may impact on attitudes, performance, and/or costs; and,
- integrate technology with easy-to-use interfaces that are reliable, effective, efficient, and transparent to the user.

The movement in sport technology research is toward identifying the needs of the various stakeholders and then addressing those needs. Many of the stakeholders themselves are unaware of what they really need or what is available to facilitate performance improvement whether for the competitor, the support personnel, or the spectator (live or virtual). Moreover, the level of training and support required to integrate these new tools into the sport environment must be addressed and factored into budgetary planning. Needs assessments must be carried out to define the proper allocation of resources. Technology is not a panacea for all the needs, but if applied appropriately and reliably, it can simplify and expedite the stakeholder’s role. Ultimately, three major factors will influence the widespread adoption of technological innovation: cost, ease of use, and reliability.
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