Internet of Things in the Game of Basketball

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Abstract. In this paper, a list of IoT technologies are introduced that are used to help basketball players, coaches and fans get to know more about the game of basketball. Several IoT tools exist to improve player and team development as well as fan experience. IoT goes hand-in-hand with basketball analytics, which has become a central part of basketball philosophy. Three technologies are explained in detail in this paper, each focusing on different areas of the game. Wilson X is strictly a shooting trainer tool, HomeCourt offers shooting, dribbling and agility drills, while the VR system is focusing on basketball tactics. These three technologies are compared in detail on eight different criteria including accuracy, comfort, user-friendliness, cross platform, price, lifetime, memory, and room to improve. By examining these tools and their features, we gain a better understanding about the power and limits of IoT within the field of sports.

Keywords: Internet of things · Basketball · Sensors · Player development · Team development · Analytics · Camera · Virtual reality

1 Introduction

Technology has come a long way since the Turing-machine. The Internet of Things (IoT) is all around us, it surrounds our existence. From smart fridges to smart cars and smart watches, the list of smart devices is endless. These devices make life easier and more efficient for people. This system of devices also connects people all around the globe and it has become one of the most important – if not the most important – network in our world. There are innovations made every day that help the Internet of Things to expand its scope. The world of sports is just one branch on the tree of IoT.

Since the ancient Olympic Games, generations have witnessed the evolution of different sports, old ones were altered, and new ones were created. In the last few years, IoT has been integrated into sports (see Fig. 1). Although, there are plenty of challenges associated with IoT in sports, such as generalized approach, energy consumption, fan interaction, privacy, security and the large amount of data produced [11], many types of sports have benefitted from using devices for player and team development. One of these sports is basketball, which has grown into a global entertainment industry.

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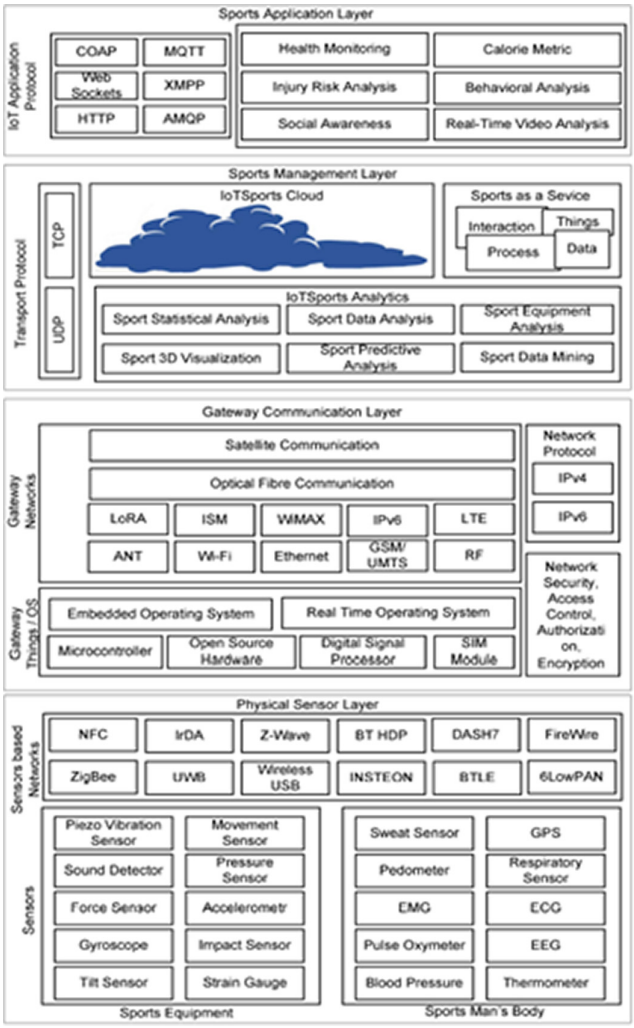

Fig. 1. - IoT sport architecture [2]

When basketball first became a game, there was no three-point line. Every field goal counted as two points. The game did not adapt the three-pointer until 1979 [1]. In recent years, the three-pointer king Stephen Curry has revolutionized the game by pulling up from 30+ feet away from the basket and taking more 3-point shots than anyone ever before. With this game changing new style, basketball analytics and technology have become a focal point of the game. Coaches have changed their game plans and now encourage their players to take more threes than ever before because advanced analytics show that 3-point shots are one of the best ones to take. The growth of IoT and the development of technology have changed the philosophy of the game. The Internet of Things serves as a bridge between basketball and basketball analytics.

Starting from youth basketball, all the way to the professionals in the National Basketball Association (NBA) and in Europe, IoT presents a great set of tools to develop players and analyze teams. Coaches know how to reach the full potential of their teams and fans can experience the game in ways that were not possible before. The game of basketball has grown into a meticulous science and a great entertainment industry. As technology develops, so does the science behind the game. People often forget or just simply not aware of the fact that the mental part of the game is a significant component to success. In basketball, you need to have awareness to see what is going on around you on the court. It is crucial that players are mentally prepared in order to outsmart the competition. Today, load-management is playing an increasing role in NBA circles, which means that players take games off to save their bodies. What if they could play a game on a mental level while resting their bodies?

The purpose of this paper is to investigate several IoT technologies present in the world of basketball including sensor-based, camera-based and Virtual Reality-based systems. In this paper, we take a look at several technologies that are closely related to what the Internet of Things represent – global connections and precise measurements. Furthermore, I have tested one video-based system called HomeCourt and reflected on my experience with the application. Players need to gain confidence from the things they do well on the court, and they need to be aware of their weaknesses in order to become better in those areas. IoT in the sport world helps players to do just that by analyzing motion and creating data, therefore, it helps sports become more sophisticated and competitive.

The rest of this paper is divided into six units. Section 2 introduces two related works. In Sect. 3, a sensor-based tracking system is examined, while Sect. 4 focuses on a camera based system and Sect. 5 talks about virtual reality approaches. Section 6 compares these three areas and Sect. 7 contains the conclusion as well as future work.

2 Related Work

2.1 IoT as a Shooting Aid

Antunes' design science research [3] focuses on the use of IoT to improve the shooting motion. This research introduces IoT Sport and breaks down the motion of a perfect shot. It is crucial to understand the proper motion in order to build a device that recognizes it. A list of existing basketball related IoT technologies are introduced as well as new artifacts are proposed. These artifacts are results of a series of interviews with players and coaches. This collaboration gives inside information for people who understand technology but does not know the game of basketball and vice versa. As a result, innovative ideas were formed for future work, such as an audio instruction system that would help the shooter correct the motion during practice. This dissertation is a great example of how the world of basketball and technology needs to work side-by-side in order to help players work on their game and therefore enrich the game with even more skilled players.

2.2 Three Men Tracker

At a European university, a prototype has been created that can identify basketball plays using sensors [4]. The system is constructed of sensors on players, three receptors placed around the court and optionally one more sensor in the ball. However, the study argues that it is possible to locate the basketball if we know which player has the ball, so the sensor in the ball is negligible. The system uses a three-player attention approach, meaning that even though there are five players on the court, only three of them are heavily involved in the given basketball play. This system is able to recognize basketball plays, such as pick-and-roll, and able to return valuable data to the coaching staff to understand the strengths and weaknesses of their team. On the first test, the proposed system achieved nearly 98% accuracy. I picked this work to survey because the system is not only smart and accurate; it also considers the fact that technology is expensive and offers a more affordable solution than the leading companies do (see Fig. 2).

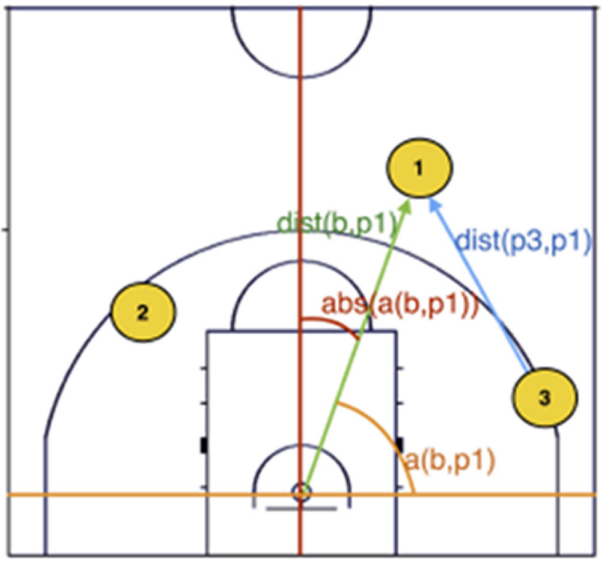

Fig. 2. 4 features from sensor system [4] player 1 distance from basket, distance between player 1 and 3; angle and absolute angle between player 1 and basket

3 Sensor Based Shot Tracker

3.1 Wilson X

Wilson X is a system that involves a basketball with built-in sensor in it and an application. The sensor connects to the smartphone and the data is displayed through the application. This technology was developed to help players improve their shots by measuring made and missed attempts along with the speed and arch of the shot.

The great thing about Wilson X is that the ball feels like a normal basketball. The sensor does not add extra weight to the product and the material of the ball has a great grip, it is not slippery (see Fig. 3).

Fig. 3. - Wilson X basketball and its application [6]

This leads to the next big advantage of Wilson X, which is instant feedback. For example, a player may be shooting, and the coach sees what areas to focus on. This feature allows a player to correct their mistakes as they are shooting, instead of going home and having to watch the recorded video all over again to analyze.

The sensor lasts for a long time - 100,000 shots, which gives more than 300 shots per day for an entire year [6] - but the battery of the sensor cannot be recharged. This means that after the battery dies, it becomes a regular basketball. Longevity is the main area in which Wilson X must improve. Perhaps magnetic charging could be an option. If the ball could be placed on a charging plate – just like newer smartphones – battery life would no longer be a problem.

The other area that needs improvement is the memory inside the ball. As opposed to a smart watch that can record the data from a workout and later synchronize it with the smartphone, the Wilson X basketball cannot store data. The ball needs to be able to connect to the phone throughout the shooting practice in order to record data. This somewhat limits the conditions in which the player can train. It would be beneficial to add a minimal memory to the sensor just as a backup. For example, if the smartphone dies, the new training data gets lost.

The third area of limitation is range. This technology is limited to only measure shots taken 7 feet or further from a regular 10 feet tall rim [6]. To make it realistic and game-like, Wilson X should be usable from any distance and perhaps should recognize dunk attempts - zero range.

4 Camera Driven Application

4.1 HomeCourt

HomeCourt, an iOS application has quickly gained popularity in the past few years in the sports world. This application helps to improve players' jump shots and recommend workout trainings to them based on their needs. As opposed to Wilson X that has a built-in sensor, this application does not require sensors in the basketball or on the player. The only device needed is a iOS product- an iPhone or iPad - which records the workout. Among many other features, the app can count the streak of made shots (see Fig. 4), and calculates the shooting percentage of each sector on the court.

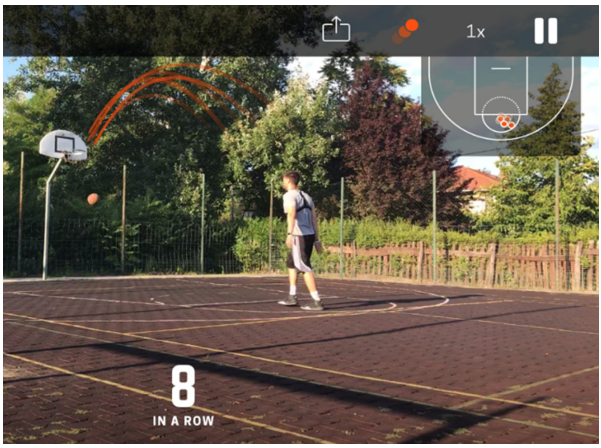

Fig. 4. - Outdoors testing

In order to make the app authentic, Apple worked alongside Steve Nash, probably the most famous and accomplished Canadian basketball player, during the development and promotion process of the application. Furthermore, the NBA and its players have collaborated with, and invested in HomeCourt [8]. The users of the app can do shooting workouts named after and presented by NBA-sharp-shooter Joe Harris and other NBA stars. The app also offers dribbling and agility workouts. The free version allows the player to take one thousand shots a month - enough for people who just shoot the ball as a hobby - and some basic drills are included.

The main reason why this app is so successful is the lack of a big, uncomfortable sensor. With no sensor, players are able to keep their natural shooting motion and stay in normal circumstances throughout the workout. This is an essential part of integrating IoT into sports: the technology cannot affect the athlete's performance. HomeCourt achieves this goal.

Another advantage of this system is its simplicity. In today's world, most people have their phones on them at all times, which come in handy for HomeCourt. Because the player does not need anything else besides an Apple device, the use of this app

becomes highly convenient. For a shooting exercise, the device automatically recognizes the basketball hoop, and prompts an error if it was not found - similar to face recognition in smartphones. The app also shows virtual basketball lines. If the app does not find automatically the actual basketball lines on the court, then it is the player's task to align the virtual lines with the actual lines of the court.

This leads us to the first problem with the app. Because at times the user has to align the virtual lines with the actual lines of the court, there is some room for error with accuracy. Because the app defines the different sectors based on the basketball lines, a precise alignment is crucial. If the alignment is faulty, it may result faulty representation of data - incorrect shooting percentage and accuracy, for example.

Another problem is the size of the screen. For dribbling workouts (see Fig. 5), the routine changes from the shooting drills. Instead of the phone cameras facing the player, now the screen is placed to see the player, who is looking at the screen. The app then recognizes the player and creates target points on the screen for the player to touch. The small screen can make it hard for the player to see the target. For this drill, it is better to use an iPad instead of an iPhone, however not all iPhone owners can also afford an iPad. Perhaps it would be a good idea to offer a cheap monitor that somehow connects to the iPhone, although it makes it more complicated to use the software.

Fig. 5. - Dribbling challenge

After testing this app both indoors and outdoors (see Fig. 4, 5 & 7), it became obvious that the lighting can cause trouble at times. In some cases, the camera recognized the attempt but did not count the shots there were made. As the first screenshot (see Fig. 6) shows, HomeCourt gives the location of every shot taken and missed during the workout. Designated symbols mark makes and misses. On the second screenshot (see Fig. 8), HomeCourt summarizes the total shooting percentages of the day per sectors.

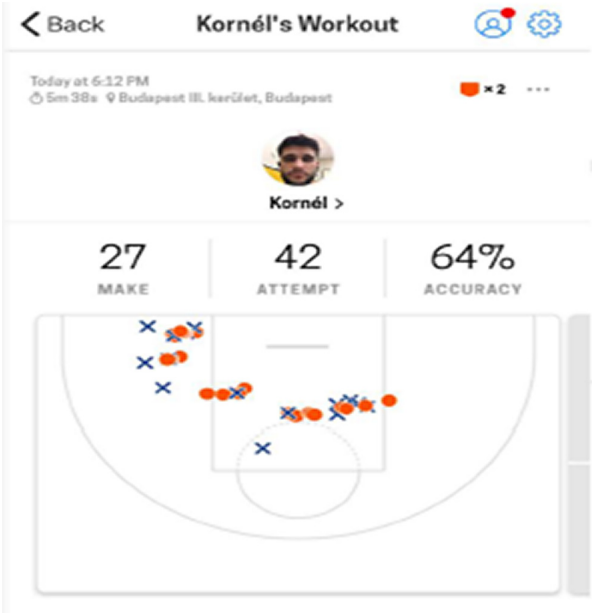

Fig. 6. - HomeCourt shot chart

After the workout, the player can play back his/her workout in the app. This is an important tool for a player who can see the movement as a whole instead of just plain evaluation of the workout in numbers. There are specific highlight types that the app offers, such as how many shots were made in a row or makes/attempt (see Figs. 4 & 7). The video also gives the option to display an orange tracking line feature in the video that shows the path of the ball (see Fig. 4), making it easy to analyze the arch and angle of the shot.

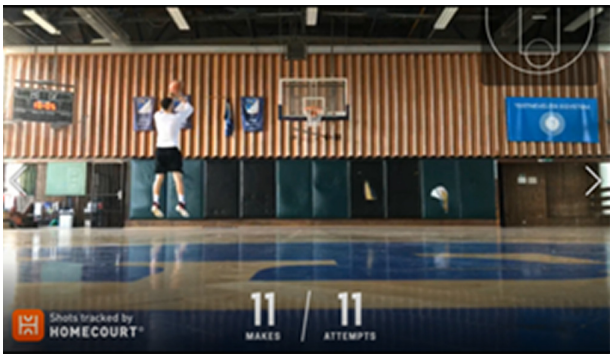

Fig. 7. - Indoors testing

The app also allows users to watch other players around the globe doing their own workouts. This feature represents perfectly the idea of the Internet of Things because it enables people to be connected through their devices regardless of the distance between them and share data with each other. Players can share workout summaries and track each other's progress, much like on a social media site. HomeCourt brings the basketball community closer all over the globe.

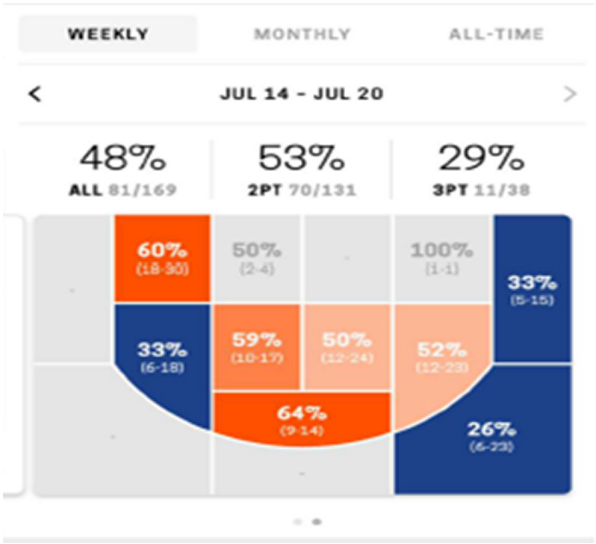

Fig. 8. - Shooting zones display

5 Virtual Reality

Virtual reality (VR) is a great aid for the game of basketball. Players, coaches and even fans benefit from the technology of VR. In the NBA, virtual reality enhances fan experience and optimizes the players' performance. Fans that are not able to afford courtside seats are now able to get the experience from their own couch, thanks to virtual reality, and players are now able to rest their bodies by doing mental training with VR. From the fans' perspective, the experience of a basketball game is much more hands-on. Fans can feel more connected to players by buying special jerseys with sensor tags to unlock exclusive highlight videos of their favorite players [10]. VR also enables kids to learn how to play basketball in schools where there is no option to play outside because of the weather or there is not enough space for a basketball court [12].

5.1 Magic Leap

Magic Leap created the Magic Leap One VR system that is composed of a headset, called Lightwear, a controller and a minicomputer called Lightpack. Furthermore, Magic Leap has begun a partnership with the NBA that enables the user of the system to

watch live games from home. This device uses spatial computing and augmented reality, which enables the user to watch multiple games or highlights simultaneously [9]. This technology helps the game to become global. There are only twenty-nine active NBA arenas in the world (Clippers and Lakers share an arena in Los Angeles), yet people all over the globe use virtual reality to feel like they are at the game (see Fig. 9).

Fig. 9. - Magic Leap headset [9]

5.2 Tactic Training

Four scholars from National Cheng Kung University, Taiwan have created a prototype of a trainer system to help players learn basketball tactics. The system involves two devices: "a tablet-based digital tactic board (2D BTB)" [5] and a VR system that allows a 3D experience. The idea behind this technology is that the coach – or someone else – draws up a basketball play in 2D on a tablet, this play is converted into a 3D content, and the player can watch the action in 3D with a VR device. In other words, the coach and players do not need to be together to practice the tactics. The unique part of this technology is that the system interprets simple drawings and creates an animated environment for the player. It is a great idea because coaches and players need to be on the same page in order to be successful.

The system offers two perspectives of viewing the play: first-person perspective (1PP) and third-person perspective (3PP). In 1PP, the player sees what he would see if he was running the play. The player is surrounded with four other players. This perspective allows seeing the play from one position. In the 3PP version, the user is viewing the events of the play from the outside. This perspective allows for an overall view, which gives a better picture of the overall flow and rhythm of the plays (see Fig. 10).

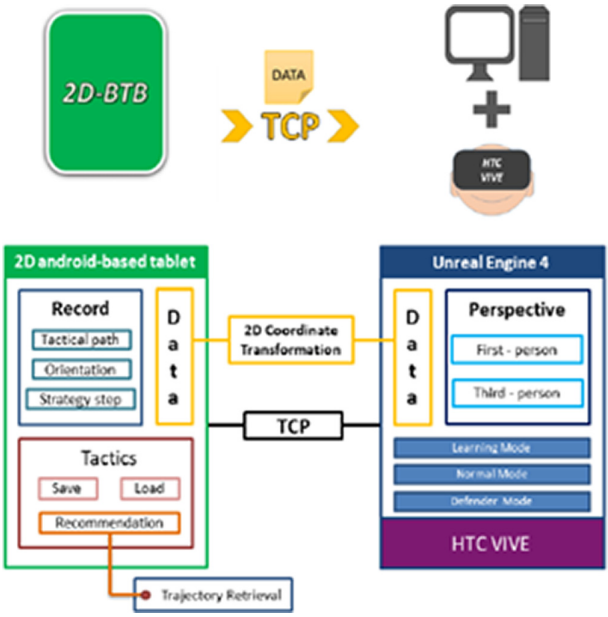

Fig. 10. - Converting 2D drawings into 3D plays [5]

The three kinds of training modes include normal mode, learning mode and defender mode. In normal mode, the play runs regardless which direction the player looks. In learning mode, the player must look at the right direction (which is the direction of the next step in the play from his perspective) in order to the animation to continue. Thirdly, in defender mode, the system adds defenders to the animation, giving the player a real in-game environment to practice the tactics.

The scholars asked 60 subjects to test the system, creating two groups of 30 people. At the end of the test, each player had to fill out a questionnaire to give feedback. The conclusion was that the 3D version makes it easier and more realistic to prepare for the game than looking at a 2D drawing because the player can be "in the game" virtually. However, there are areas such as user-interface that needs to develop before this technology becomes a big hit.

5.3 Virtual Shooting

New technologies are being developed to help players shoot using VR sets. In Covaci's work, the VR system creates a virtual environment to teach the user how to shoot a free throw [7]. This is a perfect prototype for a player who needs to rest, but wants to get in a shooting workout. Players can do that without ever leaving their homes. Just like the first related work above, this technology could use audio feedback to correct the motion of the shooter. With time, the graphics, the accuracy and the overall experience of VR systems will improve.

6 Comparison

In this paper, we analyzed three technological areas within the framework of the Internet of Things: sensor based tracking; camera based tracking and virtual reality. All three of these areas are rapidly improving. Sensors are key components of the IoT world; data is collected by measurement made with sensors. Cameras are the driving force of improvement in mobile computing thanks to social media; the quality of photos and videos are rapidly improving. Moreover, the new reality is virtual reality. In other words, all three of these technologies are unique and very valuable in today's world.

In sports, several points need to be considered when choosing the right device. In this section, these points are dissected to compare the pros and the cons of Wilson X, HomeCourt and VR shooting. Table 1 compares these three technologies in eight categories and briefly explain their main parameters in each area.

Table 1. Comparing the three technologies based on eight common parameters

Categories	Wilson X	HomeCourt	Virtual Reality
Accuracy	Good if 7+feet	Less accurate	Own accuracy
Comfort	Uneven ball	Comfortable	Improving
User friendliness	Easy to use	Good interface	Most potential
Cross platform	iOS & Android	Apple only	N/A
Price	Hardware cost	Free or paid	Expensive
Lifetime	100k shots	Smartphone	Improving
Memory	None in ball	Cloud	Live broadcast
Room to improve	Sensor size	Better cameras	Most potential

6.1 Accuracy

Accuracy is a major aspect of sport data to consider. A sensor-based tracker discussed in this paper, Wilson X, is highly accurate. Although, it has range limitations (7+ feet), the measurements are properly converted into data. The same is not true for camera-based technology. With camera, it is hard to analyze the input as accurately as a sensor can. External factors, such as wind, and foreign objects can cause interruptions in the recording. Virtual reality creates its own world, which prevents real measure of accuracy. The user "lives" in a virtual reality that has its own measuring scale.

6.2 Comfort

The next area that must be considered is the comfort factor. Because athletic movement cannot be limited while measuring, the goal is to get accurate data without affecting the movement of the player. Sensors will give data that are more accurate but will also affect the player to some degree, depending on the size and placement of the sensor. On the other hand, a camera will not be as accurate as a sensor because of reasons mentioned in Sect. 6.1 above, but the player will not be bothered during the workout.

Therefore, accuracy and comfort are contradictory. As opposed to accuracy, where Wilson X performed much better than HomeCourt, the later one is more comfortable because the player is free of restricting devices. Wilson X loses the feel of a true basketball, even though the sensor is very small. Virtual reality has its limits of comfort. Perhaps one day it will be available in the form of contact lens, but until then, we must accept the funky-looking goggles.

6.3 User Friendliness

Wilson X, HomeCourt and Covaci's work [7] all use applications. User friendliness may be the single most important feature to influence and win over customers. VR has the most potential in this area for obvious reasons. Literally, anything can be created in virtual reality so the sky is the limit. HomeCourt is designed for Apple's iOS, which is knows for great user experience. Wilson X has a good interface as well; it is just simply a hard task to compete with Apple in this area.

6.4 Cross Platform

In mobile computing, HomeCourt is the obvious loser of the cross platform aspect as it only runs to Apple devices. Wilson X can be used on both Android and iOS systems. Once again, VR stands alone as it has its own environment.

6.5 Price

At this point, VR is the most expensive technology out of the three. You can use HomeCourt for free – limited number of shots and access of content – or you can pay for unlimited use and access. Purchasing Wilson X cost money – here you pay mainly for a hardware (basketball) and get the software with it to use, as opposed to HomeCourt, where you pay specifically for the software.

6.6 Lifetime

Only Wilson X has a limited lifetime because of the hardware component – battery in the basketball. Wilson is currently working on the second version of their ball, which supposedly will have longer lifetime or an option to charge. HomeCourt gets better as cameras improve and the software improvements and maintenance helps the application to stay relevant. Virtual reality is only in the beginning phase of what's speculated as the future of computing.

6.7 Memory

Memory-wise, Wilson X does not have internal memory built into the ball, which can lead to loss of data. Cloud computing is becoming the new standard of storage; HomeCourt takes full advantage of this by storing data on the cloud. This consumes lots of memory space because of the video content. Wilson X does not contain video, whereas Magic Leap and other virtual reality devices can transmit live broadcast.

6.8 Room to Improve

All three technologies compared above and all athletes have room to improve. In this sense, sports and IoT are similar: neither is ever perfected. It is perfection why people in both areas strive daily to make improvements. These two fields not only can work together to strive for perfection but can also help each other along the way.

7 Conclusion and Future Work

Basketball is a complex game and has evolved tremendously throughout the years. Just like the three-point shot changed how basketball has been played throughout the last few years, IoT is changing in the game today. New plays, tactics, systems are being invented and applied constantly based on new data. IoT connects basketball personnel with scientists, allowing them to understand each other and work together to improve the game.

In this paper, we have introduced and compared three technologies: sensor- and camera-based IoT systems as well as virtual reality. Sensor-based technologies, such as Wilson X delivers accurate information, however the sensor can have negative impact on the performance due to its size. HomeCourt was the main camera-based app that we focused on. Due to the lack of sensors, it allows athletes to keep their natural range of movement, however external factors, such as wind, may affect the accuracy of the data collected. Virtual reality has the most potential out of the three technologies. It may become the most user-friendly interface out of the three one day and there is no limit on what can be accomplished with VR.

Perhaps the perfect solution to track basketball movement lies in combining these technologies in some sort of fashion. By pairing two of these three technologies, we can avoid some of the detriment that one of them has and emphasize only the good parameters of each technology.

My future work lies in the field of basketball analytics. It is fascinating to analyze each segment of the game of basketball. By collecting data via IoT, priceless information can be extracted which can point to the future direction of the game.

IoT has already had a tremendous impact on the game of basketball and basketball analytics. Thanks to IoT, advanced stats can be extracted from games that point out the areas to improve from an individual standpoint to a team perspective. Basketball analytics has developed into a game-changer tool; whoever has better analytics most likely has the better chance to win games. IoT represents the bridge between the game of basketball and science, or, in other words, it is the channel of communication between players and scientists.

References

1. The History of the 3-Pointer. (n.d.). https://www.usab.com/youth/news/2011/06/the-history-of-the-3-pointer.aspx. Accessed 22 May 2019
2. Ray, P.P.: Generic Internet of Things architecture for smart sports. In: 2015 International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT), Kumaracoil, pp. 405–410 (2015)

3. Antunes: Use of IoT technologies to improve shooting performance in basketball (Unpublished doctoral dissertation). NOVA Information Management School (2018)
4. Sangüesa, A.A., Moeslund, T.B., Bahnsen, C.H., Iglesias, R.B.: Identifying basketball plays from sensor data; towards a low-cost automatic extraction of advanced statistics. In: 2017 IEEE International Conference on Data Mining Workshops (ICDMW), New Orleans, LA, pp. 894–901 (2017)
5. Tsai, W.-L., et al.: Train in virtual court: basketball tactic training via virtual reality. In: Proceedings of the 2017 ACM Workshop on Multimedia-Based Educational and Knowledge Technologies for Personalized and Social Online Training, pp. 3–10 (2017)
6. Quin, C.: Hands-on Test: Wilson X Connected Basketball. RSS, 17 May 2017. eandt.theiet.org/content/articles/2017/05/hands-on-test-wilson-x-connected-basketball/
7. Covaci, A., Postelnicu, C.-C., Panfir, A.N., Talaba, D.: A virtual reality simulator for basketball free-throw skills development. In: Camarinha-Matos, Luis M., Shahamatnia, E., Nunes, G. (eds.) DoCEIS 2012. IAICT, vol. 372, pp. 105–112. Springer, Heidelberg (2012). https://doi.org/10.1007/978-3-642-28255-3_12
8. NEX Team Inc.: https://www.homecourt.ai/about. Accessed 6 June 2020
9. The new NBA App on Magic Leap is a game changer (2019). www.magicleap.com/en-us/news/product-updates/nba-app-launch. Accessed 19 June 2019
10. Behr, O.: Fashion 4.0 – digital innovation in the fashion industry. J. Technol. Innov. Manage. **2**(1), 1–9 (2018)
11. Ray, P.P.: Internet of Things for sports (IoTSport): an architectural framework for sports and recreational activity[Scholarly project]. In: Academia.edu (2015)
12. Yao, H.-P., Liu, Y.-Z., Han, C.-S.: Application expectation of virtual reality in basketball teaching. Procedia Eng. **29**(C), 4287–4291 (2012)