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Fig. 1

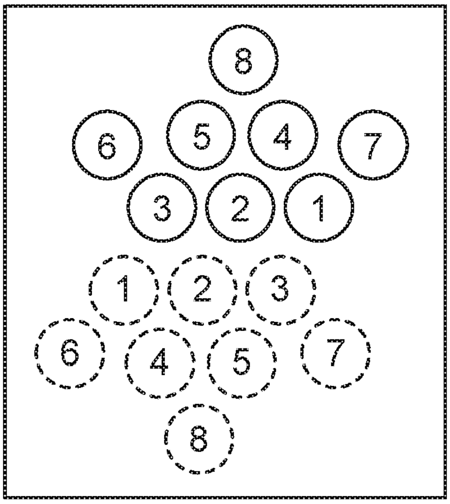


Fig. 2

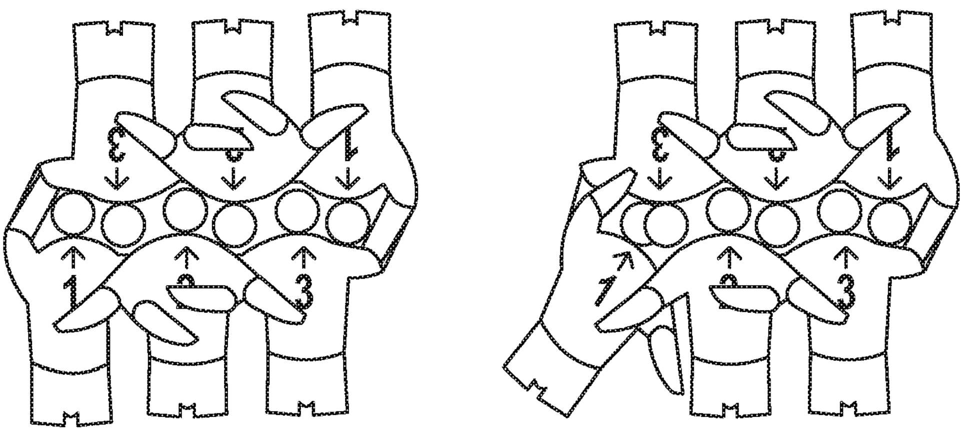


Fig. 3

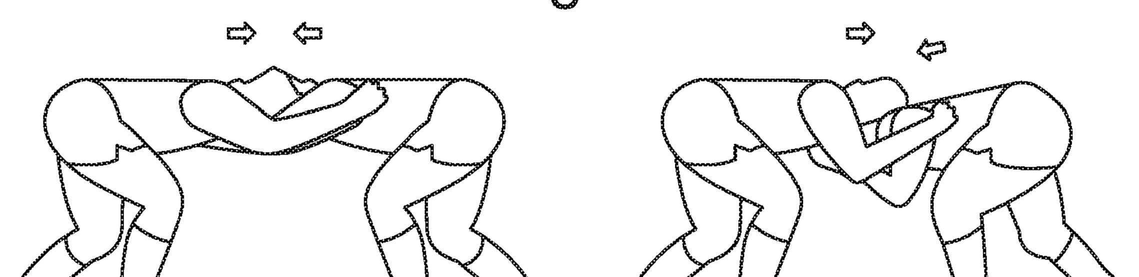


Fig. 4

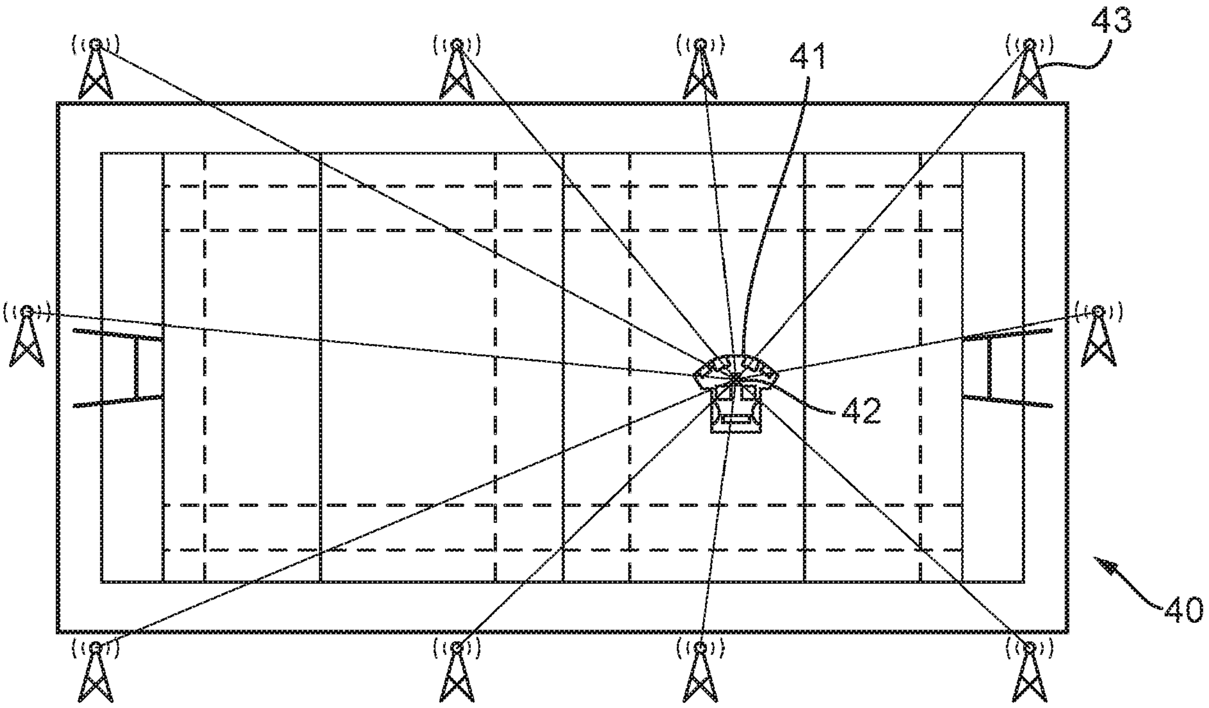


Fig. 5

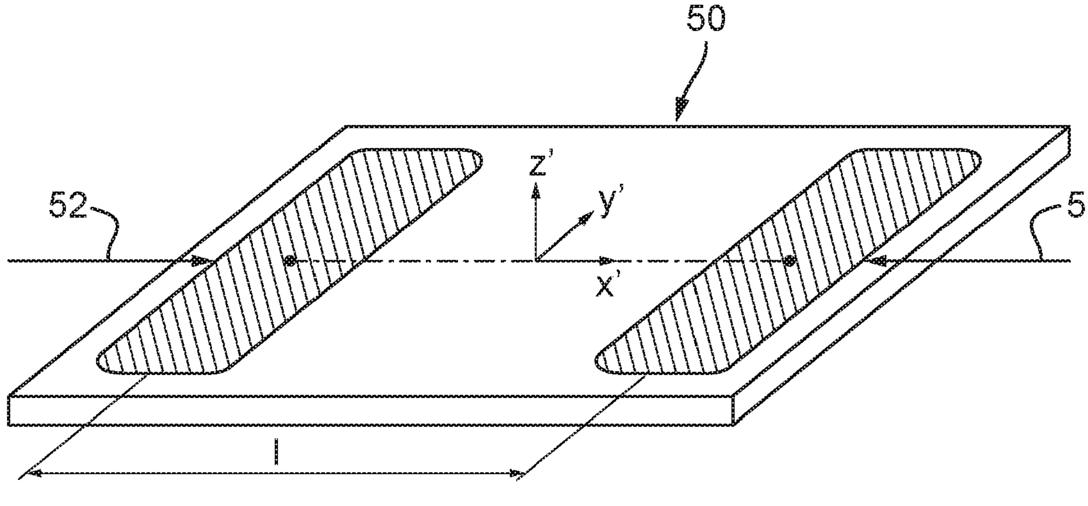


Fig. 6

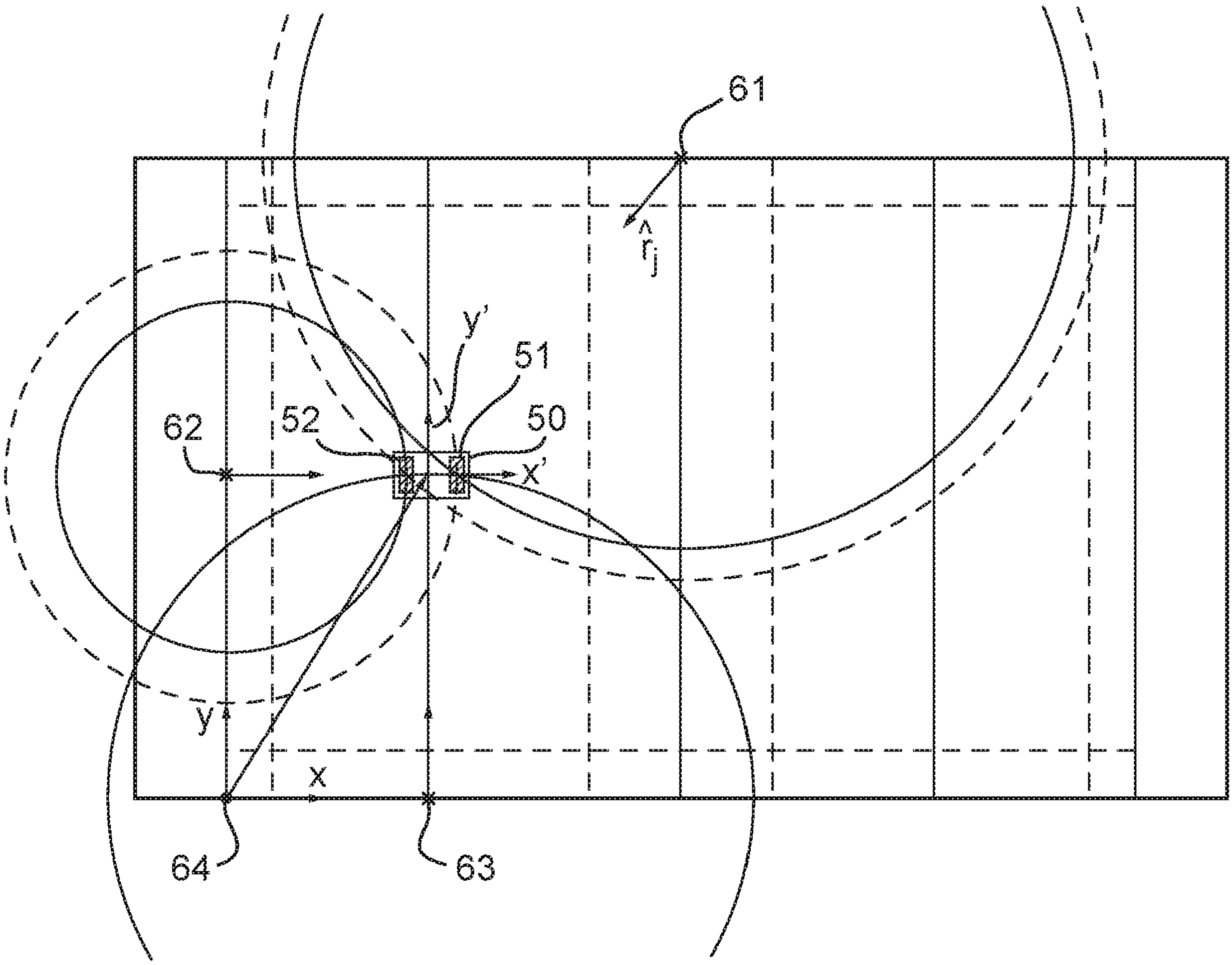
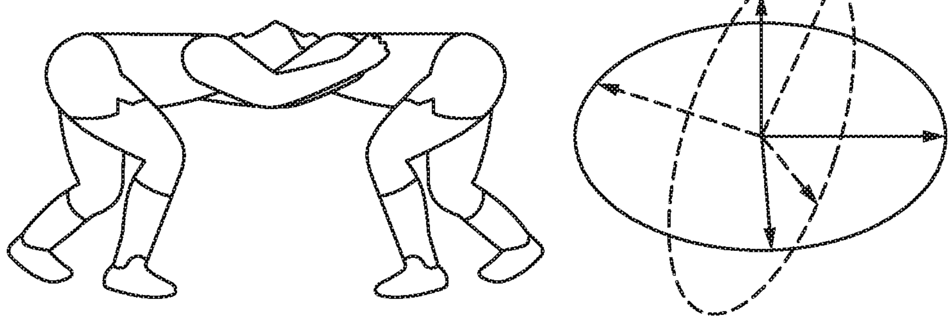


Fig. 7



SPORTS OFFICIATING SYSTEM

Background

Improvements in the technology for tracking players on a sports field have led to increased usage of wearable technology for performance analysis and for training purposes. The systems are used by coaches and athletes to monitor distance covered during the game as well as to analyse game plans and perform time motion analysis, which considers the time spent by each player performing a specific task. A key usage of these systems is in monitoring player activity for fatigue and for injury prevention.

Typical data loggers utilise the Global Navigation Satellite System (GNSS) as well as accelerometers and gyro sensors to track position and record the speed and position of a player as they move around a pitch. The position of the player and their wearable device is triangulated using a series of satellites or nodes positioned around the playing area which communicate with the device using 2.4Ghz wireless communication, such as Wi-Fi (RTM) or Bluetooth (RTM).

There has been a trend in global sport to utilise technology in officiating sporting contests. There is an acceptance from the public and from officials that technology, when utilised correctly, can provide greater certainty of decision making. Examples include hindsight video analysis in American Football and Rugby Football and goal-line technology used in football (or soccer) to identify if the ball has crossed the goal-line. Currently employed options for implementing goal-line technology include video analysis and also sensors placed within the ball and in the goal area which detect if the ball has crossed the plane of the line.

The key requirements for technology when used in officiating are accuracy and reliability. At present systems that utilise wearable technology are unable to provide the necessary accuracy, reliability and tracking of the full range motions to enable the technology to be used in officiating. Wearable technology has only recently been able to determine positional accuracy to around 15-20 cm, which is still not sufficient to determine infringement reliably. Moreover, the data must be provided in real-time. At present, wearable devices suffer significantly from noise in sporting stadiums resulting from the volume of interfering signals and are unable to reliably retrieve real-time data from the devices.

In addition to interference affecting the calculations, known systems also suffer from 'losing track' of the devices and their angular displacements. To consider movement, the systems utilise accelerometers. The data is integrated once to derive velocity and again to derive displacement and hence relative position. Errors in the acceleration data that may be caused, for example by noise, are compounded such that the displacement data cannot be relied upon accurately.

To improve the data collected, some wearable devices include a gyrometer as described for example in US 8,036,826, to determine orientation and angular displacement. However systems using gyrometers are inaccurate as they suffer from drift errors which cause misalignment and bias. Although to some extent these errors can be mitigated through combined analysis with accelerometer data, systems require the sensors and data to be regularly reset from a static point such as impact of the wearer with the ground. This is clearly problematic.

Moreover typical wearable tracking solutions suffer from speed of analysis problems since the computations are complex and the communications upon which assessment is based are periodic.

There is therefore a need to provide an improved system for tracking movement on a sports field. In addition to improving performance and training analysis the systems must be accurate, fast and reliable enough to be used to judge infringement in an officiating system as might be required in for example a rugby scrum where the detection of angular movement in real-time would be essential.

Alternative methods of analysis such as radar reflectors or video analysis have not yet progressed to the stage where they are viable either for cost or accuracy reasons.

Summary of the invention

The present invention provides systems and methods for improved tracking which is particularly beneficial for officiating sporting events. The invention is able to accurately, reliably and in real-time determine orientation of the wearer of a device and accordingly determine infringement as appropriate.

According to a first aspect of the invention there is provided a system to determine orientation on a sports field. The system comprises: an electronic device comprising two or more antennas each connected to a respective transceiver and spaced apart by a predetermined distance; an antenna arrangement comprising three or more antennas, each antenna arranged around a periphery of the sports field; and, an analytics controller configured to detect signals transmitted between each of- the antennas of the electronic device and the antenna arrangement and, based on the detected signals, determine orientation of the device by evaluating the time taken for signals to travel between each of the antennas of the electronic device and the antenna arrangement, such that when the electronic device is embedded within sports equipment the orientation of the equipment can be determined.

By determining the orientation of the device by evaluating the time taken for signals to travel between each of the antennas of the electronic device and the antenna arrangement, the system can determine the orientation in a fast, accurate and reliable way. Thus the system is able to be used for officiating where tolerance for error and speed are critical. The system may be used for example in analysis and officiating where orientation is key such as a rugby scrum or analysis of ball orientation during travel.

Preferably each antenna of the electronic device and the antenna arrangement is associated with an ultra-wide band transceiver. The use of ultra-wide band transceivers minimises the impact of noise on the data retrieval and orientation determination. Ultra-wide band transceivers help the system to localise the determination in time and space. The transceivers may also be used to transmit data acquired from a plurality of sensors embedded in, or on, the sports equipment. The use of the UWB transceiver allows the acquired data to be transmitted, with high data transmission speeds currently in excess of 6.5 Mbps, to equipment located remotely for example at the side of field.

The electronic device may be configured in an example to be embedded within sports equipment. Accordingly the device is able to determine the orientation of the sports equipment in which it is embedded. Once the sports equipment is fixed in place, the orientation of the wearer of the equipment can be determined. Additionally, should the equipment be for example a ball or training equipment, the orientation of that equipment can be determined which will aid in training and performance analysis.

The electronic device may preferably comprise an inertial measurement unit (IMU) and the analytics controller may be configured to determine the orientation using signals generated by the IMU. In this way the reliability and robustness of the system is improved through the combination and calibration of measurement methods. The IMU may for example be a 9-axis IMU which may for example collect linear acceleration, angular acceleration and orientation data using magnetic field intensity data, that is, orientation relative to a magnetic field. The IMU may also optionally be used to calculate the angular velocity components, and therefore for example the revolutions per minute, of sports equipment for example in conjunction with AoA calculations.

The antenna arrangement may comprise a plurality of antenna arrays each comprising a plurality of antennas. Preferably the antenna arrangement comprises at least 10 antenna arrays each comprising at least 1 antenna. Each antenna array will preferably be associated with at least one ultra-wide band transceiver. The antennas within each array enable the system to improve the determination in three-dimensions.

The analytics controller may be configured to determine position of the electronic device relative to the antenna arrangement based on the detected signals. The antenna arrays which may be positioned around the sports field in one embodiment enable improved position and orientation determination.

The antenna arrangement and associated transceivers may together be optionally configured to transmit a signal from each antenna, the analytics controller being configured to detect signals received by the antennas of the electronic device. The data may be subsequently retrieved from the device in real-time.

The analytics controller may be configured to determine a change in orientation of the device between a start time and an end time. Optionally the analytics controller may be configured to: determine a first orientation; and, subsequently monitor the orientation to identify a change in orientation. The first orientation may be determined upon receipt of an instruction from an operator of the system. Alternatively the first orientation may be determined based on voice analysis of voice data received from a microphone positioned on the sports field.

The analytics controller may be configured to identify if the change in orientation of the device exceeds a predetermined envelope of acceptable change and output an indication if the envelope has been exceeded. Accordingly, the system may be able to identify if an infringement has been committed, for example, in a rugby scrum if the device, and hence the player, has exceeded his defined orientation envelope he may be pushing at an illegal angle and accordingly infringing the laws. Other examples include leaving the scrum too early, collapsing the scrum, scrumming in etc.

The system may comprise two or more electronic devices and the analytics controller may be configured to compare the orientation of each electronic device. Accordingly in an officiating scenario, the system may be able to compare the actions of two players. Additionally, if the two devices were positioned on the same player, the system could compare the orientation of multiple body parts for infringement purposes.

The system may comprise two or more electronic devices and the analytics controller may be configured to compare the relative timing of the change in orientation of each electronic device. Thus the first player to change orientation can be determined and accordingly a particular infringement can be determined based on the laws of that game.

In one embodiment the system may comprise a force transducer configured to be embedded within the sports equipment, the analytics being further configured to detect signals received from the force transducer and monitor the force exerted on the sports equipment at a region in which the force transducer is embedded. Preferred force transducers may be flexible conductive polymer force transducers.

The electronic device may comprise a control unit and a power supply. The sports equipment may include a power supply to supply electrical power, for example to those sensors and/or transceivers which require power to operate as well as to the components of the control unit. The precise form of the power supply is not of the essence of the invention but could for example preferably be a lithium polymer battery or alternatively a lithium ion polymer battery. The power supply may be provided on the same part of the sports equipment as the sensors but this is not essential. For example, where the sports equipment comprises body armour the power supply may conveniently also be located on the body armour. However, this is not essential and the power supply may instead be located elsewhere on the wearer of the body armour or other sports equipment.

Where the sports equipment is a rugby ball, the electronics unit could for example be located inside the ball. Where the sports equipment is body armour, the electronics unit may be located in a position corresponding to a point between the player’s shoulder blades.

Preferably the orientation is determined relative to a reference frame generated by the antenna arrangement. Additionally the orientation may be determined relative to a set of reference coordinate axes or the sports field or a part thereof.

In an example, there may be provided an electronic device when used in the system of the above aspect. In an example, an analytics controller when used in the system may also be provided. In an example, a computer program may be provided which, when executed by a processor, causes the processor to carry out the steps of the analytics controller. Further in another example a computer-readable medium storing the computer program may be provided.

Detailed Description

Examples of systems and methods in accordance with the invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 shows a scrum;
Figures 2 and 3 show set scrums and scrum infringements;
Figure 4 shows a high-level diagram of a system of the present invention;
Figure 5 shows an exemplary electronic device showing reference axes;
Figure 6 shows the exemplary electronic device of Figure 5 in a system of the invention on a sports field; and,
Figure 7 shows orientation of a player relative to the sports field.

The following are examples of systems and methods for officiating complex sports such as Rugby Football. It will be understood of course that the following are merely examples. The principles described are equally usable for performance analysis and training purposes.

The concepts described herein have particular utility in and in some cases provide a real-time officiating system for rugby. More specifically the exemplary concepts relate to a set of wearable devices on the players, devices embedded into the sports equipment, and a set of side of field devices which enable real-time rugby officiating decisions to be made with high accuracy and precision.

In the described detailed example, the wearable devices use a combination of ultra-wide band (UWB) transceivers and embedded flexible force transducers. These devices make it possible to determine of the location, velocity, acceleration and angular orientation of the player while measuring the direction, magnitude and location of the static and dynamic forces experienced by the player. An UWB transceiver and a 9-axis Inertial Measurement Unit (IMU) may

23 12 16

be embedded within the rugby ball to allow for the location, velocity, acceleration and angular velocity components of the ball to be determined. These devices may broadcast their data in real-time to equipment at the side of the field. At the side of the field is arranged a set of antenna arrays. The data is processed in real-time to determine if a rule has been transgressed and the data is made available for the referee. The data may also be made available for the fans and the broadcaster.

Reliable officiating of the scrum, one of rugby’s most critical features, is in crisis. Scrum officiating has become increasingly difficult to perform accurately, leading to controversial decision making, which has, ultimately, led to questions over the game’s integrity. The scrum, shown in Figure 1, is a critical component in every team's strategy and is commonly viewed as the most important aspect of a team's game from both a technical and psychological perspective. When executed correctly the scrum can be used as a psychological weapon, a platform to attack, and a defensive tactic.

Figure 1 illustrates the scrum in which each team has three front row players, numbers 1 to 3, two locks, numbers 4 and 5, two flankers, numbers 6 and 7 and one 8th man.

The intense technical nature of the scrum, combined with limited officiating support has led to poor officiating decisions, which has ultimately led to the scrum becoming a highly problematic area of the game. Such a critical aspect of a sporting event cannot be continuously marred by controversy. An inability to make the correct decisions has severe implications not just for the integrity of the game, but for teams' and athletes' careers.

There are a host of regulations governing the scrum. However, the most problematic areas of the scrum, and those to which this example focus on, relates to infringements concerning twisting, dipping, collapsing, charging and pushing before the ball is in.

In the case of a transgression occurring, the problem for officials lies in the difficulty of identifying the guilty party. In order to accurately identify fault an official must make a split second assessment as to the angle and direction in which each front row forward engages and pushes and then make a decision as to the order of events in terms of each individual's actions. i.e. he/she will assess the state of the scrum as it engages, thereafter should the scrum collapse the official is required to identify which front row forward was responsible for the collapse which means being constantly cognisant of each player's body position and angles relative to each other and the commands of the official.

This is illustrated in more detail in Figure 2 where the scrum is set in the left image. In the right image, the loose-head prop (player 1) has rotated inwards (scrumming-in) which is an infringement. A further infringement is shown in Figure 3 in which again the scrum is set in the left image. In the right image, the player on the right is scrumming downwards (dipping/collapsing) and infringing.

The examples described herein provide a means to officiate rugby scrums in real-time with high accuracy and precision. The ability to locate the players and to determine the orientation of the electronics units between their shoulder blades, as the scrum is set, allows for the near instantaneous detection of a player scrumming upwards, or driving inwards. The ability to measure the applied force experienced by the players, at various locations, allows the near instantaneous detection of scrumming before the ball has been fed into the scrum. The officiating system focuses on the scrum; however the information may also be used to detect forward-passes and to locate the position of the ball with respect to the try line.

Figure 4 illustrates a rugby pitch 40 on which is positioned an article of body armour 41. Positioned around the pitch 40 are a series of antenna arrays 43 or anchors. The terms antenna array and anchor will be used interchangeably throughout the present description.

A central server (not shown) is used to process the data channelled from the players and equipment via the receivers. Throughout the present description the terms analytic controller, central server and microcontroller will be used to describe processing units which perform certain functions. It will be understood that the terms used are not essential. What may be essential is the functionality described. However, the functionality may often be performed by processing and control units located remotely, within the described entities or elsewhere in the system as appropriate.

Embedded within the body armour 41 is an electronic device 42 which includes at least two antennas and at least two ultra-wide band (UWB) transceivers. A similar device may also be embedded in other equipment such the ball or training equipment. The UWB transceivers in the electronics device transmit a narrow pulse in the time domain, or 'chirp', which is detected by the antenna arrays at different times. The arrays, which contain at least one UWB transceiver and an antenna array, perform Angle of Arrival (AoA), Time Difference of Arrival (TDoA) and Time of Arrival (ToA) calculations to determine the player's position. The principles behind AoA, TDoA and ToA are well known and will not be described in detail here.

The antenna arrays 43 may each also transmit a narrow pulse in the time domain, or a 'chirp', which is detected by the UWB transceivers on the device at different times. From this latter measurement the device is able to determine its orientation to high accuracy. A 'chirp' may also be equivalent to a data packet.

Each electronic device 42 for positioning on the field comprises two or more antennas spaced apart by a predetermined distance. The time taken for a signal to travel between the antenna at the side of the field and the antenna on the device is proportional to the distance between the antennas (calculated by knowing the speed of travel of the signal). To determine position, multiple signals can be compared to trilaterate and/or multilaterate the position once the relative positions of the fixed antennas are known. To determine orientation, the difference in distance between the two antennas on the device may be used as a constant in the calculations. Other constants include the speed of light and the speed of the travel of the signal in the electronics. The time that the signals arrive at each antenna is a function of the orientation of the device.

Figures 5 and 6 illustrate these principles. Figure 5 illustrates two antennas 51 and 52 positioned on a tag 50 separated by a length l. Reference coordinates (x', y', z') relative to the tag are illustrated. A tag 50 may be positioned inside an electronic unit 42 which may for example be a plastic housing which preferably houses other components. When the tag 50 is positioned on the field as illustrated in Figure 6, the orientation relative to the field can be seen. Signals propagate from antenna arrays or anchors 61, 62, 63 as illustrated. The signals can be thought of as a wavefront. The time for each signal to arrive at the antennas 51, 52 is illustrated by the solid lines and dotted lines each propagating from arrays 61, 62. The solid line and dotted line wavefront are each the signal but demonstrate the wavefront arriving at each antenna at a later time due to the relative distance from the array from which the signal originated. The origin for the calculation is shown as item 64. The time delay as seen on the tag from the array 61 is proportional to the angle between the vector from array 61 to the tag and the tag's x' axis.

The number of arrays and the number of antennas in each array improves resolution. Greater than 10 arrays having 3 antennas may for example be preferable. In practice greater than 5 side of field arrays and greater than 2 device antennas provides increased resolution. To determine the tag's 2D position at least three anchors in the same plane may be needed. To determine the tag's 3D position at least four anchors may be needed where at least one are at a different height. To determine the tag's 3D orientation, given the tag's position vector, at least three anchors (and their position vectors relative to a Master anchor) may be needed. Increased resolution may be provided by an increase in anchors.

In addition to their use in locating the sports equipment, the data packets can also be used to transmit data acquired from a plurality of sensors embedded in, or on, the sports equipment. The use of a UWB transceiver allows the acquired data to be transmitted, with high data transmission speeds in excess of 6.5 Mbps, to the side of field equipment.

It will be understood that the arrays may also determine the orientation from the chirps of the device. Further the antennas on the device may act as a mirror reflecting the signals from the arrays such that the orientation can be determined remotely from the device from signals transmitted by the arrays. In this case the arrays could be referred to as “retroarrays” or “retroreflectors”.

The system is capable of measuring the position of the players and their orientation with respect to a convenient set of coordinate axes. In this example the orientation data is determined from a combination of the data from Angle of Arrival (AoA) calculations and data from a 9-axis IMU which is also housed in the device. Figure 7 shows a possible player orientation (dotted lines), relative to the field (solid lines). The relationship between the coordinate axes for the player and the field can be represented in different ways, which may include Euler angles or a quaternion representation.

When the scrum is set, the orientation of the players is determined and if the player’s orientation changes more than a prescribed amount an infraction is detected and the referee is alerted. To trigger the initial orientation determination the system may allow for manual input by an operator to indicate when the sensor is set. Alternatively, the voice analysis may indicate that the referee has called the scrum set. The voice data could be received at the central server from a microphone on the referee or from a microphone embedded within the electronic device itself.

As described above, the antenna array may comprise at least one antenna and UWB transceiver. Each antenna array may be connected to the others wirelessly or through fixed or wired communications. Each antenna array may also be connected solely to a master array which gathers together data from each array and instructs each array to act. The master array may be connected to a server or the server may act as the master and coordinate the arrays.

The master array also functions to set the reference coordinates to (x,y,z) (0,0,0) shown as the origin 64 in Figure 6. Thus the reference frame against which the orientation of the device is determined is set by the master array. The coordinates of the reference frame are then based on the position of other arrays. In order to determine the reference frame for position and orientation, more than one point is needed. Each array position is determined relative to each other and then positioned on the frame, all relative to the master. The orientation of the device can therefore be considered to be relative to the frame generated by the arrays.

Exemplary sports equipment which is designed to communicate with the antenna arrays will now be described. The sports equipment has two transceivers and antennas and a microcontroller.

The UWB transceiver on the sports equipment communicates with the arrays. Data packets received by the anchors, from the sports equipment, are used to perform time difference of arrival (TDoA), time of arrival (ToA) and angle of arrival (AoA) calculations to locate the position and orientation of the sports equipment with high accuracy. Analysis of the data packets is also used to determine the angular orientation of the sports equipment with respect to a convenient set of reference coordinate axes. In this manner the position and orientation of the sports equipment can be determined to high accuracy.

The sports equipment may have at least one 9-axis IMU for collecting linear acceleration, angular acceleration and orientation data. Data from the IMU can be combined with the orientation data calculated by the side of field equipment, which constitutes a form of sensor fusion, to increase system robustness. The IMU may also be used to calculate the angular velocity components, and therefore the revolutions per minute, of the sports equipment.

On the player there is an electronics unit which has two antennas. If a vector is drawn between these two antennas, its direction can be determined with respect to the reference frame generated by the side of field equipment by performing AoA calculations. However, if the electronics unit, containing the two antennas, is rotated about this vector, this rotation is indeterminate, since the direction of the vector is unchanged.

This is a problem in the case of the rugby scrum. Take, for example, a prop who is engaged in the scrum, and whose torso is approximately parallel to the ground. In this case the vector between the antennas is parallel to the ground and parallel with the sides of the field. If the prop drops a shoulder, this corresponds to a rotation about the antenna displacement vector and it is not measured.

This situation can be fixed by using an alternative arrangement, such as by adding a third antenna, which thus allows the Euler axis (same as the antenna displacement vector) and orientation angle (about the axis) to be determined. This allows for a rigorous calculation of the orientation of the electronics unit. However, a third antenna may be undesirable for a number of reasons (size, cost, complexity etc.). In this situation the direction of the antenna displacement vector is calculated as usual, and the rotation about the vector may be determined by making use of the data from the 9-axis IMU as well as information that is known a priori about the antenna radiation pattern.

The gain of the antenna has an angular dependency, and rotations about the antenna displacement vector therefore affect the side of field equipment's signal strength, as seen by the antennas on the player. By carefully combining data from the IMU and from the received signal strength, the orientation of the player can be determined to very high accuracy, without resorting to the use of a third antenna.

The sports equipment may have at least one sensor for collecting data. The sensor could be a force transducer for monitoring forces imposed upon a portion of the equipment. Preferably a plurality of force transducers are provided on the sports equipment. In the case of the equipment being body armour, force transducers may be provided at a locations corresponding to a wearer’s shoulders, arms, sternum, abdomen, sides, left middle back, right middle back and lower back. Preferred force transducers are conventional flexible conductive polymer force transducers. To determine static forces and pressures, force transducers are preferable over accelerometers which can be used to determine impact.

Other types of transducers can also be provided. For example a transducer could measure heart rate or monitor body temperature. A microphone could be used to collect audio data and a digital video recorder could collect video. The data reported by the device to the central server.

The sports equipment preferably comprises a control unit, for example comprising a microcontroller. The sports equipment preferably includes a power supply to supply electrical power, for example to those sensors which require power to operate as well as to the components of the control unit. A lithium ion polymer battery may be used. The power supply may be provided on the same part of the sports equipment as the sensors but this is not essential. For example, where the sports equipment comprises body armour the power supply may conveniently also be located on the body armour. However, this is not essential and the power supply may instead be located elsewhere on the wearer of the body armour.

The control unit and power supply may be provided in an electronics unit or device. Where the sports equipment is a rugby ball, the electronics unit could be located inside the ball, held in place at the ball's centre of gravity using tensile guide-wires. Where the sports equipment is body armour, the electronics unit may be located in a position corresponding to a point between the player's shoulder blades, which is already common practice for devices which use GNSS enabled chipsets for location.

As described above, the exemplary system comprises a device to be located on the field on either the player or in some other equipment and a set of antenna arrays positioned around the field. From data packets sent between the arrays and the device, the system is able to determine position and orientation of the device by analysing the ultra-wide band signals and determining AoA, TDoA and ToA and combining this with IMU data generated on the device. The intelligence to perform this analysis may be spread across each node or may be performed centrally at a central server. The data may be logged in a database for subsequent retrieval and analysis.

Methods and processes described herein can be embodied as code (e.g., software code) and/or data. Such code and data can be stored on one or more computer-readable media, which may include any device or medium that can store code and/or data for use by a computer system. When a computer system reads and executes the code and/or data stored on a computer-readable medium, the computer system performs the methods and processes embodied as data structures and code stored within the computer-readable storage medium. In certain embodiments, one or more of the steps of the methods and processes described herein can be performed by a processor (e.g., a processor of a computer system or data storage system). It should be appreciated by those skilled in the art that computer-readable media include removable and non-removable structures/devices that can be used for storage of information, such as computer-readable instructions, data structures, program modules, and other data used by a computing system/environment. A computer-readable medium includes, but is not limited to, volatile memory such as random access memories (RAM, DRAM, SRAM); and non-volatile memory such as flash memory, various read-only-memories (ROM, PROM, EPROM, EEPROM), magnetic and ferromagnetic/ferroelectric memories (MRAM, FeRAM), and magnetic and optical storage devices (hard drives, magnetic tape, CDs, DVDs); network devices; or other media now known or later developed that is capable of storing computer-readable information/data. Computer-readable media should not be construed or interpreted to include any propagating signals.

Referring now to the specifics of a rugby officiating system and with reference to Figures 2 and 3, a specific example will be described. When the scrum is set in the left image, the lateral orientation of the players is captured by the Officiating System. This may be through voice capture or manual triggering. In the right image, the loose-head prop (player 1) has rotated inwards (scrumming-in) and the change of his orientation is measured by the Officiating System and the infraction has been detected. The system has defined an envelope or window of acceptable change in which the orientation is allowed to change. Once the device or player exceeds that envelope, an alert is triggered. The alert may be to the referee directly or to a remote operator who may report it. Alternatively a traffic light signal on the device could be used or an audible alert.

In Figure 3, the scrum is set in the left image and the vertical orientation of the players is captured by the Officiating System. In the right image, the blue player is scrumming downwards (dipping/collapsing) and the change of his orientation is measured by the Officiating System as above and the infraction has been detected.

CLAIMS

1. A system to determine orientation on a sports field, the system comprising:

an electronic device comprising two or more antennas each connected to a respective transceiver and spaced apart by a predetermined distance;

an antenna arrangement comprising three or more antennas, each antenna arranged around a periphery of the sports field; and,

an analytics controller configured to detect signals transmitted between each of the antennas of the electronic device and the antenna arrangement and, based on the detected signals, determine orientation of the device by evaluating the time taken for signals to travel between each of the antennas of the electronic device and the antenna arrangement, such that when the electronic device is embedded within sports equipment the orientation of the equipment can be determined.

2. A system according to claim 1 in which each antenna of the electronic device and the antenna arrangement is associated with an ultra-wide band transceiver.

3. A system according to claim 1 or 2 in which the electronic device further comprises an inertial measurement unit (IMU) and which the analytics controller is further configured to determine the orientation using signals generated by the IMU.

4. A system according to any preceding claim in which the antenna arrangement comprises a plurality of antenna arrays each comprising a plurality of antennas.

5. A system according to claim 4 in which the antenna arrangement comprises at least 10 antenna arrays each comprising at least 1 antenna.

6. A system according to any preceding claim in which the analytics controller is further configured to determine position of the electronic device relative to the antenna arrangement based on the detected signals.

7. A system according to any of claims 2 to 6 in which the antenna arrangement and associated transceivers are together configured to transmit a signal from each antenna, the analytics controller being configured to detect signals received by the antennas of the electronic device.

8. A system according to any preceding claim in which the analytics controller is configured to determine a change in orientation of the device between a start time and an end time.

9. A system according to any preceding claim in which the analytics controller is configured to:

determine a first orientation; and,

subsequently monitor the orientation to identify a change in orientation.

10. A system according to claim 9 in which the first orientation is determined upon receipt of an instruction from an operator of the system.

11. A system according to claim 9 in which the first orientation is determined based on voice analysis of voice data received from a microphone positioned on the sports field.

12. A system according to claim 8 to 11 in which the analytics controller is configured to identify if the change in orientation of the device exceeds a predetermined envelope of acceptable change and output an indication if the envelope has been exceeded.

13. A system according to any preceding claim in which the system comprises two or more electronic devices and the analytics controller is further configured to compare the orientation of each electronic device.

14. A system according to any of claims 9 to 12 in which the system comprises two or more electronic devices and the analytics controller is further configured to compare the relative timing of the change in orientation of each electronic device.

15. A system according to any preceding claim in which the electronic device further comprises a control unit and a power supply.

16. A system according to any of claims 2 to 15 in which the system further comprises a force transducer embedded within the sports equipment, the analytics controller being further configured to detect signals received from the force transducer and monitor the force exerted on the sports equipment at a region in which the force transducer is embedded.

17. A system according to any preceding claim in which the orientation is determined relative to a reference frame generated by the antenna arrangement.