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Integrating Wearable Technologies and Sport Analytics for Personalized Immersive Training and Learning

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Abstract Wearable technology, wearable computers and electronics, possess a significant role in sport analytics. The Immersive Learning Research domain gets excellent insights from the integration of wearable technologies in the sports domain. Personalized Training of Athletes and design of active learning scenarios for professional athletes and amateurs, based on Wearable and Mobile Analytics is an emerging domain of research with great potential. The purpose of this research paper is to provide an overview of Wearable Technology, how it started, how it is used up to nowadays and to elaborate critically with the state of usefulness of wearable technologies in sport analytics. The main contribution of this research work is a methodological framework for the exploitation of Sports Analytics for Advanced Decision Making. The provision of a research model integrated with a general architecture for an Open Cloud Service aiming to provide advances Analytics services sets the milestones for the launch of a relevant prototype.

1. Wearable technologies as a critical domain of Immersive Learning Environments Research.

The study of Wearable Technologies can be performed in relevance to many different scientific domains. The integration though of this technology in the Sports domain is still in early stages with many unexploited opportunities. The purpose of this limited literature review section is to highlight that the next wave of significant contributions in the domain will integrate some or all the following aspects of advanced information systems and information technology integration:

- Systematic profiling of athletes and non-professional profiles for sport activities. The standardization of various complementary tacit and explicit elements of knowledge related to sport activities is critical
- Integrated annotation of sport activities with metadata standards available for general and special purposes.

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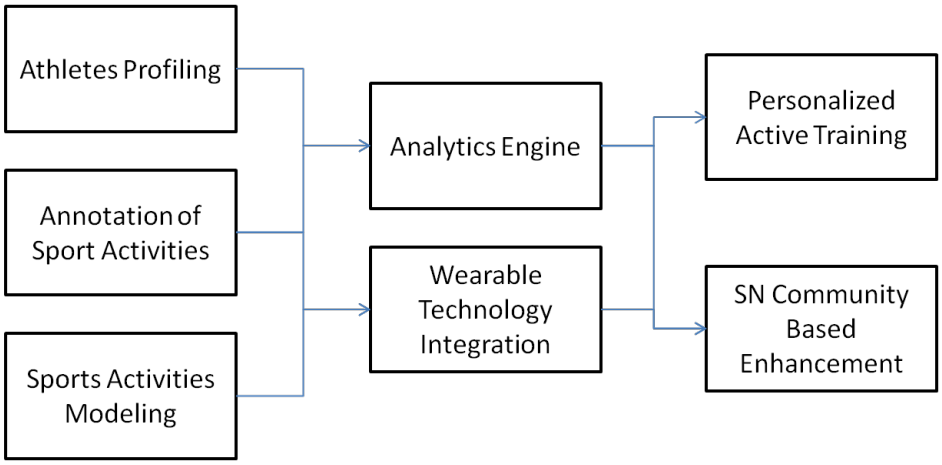
- Sophisticated design of interactivity scenarios for active learning and a-posteriori enhancement through monitoring of actual performance, and analytics
- Integration of Immersive Techniques for Sports Training.
- Design of a cloud infrastructure for the open sharing of resources related to sports analytics and personalized training programs.
- Implementation of a self-sustained social network for the provision, creation and consumption of Wearable Data and Analytics

The research problem we try to address in this research study is related to the integration of the above areas as follows:

How can we implement a flexible, open, Immersive Environment in which personalized training and learning will be enabled by the integration of distributed data related to sport activities? The detailed analysis of requirements for the codification of sport activities and human entities and the detailed analysis of use cases scenarios are the first steps towards the development of an Open Cloud Immersive platform for the provision of advanced Sports Analytics enabled by wearable technology interactions. In figure 1, below, we provide a first abstract overview of the research context and vision of this study.

Figure 1. The Integration of Wearable Technology and Advanced Sports Analytics for Social Enhanced Personalized Active Training.



Wearable technology refers to the electronic parts or devices that can be worn by someone and require no hands use. Per McCann & Bryson (2009) "*A true piece of wearables electronics is also required to be worn to function, i.e. conceptually linked to the wearer's bod*y". The first attempt to implement wearable technology has been made by the military during the cold war, mostly with GPS tracking systems, mines detecting systems or explosive systems that were attached on soldier's clothes. With

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the evolution of the WWW, in the 1990s people did not only have access to wearable components but also, they had the ability to use web based services for the tracking, storing, and use of data in wearable scenarios. The exploitation of wearables in the sports domain is an evolving process. The latest developments in Sensor Networks, in Distributed Information Systems, and in Wearable Technology and Virtual Reality, offer the opportunity for ubiquitous and pervasive immersive learning networks. The Sports domain is in the focus of our research. As Bernard Marr (2015) states, "*Smart technology is now widely used in sport to find and recruit talent as well as monitor and improve performance – both for the amateur and the professional*" and wearable technologies and analytics are frequently used in every day's life to increase his/her health condition.

In addition, wearable technologies in sport analytics played a significant role the last decade for the support of decision making process. In the next section, we analyze the critical role of knowledge management for the justification of Sports Analytics as a Knowledge Management case for Advanced Decision Making.

2. An integrated Knowledge management consideration of wearable technology in sports

Nowadays, there are many initiatives related to advanced decision making in sport analytics. Athletics, football, basketball and especially baseball teams from all over the world are trying to implement innovative ideas and to invest to make an effective use of wearable technology. Our research is a knowledge management primer. In fact, we recognize that several critical knowledge elements are necessary for the creation of a Sports Analytics Ecosystem through wearable technologies. As reported by Koenig (2012) "*The origin of KM, as the term is understood today, arose within the consulting community and from there the principles of KM were rather rapidly spread*". Per Duhon (1998), "*Knowledge management is a discipline that promotes an integrated approach to identifying, capturing, evaluating, retrieving, and sharing all of an enterprise's information assets. These assets may include databases, documents, policies, procedures, and previously un-captured expertise and experience in individual workers*". Knowledge management systems, are frequently used by large organizations – corporations, because they have realized their importance in terms of transferring, sharing and managing information and knowledge.

As Hahn and Subramani (2000) and Davenport (1998) discussed, "K*nowledge Management Systems (KMS) are tools to affect the management of knowledge and are manifested in a variety of implementations*". The legendary work of Nonaka, on knowledge creation, and his proposition of the SECI model, which is essentially a theory that describes the conversions between the two types of knowledge, tacit and explicit, has an impact in our research study. Based on Nonaka's propositions we are looking for wearable generated data transformations related to the four significant knowledge creation processes namely, Socialization, Internalization, Externalization and Combination. This objective links the process on answering the question of how

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the analytical data taken from wearable components are translated into meanings and insights for a regular user or a professional analyst of Sports Analytics, e.g. athletes, trainers etc.

This kind of "translation - conversion" can be called knowledge creation where according to Jantarajaturapath et al, (2016) "*Knowledge creation is activities for developing new content or replacing existing content within the interactions of tacit and explicit knowledge*". Following Nonaka's theory about the two types of knowledge it should be mentioned that tacit knowledge is the knowledge a person can have from its experiences, ideas ore emotions, and explicit knowledge as reported by Nonaka (2000) "*can be expressed in formal and systematic language and shared in the form of data, scientific formulae, specifications, manuals and such like*". A key question related to our research is the detailed analysis of tacit and explicit knowledge components that are required for the detailed profiling of Sports people. This is critical not only for an ontological approach to the specification of related semantics for the enrichments of data but also for the understanding of the key use cases and scenarios for the exploitation of data insights for decision making. From an immersive point of view, the detailed analysis of these critical data derived from wearable technologies can enhance several immersive virtual reality stories.

The convergence of Data Science and Knowledge Management in the Sports Management domain is very interesting. The human actors in the context of sports activities define a variety of knowledge flows, while several critical decisions are associated. Several Editions discuss in details the role of Analytics in Sports and their critical influence in the sports industry. A significant aspect of our research is related with the detailed analysis of requirements for the use of analytics in the sports industry. For this purpose, we plan to run an international survey aiming to codify and to map the variety of different types of analytics.

The legendary work of Nonaka (2000) *on SECI, Ba, and Leadership: A unified model for dynamic knowledge creation,* has a significant implication for our research study. The definition of immersive Ba for the provision of Active Training sessions in the sports industry needs a further investigation. The ideas of Nonaka for Tacit knowledge are linked with mental and psychomotor abilities of athletes and nonprofessional trainees. A first interpretation of the way that big organizations manage knowledge, is a model for knowledge creation which explains extensively the ways knowledge (tacit or explicit) is converted. In our work this metaphor help us connect the internalization process of the SECI model with our research in how sport data analytics are being analyzed by experts and how they are transformed in to performance.

The integration of wearable electronics and sensors in our days provide a very wide range of applied scenarios for the Sports Industry. In the work of Howcroft (2016) a systematic discussion of such a classification model is provided with implication for our research. It is an aim of our study to investigate which are the use case scenarios

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for the provision of meaningful active learning sessions to athletes powered by systematic analysis of wearable analytics.

The above discussion becomes more complex if we add in to the perspective the role of Big Data. Many scientific works in various domains discuss the efficiency of Smart Big Data, Analytics and Metrics to Make Better Decisions and Improve Performance. This is rather the ultimate objective of our research. To provide a prototype system capable of managing Smart Big Data and Analytics and Metrics for the Sports domain.

In our research, it is understood that the data that are retrieved from the wearable devices are results of explicit knowledge since they are numbers, statistics, and formulas. However, the person who will have the task to translate these data into actions and advanced decision making and give them a meaning must have the tacit knowledge to do that. For example, if an athlete has a high heart rate, only a doctor can understand what this athlete needs to do to decrease his heart rate during a specific exercise so he will not harm himself. Another example is, when an analyst sees an athlete who covers pointless meters into the pitch only he/she and the coach can tell him/her that he/she is doing pointless moves and to focus his/her game in another area. The detailed specification of these kind of data is an ongoing objective for our research. The detailed mapping of explicit and tacit knowledge attributes to sport activities is a time-consuming process that requires the involvement of the community from different scientific domains. Nowadays and for our study the data population and metadata annotation of sport activities seems to be a complicated phenomenon since with social networks and wearable technology integration we can realize unforeseen before data flows. Table 1, below, contains some examples of the conversion from explicit to tacit knowledge in data sports analytics:

Table 1. Tacit and Explicit Knowledge Attributes in Sports Analytics

TYPES OF KNOWLEDGE THROUGH WEARABLES FOR SPORTS	
Explicit	Tacit (and Analytics Scenario)
Heart Rate	Check for how many minutes this player can play without hurt himself, and prepare the best training program for him
Dynamic Stress Load	Check under what circumstances this player plays better
Max. Speed – Acceleration – Deceleration	Check in which position this player would be more productive, and provide him/her with a nutrition program to increase his/her stats
Distance Covered	Check how many meters can a player cover into a game
GPS Tracking	Check in which part of the field the player contributes the most

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Training profiles	Systematic analysis of most effective scenarios
Immersive Data	Which is a feasible learning environment for the integration of actions into an aposteriori adjustment of training practice

The above table is indicative. Several other more complex decisions can be supported in an end-to-end ecosystem of Wearable Sports Data Analytics.

Consider for example the following cases:

- How the know-how of advanced trainers can be integrated to personalized training plans of individuals, adopting collaborative filtering approaches? How this can modify significantly the mental models of trainees (Socialization)?
- How can the explicit knowledge sports data can be integrated in an advanced model (combination) which can be used as a basis for advanced decision making?
- How the four knowledge creation processes can serve as value carriers in group training?
- Which are the basic scenarios for the consumption of Big Data generated in Sports Analytics ecosystem?
- How sportsmen can promote synergetic approaches for socialization and advanced sports training?
- How a knowledge repository powered by advanced distributed data infrastructures e.g. lie Hadoop can be implemented?
- Is it possible to provide an Open Cloud Eco System for the creation and the consumption of sport data oriented applications?
- How immersive research can provide new motivating and engaging scenarios for active learning?

This list is not exhaustive for sure. In a journal publication, we intend to present some interesting findings. From the aspect of the Analytics methods it is true that the variety of industrial solutions like SAS.com or Tableau, can provide a collection of applicable data mining methods. It is though much more demanding the specification for a prototype capable of managing wearable and mobile sports analytics. Because of the above considerations, the emphasis of this research work is on advanced data mining methods in sports analytics, and it is linked directly to the internalization process of Nonaka's SECI model since explicit knowledge is converted into tacit. In the next section, we provide the main aspects of our research model.

3. An integrated Research Model for the Study of Sports Analytics in Immersive Learning Environments.

DOI: https://doi.org/10.3217/978-3-85125-530-0-21

The research model in our study is organized around two significant research questions:

Research Question 1: *Can the Wearable Technology and Sensor Networks technology be successfully applied in the sports domain, be available in amateurs and increase the effective knowledge management of its users? And is it worthy for the teams to start invest in the sport data analytics domain, instead of wasting huge amounts in non-value adding activities?*

First of all, wearable technology can be successfully applied in sports' domain, due to the fact that it is an improved and an already applied technology and as Howcroft (2016) notes in her research article, "Wearable-sensor based models were able to predict retrospective fall occurrence in individuals and outperform the predictive ability of models", since wearable sensors have such capabilities why they cannot be used to improve the performance of an athlete? Not only it can improve his/her performance but also it can prevent him/her from possible injuries. Moreover, this technology has been improved so much that its cost is not big and it has been available for amateurs through mobile phones and watches that can measure the heart rate, the distance someone walked or even provide the person with a training program per its characteristics (how many times per week he/she exercises, weight, height, nutrition habits). Thus, it can be easily observed that not only this technology can be applied in sports, for professionals and amateurs, but also it needs to be part of our life if we want to improve our health habits. This statement provides also the motivation of our study.

Research question 2: *Which are the critical requirements that must be integrated in a real world open, cloud, flexible, ecosystem of shared Sports Analytics?*

This research question is directly linked to the interpretation of SECI model and its integration with advanced Data Science and Big Data propositions. For each of the knowledge creation processes several Use Cases Scenarios for distributed shared Sports Analytics can be defined in relation to Sport Activities. A detailed

Davenport (2014) states "even relatively wealthy teams cannot afford large investments in technology, data, and analytical tools". One thing that needs to be mentioned in this part, is that data analysis is a science and it needs people with specific skills to make this science applicable in an industry and sport data analysis is a domain that needs both sport and data analysis experts, who will be able to combine their tacit knowledge and conclude to a profitable result for an organization. As correctly O'Donoghue and Holmes mention in their book "Data analysis applied to sports performance data include statistical analysis, temporal, analysis, artificial neural networks, simulation and data mining" so a combination of three sciences has to take place in order to make an effective use of sport data analysis. Taking under consideration the research of Davenport (2014) "It's impossible to equate winning records with more analytical capability, but the recent success of highly analytical teams—the Boston Red Sox and New England Patriots, the San Francisco Giants and 49ers, the Dallas Mavericks and

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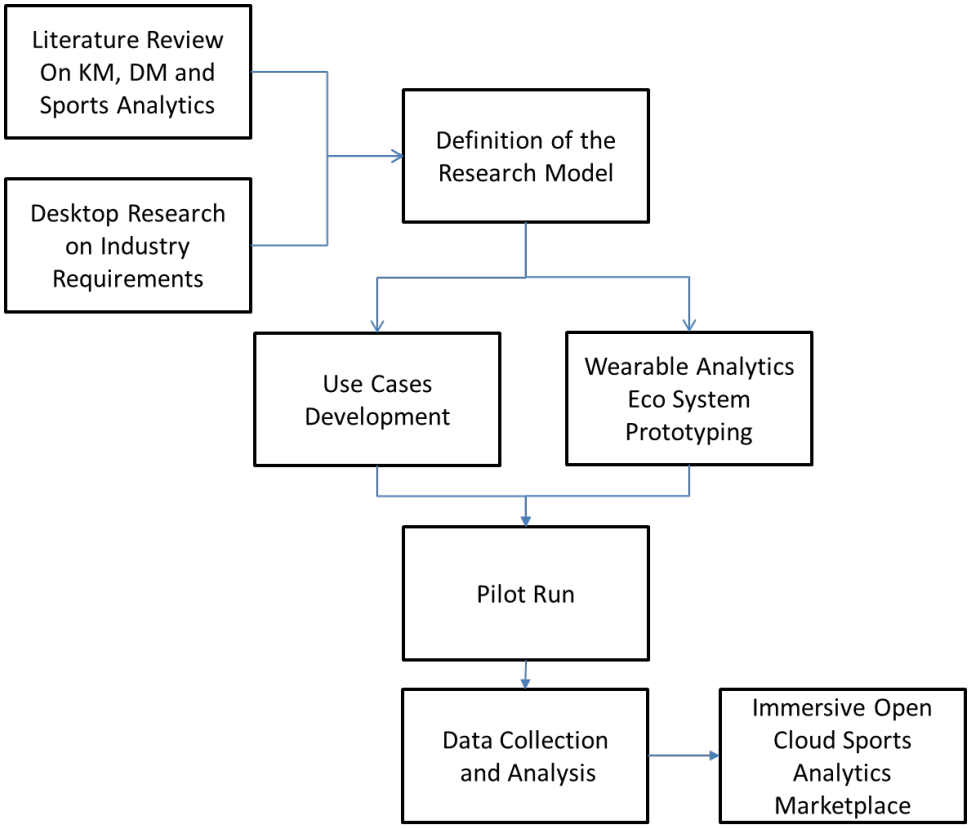
San Antonio Spurs—suggests an important role" it is easily observed that analytics can make a contribution in the sport domain and if the teams invest more on this, it is sure that they are going to improve their results not only in terms of players' performance but also in terms of money. They may need to increase the cost to hire data analysts but they will stop pay big contracts to players who have been hired without any research and they proved to be failures, and the number of injuries would be much smaller during a year using a sport doctor analyst. It is well known, that a science like mathematics can never fail.

Figure 2. The Research Methodology of our Study



In figure 2, we provide our ongoing research methodology with a target to launch the first prototype very shortly. The overall idea is that the integration of theory with detailed structured desktop research has resulted to our research model that investigates the integration of sports analytics in the provision of immersive learning scenarios for athletes and people who are practicing. In the current stage we are elaborating on the basic use cases for the prototype and we are considering a number of scenarios

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organized around SECI model. In the next section we provide the basic technical aspects and the main business requirements for the intended system.

4. A prototype architecture for an advanced Open Cloud Distributed Agora of Sports Analytics

The detailed study of literature and the intervention with several initiatives in the areas of Big Data, Analytics in Business and in Learning, have resulted to critical requirements for a new eco system of Sports Analytics towards the provision of personalized and community enhanced Learning Experiences. As discussed in previous section the basic idea is that Wearable technology will be used as the main enabled of a variety of Sports Big Data, and then a sophisticated system will analyze, transform and enable services capitalizing on the value of Analytics.

The best electronic component - tool that is mostly used in sport data analytics, is a little GPS tracking system, which has more abilities than a simple GPS. This device is used by the best teams which participate in the biggest leagues in the world such as Premier League, La Liga, NFL and NBA. It is inserted under the clothes of athletes and it is strongly held by a vest or base layer close to their chest or their back. Its size is approximately 30mm width and 90 mm height, and weight less than 50 grams, very small and light. As it is easily understood, we are talking about a revolutionary product and the peak of internet of things. This electronic component contains an accelerometer, GPS module, gyroscope, digital compass, and heart rate receiver. What all these features are capable of? Firstly, we must mention that the output of this device is in a computer and it cannot be reviewed by only one person, it provides results that a doctor, a psychologist, a coach or a data analyst must read. For example, by checking an athlete's heart rate for the entire game, it gives the possibility to the coaching staff to know not only the feelings of the athlete but also his/her level of tiring. With the accelerometer, an athlete's stats can be checked like speed and acceleration. And one of the most important functionalities of this device is that it can track an athlete's position in a field. With the compass, the gyroscope and GPS module the analysts can check which part of the field this player like to move more and in which period of the game. Moreover, they can check if, in situations with high pressure, he/she can still keep his position or if he/she is running for no reason when he/she feels angry. This electronic pod is most probably the best technological tool that is used in sport data analytics since it provides all the results that a coaching team would need to know about a player. Our analysis for the value contribution of our research is provided in the overview of an under construction prototype system for Immersive Learning Experiences.

5. Proposed Prototype

The proposed prototype of our research is based on an input device / collector consisted of a wearable bracelet which functions in the almost the same way as the device that has been described above. The difference is that this bracelet will be worn in the hand

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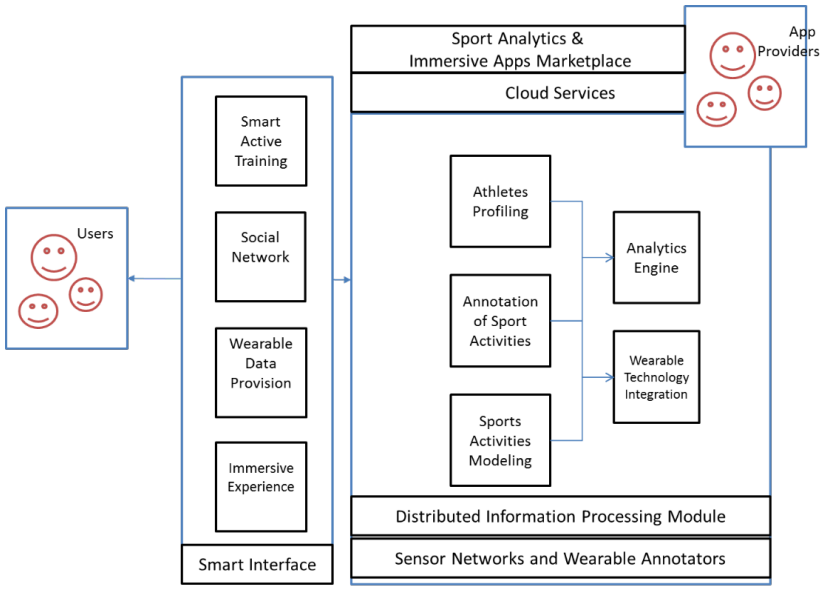
of the athlete so he will not have to carry a device on his chest or back which could cause an injury in a serious tackle. Also, this device is going to be much lighter and will be rubber band to avoid any possible injury of the athlete who wears the device or his opponents.

Regarding the technical part, this bracelet will be able to be calibrated by the preferences of each user so he/she can compare the results based on their personal singularities and not an average person's ones. In addition, the device will run with android software which means that the user will be able to completely modify the interface of the software used, the timers, the alarms or the sounds of the device.

Moreover, for the implementation of the first prototype some hardware and software will be needed except from the bracelet, a server and a database.

Figure 3. The Proposed Prototype Architecture and Requirements Model



In figure 3, we present the basic modules of the proposed Architecture with a 3-tier approach. The basic Systems are presented briefly below:

- ***The Smart Interface***: Provides the main modes for interaction with the systems from a variety of users, including athletes, nonprofessionals, and community groups. The basic components capable of calibrating are the Wearable Data Provider, the Social Network Collaborative Enhancer, the Immersive Experience Module and the Smart Active Training and Learning Wizard. Through these systems users can design a personalized Learning Experience

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- ***The Sports Analytics Ecosystem***: It is the main component of the architecture and has four basic modules. The Sensor Networks and Wearable Annotator that is attaching a number of metadata to all the Wearable data based on specific considerations of Sports Activities and Performance from different scientific perspectives. The Distributed Information Processing module that enables the integration of Big Data from users community. The main module is related to the Analytical Capability of the system. The athletes and users profiling module together with the Annotator of Sport Activities and the Modeler of Sports Activities and Use Scenarios provide the parameterization of the system. The Analytics Engine permits a variety of Data Mining Methods and enables advanced decision making. The Wearable Technology Integrator is in fact an Immersive component that allows the evolution of different wearable technologies and sensors. At the top of this architecture that sets the business requirements systems, we have the design of various cloud services and a marketplace of wearable analytics applications. In fact our prototype serves as an agora of advanced sports analytics services and applications that serve as value integrators.

6. Conclusion

It is fully observable that wearable technology can have a very important role in the sports domain and maybe in the next years, big sport organizations will focus more on this science. In this research paper is presented, an overview of this technology, the way it can affect the decision making process of an organization and how it can improve the management of knowledge in sport teams in order to produce better and more profitable results. It needs to be said, that this is only the beginning, the first attempt to enhance wearable technology in sports but there is a lot of time and space for future research to make new things and to improve new technologies. A possible scenario – idea for future research would be, instead of making the athlete to carry a device on him, it would be better to enhance this technology in the fabric, this would be revolutionary. To sum up, big sport organizations must implement technologies like this if they want to increase their efficiency and amateur athletes should follow such technological achievements in order to protect themselves, keep track of their heart condition and have a more effective and healthy exercise.

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