New Technologies in Sport through the Internet of Things Systems

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Abstract
In recent years, the Internet of Things (IoT) technology has revolutionized the global market in the sports sector. It is interesting to learn about digital technological innovations and their connection to athletic performances. The use of these technologies is largely developed in the performance evaluation and monitoring; new cutting-edge equipment allows sports operator identifying parameters and indexes of considerable interest for the sports performance. The application of new technologies allows researchers investigating and increasing the focus of the research activity on the new possibilities of objectively observing aspects concerning the match-analysis, such as wearable technologies, motion capture systems, and other systems allowing professionals implementing new training methods through the use of tools connected to reality by applying IoT technology-based systems.

Keywords*: Systems, Sports, Match-Analysis, Parameters, Technology, Application.*

Introduction

The conception of the Internet of Things refers to the extension of the Internet to concrete objects and places. This is the evolution of the network through which connected objects enter into communication with other objects (such as mobile phones), to which they transfer their data. The IoT makes it possible to manage remotely (by monitoring and controlling) commonly used objects such as refrigerators and other household appliances, and makes it possible to carry out daily activities completely automatically, such as managing the home temperature. In short terms, the Internet of Things allows objects taking an active role by connecting to the network.

Potentially, the Internet of Things can be applied in countless sectors. If for some of them, such as home automation for the control of one's own home and the remote use of air heating/conditioning systems, household appliances and window frames, this is a practical reality, for some others this process is still under development, such as in the automotive industry for which we are currently speaking of automated guided cars. For some years now, the production of sports equipment has also shown great interest in the development of technologies connected to the IoT; more specifically, interest in the in-depth analysis of the performance monitoring systems, able to make its measurement more immediate, has increased. This is possible by means of both wearable and performance observation instruments.

Relationship between Performance and IoT systems

Leaders in the Internet of Things (IoT) applications progresses, concerning the analysis of the athletic performance, have been able to understand something significant: more than ever, today's technology can be useful to the mind and the human body, because athletes can mentally correlate their perceived performance (how quickly they think they are moving, how tired they think they are) with respect to their actual performance (based on real and instant data). The use of innovative technologies, such as a wearable sensor, allows coaches and team personnel monitoring the information on the player, such as his movement, heartbeat and other parameters useful for his health state and performance. This information, combined with player's location and environmental data, is typically sent to a secure, cloud-based analysis platform that provides critical information to team personnel via a dashboard. By informing about the best player interventions and improving tactical game decisions, the IoT solution helps provide significant competitive advantage to teams. In addition, the user interface can be designed to allow for a better overall health management, recovery and elimination of injuries, extending benefits far beyond a single game. The potential of this approach is so high that even a market leader, such as IBM, has started several activities in this area. For example, it set up a collaboration with the USA Cycling team through their IoT service, in the framework of a project called "IBM jStart". Through their service, they provide information to cyclists immediately after a training session and in real time during a competition, by means of smart glasses. These real-time feedbacks and data improve the efficiency of the cyclists, drive them on when to cycle faster, and help them avoid the much feared "bonk ", i.e. the moment when the reservoir, intended as energy storage, has no more fuel. Wearable technologies are starting to be a turning point for coaches, athletes and fans. The ability to measure and track performance data and take advantage of the analysis will ultimately allow teams being more sophisticated about their game plan, athletes' performance and injury prevention.

Therefore, some key factors behind the competitive advantage of the IoT technology applied to athletic performance have been recognized:

- Track power; it measures strength production during flight in real time, providing data to maximize the athlete's live performance.
- Energy Tracking; this allows athletes better understanding the production and use of energy in order to optimize training load and recovery, since there are metrics (such as muscular oxygen) that are unique for the individual, and can be related to many physiological conditions.
- Wide Eyes; by using an optical sensor to observe large sizes (such as a microchip in an American football helmet), a high-performance essential product can encompass wearable technologies and include innovative heads-up display and audio technologies.
- Performance Analysis Structure; computer interfaces first convert raw data into user-friendly messages, then automatically send messages almost in real time to an IoT; for more immediate feedback and integration with other data feeds (power, heart rate, etc.), in order to highlight correlation and advanced analysis, it is possible to derive value from things. Through the IoT analysis, team members can get a clear analytical framework of what they have to do to win. The IoT now allows them reading both structured and unstructured data to create a comprehensive overview.

Further insights from which to consider that the team can calculate the metrics in real time, will allow the team coaches monitoring the performances not only after the training session, but while it is still in progress. It can also collect and share IoT data in a virtual cloud database: the cloud solution removes the complexity of mobile app development and management, and allows teams focusing on the needs and demands of the user dynamic mobile; this means having relevant information at the right time with the ability to act immediately. Since this new training solution is mobile and cloud-based/IoT platform-based, teams can train anywhere and benefit from real-time monitoring, analysis and communication. By bringing together not only tools to connect wearable devices but also data and analysis services, providers can create personalized experiences for end users, drive progress and reduce costs. While using their mobile app, coaches can also access training sessions in real time, at any time and from anywhere, allowing for a remote involvement when everyone cannot be in the same place at the same time. This provides a lot of flexibility for the team of professionals who are constantly on the move.

At this point we can understand that, in today's sports training and performance analysis, almost all the performances are captured on a video or via IoT sensors. The captured videos and sensor data are then displayed by expert instructors/analysts. It is in this field that platforms and software applications play the most important role, in a range that goes from reducing or eliminating time to manually taking note of and labeling important performance indicators to evaluate performance, computer-aided self-training systems for sports exercise, and tactical information extraction alongside periodic event detection, by also taking advantage of virtual reality and acceleration sensors on the body to perform motion and force analysis.

Motion Capture System and Biomechanics

Motion Capture (MoCap) is another performance monitoring system, and is also defined as "the practice of dynamically recording positions of various predefined points on the body or object in 3D space". In addition to general studies on motion, biomechanics intends to measure and relate it to the underlying musculoskeletal function. This provides information for the performance of a single athlete, but it can also provide information on the health status of the individual in relation to his musculoskeletal system. The whole model is known as the biomechanical model. The complexity behind these models is not only linked to the methodology underlying the analysis, but also to the applied technology: a very wide range of technologies is available for the acquisition of motion, thus the result differs significantly from each system. Optical tracking devices employ multiple infrared-sensitive cameras to track the positions of the "markers" attached to the objective (to the body joints, for example). The "passive" systems illuminate the scene with infrared light and detect the positions of retro-reflecting markers. "Active" systems use infrared light-emitting diodes as markers, but they are similar anyway. Provided that the positions of the cameras in space are known (i.e., if the system is calibrated) the 3D position of each marker can be retrieved by analyzing its position in the image of each camera (at least two are needed to recover the 3D position of a marker).

These systems often work in conjunction with the IoT sensors, but in this specific field of analysis, they have some constraints; the non-functional requirements of the system are mainly related to its wearability: the system must be portable and wearable, and easily usable as part of the athlete's ordinary training program. This limits the range of usable sensors, since they must be non-invasive and minimally influenced by physical and biological responses, such as vibrations and sweating. The size and weight of the system must also be minimized, avoiding any performance limitations or movement. It should also have a sufficient power supply, at least for a full training session, while wearability also implies that information between the athlete and the system's main control unit should be transmitted wirelessly. In addition to technologies that capture human and object movement, eye and gaze tracking technology can also be used in sports training: gaze behavior can differ significantly between experts and beginners (for example, when keeping track of a ball), bad habits and unconscious actions conditioning performance can also be identified by monitoring the athlete's eyes during the game. Furthermore, technique and analysis are very different depending on the methodology employed. For example, animation needs a continuous and constant signal, but it does not need an individual’s physiological precision. The latter would be essential for clinical science, in which motion capture must be integrated with other systems, such as force measurements and electromyography. This is necessary to not only measure motion, but to analyze and understand the reason of the movement. This is why the general motion analysis is usually applied in the field, while the clinical motion analysis is more restricted to specialized laboratories that consist of complex technologies and specialized professionals to manage them. MoCap systems have been developed over the past two decades to track and record human movements at high spatial and temporal resolutions. These applications require efficient methods and tools for the analysis, synthesis and automatic classification of motion capture data.

The main challenge in articulating the movement of the articulated body is the large number of degrees of freedom (about 30) to be recovered. Research has generally focused on two opposing approaches: one consists in introducing hypothesis constraints on motion trajectories or visualization restrictions, both by labeling and using markers or color code. The other approach consists in relaxing the constraints deriving from articulation, and following the limbs as if their movements were independent. In both cases, the analysis is challenging due to the technological and practical difficulties associated with the resolution and accuracy of 3D video analysis across large volumes. Since even a hundredth of a second improvement between two different movements could be significant for the outcome of the gesture, improving performance for elite athletes could result in technical adjustments that go beyond the capabilities of video-based systems, and have to rely on the coach-athlete intuition instead.

To solve this complexity, an innovative system called motion capture fusion (MCF) has been developed. It is able to capture3D kinematics and kinetics by overcoming the technological difficulties associated with the monitoring of the athlete’s performance in an elite environment. MCF is a term that describes the motion capture when different streams of different data are merged to measure the athlete's movement: inertial measurement unit (IMU), global positioning system (GPS), pressure sensitive insoles and video measurements have been combined. The core of the MCF is the fusion of IMU and GPS data: the IMU typically contains accelerometers, gyroscopes, magnetometers and a thermometer, and tracks the local orientation and acceleration of each segment of interest. GPS data are merged with local acceleration data to track the athlete's overall trajectory. In this way, the software is able to draw a complete picture of the athlete's gesture, highlighting also the different vectorial forces and the momentum of each part of the body during the activity. In addition, the most advanced software also includes an eye-mark recorder, a device to measure a subject's focus point and his pupil diameter, which is able to draw a precise single-eye or double-eye movement of vision lines. These data can then be synchronized with the motion capture systems, in order to display them both in real time and in post-processing.

Notational Analysis and Tracking

Both during training sessions and during the game, efforts on tracking the player's movement in the field have traditionally involved a series of data collection techniques, from live observation to post-event video analysis, where the players' patterns of movement are registered manually and classified to determine the effectiveness of the performances. This process is called Notational Analysis and involves the subjective quantification of single players' movements by an investigator, and the frequency and timing of particular movements are therefore linked to their relative success. Obtaining accurate positional information about sports players is interesting for coaches and high performance support teams, because of the ability to correlate performance with tactics and help planning better training programs. The complex nature of the movement inherent in many physical activities is also a significant obstacle to overcome: athletes tend to produce rapid and agile movements, with many unpredictable changes in direction and frequent collisions with other players. Each of these characteristics of the player's behavior violates the hypotheses of fluid motion, on which computer tracking algorithms are generally based. However, the increasing ability of digital technology to collect, manage and organize video images has allowed improving the specific current analytical procedures for sport: these are the localization systems based on the automated vision, which consist of a variety of methods used to analyze the athletes' movement during sports in which the movements vary in duration, field position and surface, speed, technique of direction and tactics. Unlike manual visual tracking systems, automatic motion tracking does not require human operators to manually locate and continuously record the position of the tracked object. There are many potential applications of an automatic motion detection system, such as: tactical planning and strategies, measurement team organization, provision of significant kinematic feedback, and objective measures of the effectiveness of the intervention in the sports team, which could provide benefits to coaches, players and sports scientists.

Object tracking is widely used in sports analysis. Balls and players are the most frequently monitored subjects, since significant events are mainly caused by player-player interactions. The most common tracking techniques include the trajectory-based analysis and tracking of the small balls, the reconstruction of the physical model-based 3D trajectory, and the estimation of the 3D position with multiple cameras.

The visual signals used for the highlights detection are the movement of the ball, the game field zone, the players' positions and the colors of the uniforms: for example, a model can use the dominant chromatic ratio and the intensity of the movement to map the structure of a specific sports video, based on the syntax and characteristics of the video content, since in a sports game the positions of the cameras are generally fixed and the rules for showing the game progress are similar in different channels. Other algorithms are able to exploit the markers lines on the ground to determine the calibration parameters: they are based on a specialized court line detector followed by a combinatorial optimization phase to locate the court within the set of line segments detected, and an iterative phase of court model tracking. By taking advantage of these properties, object tracking methods are able to perform a classification based on mid-level representations, including a vector field model in motion, physics-based algorithm, color tracking model, and shooting rhythm model. With the statistical chart for ball movements, the coach is able to observe the game actions distribution at a glance, and quickly understand where players can be more effective. As for object tracking strategies, many shot classification methods are proposed on the basis of camera motion, color information, weave information or face detection. Most of the existing shot classification approaches follow the same procedure too, focusing on grouping key photograms or shots with similar low-level features. In addition, the bullet classification scheme can employ a supervised learning process to perform a video shot classification from top to bottom. This scheme is made up of three main phases: identifying the video shot classes for each sport; developing a common set of representations of the movement, color, dots related to length, and supervised learning of sports video data. Thanks to space analysis for mapping low-level functions to the semantic attributes of mid-level video recording (such as player movement, camera motion patterns or field shape, etc.), a match analyst can combine these mid-level shot features and classify the videos into a small number of predefined shots classes, which are able to cover a 90% -95% of the broadcasted sports videos. A recently introduced system has been named 3DRSBA: it stands for 3D Remote Sports Biomechanics Analysis, and its purpose is to establish a remote biomechanical service for athletes' health screening. "Remote" means that, by combining existing high-end 3D acquisition systems with modern communication tools, such as high-speed Internet, cloud storage and the new 4G mobile network, biomechanics studies can be carried out outside the training sphere, without losing the medical support that a motion laboratory can provide. This is a response to one of the main obstacles to laboratory studies: the limited availability of biomechanically-trained technical personnel and trainers. Currently, the professional training of these professionals is extensive and requires many years of experience; therefore, the availability of such experts is limited. In addition, a complete analysis session in the laboratory is an interruptive event in the already short program of an elite athlete with a professional training plan and a life. On the other hand, the laboratory approach provides high technical quality outcomes, with carefully controlled parameters. Therefore, the ability to combine the power of 3D motion capture in biomechanical laboratories with the needs of sports analysis to provide an environment close to actual measurement, is the real key factor that is driving the success of 3DRSBA systems.

Conclusions

Ultimately, we believe that new coaching and training concepts can become interactive through the use of new technologies. This concept offers the trainer the opportunity to concentrate on new specific areas within the training, in spatial and temporal terms, able to provide users with different points of view with respect to performance; moreover, it is important both for evaluation and purely didactic purposes that sportsmen must learn, study and know how to use these new forms of sharing performance, and focus more on the development of increasingly innovative solutions to transmit more information to athletes and improve sports practice.

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