International Journal of Advanced Culture Technology Vol.6 No.3 216-225 (2018)
DOI https://doi.org /10.17703//IJACT2018.6.3.216

IJACT 18-9-25

Automatic Offside Judgement System based on Position Information in a Soccer Game

Taejun Park, Jinho Park*

Department of Global Media, Soongsil University, Korea

go04go05@naver.com, c2alpha@ssu.ac.kr*

Abstract

Strangely enough, there has not been much effort in applying the latest technologies to help referees make accurate calls in a soccer game compared to other sports. Modern soccer tries to apply VAR (Video Assistant Referee) technology to correct inaccurate calls such as an offside, but this is being put off due to the fact that real time decision-making cannot be carried out by using this technology. This has led this study to decide developing a device that will accurately identify offsides on a real time basis using various latest sensors and related technologies. This device will aid referees in calling offsides in a soccer match.

Keywords*: Beacon, Bluno, Bluetooth 4.0 BLE, Heron's Formula, Offside, RSSI.*

1. Introduction

Recently, various sports leagues have adopted latest technologies to aid referees, and complaints from bad calls have been decreasing as a result. For example, a system called VAR (Video Assistant Referee) is currently being used in tennis, baseball, and other sports. VAR uses high speed cameras, letting the referees to see a certain moment in a very slow speed and helping them make correct judgements. However, major drawback of this technology is that it disrupts the flow of the game. Video based technologies inevitably forces the referees to stop the game in order to review the recorded material. This is why they are not suitable in soccer, where every second is important in a limited amount of game time. This is especially important in a soccer match, where even a small change in a game flow can lead to a goal and victory, and therefore the VAR degrades the quality of the game, increasing the discontent of fans and players alike. In fact, in the 2018 FIFA World Cup Russia, the VAR system has shown more negative sides than positive ones, and many experts view VAR with much skepticism.

As it can be seen, real time calls and decision making are required in a soccer match, and this is why VAR is not gaining popularity even though it can make accurate calls. So in order to reduce dependency on VAR and facilitate game management, there is a need to accurately discern an offside, which is one of the most

Manuscript received: August 6, 2018 / revised: August 24, 2018 / Accepted: August 30, 2018
Corresponding Author: c2alpha@ssu.ac.kr
Tel:+82-2-828-7040
Department of Global Media, Soongsil University, Seoul, Korea

important violations in the game, in real time. Therefore, to meet these expectations for a real time decision making, this study will focus on developing a device for detecting offsides in a soccer match.

2. Backgrounds

2.1 General terms

An offside occurs when a player in offense is in front of the ball in the opponents' half of the pitch and there are less than two opponents between that player and the goal line. When this player receives a pass from his or her teammates from behind, a violation occurs. An offside originally referred to the area in which the violation occurred. but it is generally known as an offside violation. The exception of an offside violation is when a player is between the half line and his team side's end line, and when he receives the ball from goal kicks, corner kicks, throw-ins, and directly from referees[1]. Figure 1 shows the case of an offside.

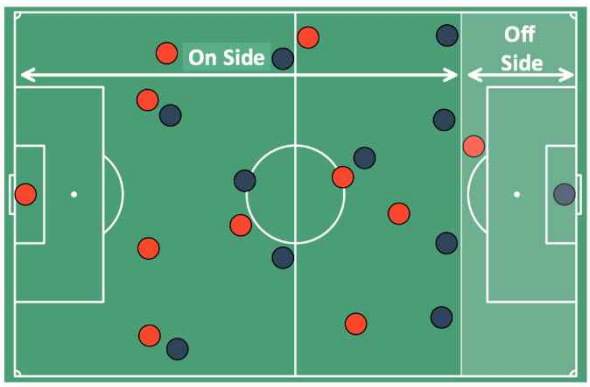

Figure 1. Offside

2.2 Analysis on the failure of adopting advanced technology

Because offside violation has various number of vases, it is not possible to evaluate each one of them with current technology levels. There are some factors one should know in order to discern an offside, which are 1) the moment a team's player touches the ball, 2) location of each player, 3) a player who last touched the ball. The only way to analyze all of these factors is to attach sensors in every part of the players' body, which is very inefficient. There have been many papers [2] and theories in the past regarding the making of automatic sensors, but no actual research has been conducted so far. This is because as mentioned above, technology cannot handle all of the number of cases for an offside. This paper will appropriately utilize both the referee's judgement and scientific technology, as pursuing technological perfection will not lead to concrete results. The conclusion is that if we can single out core situations from all the number of cases for an offside and judge them with technology, it will be possible to make a device that will reduce the number of bad calls.

The drawback of using VAR is that its decision making is not carried out in real time. In order to make judgements in real time, specific electronic technology is needed to make referees aware of a violation the moment it occurs. For example, one of the technologies that is applied in modern soccer to help real time judgement is the Hawk Eye system. In a Hawk Eye system, 14 high speed cameras are installed near the goal post, and using ball tracking algorithms, it is able to accurately measure even within 5mm around the post. Using this technology, the information regarding whether or not a goal has been made is sent to the referee via special devices within half a second. Because the Hawk Eye makes accurate decisions in a very short span of time, there are almost no controversy surrounding this technology, and most people accept this in a positive

manner.

However, while there is a technology for deciphering the most important part of the game, which is a goal, there is no technology for deciphering perhaps the next most important aspect, which is an offside violation, in real time. Offside is one of the most common violations in a soccer game, and it is the one that incurs the biggest number of bad calls. The current method of deciphering an offside is by assistant referees each at the opposite side of the field, who visually makes judgements and then deliver to the head referee. Because this method relies on the assistant referees' visual judgements, it is not easy to make correct judgements every time in a game that is very dynamic in nature. In fact, during the 2002 World Cup, a total of 337 offside violations have occurred in 64 matches. 26.2% of these turned out to be bad calls [3,4]. In order to correct these bad calls in real time, this study aims to research and develop technology that will help real time offside judgements.

3. Methods

3.1 Measuring devices

This study uses the Bluetooth-based technology called Beacon, which was developed by Google. Beacon supports Bluetooth 4.0 BLE, and the advantage of BLE is that multiple pairing is possible. The device that will be paired with Beacon is Bluno or SmartPhone. Bluno is an Arduino product that supports Bluetooth 4.0, and can substitute smartphones that supports Bluetooth 4.0. It will calculate Beacon's location using RSSI signal values created by the connection between Beacon and the receiving device.

Figure 2. Beacon and Bluno

3.2 Procedure

This paper aims to develop a device that will figure out a player's location in real time, and if that player is in an offside location, it will continuously send signals that will make the referee's watch vibrate and help the referee make correct offside calls. The moment of an offside is decided by the head referee, and if he is receiving signals at that moment, that decision is valid. Figure 3 visualizes the process mentioned above.

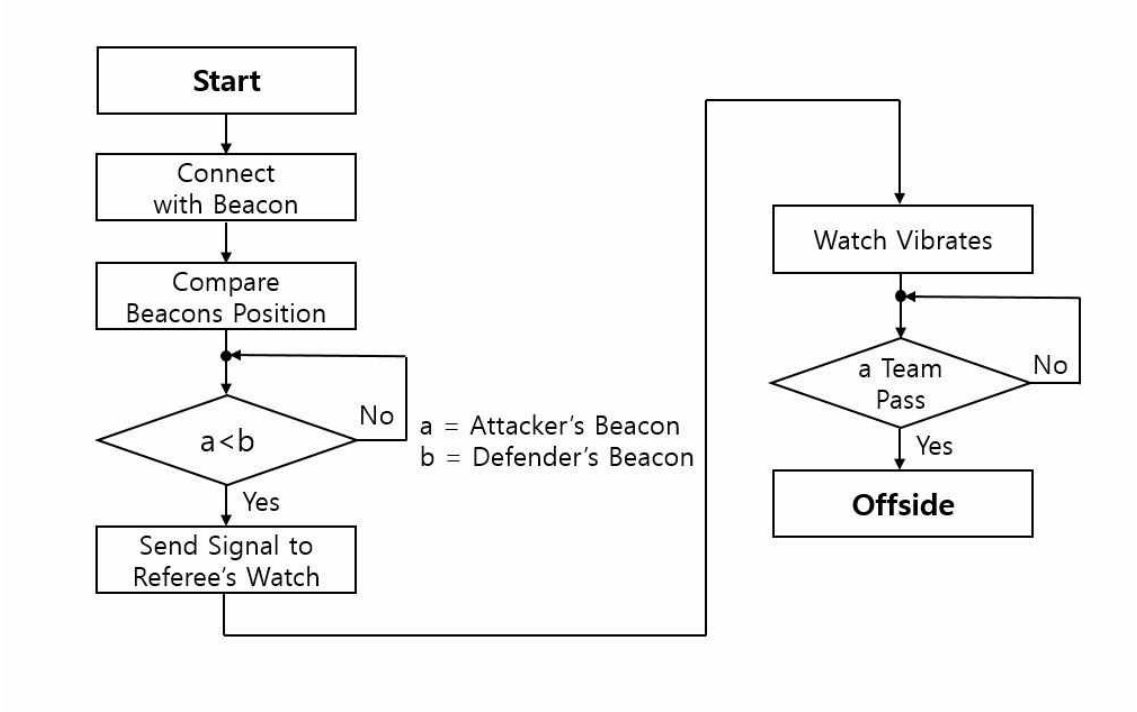

Figure 3. Flowchart of the whole process

The core role of the offside detecting device is to communicate with beacons that are attached to each player, tracking and comparing their locations in real time and send this information to the head referee. Table 1 shows the operation process of the offside detecting device.

Table 1. Device for Operation process of the offside

Measuring device	Beacon , Bluno, 2 of each or 2 SmartPhones
1	Paring each beacon with receivers
2	Measuring RSSI values
3	Designating location of Bluno or SmartPhone
4	Detecting offsides in each respective location
5	Transmitting signal in case of an offside position

3.3 Paring each beacon with receivers

Each beacon will be attached to the players, and their location will be tracked via beacons and receivers. First, the beacon and the receiver should be paired and ready for real time communication. The advantage is that Bluetooth 4.0 and later versions support BLE, which allows multiple devices to be paired at once, not just one-on-one paring. Collecting information of all the beacons in real time is possible using this advantage.

3.4 Measuring RSSI values

The beacon transmits information such as its own ID, number of majors, number of minors, and tx power information to the paired device. Out of these, tx power values are used to figure out how close the receiver is

to the beacon. Figure 4 shows the structure of data packet used by the beacon[5,6]. This study calculated the distance between the beacon and the receiver by using an application (Figure 5) that receives RSSI values using the most basic distance measuring formula by Android Beacon Library provided by Radius Networks. This RSSI value is used later on in a formula that compares the players' locations.

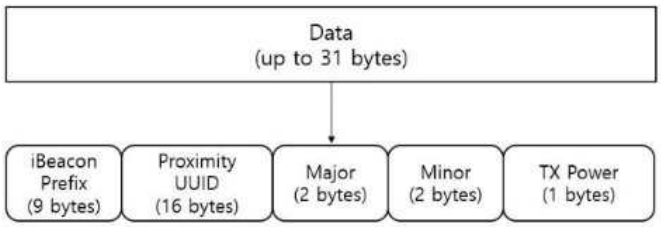

Figure 4. Beacon data Packet

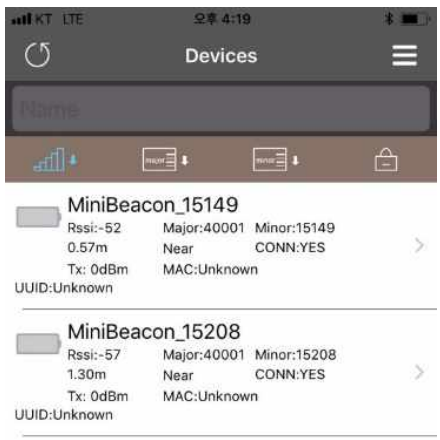

Figure 5. Smartphone screen showing connection with Beacon

3.5 Designating location of Bluno or SmartPhone receivers

There are many ways to track the location of a beacon by using a beacon and receiver, such as calculating the coordinates by using triangulation method via three receivers. However, because the beacon itself is a technology that is interfered by nearby electronic waves, it helps to minimize the number of receivers and complexity of formulas for figuring out locations. Thereby this study tries to calculate the location of a player wearing a beacon by using two receivers. As it is shown in Figure 6, an offside will be detected by symmetrically placing each receivers in the defending side's corners, taking the shortest straight distance between the two devices as the base line and calculating the shortest distance between that base line and each beacon.

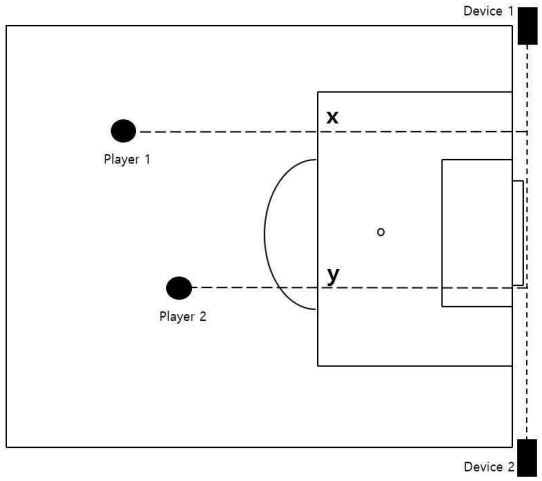

Figure 6. Calculating location according to receiver placements

3.6 Detecting the beacon's location by using Heron's formula

By using procedures above, values of a, b, and c in Figure 7 can be calculated.

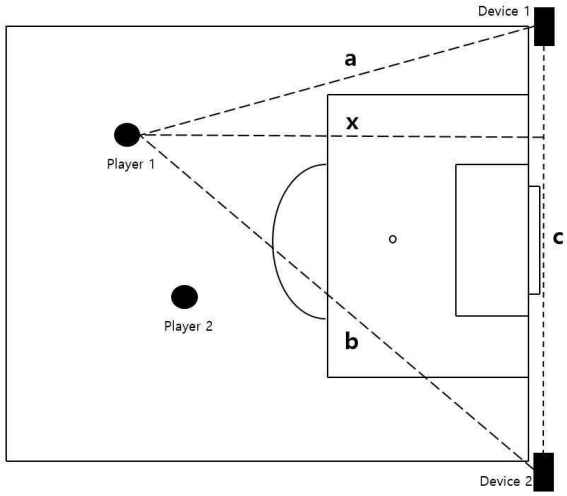

Figure 7. Calculating player location

Values of a and b can be substituted by RSSI values of the beacon and receiver, and since c is a constant, placement distances can be directly inputted. The area of the triangle can be calculated by using the values of a, b, and c, through Heron's formula[7,8]. Pseudo-code for this process is as follows:

Pseudocode:
procedure Heron_formula
Input: base

```
 get rssi_a, rssi_b; // get RSSI length from transmitter
 a = rssi_a;
 b = rssi_b;
 c = base; // base must be input
 s = (a+b+c)/2.0;
 formula = (s*(s-a)*(s-b)*(s-c));
 triangle area = Math.pow(formula);
Return triangle area
End
```

By using the area of the triangle which was calculated by utilizing the Heron's formula, value of x can be calculated.

$$x = \text{triangle area} * 2 / c$$

3.7 Confirming offside locations through each height values

Using the calculated values, and assuming that player 1 is the last defender and player 2 is the offender, the offender is in an offside position when the value of x is greater than the value of y. This study used two beacons, but if larger number of beacons were to be used for distance comparison, pseudo- code will be as follows:

Pseudocode:

```
procedure offside
x : defender's distance
y : attacker's distance
   if smallest x > any y then offside // judgement of offside
   else nothing
End
```

3.8 Sending signals in case of an offside position

By using aforementioned processes, the system sends additional signals to the referee's watch in case of an offside. The watch vibrates when it receives signals. So if the offending team passes to an offender who is behind the last defender when the watch was vibrating, offside violation has certainly occurred.

4. Experiments

4.1 Measuring devices

This study used LG G5 smartphone and Apple iPhone 6S for receivers, and ibeacon-i4 by Basbea for beacon. The experiment was carried out in Gwanak Sports Field in Seoul, which has the least influence by electronic waves. First, to check the electronic wave interference level between the beacon and receivers, experiments have been carried out in both indoor and outdoor places. As it can be seen in Figure 8 and 9, the actual and measured distance between the beacon and the three receivers placed indoors and outdoors respectively, can be identified. The x-axis shows the actual placement distance between the beacon and the receivers, and the y-axis shows the RSSI values taken by the receivers.

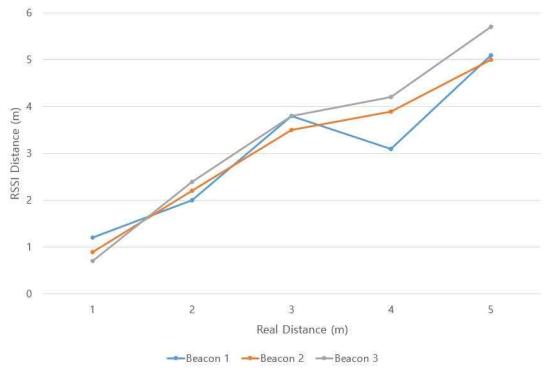

Figure 8. Measurement indoors

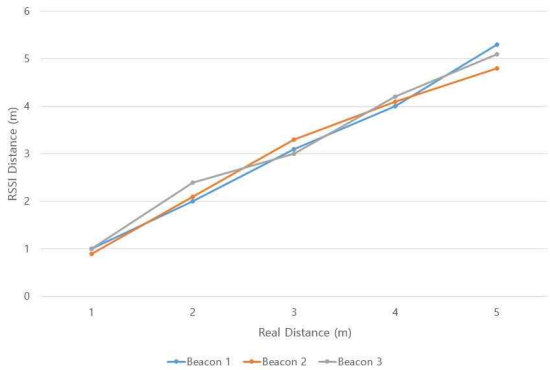

Figure 9. Measurement outdoors

Comparing Figure 8 and Figure 9, it can be confirmed that in fact, there is a margin of error from the actual distances depending on the level of electronic wave influences. Near the 4m area, 3 beacons are showing different values from actual distances caused by specific electronic wave interferences. On the other hand, measurements outdoors where there are relatively less interfering factors, they are considerably more accurate. This shows that beacon is a suitable device for soccer, which is an outdoor sport.

4.2 Detecting an Offside

Figure 10 below shows an arrangement of two beacons and two receivers.

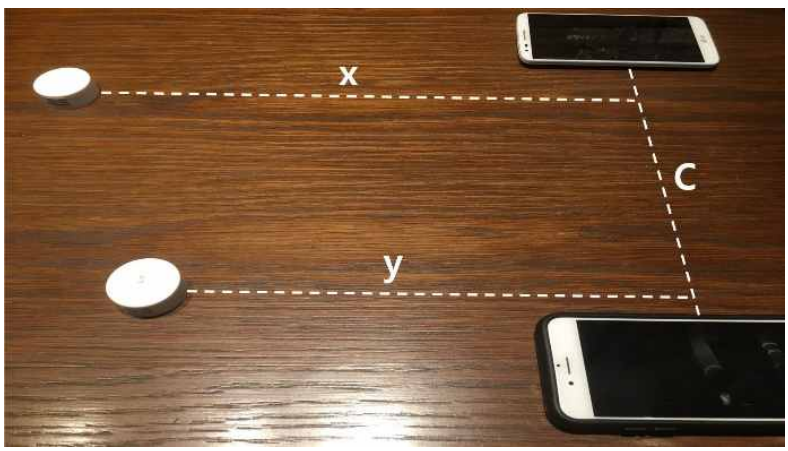

Figure 10. Experiment arrangement

Table 2 shows the result of experimenting the limits of an offside detecting accuracy as the value of c increases, assuming that x-y value is less than 50cm and that the upper beacon in Picture 7 is a defender and the lower beacon is an offender. Experiment results: The margin of error in signals from a receiver is over 50cm for distance greater than 4m.

Table 2. Offside results, assuming x – y < 50

c (cm)	x > y
100	Yes
200	Yes
300	Yes
400	Yes or No
500	Yes or No
600	Yes or No
700	Yes or No
800	Yes or No

5. Conclusion

This paper carried out research and experiment for developing an automatic offside judgement system by using Bluetooth 4.0 BLE technology. This study assumed each beacon as a sensor that will be attached to the players and experimented an offside detecting device by using smartphones or Bluno. As a result, although the application range of Bluetooth BLE is said to be 50m, the device has shown more than 50cm margin of error in distances over 5m, depending on the nearby environment, battery capacity, and interference by electronic waves, making it difficult to be actually applied in professional soccer matches. However, in amateur soccer matches, in which there is only one head referee, this technology has room for application, as offsides are hard to be detected by one referee and therefore susceptible to high chance of bad calls. By using this device, much discontent resulted by bad calls can be alleviated.

Also thorough this study, one can see a possibility of this device being applied to professional matches in the future, as Bluetooth technology progresses. The new Bluetooth 5.0 increased the slow transmitting speed of 4.0 BLE protocol by about two times to 2 Mbps, and expanded the possible transmitting distance by four times[9]. It also included the SAM (Slot Availability Mask) feature that minimized interference by nearby electronic waves. So by utilizing Bluetooth technology that is constantly improving and using methods such as Kalman filter and path loss algorithms[10] for improving measurement accuracy and minimizing margin of error, it is expected that this device will be applicable to professional soccer matches in the future.

References

[1] The Naver Encyclopedia, off-side. *https://terms.naver.com/entry.nhn?docId=1206168&cid=40942&categoryId=31969.*

[2] Clive Griffin-BraeMar, "Offside Detection Device," *football and technology white papers*, 2010.

[3] Werner Helsen, Bart Gilsis, and Matthew Weston, "Errors in judging ''offside'' in association football: Test of the optical error versus the perceptual flash-lag hypothesis," *The Journal of Sports Sciences*, May 2006.

[4] The Premier League Player Stats, Stats page of Premier League. *https://www.premierleague.com/home.*

[5] The ArsViator, Understands of Beacon. *https://arsviator.blogspot.com/2015/02/beacon.html.*

[6] Ugur Bekcibasi and Mahmut Tenruh, *Increasing RSSI Localization Accuracy with Distance Reference Anchor in Wireless Sensor Networks,* Thesis of Acta Polytechnica Hungarica,Hungary, Hyngary, 2014.

[7] Jung Hee Park, *Explanation and Experiment of Heron's Theory,* Ph.D. Thesis. University of YoungNam,, Gyeongsangbuk-do, Korea, 2013.

[8] The Naver Encyclopedia, Heron's Formula.

https://terms.naver.com/entry.nhn?docId=3350242&cid=60210&categoryId=60210.

[9] The Naver Post, Differences of Bluetooth 5.0. *https://m.post.naver.com/viewer/postView.nhn?volumeNo=9942139&memberNo=32922216&vType=VERTICAL.*

[10] Won Jin Kim, *Optimized BLE Beacon System for Indoor Positioning,* Ph.D. Thesis. University of MyungJi, Seoul, Korea., 2018.