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(54) METHOD OF AUTOMATICALLY DETECTING OFFSIDE IN SOCCER USING FIXED AND WIRELESS SENSORS AND CENTRAL SERVER

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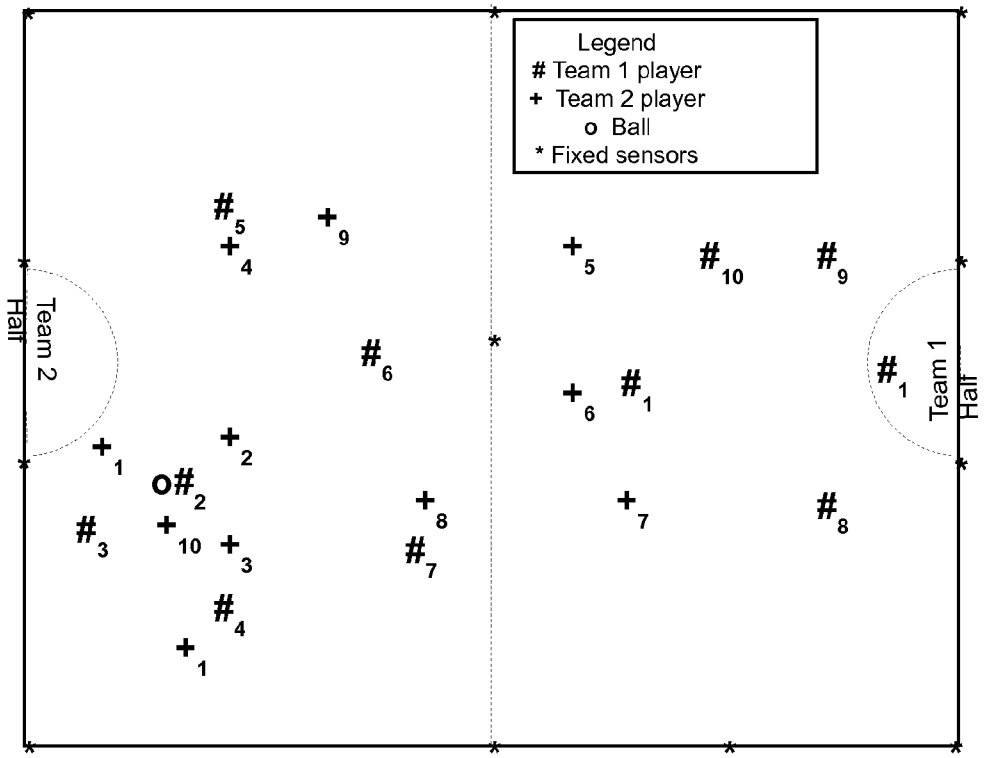
(57) **ABSTRACT**

Broadly speaking, the embodiments of the present invention fill the need for a method of accurately determining if an offense soccer player is in an offside position. This is determined using a combination of sensors on the players and the ball which are then sensed using fixed sensors on the field. The instantaneous sensor readings are used to locate each player, offense and defense with respect to the location of the ball and goal posts. These data are analyzed using an algorithm on a computer which can then determine if the player was in an offside position.



An example snapshot of sensors, fixed and mobile on a soccer field

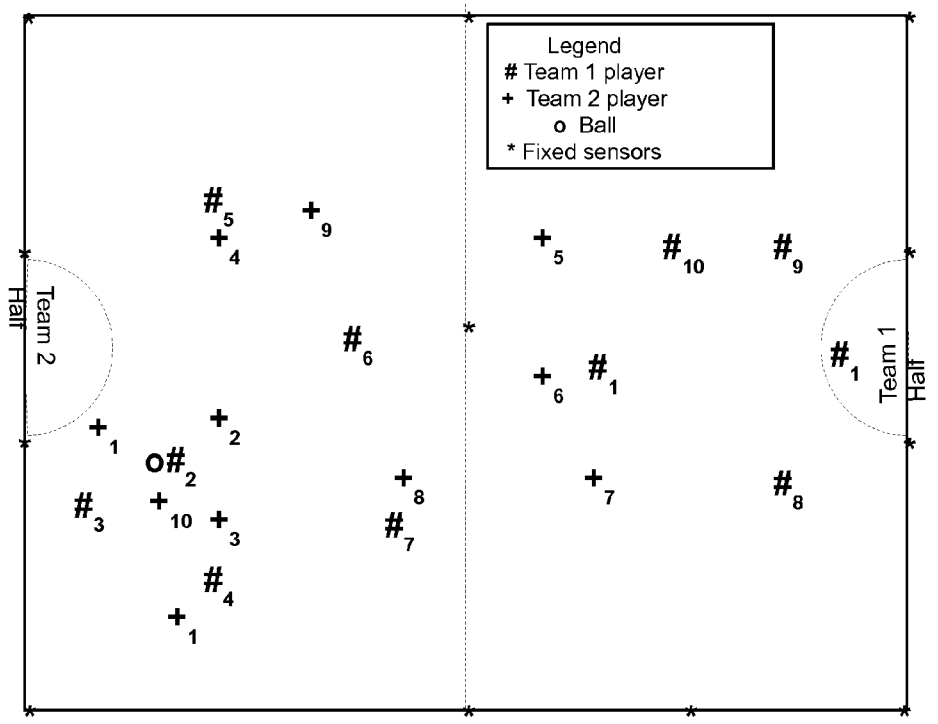


Figure 1: An example snapshot of sensors, fixed and mobile on a soccer field

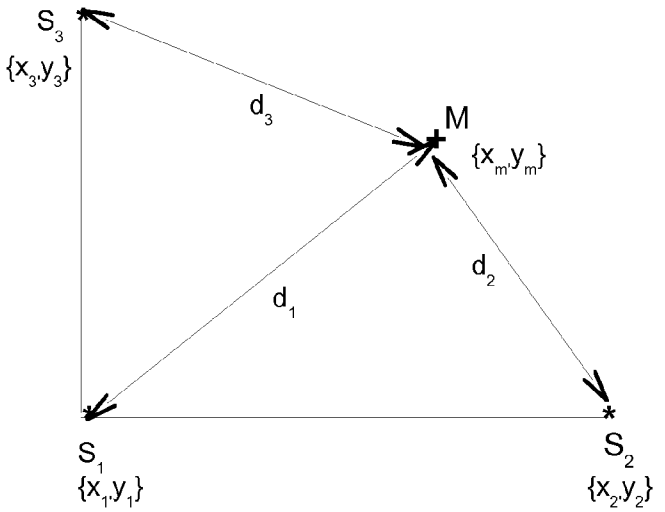


Figure 2: An example locating an object using fixed and mobile sensors

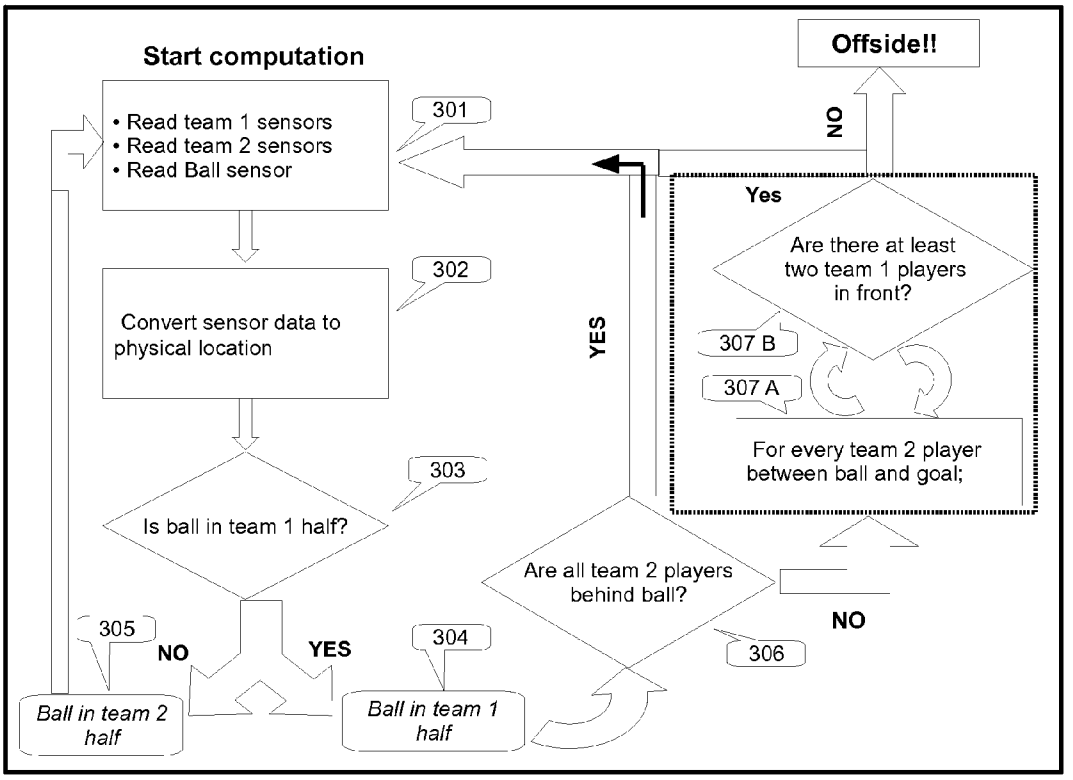


FIGURE 3: Flow Chart

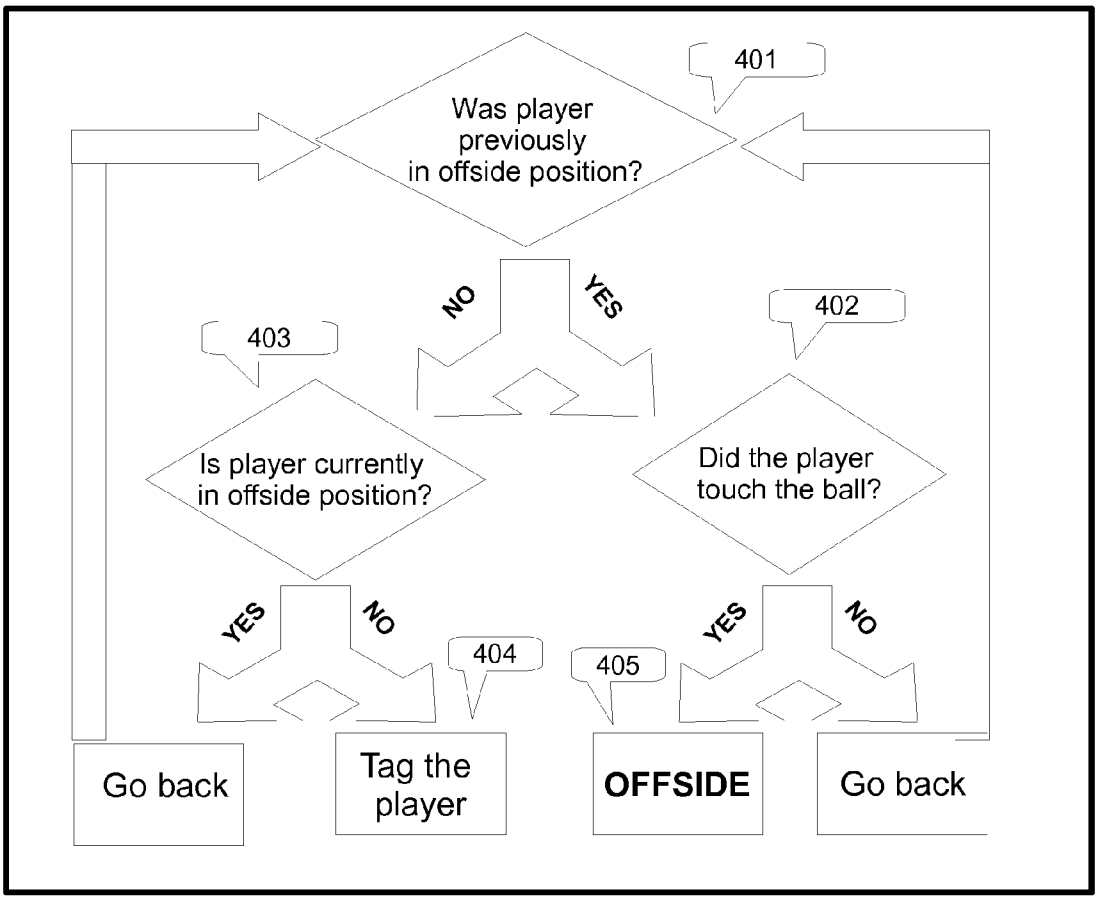


FIGURE 4: Offside determination flow chart

METHOD OF AUTOMATICALLY DETECTING OFFSIDE IN SOCCER USING FIXED AND WIRELESS SENSORS AND CENTRAL SERVER

BACKGROUND

[0001] Soccer[1] (or football outside the USA) is a fairly simple game with simple rules. In its official FIFA form, 11 players on each side (one of whom is a goalkeeper) attempt to put a ball into the opponents goal using only their feet, chest or head. Only the goalkeeper is allowed to use his hands when the ball is in play. While there are 22 players on a field, they are only 3 referees supervising an area of nearly 100×130 yards. This makes ruling on fouls and infraction limited to visual verification of one of the referees. One particularly complicated rule is the one the decides if an offense player is to be ruled offside.

1 http://en.wikipedia.org/wiki/Soccer

[0002] Offside[2] effectively limits how far forward attacking players may be when involved in play. This prevent a player from gaining an advantage by waiting for the ball near the opposing goal with only the goalkeeper between him and the goal. A player is in an offside position if "he/she is nearer to his opponents' goal line than both the ball and the second to last opponent," unless he is in his own half of the field of play. A player level with the second to last opponent is not in an offside position. In addition, a player can stay in a "offside" position so long as he/she is not the first offense player to field the ball. To complicate matters further, if two players of the attacking team only have one defender (typically the goalkeeper) between them and the goal, it is allowed for them to pass the ball between each other, as long as the player passing the ball is ahead of the player receiving it because the ball is nearer to the goal line than the receiver, therefore he/she is not at an offside position

2http://en.wikipedia.org/wiki/Offside_%28football%29

[0003] As a consequence, offside one of the most incorrectly called infraction leading to fan discontent and, in extreme cases, violence. Therefore, a neutral, technologically sound solution is needed to accurately decide on this complicated rule.

SUMMARY

[0004] Broadly speaking, the embodiments of the present invention fill the need for a method of automatically detecting if a player is in an offside position. The embodiments describe methods that are based on using wireless sensors on players and the ball. These sensors are read or sensed using fixed detectors at several locations on the field. The fixed detectors provide and accurate location of all players at any given instant and their relative location with respect to the ball. The two teams will have distinct sensors and each player with the team can be equipped with a individualized sensor. A central computer will be continually reading the inputs from the fixed detectors and constantly update the position of each individual players and the soccer ball. A specialized algorithm will then evaluate for an offside infraction in accordance with the rules.

[0005] It should be appreciated that the present invention can be implemented in numerous ways, including as a process, an apparatus, a system, a device, or a method. One inventive embodiment of the present invention is described below.

[0006] In one embodiment, each player has an individualized wireless sensor distinguishing him/her from the other team as well as ones own team mates and a distinct sensor on the ball. The field has fixed detectors on several locations along the edge. The method includes (1) read in sensor signals from the fixed detectors to a central server, and (2) use "triangulation"[3], "trilateration"s[4] or "multilateration"[5] methods to accurately detect the location of each player and the ball. The method also includes (3) determining if the players are in the opposite half of the field. The method further includes (4) determining if the ball is in front of the offense player. If the ball is not in front of the offense player, (5) determine if at least two defenders are in front of the offense player AND the ball is behind the offense. Further (6) If (5) is true, check if the offense player stays behind defenders until ball is launched.

3http://en.wikipedia.org/wiki/Triangulation

4http://en.wikipedia.org/wiki/Trilateration

5http://en.wikipedia.org/wiki/Multilateration

[0007] The advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The present invention will be readily understood by the following detailed description in conjunction with the accompanying drawings, and like reference numerals designate like structural elements.

[0009] FIG. **1** shows a representation of a soccer field with the players of either side represented by their sensors, the ball sensor and the fixed sensors marking the extent of the field.

[0010] FIG. **2** shows an example of how a player's location can be determined using a combination of fixed and moving sensors. The location of the mobile sensor is determined using time of flight of the signal between the multiple sensors.

[0011] FIG. **3** is a flow chart that provides an algorithm flow to detect if a player is in an offside position.

[0012] FIG. **4** demonstrates the algorithm that uses a players current and previous positions along with that of the ball to determine offside infraction.

DETAILED DESCRIPTION

[0013] In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be apparent to one skilled in the art that the present invention may be practiced without some of these specific details. In other instances, well known implementation details have not been described in detail in order to avoid unnecessarily obscuring the invention.

[0014] As described earlier, offside rules are determined based on a complicated set of rules that need visual confirmation of the relative locations of the ball and offense player with respect to the defense, not only at the instance in question, but also their relative positions prior to the infraction.

[0015] It is impractical and expensive to locate several cameras across the field recording the game which would then have to be synchronized to study the relative positions of all involved players during the period in question. In addition, the limited vision of each camera would neccessitate several closely spaced locations each of which would need the video information stored to be readily accessed.

[0016] Therefore, a simple, yet robust technological solution that causes minimal impact on either the players or the field of play is needed. This solution should not require a large infrastructure demand and the results should be easily and quickly accessible.

[0017] The current invention solves the above problem of determining relative positions of each of the players and the ball at all times by attaching small wireless sensors on to each player and the ball. The sensors are uniquely coded and can be understood as providing the same function as the individual jersey numbers on the back of each player. In addition, the ball will also have a unique sensor affixed to it, providing a way of locating its position in the field of play. Finally, the locations of each of these mobile sensors are determined using an array of fixed sensors located at predetermined locations on the edge and inside the field of play.

[0018] FIG. **1** shows a snapshot of a soccer field with each player represented by a unique sensor symbol. The offense and defensive players, as determined by the location of the ball at that instant can be uniquely identified by their sensors tags ("#" and "+"). The soccer ball, identified by the symbol "o" has a unique sensor different from all other sensors and is the only one of its kind on the field at any given time. In addition, several fixed sensors ("*") along and on the field that will be used to determine the location of each player and ball is also shown on the figure.

[0019] The fixed sensor locations are predetermined and each one is connected to a central server or a combination of connected computers that perform the analysis of the data collected by the sensors. The fixed sensors can be connected to the central computation device using a combination of wired and wireless methods.

[0020] Each fixed sensor can locate the physical location of any mobile sensor, in this case, the ball and any player on the field from either side. In addition, the sensors can be designed to provide a unique signal identifying the half of the field that it is located in. The determination of the half of the field will determine which team is "offense" and which one is "defense". For example, of the ball is in Team **1**'s half, all Team **2** players in that half are considered "offense" and Team **1** players are defense and vice-versa. By definition, no player can be offside in their own half.

[0021] There are several methods that can be used to determine the physical location of a moving object in a two-dimensional (2D) or three-dimensional (3D) system. Common amongst these are triangulation, trilateration and multilateration. FIG. **2** presents an example of determining the location of an unknown object using three fixed sensors. The distance between each of the sensors in a Cartesian 2D plane is known and fixed for the duration of the exercise. The absolute distance of the mobile object from the fixed sensors is calculated using time of flight measurements (TOF) which locate the distance using the time needed for a signal to complete the round trip to the mobile sensor and back.

[0022] Trilateration on a 2 dimensional plane needs three known fixed points (relative to each other) to determine a fourth arbitrary point. The distance between the fixed sensors **S1**, **S2** and **S3** on FIG. **2** are known and assumed to be fixed at all times. The distance from the mobile sensor, M, to any of the fixed sensors is determined by measuring the time of flight (TOF) from each fixed sensor to the mobile one. The location of mobile sensor at any given instant can be reduced to a simple set of simultaneous equations via a set of Cartesian transformations.

[0023] Since each of the distances in FIG. **2** are known at any instance of time, the calculation the location of the mobile sensor into Cartesian coordinates is relatively simple involving well know translation of distances into (x,y) coordinates. This can be programmed into a computer to provide instantaneous (x,y) locations of all relevant objects on the field of play.

[0024] FIG. **3** shows a flow chart of the logic used in determining if a player was in an offside position at any given time. This flow chart represents a continuous loop of a computer program used to determine positions of players and the ball during the game. At step **301**, the locations of all the individual mobile sensors are read into the system. Since a mobile sensor can be close to several of the fixed sensors on the field, there will be several relative distance measurements reported for each mobile sensor. These relative distances are determined by the time of flight; i.e., the time taken for a signal to travel from the fixed sensor to the mobile sensor and back. Since the signals used in most of these techniques are in the electromagnetic spectrum, the distance can then be simply calculated using the speed of light, which is for purposes of this discussion considered a universal constant.

[0025] Step **302** involves converting the relative distances of the mobile sensors to a fixed coordinate system. There are several well know techniques that are used in locating positions of an unknown object using its relative distance from several know fixed objects. Triangulation, trilateration and multilateration are a few of these well understood numerical techniques.

[0026] Step **303** of FIG. **3** involves physically locating the ball into one of the two halves of play. This step is very important since this uniquely determines the status of any player as "offense" and "defense". If the ball is in Team **1**'s half, then all Team **1** players are automatically considered "defense" and vice-versa. If the ball is being propelled by Team **2** players in Team **1**'s half (step **304**) then the next step (**306**) is to determine if all Team **2** players (constituting offense at this particular instant) are behind the ball. If this is the case, no further analysis is needed and the algorithm returns back to step **301**.

[0027] If there is at least one team **2** player in team **1**'s half between the ball and the goal post, then a determination of potential offside infraction has to be made. Step **307**(*a* and *b*) of FIG. **3** is in itself a mini loop locating the positions of each of the team **2** players (offense) in potential offside locations with respect to team **1** players (defense) and the goal post. For each offense player that is located between the ball and the goal post, the algorithm determines if there are at least two defense players between the offense player and the goal post. If this is true, then the offense player is not ruled offside.

[0028] If at least one offense player is located between the ball and the goal post with less than two defensive players between them, then the person is tagged as being in an offside position. However, the ruling of offside cannot be called unless this particular player interacts with the ball, if and only if a player in an offside position touches the ball will he or she be ruled offside. Therefore, the program implementation of this algorithm will have to save several chronologically previous positions for each player to ensure a correct ruling.

[0029] FIG. **4** elaborates the algorithm used in steps **307***a* and **307***b* to determine offside based on current and previous positions. In step **401**, an offense player that is currently between the ball and goal is determined to check if he/she was previously in offside position.

[0030] Step **402** determines if the a player in previously offside position touched the ball, if true, an offside infraction is called. If not, the loop goes back to the next player.

[0031] If the a player was not previously tagged to be in an offside position, step **403** is followed to determine if the player is currently in an offside position, if true, the player is tagged to be so and the loop goes back to the top.

[0032] If none of the above offside criterion are met, the algorithm in FIG. **3** loops back to step **301** and begins collecting the sensor readings for the next time step.

What is claimed is:

1. A method of determining offside in soccer using a combination of sensors on the players and detectors on the field, all analyzed using a central server:

(1) assign distinct wireless sensors for players, with the two teams being clearly distinguishable;

(2) a third distinct class of sensor on the ball to allow it to clearly distinguished from the others;

(3) A network of fixed detectors along the field which read inputs from the sensors; these detectors can be on the field as well as on the goal posts.

(4) determine the location of each player and the ball using "triangulation" or other location detection methods,

(5) determine if the ball and the offense player is on the opposite side of the field,

if the ball is not near the offense player, ensure that there are at least two defense players between the offense player and the opposite goal,

(6) determine if the offense player was not offside when the ball was passed to him,

if the offside criterion are met, enable a signal to indicate the infraction

2. The method of claim **1**, wherein the fixed detectors can be connected to the central server using wireless techniques

3. The method of claim **1**, wherein the fixed detectors can be connected to the central server using wired techniques

4. The method of claim **1**, wherein the sensors can be battery powered or self powered.

5. The method of claim **1** wherein the centralized server can be made up of several computation units.

6. The method of claim **1** wherein the number of players on the field is less than the standard regulation of eleven per side.

7. The method in claim **1** where the size of the soccer field differs from regulation standards.

8. The method in claim **1** where the game can be played indoors as well as outdoors.

9. The method in claim **1** where the location of the players and the ball is determined using triangulation.

10. The method in claim **1** where the location of the players and the ball is determined using Multilateration.

11. The method in claim **1** where the computer program saves limited time stamped players' physical locations.

12. The method in claim **1** where the computer program saves time stamped players' physical locations for the entire game.

13. The method in game **1** where the stored information can be used for post-game analysis and learning.

14. The method claim **1** where the sensors for all members of the same team need not be uniquely identifiable other than uniquely distinguishing between the two teams.

15. The method in claim **1** where the sport or application other than soccer needs substantially similar relative physical location determination.

16. The method in claim **1** where the distance between sensors are measured using electromagnetic signals.

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