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(71) Applicant: KERILAB [FR/FR]; 57 Rue d'Amsterdam, F-75008 Paris (FR).

(72) Inventor: DE TROGOFF DU BOISGUEZENNEC, Erwan; 85 Boulevard Malesherbes, F-75008 Paris (FR).

(74) Agent: THIBON, Laurent; Cabinet Beaumont, 1 Rue Champollion, F-38000 Grenoble (FR).

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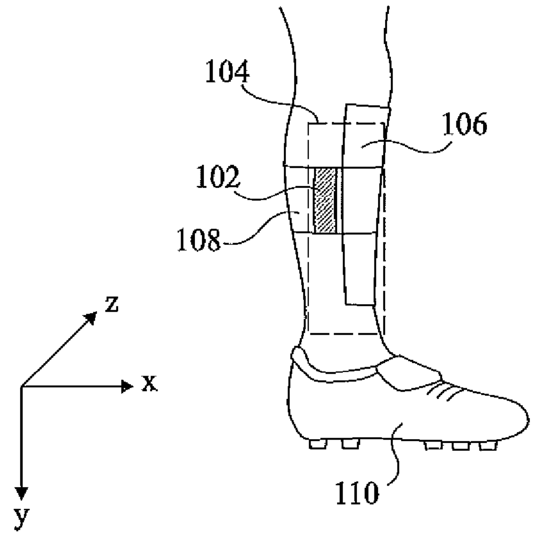


Fig 1

**(57) Abstract**: The invention concerns a method comprising: receiving, by a data processing device, movement data comprising at least rotation data indicating the rotation of a sensor device (102) attached to a leg or foot of a football player; and processing the movement data to generate a data value indicating whether or not the football player made a ball kick, wherein processing the movement data comprises: detecting, based on the rotation data, a period of movement of the leg or foot in a first direction; and generating the data value based on the detection of an impact during said period of movement.

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# METHOD AND DEVICE FOR DETECTING A BALL KICK

The present patent application claims priority from French patent application No. 14/54185, the contents of which is hereby incorporated by reference.

## FIELD

The present disclosure relates to the field of methods and devices for detecting ball kicks, and in particular for detecting, using a sensor device attached to a player's leg or foot, when the player kicks a football.

## BACKGROUND

As an aid for measuring player performance or for other types of statistical analysis during a football game, it has been proposed to provide capturing devices that permit a detection of each time a player kicks the football. For example, it may be desirable to automatically detect the number of times each player kicks the ball during a football match to provide a measure of each player's involvement in the game, or a measure of the level of ball possession of each team.

Existing solutions for detecting ball kicks tend to rely on sensors, incorporated into the football boots of the players, which detect when they come into close proximity with a transponder or the like incorporated into the football.

However, such existing solutions tend to be complex, highly energy consuming and/or costly. Furthermore, it is not always desirable that the football itself is modified to incorporate a transponder.

There is thus a technical need in the art for an alternative system for detecting ball kicks made by football players.

**SUMMARY**

It is an aim of embodiments of the present description to at least partially address one or more problems in the prior art.

According to one aspect, there is provided a method comprising: receiving, by a data processing device, movement data comprising at least rotation data indicating the rotation of a sensor device attached to a leg or foot of a football player; and processing the movement data to generate a data value indicating whether or not the football player made a ball kick, wherein processing the movement data comprises: detecting, based on the rotation data, a period of movement of the leg or foot in a first direction; and generating the data value based on the detection of an impact during said period of movement.

According to one embodiment, the sensor device is attached to the leg and not to the foot of the football player.

According to one embodiment, the movement data indicates the acceleration of the sensor device along at least a first axis and the rotation of the sensor device around at least the first axis or a different axis.

According to one embodiment, the acceleration of the sensor device along at least the first axis is based on a different between a first acceleration signal captured by a first accelerometer of the sensor device and a second acceleration signal captured by a second accelerometer of the sensor device, the first and second accelerometers for example being spaced apart by at least 2 cm.

According to one embodiment, the data processing device is part of the sensor device.

According to one embodiment, the movement data comprises rotation samples provided at a sampling rate of between 70 and 150 Hz.

According to one embodiment, the method further comprises generating, based on at least the direction of rotation of the sensor device prior to the ball kick, a further data value indicating a zone of the foot used to make the ball kick.

According to one embodiment, the data value indicating whether or not the football player made a ball kick is further generated based on a sound signal detected using at least one microphone of the sensor device and filtered by a high pass filter applying an attenuation of 10 dB or more to frequencies of 250 Hz and lower.

According to one embodiment, the method further comprises determining an angular displacement of the movement of the leg or foot in the first direction, wherein detecting the period of movement comprises comparing the determined angular displacement with a threshold level, the period of movement being detected if the angular displacement exceeds the threshold level, the threshold level for example being between 20 and 30 degrees.

According to one embodiment, detecting an impact is based on the Nth order derivative of the movement data, wherein N is a positive integer.

According to one embodiment, generating the data value indicating whether or not the football player made a ball kick comprises comparing the time that the impact occurred during the period of movement in the first direction with low and high thresholds.

According to one embodiment, generating the data value indicating whether or not the football player made a ball kick comprises generating a further data value indicating the occurrence of an impact between the player's foot and the ground.

According to one embodiment, generating the data value indicating whether or not the football player made a ball kick comprises generating another data value indicating the occurrence of a control contact between the player's foot and a ball by detecting whether a level of movement of the sensor device was below a threshold value prior to an impact with the ball.

According to one embodiment, the method further comprises estimating by the processing device a direction of a detected ball kick based on a direction of movement of the player's leg or foot during a detected ball kick, the direction of movement being determined based on orientation data provided by a magnetometer of the sensor device.

According to one embodiment, the method further comprises estimating by the processing device the altitude of the player's leg or foot during a detected ball kick based on altitude data provided by a barometer of the sensor device.

According to a further aspect, there is provided a data storage medium storing a computer program, that when executed by a processing device, causes the above method to be implemented.

According to a further aspect, there is provided a sensor device adapted to be attached to a leg or foot of a football player, the sensor device comprising: a detector adapted to detect rotation of the leg or foot; and a processing device adapted to: receive movement data from the detector, the movement data comprising at least rotation data indicating the rotation of the sensor device; and process the movement data to generate a data value indicating whether or not the football player made a ball kick, by: detecting, based on the rotation data, a period of movement of the leg or foot in a first direction; and generating the data value based on the detection of an impact during said period of movement.

According to a further aspect, there is provided a method comprising: receiving, by a data processing device, movement data comprising at least rotation data indicating the rotation of a sensor device attached to a leg or foot of a football player; and processing the movement data to generate a data value indicating the occurrence of a control contact between the player's foot and a ball, wherein processing the movement data comprises: detecting based on the movement data an impact to the player's foot or leg; and detecting that a control contact occurred if a level of movement of the sensor device was below a threshold value in a time period just prior to the detected impact, for example during a period D before the detected impact, where D is in the range 50 to 500 ms, and for example equal to around 200 ms.

According to a further aspect, there is provided a method of detecting a ball kick comprising: detecting, by a microphone of a sensor device attached to a football player, a sound signal; filtering the sound signal by a high pass filter to filter out at least frequencies lower than 250 Hz; and generating, based on the filtered sound signal, a data value indicating whether or not a ball kick occurred.

According to one embodiment, the high pass filter has a lower cut-off frequency of between 500 and 4000 Hz.

According to one embodiment, generating the data value based on the filtered sound signal comprises generating an amplitude signal by performing envelope detection on the filtered sound signal and comparing the amplitude signal with a threshold level.

According to one embodiment, the data value indicates the occurrence of a ball kick if the level of the amplitude signal is above the threshold value for more than a minimum time duration, and for example less than a maximum time duration.

According to one embodiment, the minimum time duration is between 15 and 25 ms, and the maximum time duration is between 70 and 90 ms.

According to a further aspect, there is provided a sensor device to be attached to a football player for detecting the occurrence of a ball kick comprising: a microphone adapted to detect a sound signal; a high pass filter adapted to filter the sound signal to filter out at least frequencies lower than 250 Hz; and a circuit adapted to generate, based on the filtered sound signal, a data value indicating whether or not a ball kick occurred.

According to a further aspect, there is provided a method comprising: receiving, by a data processing device, movement data generated by at least first and second accelerometers of a sensor device attached to a leg or foot of a football player, the movement data being equal to the different between a first acceleration signal generated by the first accelerometer and a second acceleration signal generated by the second accelerometer; and processing the movement data to generate a data value indicating whether or not the football player made a ball kick.

According to a further aspect, there is provided a sensor device for detecting the occurrence of a ball kick, the sensor device comprising: a first accelerometer adapted to generate a first acceleration signal; a second accelerometer adapted to generate a second acceleration signal; and a processing device adapted to generate movement data based on the difference between the first and second acceleration signals, and to generate, based on the movement data, a data value indicating whether or not the football player made a ball kick.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages will become apparent from the following detailed description of embodiments, given by way of illustration and not limitation with reference to the accompanying drawings, in which:

Figure 1 represents a sensor device attached to a football player's leg according to an example embodiment of the present disclosure;

Figure 2 schematically illustrates a system for detecting ball kicks made by one or more football players;

Figure 3 is a graph illustrating examples of a rotational speed signal Gz, a detected movement phase, acceleration signals Ax, Az and Ay, and a signal IMPACT, in the case of a ball kick made by a player with the sensor device attached to his/her leg or foot according to an example embodiment of the present disclosure;

Figure 4 is a flow diagram illustrating operations in a method of detecting a ball kick according to an example embodiment;

Figure 5 shows an outline of a foot showing examples of zones of the foot used to make a ball kick according to an example embodiment;

Figure 6 is a flow diagram illustrating operations in a method of detecting a ball kick according to a further example embodiment of the present disclosure;

Figure 7 is a graph illustrating test data showing acceleration values Ax, Ay and Az, and rotation values Gx, Gy and Gz;

Figure 8 schematically illustrates a circuit for detecting a sound signal corresponding to a ball kick according to an example embodiment; and

Figure 9 is a spectral diagram illustrating an example of frequencies detected by a microphone during an impact of a foot with the ground and with a ball according to an example embodiment of the present disclosure.

**DETAILED DESCRIPTION**

Figure 1 illustrates a sensor device 102 attached to a football player's leg. In some embodiments, the sensor device 102 is attached to the player's dominant leg, which the player uses most often to kick the ball. In the example of Figure 1, it is attached to the player's right leg. In alternative embodiments, for example for players who are ambidextrous, a sensor device 102 could be attached to each of their legs.

The sensor device 102 is for example attached within a zone 104 of the leg, delimited by a dashed rectangle in Figure 1, corresponding to the outside of the lower leg, between the shin and calf muscle. However, in alternative embodiments, the sensor device 102 could be attached anywhere on the lower leg below the knee. The sensor device 102 is for example positioned between the skin of the shin and the shin guard. For example, the sensor device 102 is integrated into the shin guard 106, by being attached to an inner wall of the shin guard. Alternatively, it could be fixed within a housing moulded into the shin guard, so that the sensor device 102 can be inserted into and detached from the housing at will. As a further example, the sensor device could be incorporated into the footballer's sock, and/or into the sleeve that holds the shin guard in place.

The sensor device 102 may also be attached using a strap 108, which may be elasticated, and which wraps around the lower leg and for example is fastened with Velcro or the like (the name "Velcro" may correspond to a registered trademark). Alternatively, in some embodiments, rather than being position on the player's leg, the sensor device could be attached to the player's football boot.

The sensor device 102 is for example a mobile device, meaning that it has an internal power source, such as a battery. Furthermore, in some embodiments, it is capable of wireless communications.

As represented in Figure 1, the sensor device 102 is for example capable of capturing motion data relative to at least one of three axes, an axis x that corresponds substantially to an axis running along the length of the foot of a football player when the player is standing on the ground, an axis y, perpendicular to the axis x, which corresponds to an axis substantially running along the length of the low leg, and an axis z, which is perpendicular to the axes x and y. In some embodiments, rather than using both of the axes x and z, a combined axis could be used, for example corresponding to 2/3 of the z axis and 1/3 of the x axis. Throughout the present specification, the term "substantially perpendicular to X" is assumed to mean perpendicular to X with a tolerance of plus or minus 30 degrees. Similarly, the term "substantially along the length of X" is assumed to mean along the length of X with a tolerance of plus or minus 30 degrees.

As will be explained in more detail below, the sensor device 102 is for example capable of detecting at least a rotation around either or both of the axes z and x, and may also be capable of detecting acceleration along the axis z. In certain embodiments, the sensor device is also capable of detecting acceleration along each of the axes x, y and z, and rotation around each of the axes x, y and z. Generally, the signs applied to the acceleration signals herein assume positive values shown by the directions of the corresponding arrows in Figure 1, i.e. acceleration along the axis x is positive in the direction of the front of the foot, acceleration along the axis y is positive in the downwards direction, and acceleration along the axis z is positive in the direction of the inside of the foot, assuming that the sensor device is attached to a player's right leg or foot. The signs applied to the rotation signals herein, again assuming that the sensor device is attached to a player's right leg or foot, assume a positive rotation around the axis x when the foot is rotated in the inside direction, a positive rotation around the axis y when the point of the foot is pivoted outwards, i.e. in a clockwise direction, and a positive rotation around the axis z when the foot is rotated backwards. In the case of a sensor device attached to the left leg of a player, a positive acceleration along the axis x and a positive rotation around the axis x are for example in the opposite directions. Of course, the opposite signs could be used for one or more of the signals.

Figure 2 schematically illustrates a system 200 for detecting ball kicks according to an example embodiment.

The system 200 comprises one or more sensor devices 102, one of which is illustrated in Figure 2. Each sensor device 102 is for example capable of communicating with a central unit 204. The sensor device 102 for example comprises a processing device (P) 206, under the control of an instruction memory (INSTRU MEM) 208. In alternative embodiments, the functions of the sensor device 102 could at least partially be implemented by dedicated hardware, such as an ASIC (application specific integrated circuit), FPGA (field programmable gate array), or the like, and in such a case, the instruction memory 208 could be omitted.

The sensor device 102 further comprises a data memory (DATA) 210, which for example stores at least recently captured movement data captured by a rotation detector (R) 212 and an acceleration detector (A) 214 of the device 102. In some embodiments, the sensor device 102 may comprise, in addition to the acceleration detector 214, a further acceleration detector 214', which is for example spaced from the detector 214 by at least 2 cm. Such an arrangement for example permits gravity to be eliminated by determining the difference between the signals from the detectors. When the use of acceleration data is described herein after, it should be understood that this data may be derived from a signal accelerometer, or from a pair of accelerometers as described here.

The rotation detector 212, which is for example a gyroscope, for example detects the speed of rotation of the sensor device 102 around each of the three axes x, y and z of Figure 1. As will be explained in more detail below, the signal indicating the speed of rotation around each axis is for example integrated in order to detect an angular displacement around each axis. Alternatively, rather than providing the rotational speed, the rotation detector 212 may directly provide the angular displacement.

The acceleration detectors 214, 214', which are for example accelerometers, for example each detect the acceleration of the sensor device 102 along the three axes x, y and z of Figure 1. Of course, in some cases, the sensor device 102 may be oriented in such a way with respect to the player's leg or foot that the data provided by the detectors 212 and 214 does not correspond to the axes x, y and z. However, it will be appreciated by those skilled in the art that the processing device 206 can be configured to map the available data onto the axes x, y and z. For example, a vertical orientation of the sensor device 102 can be detected using the acceleration signals, based on the direction of gravity, while the player is standing with both feet on the ground.

The rotation and acceleration detectors 212, 214, 214' are for example adapted to provide data at a sampling rate of at least 50 Hz, and preferably between 70 and 150 Hz. Detection has been found to work particularly well at a sampling frequency of around 100 Hz, for example of between 90 and 110 Hz.

The sensor device 102 for example further comprises a GPS (global positioning system) 216 and/or one or more other systems for determining the location of the player with a precision of a few metres at most, as well as the speed and acceleration of the player. Furthermore, in some embodiments the device 102 comprises a communications interface 218 allowing wireless communications with the central unit 204 via a wireless transmission unit 220 and an antenna 222. The sensor device 102 for example further comprises a battery 224.

In some embodiments, the sensor device 102 further comprises a sound detection circuit (M) 225 comprising a microphone for detecting a ball kick. Furthermore, a further sound detection circuit 225' comprising a further microphone may permit stereo detection. In the case that there are two sound detection circuits, the microphones of the circuits are for example spaced from each other by at least 2 cm.

While not illustrated in Figure 2, the sensor device 102 may further comprise a magnetometer and/or a barometer coupled to the processing device 206.

The central unit 204 for example comprises a processing device (P) 226 under the control of an instruction memory (INSTR MEM) 228. In alternative embodiments, at least some of the functions of the central unit 204 may be implemented by dedicated hardware such as an ASIC, an FPGA or the like, and in such a case, the instruction memory 228 could be omitted.

The central unit 204 further comprises a data memory (DATA) 230 coupled to the processing device 226, and for example adapted to store data transmitted from the one or more sensor devices 102. Thus the central unit 204 for example comprises a communications interface 232 allowing wireless communications with each of the sensor devices 102 via a transmission unit 234 and an antenna 236.

The wireless communications between the sensor device 102 and the central unit 204 are for example performed at a frequency of between 300 MHz and 6 GHz, a frequency range that the present inventor has found to be particularly well suited to wirelessly transmitting, during a football game, signals from one or more of the players to the central unit 204 located close to the edge of the pitch. Indeed, the present inventor has found such a frequency range provides sufficiently high data transmission rates over the distances involved of up to 100 m and also in view of the interference that may be caused by the presence of a human body close to the sensor devices 102. For example, the frequency chosen for transmission is between 850 and 950 MHz, such as 868 MHz or 915 MHz.

In alternative embodiments, the sensor device 102 and central unit 204 could communicate via a wired interface. For example, data gathered by each sensor device 102 is stored in the memory 210 until the next time the player leaves the pitch, and at that time this data is transferred to the memory 230 of the central unit 204 by connecting the devices together using a suitable cable. In such a case, the wireless interfaces of the sensor device 102 and central unit 204 could be omitted.

In some embodiments, the system 200 further comprises a server 240, which for example communicates with the central unit 204 via the internet during the game or at the end of the game in order to transfer the data received from the sensor devices 102 to a memory of the server 240. The server 240 may perform additional processing of the player data, and for example makes the data available to devices (not illustrated in Figure 2) of interested parties, such as the football coach and the players themselves. For example, the data could be made available to web applications, mobile telephone applications such as iOS or Android applications, and/or to desktop computers or laptops for more in depth analysis of the data. Furthermore, the data may be transmitted to other interested parties, such as match commentators, sports websites, football federations, etc.

While the system of Figure 2 comprises a central unit 204, in alternative embodiments each sensor device 102 may be a standalone unit, capable of measuring individual performance of a player, and of communicating data to the server 240 and/or to other equipment, at the end of each playing period.

Figure 3 is a graph illustrating examples of the rotational speed signal -Gz, a corresponding detected movement phase, the acceleration signals Ax, Az and Ay, and a signal IMPACT, in the case of a ball kick made by a player with the sensor device 102 attached to his/her leg or foot. The signals of Figure 3 will now be described in more detail with reference to Figure 4.

Figure 4 is a flow diagram illustrating operations in a method of detecting a ball kick according to an example embodiment. These operations are for example performed by the processing device 206 of the sensor device 102 in near real time, for example with a delay of just a few seconds, or even in less than one second, after the events being captured. It is assumed that a sensor device 102 has been attached to the leg or foot of one or more players and activated such that at least the rotational speed detector 212 is providing samples to the processing device 206 for analysis. Furthermore, if not already paired together, each sensor device 102 may be paired with the central unit 204, for example by passing it within relatively close proximity of this unit, e.g. within a few meters, or using a suitable contactless communications standard, such as Bluetooth, Bluetooth Smart v4 / Low Energy and/or RFID (radio-frequency identifier) NFC (near field communication) technologies to pair the devices.

In a first operation 401, movement data is received by the processing device 206. The movement data indicates at least the rotation of the sensor device 102 around the axis z and/or x, or an axis corresponding to a combination of these axes, and in some embodiments also indicates the acceleration Az along the axis z. In some embodiments, the data memory 210 buffers at least the latest three samples of the rotational speed and acceleration signals. Furthermore, in some embodiments, one or more filters or algorithms may be applied to the raw data before it is processed, such as a simplified Kalman filter, Wavelet transform or the like.

In a subsequent operation 402, an impact is detected based on the movement data. The occurrence of an impact is for example determined based on an analysis of one or more of the acceleration signals Ax, Ay and Az. As represented in the example of Figure 3, the acceleration signals Ax, Ay and Az along the axes x, y and z for example generally vary with relatively shallow sloped gradients, except at moments of impact, at which moments the gradients spike high or low.

Spikes labelled 308, 310 and 312 in Figure 3 of the signals Ax, Az and Ay respectively for example correspond to a ball kick, and each occur approximately halfway through period 304. Spikes labelled 314, 316 and 318 for example correspond to the player's foot landing on the ground, and occur during the phase 0 period following the movement. Thus only the spikes 308, 310 and 312 will be taken into account as potential impacts.

The impact is for example detected based on the derivative of one or more of the acceleration signals, for example based on the following formula for a value IMPACT:

$$IMPACT = \|A(n) - A(n-1)\|$$

where $\|x\|$ is the norm of x, and A(n) is a current acceleration sample, and A(n-1) is a previous acceleration sample. In some embodiments, the acceleration samples are samples of Az alone, indicating the acceleration along the axis z. In alternative embodiments, the acceleration samples are vectors comprising acceleration samples along two or three of the axes x, y and z. For example, in the case that the vector comprises samples of Ax and Az, the value IMPACT is for example determined by:

$$IMPACT = \sqrt{\left(Ax(n) - Ax(n-1)\right)^2 + \left(Az(n) - Az(n-1)\right)^2}$$

In alternative embodiments, an impact is determined based on the second derivative of one or more of the acceleration signals. The second derivative has been found by the present inventor to provide a particular good indicator of an impact caused by kicking a football. For example, an impact is determined based on the following formula:

$$IMPACT = \|deltaA(n) - deltaA(n-1)\|$$

where delta(n) is equal to $\|A(n) - A(n-1)\|$, and delta(n-1) is equal to $\|deltaA(n-1) - deltaA(n-2)\|$.

In alternative embodiments, an impact is determined based on the first or second derivative of one or more of the rotational speed signals Gx, Gy, Gz, based on the above formulas with the acceleration signal or signals replaced by the appropriate rotation signal or signals. In yet further embodiments, the third or Nth order derivatives of one or more of the rotation or acceleration signals could be used to detect an impact, where N is an integer equal to 1 or more.

The IMPACT value is for example determined for each sample occurring during the phase 1 period, in order to generate a signal, an example of which is represented in Figure 3 labelled IMPACT. An impact is for example considered to have occurred if the value of IMPACT exceeds a threshold level at least once during the detected movement phase 1. An example of such a threshold value is labelled TH1 in Figure 3.

Alternatively or additionally, other characteristics of the IMPACT signal could be used to determine the presence of an impact, such as the presence of a peak having a rising edge of a relatively high gradient, and/or that the duration of the impact, labelled $t_{IMPACT}$ in Figure 3, is between a low threshold of between 10 and 30 ms, for example 20 ms, and a high threshold of between 100 and 150 ms, for example 120 ms. The duration for example corresponds to a period between times T1 and T2 during which the impact values are higher that a further threshold. An example of the further threshold is labelled TH2 in Figure 3, and is for example lower than the threshold TH1.

Referring again to Figure 4, in a subsequent operation 403, based on the movement data, a movement of the leg or foot is detected, and it is determined whether or not the impact occurred during the movement.

Movement detection is for example based on the rotation data corresponding to the axes x and/or z. Figure 3 illustrates an example in which a movement is detected based on the inverse -Gz of the rotational speed signal Gz along the axis z. The signal -Gz starts negative during a period 302, then goes positive during a subsequent period 304, and returns negative during a subsequent period 306.

A movement in one direction is for example detected by detecting when the rotational speed signal turns positive, implying the start of movement of the leg or foot in that direction. The end of the movement is for example detected by detecting when the rotational speed signal turns negative, implying the start of movement of the leg or foot in the opposite direction. Thus, calling the period of movement for a given signal "phase 1", and other periods "phase 0", the signal -Gz is in phase 0 during the periods 302 and 306 while the signal -Gz is negative, and in a phase 1 while the signal -Gz is positive.

In order to detect movements in each direction along the axis z, the same movement detection operation is for example performed on both the signals –Gz and Gz. Similarly, the movement detection may be performed on the signal Gx, and on its inverse -Gx.

In some embodiments, only angular displacements of the sensor device of a minimum amount are detected as movements. For example, the angular displacement of the sensor device is determined by integrating the rotational speed signal Gx and/or Gz during the phase 1 period. In one example, the integration is determined by adding together the samples of Gx and/or Gz during the phase 1 period, in other words while the signal Gx, -Gx, Gy or –Gy is positive. For example, the threshold level of the angular displacement is selected to correspond to a displacement of between 20 and 30 degrees.

Referring again to Figure 4, if in operation 403 the impact was detected during a movement, the next operation is 405, where the presence of such an impact is for example interpreted as a ball kick. In some embodiments, when a kick is detected, the processing device 206 may generate a value directly indicating that a ball kick occurred, while in other embodiments, the processing device 206 may generate a value indicating the probability of whether or not a ball kick occurred, and other data can be used to validate or discredit the presence of a ball kick. For example, the central unit 204 may discredit the occurrence of a ball kick by one player if there is a higher probability that another player kicked the ball at the same time.

In alternative embodiments, rather than detecting a kick based on solely on the presence of an impact during a period of movement, further factors are used to verify the presence of a kick, as will be described in more detail below. In such cases, certain characteristics of the impact are for example recorded, such as:

- the start time of the impact;
- the duration of the impact, which is for example expressed as the number of samples for which the impact value is above a threshold level;
- a value of the impact, for example corresponding to the maximum value of the IMPACT signal, or the sum of the values of the IMPACT signal during the impact;
- an estimated zone of the impact, described in more detail below; and/or
- the values of Ay, Gx and Gz at the start of the impact, for example at the start of the duration $t_{IMPACT}$ of Figure 3.

While Figure 4 illustrates an example in which an impact is detected, and it is then verified whether the impact occurred during a detected movement, in alternative embodiments it would be equally possible to additionally or alternatively detect a movement, and then verify whether an impact occurred during the detected movement.

Figure 5 shows an outline of a foot illustrating examples of zones of the foot used to make a ball kick. As illustrated, the zones of the foot are for example expressed as hours on a clock face, with:

- 12 o'clock corresponding to a kick made straight forwards using the toe, also known as a toe kick, or using the instep of the foot, also known as a "laces" kick;
- 3 o'clock corresponding to kick made with the outside of the foot, also known as an outside kick;
- 6 o'clock corresponding to a kick made with the heel of the foot, also known as a back heel kick; and
- 9 o'clock corresponding to a kick made with the inside foot, also known as a push kick or inside-of-foot kick.

The direction 502 between 9 and 12 for example corresponds to an inner side of instep kick (in French "coup de pied"), for example at between 10 and 11 o'clock.

The 3 o'clock / 9 o'clock axis corresponds to the axis z of Figure 1, and the 12 o'clock / 6 o'clock axis corresponds to the axis x of Figure 1. The zone of the foot used to kick the ball is for example determined based on the values of the signals Gx and Gz just prior to the impact. It is assumed that the foot swinging forwards corresponds to a negative rotation around the Gz axis, and that the inside foot and leg swinging forward corresponds to a positive rotation around the Gx axis. Thus a low absolute value of Gx and a positive and relatively high value of Gz corresponds to a kick made in or around the 12 o'clock zone, e.g. 11 o'clock to 1 o'clock, a low absolute value of Gx and a negative and relatively high value of Gz corresponds to a kick made in or around the 6 o'clock zone, e.g. 5 o'clock to 7 o'clock, a low absolute value of Gz and a positive and relatively high value of Gx corresponds to a kick made in or around the 9 o'clock zone, e.g. 8 o'clock to 10 o'clock, and a low absolute value of Gz and a negative and relatively high value of Gx corresponds to a kick made in or around the 3 o'clock zone, e.g. 2 o'clock to 4 o'clock. Positive values of both Gx and Gz, each relatively high, for example corresponds to a kick made in or around the 10:30 zone, e.g. 10 o'clock to 11 o'clock.

In addition to determining a zone of the foot used to make a ball kick, other characteristics may be estimated, such as the orientation and altitude of the foot when the ball was kicked, and the direction in which the ball was kicked.

For example, in the case that the sensor device 102 comprises a magnetometer, this for example provides orientation data indicating the orientation of the sensor device with respect to the horizontal plane, and this information can be used to estimate the orientation of the leg or foot of the player at the time the ball is kicked. Additionally or alternatively, the magnetometer provides an indication of the direction of magnetic north, and this information can be used to estimate the direction in which the ball is kicked. For example, the direction is estimated based on the average direction of movement of the foot, with respect to magnetic north, during an impact with the ball.

In the case that the sensor device 102 comprises a barometer, this can provide data indicating the altitude of the foot with respect to the ground during an impact with the ball. For example, the altitude of the ground can be estimated based on the reading from the barometer during a recent detected impact of the foot with the ground, for example a reading taken within the 5 seconds preceding the impact with the ball. The altitude of the foot is for example the average altitude during a detected impact with the ball.

Figure 6 is a flow diagram illustrating operations in a method of detecting a ball kick according to a further example embodiment. These operations are for example performed by the processing device 206 of the sensor device 102 in near real time, for example with a delay of just a few seconds, or in even less than one second, after the events being captured.

Furthermore, it is assumed that a sensor device 102 has been attached to the leg or foot of one or more players and activated such that at least the rotational speed detector 212 is providing samples to the processing device 206 for analysis. It will be apparent to those skilled in the art that the levels of the various thresholds described herein can be calibrated during a calibration phase based on the magnitudes of the signals provided by the detectors of the sensor device.

In a first operation 601, the end of an impact is detected, for example corresponding to the time T2 in Figure 3. The impact is for example detected in the same fashion as described above with reference to operation 402 of Figure 4.

In a subsequent operation 602, it is determined whether or not the impact is valid, for example based on the peak level, gradient and/or duration of the IMPACT signal as described above in relation to operation 402 of Figure 4. If the impact is not valid, the method ends. Alternatively, if the impact is valid, the next operation is 603.

In operation 603, a value of the impact is determined, for example based on the maximum value of the IMPACT signal, or based on the sum of the values of the IMPACT signal during the impact. Furthermore, other characteristics relating to the impact may also be determined, such as a zone of the impact, the time T1 of the start of the impact, and the duration tIMPACT of the impact corresponding to T2-T1. The zone of the impact is for example determined as being in either the interior or exterior of the foot, based on the signal Az representing the acceleration along the axis z. For example, minimum and maximum values of the signal Az during the impact are detected, and compared to the value of Az at the time T1 at the start of the impact. If the first peak after the start of the impact is the minimum value of the signal Az, in other words, the peak is a negative peak, the zone is considered to be the interior zone, for example between 7 and 11 o'clock in the representation of Figure 5. If however the first peak after the start of the impact is the maximum value of the signal Az, in other words, the peak is a positive peak, the zone is considered to be the exterior zone, for example between 1 and 5 o'clock in the representation of Figure 5.

In a subsequent operation 604, it is determined whether or not a movement is in progress.

If not, the next operation is 605, in which it is determined whether a ball control has been made by a player, where the ball moves into contact with the foot while the foot is off of the ground and relatively static. For example, it is determined whether, during a certain period D before the detected impact, the player's leg and/or foot were relatively static. For example, the period D is in the range 50 to 500 ms, and for example equal to around 200 ms. If so, in some embodiments the probability $P_{CONTROL}$ of the occurrence of a ball control, and the probability $P_{STEP}$ of an impact with the ground, in other words a foot step, are then determined.

The probability $P_{CONTROL}$ of a ball control is for example determined based on one or more of the following indicators:

- the magnitude of the impact is above a lower threshold;

- the duration of the impact is below an upper threshold, for example of between 50 and 70 ms, such as 60 ms;

- movement levels just prior to and/or just after the impact are below an upper threshold, the movement levels for example being determined by the norm of one or more of the signals Gx, Gy, Gz, Ax, Ay and Az; and

- the signal IMPACT described above has a peak higher than a lower threshold.

The probability $P_{STEP}$ of an impact with the ground, in other words a foot step, is for example determined based on one or more of the following indicators:

- at the start of the impact the signal Ay has a level lower than an upper threshold;

- during the impact, the signal Ay has a peak significantly greater than the initial level, for example of at least four times greater;

- after the peak, the signal Ay falls to trough lower than an upper threshold; and

- the signal Gx, Gy and/or Gz has a trough, in other words a negative peak, during the impact.

The probability of an impact with the ground is for example a function of the number of the above indicators that are present. Alternatively, the probability may be a function of the level of one or more of the signals involved in determining the presence of the indicators.

In a subsequent operation 606, it is for example determined whether the probability $P_{CONTROL}$ is greater that the probability $P_{STEP}$. If not, the method for example ends. Alternatively, if the probability of a ball control is higher, the next operation is 607.

In operation 607, the probabilities $P_{CONTROL}$ and $P_{STEP}$ are for example transmitted from the sensor device 102 to the central unit 204, and/or stored in the data memory 210 of the sensor device 102. In alternative embodiments, rather than transmitting each of the probabilities determined in operation 605, only the difference between these probabilities is transmitted and/or stored. The probability value or values is/are for example accompanied by an indication of the zone of impact, and of the time of impact.

If in operation 604 it is determined that a movement is in progress during the detected impact, the next operation is for example 608, in which the end of the movement is awaited, and then detected. In some embodiments, the operation 608 may also be triggered by the end of any detected movement, independently of the operations 601 to 607.

When the end of the movement is detected in operation 608, the next operation is 609, in which it is determined whether or not the movement is valid, for example based on the duration and/or angular displacement of the movement, as described in relation to operation 403 of Figure 4. If the movement is not valid, but an impact has been detected, the method for example goes to operation 605, described above. Alternatively, the next operation is 610.

In operation 610, it is determined whether the/an impact occurred during the movement, in other words after the start T1 and before the end T2 of the detected movement. If not, the method for example ends. If however the impact did occur during the movement, the next operation is 611.

In operation 611, probabilities $P_{STEP}$ of an impact with the ground, and $P_{KICK}$ of a ball kick, are for example determined. The probability $P_{STEP}$ is for example determined as described above with reference to operation 605. The probability $P_{KICK}$ of a ball kick is for example determined based on one or more of the following indicators:

- the angular displacement of the sensor device is higher than a lower threshold, for example of between 20° and 30°;

- the speed of rotation at the start of the impact is higher than a lower threshold, for example of between 20 and 40° per second, such as 30° per second; and

- the impact occurs between a minimum and maximum percentage of the way through the movement period, in other words through the phase 1 period, the minimum percentage for example being between 30 and 45 percent, and the maximum percentage for example being between 60 and 75 percent.

The probability of a ball kick is for example a function of the number of the above indicators that are present. Alternatively, the probability may be a function of the level of one or more of the signals involved in determining the presence of the indicators.

In the subsequent operation 612, it is determined whether $P_{KICK}$ is greater than $P_{STEP}$. If not, the method for example ends. If $P_{KICK}$ is greater than $P_{STEP}$, the next operation is 613.

In operation 613, the probabilities determined in operation 611 are for example transmitted from the sensor device 102 to the central unit 204, and/or stored in the data memory 210 of the sensor device 102. In alternative embodiments, rather than transmitting each of the probabilities determined in operation 611, only the difference between these probabilities is transmitted and/or stored. The probability value or values is/are for example accompanied by an indication of the zone of impact, and of the time of impact.

The method of Figure 6 is for example applied to an impact detected based on any of the signals Gx, Gy, Gz and Ax, Ay and Az. If an impact is detected on more than one of these signals, they may correspond to a single event, and this can be confirmed by comparing the times of impact, to check whether they occur at substantially the same time. If so, the probability of a ball kick is for example increased.

It will be apparent to those skilled in the art that the flow diagram of Figure 6 provides just one example, and that various modifications could be applied to this method. For example, the order of the operations could be changed, such as the order of operations 605 and 611.

An advantage of the embodiments described herein is that a data value indicating the occurrence of a ball kick can be determined directly by a processing device of a sensor device attached to a player's leg or foot. This leads to the advantage that there is a relatively small amount of data to be transmitted to a central unit and/or stored in a memory of the sensor device. Furthermore, the processing device can be of relatively low power. For example an 8-bit processor operating at 8 MHz with 2 Kb of memory, could be used, leading to low energy usage. It has been found by the inventor that the data value generated based on at least rotation data accurately indicates the occurrence of a ball kick in the majority of cases.

An advantage of attaching the sensor device described herein to a player's leg rather than to a players boot is that the cost of such a solution is significantly lower. Indeed, integrating the device into a football boot is a complex task and may impact the player's performance if placed in a zone of the boot that the player uses to kick the ball. An advantage of the described methods for detecting a ball kick is that they work when the sensor device is attached to the player's leg or foot.

Furthermore, it has been found that the method described herein in relation to Figure 4 is particularly effective for distinguishing a ball kick from other impacts such an impact with the ground. This is demonstrated by the test results shown in Figure 7.

Figure 7 illustrates acceleration signals Ax, Ay and Az, and rotation signals Gx, Gy and Gz captured during a period t of 1.7 seconds, for a sensor device attached to a player's leg, for example to the player's shin. The figure illustrates examples of two steps P1 and P2 in which the player's foot impacts with the ground, and then a ball kick K1 followed by a further step P3 during which the player's foot impacts with the ground again.

It can be seen that, based on the acceleration data alone, it is not possible to distinguish a ball kick from an impact with the ground. Indeed, discontinuities created by an impact with the ground can actually be greater than those generated during a ball kick. Furthermore, the kick cannot be distinguished from a ground impact by the intensity of the acceleration signals, in one axis rather than another, or by a particular timing. Additionally, the acceleration signals are different from each other during the three ground impacts.

Furthermore, based on only one of the rotation signals it is also not possible to distinguish a ball kick.

However, by detecting when an impact occurs during a period of movement of the sensor device in a same direction, a kick can be detected with high precision. Indeed, during the three ground impacts, the acceleration data clearly highlights the presence of an impact. The rotation data shows the direction of rotation changing, or some gentle backwards rotation around the z axis. This is because as the player walks or runs and the foot touches the ground, the knee continues to turn around the foot, and thus rotation continues at the level of the player's leg. However, the extent of rotation during such a ground impact will be relatively low when compared to the rotation occurring during a ball kick, and thus this rotation will not be detected as corresponding to a period of movement. Such a backwards rotation would not be present if the sensor device is positioned in the boot of the football player..

During the ball kick, the signal Gz shows that the leg clearly has a forwards rotation component around the z axis when the impact arrives, indicating the occurrence of a ball kick with a front part of the foot.

In some embodiments, a ball kick may additionally or alternatively be detected based on sound detected by the sound detection circuit 225. The sound created by the impact of the foot with the ground can be distinguished from the sound created by the impact of the foot with a ball.

Figure 8 schematically illustrates the sound detection circuit 225 in more detail according to an analog implementation.

As illustrated, the circuit 225 for example comprises a microphone 802 adapted to detect sound in the environment of the sensor. The signal detected by the microphone 802 is for example filtered by a high-pass filter 804. This filter 804 for example has a lower cut-off frequency of between around 500 Hz and around 2 kHz. For example, the filter 804 is implemented by a second or third order filter having a lower cut-off frequency of between 250 and 1000 Hz, or by first order filter having a lower cut-off frequency of between 1000 and 4000 Hz. The filter could also be of an even higher order. The filter for example applies an attenuation of at least 10 dB to frequencies of 250 Hz or lower, and for example an attenuation of 20 dB or more to these frequencies.

The filtered signal is for example provided to an envelope detector 806, which detects the amplitude of the signal. The output of the envelope detector is for example provided to a comparator 807, which compares the detected signal with a threshold voltage $V_{TH}$. The output of the comparator 807 is for example coupled to a block 808, which detects when the output of the comparator is high for a duration d between a lower limit $d_{min}$ and an upper limit $d_{max}$. In one example, $d_{min}$ is equal to between 15 and 25 ms, and is for example around 20 ms, and $d_{max}$ is equal to between 70 and 90 ms, and is for example around 80 ms. For example, this determination could be performed using a counter to generate the lower and upper time limits. When this condition is met, a signal $S_{OUT}$ of the sound detection system 225 is for example asserted to indicate that a ball kick occurred. This signal is for example provided to the processing device 206 of the sensor device 102 of Figure 1.

Rather than the analog implementation of Figure 9, in alternative embodiments, at least part of the circuit could be implemented digitally. For example, the signal from the microphone 802 could be converted into a digital signal by an analog to digital converter, for example operating at a sampling frequency of at least 4 kHz, and in some embodiments at least 8 kHz. For example, the converter is at least an 8 bit converter, and in some embodiments, a 12 bit, 16 bit or an even higher bit rate converter could be used. The filtering operation, amplitude detection, comparison with a threshold, and detection of the duration of the signal can then be performed digitally.

Furthermore, in some embodiments, the sound detection circuit 225 could be implemented by an integrated circuit having integrated thereon a microphone, for example in the form of a MEMS (micro-electro-mechanical system), and an analog to digital converter providing a digital signal to the processing device 206. The processing device 206 may then perform the frequency filtering and amplitude detection.

The threshold voltage $V_{TH}$ corresponds for example to a level of between -25 and -50 dB with respect to the maximum signal value generated by the microphone.

Figure 9 is a spectral diagram illustrating the amplitude of sound over a frequency range of 125 to 2000 Hz for an impact between a foot and the ground (solid curve) and between a foot and a ball (dashed curve). The frequencies are shown on a log scale. As illustrated, below a frequency of around 500 Hz, the levels for a ball kick and for a ground impact are very similar. At around 500 Hz, the signals are both relatively low. However, while the ground impact has a relatively low sound level at frequencies over 500 Hz, the sound level of the ball kick rises again. Thus by detecting the level of frequency components in the frequency range of 500 to 2500 Hz or higher, the occurrence of a ball kick can be distinguished from a ground impact.

In some embodiments, the sound detection system 225 can be relied on independently of the any other ball kick detection system to detect the occurrence of a ball kick. In alternative embodiments, the sound detection system 225 is used in conjunction with the impact detect system described above based on movement data to confirm the presence of a ball kick. For example, a ball kick may be detected with greater certainty if, during a period of movement of the leg or foot, not only is an impact detected, but also the sound signal of a ball kick is detected. Additionally or alternatively, the sensitivity of detection of a ball kick can be increased by basing it on the combination of movement and sound detection. For example, a detected movement of relatively low amplitude may be identified as a ball touch if detected at the same time as a sound signal corresponding to a ball kick.

As described above in relation to Figure 1, the sensor device 102 may comprise a pair of sound detection circuits 225, 225' providing stereo detection. Such a configuration for example permits a localization of the source of the sound with respect to the sensor device 102. For example, sound localization using a pair of microphones is described in more detail in the publication by G. Reid et al. entitled "Active Binaural Sound Localization", IX European Signal Processing Conference (EUSIPCO), IV:2353{2356, September 1998, and in the publication by G. Reid et al. entitled "Active Stereo Sound Localization", J. Acoust. Soc. Am. 113, 185 (2003), the contents of these publications being hereby incorporated by reference. For example, such a technique can be used to localize ball kicks with respect to one or more of the sensor devices attached to the player kicking the ball and/or to other players on the field.

In some embodiments, the sound signal provided by one or more microphones of the sound detection circuit 225 and/or 225' could additionally be used to detect other useful information, such as the position of the players on the pitch without the use of video or GPS. Indeed, such a solution could for example be employed in an indoor environment where a GPS signal is not available. Furthermore, by relying on microphones in sensor devices attached to players, it is not necessary to install radio or optical beacons around the pitch. Sounds picked up by any microphone, such as kicks, cries, panting, whistles, etc., are for example picked up by the sensor device of each player, and the levels of these signals and the time instants at which they occur will be slightly different from each other depending on the distance of each player to the sound. By using the signals captured by a plurality of the microphones, it is thus possible to estimate the position of the players with respect to the origins of these sounds. For example, the sound signals picked up by the sensor device of each player are transmitted to the server 240 of Figure 2, along with an identifier of the sensor device. The server 240 for example analyses the signals with respect to each other in order to estimate the relative positions of the players on the football pitch.

It is also possible to capture the referee's whistle, using one or more microphones of the sound detection circuit

225/225' in order to provide an automatic entry of refereeing events, such as fouls, etc.

In some embodiments, the sensor device 102 may additionally comprise an ultrasound emitter, similar to the system used in modern cars for alerting drivers when reversing. The return signal is for example picked up by the microphone, and can be used in order to detect when objects approach the player. For example, such a signal can be used to provide a further confirmation of the occurrence of a ball kick, by verifying that an object approached the player just prior to a detected impact and moved away from the player just after the detected impact. By combining this type of detection, which is a type of spatial detection, with the detection based on movement data and/or with the sound based detection, a very high overall precision for the detection of a ball kick can be achieved.

Having thus described at least one illustrative embodiment, various alterations, modifications and improvements will readily occur to those skilled in the art.

For example, it will be apparent to those skilled in the art that, while it has been described herein that the processing device 206 performs the processing of the acceleration and rotation data to generate a data value indicating whether or not a ball kick occurred, in alternative embodiments, at least some of this processing could be performed by the central unit 204 or other hardware.

Furthermore, it will be apparent to those skilled in the art that the directions of movements and the accelerations detected by the rotation and acceleration detectors may not correspond directly to the axes x, y and z described herein, but values corresponding to these axes could be deduced based on the data available.

# CLAIMS

1. A method comprising:

receiving, by a data processing device (206), movement data comprising at least rotation data indicating the rotation (Gx, Gy, Gz) of a sensor device (102) attached to a leg or foot of a football player; and

processing the movement data to generate a data value indicating whether or not the football player made a ball kick, wherein processing the movement data comprises:

detecting, based on the rotation data, a period of movement of the leg or foot in a first direction; and

generating the data value based on the detection of an impact during said period of movement.

2. The method of claim 1, wherein the movement data indicates the acceleration of the sensor device (102) along at least a first axis (Ax, Ay, Az) and the rotation of the sensor device (102) around at least the first axis or a different axis (Gx, Gy, Gz).

3. The method of claim 2, wherein the acceleration of the sensor device (102) along at least the first axis is based on a different between a first acceleration signal captured by a first accelerometer (214) of the sensor device and a second acceleration signal captured by a second accelerometer (214') of the sensor device.

4. The method of any of claims 1 to 3, wherein the data processing device (206) is part of the sensor device (102), and wherein the sensor device is attached to the leg and not to the foot of the football player.

5. The method of any of claims 1 to 4, wherein the movement data comprises rotation samples provided at a sampling rate of between 70 and 150 Hz.

6. The method of any of claims 1 to 5, wherein the data value indicating whether or not the football player made a ball kick is further generated based on a sound signal detected using at least one microphone of the sensor device and filtered

by a high pass filter applying an attenuation of 10 dB or more to frequencies of 250 Hz and lower.

7. The method of claim 6, further comprising determining an angular displacement of the movement of the leg or foot in the first direction, wherein detecting the period of movement comprises comparing said determined angular displacement with a threshold level, the period of movement being detected if the angular displacement exceeds the threshold level, the threshold level for example being between 20 and 30 degrees.

8. The method of claim 6 or 7, wherein detecting an impact is based on the Nth order derivative of the movement data, wherein N is a positive integer.

9. The method of any of claims 6 to 8, wherein generating the data value indicating whether or not the football player made a ball kick comprises comparing the time that the impact occurred during the period of movement in the first direction with low and high thresholds.

10. The method of any of claims 1 to 9, wherein generating the data value indicating whether or not the football player made a ball kick comprises generating a further data value indicating the occurrence of an impact between the player's foot and the ground.

11. The method of any of claims 1 to 10, wherein generating the data value indicating whether or not the football player made a ball kick comprises generating another data value indicating the occurrence of a control contact between the player's foot and a ball by detecting whether a level of movement of the sensor device was below a threshold value prior to an impact with the ball.

12. The method of any of claims 1 to 11, further comprising estimating by the processing device a direction of a detected ball kick based on a direction of movement of the player's leg or foot during a detected ball kick, the direction of movement being determined based on orientation data provided by a magnetometer of the sensor device.

13. The method of any of claims 1 to 12, further comprising estimating by the processing device the altitude of the player's leg or foot during a detected ball kick based on altitude data provided by a barometer of the sensor device.

14. A data storage medium storing a computer program, that when executed by a processing device, causes the method of any of claims 1 to 13 to be implemented.

15. A sensor device adapted to be attached to a leg or foot of a football player, the sensor device comprising:

a detector (212) adapted to detect rotation of the leg or foot; and

a processing device (206) adapted to:

receive movement data from the detector, the movement data comprising at least rotation data indicating the rotation (Gx, Gy, Gz) of the sensor device; and

process the movement data to generate a data value indicating whether or not the football player made a ball kick, by:

detecting, based on the rotation data, a period of movement of the leg or foot in a first direction; and

generating the data value based on the detection of an impact during said period of movement.

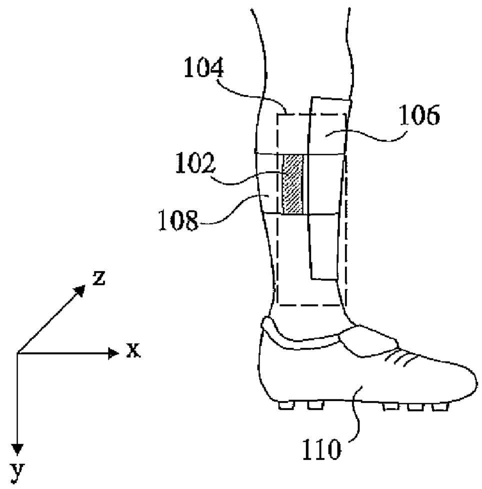
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Fig 1

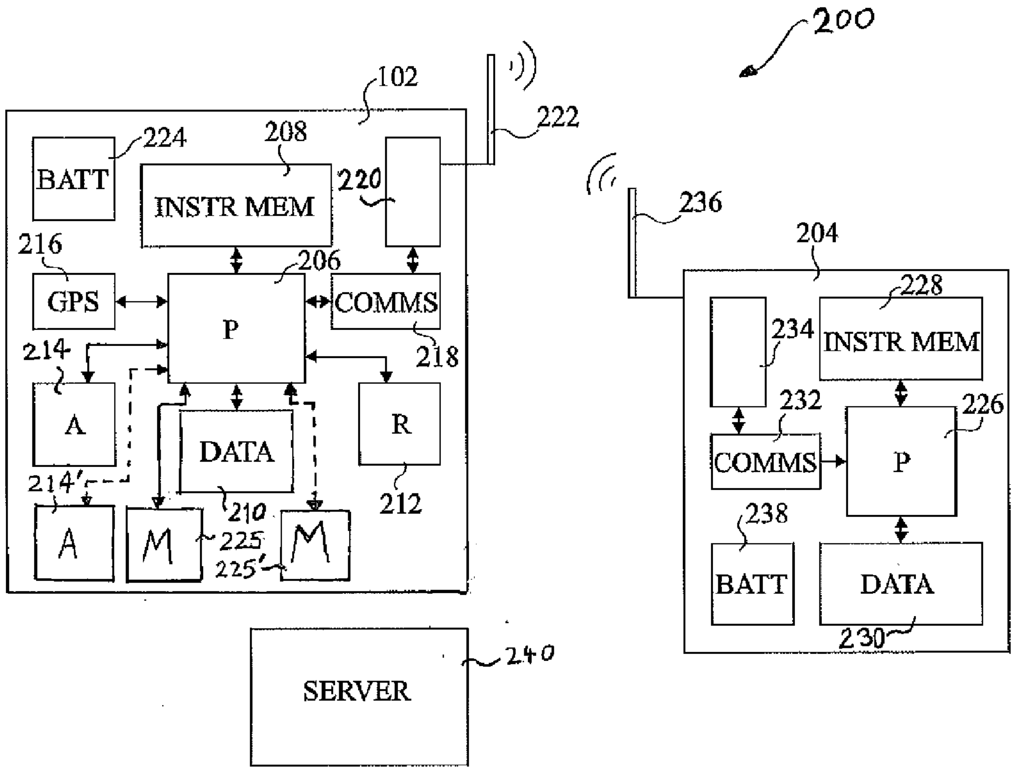
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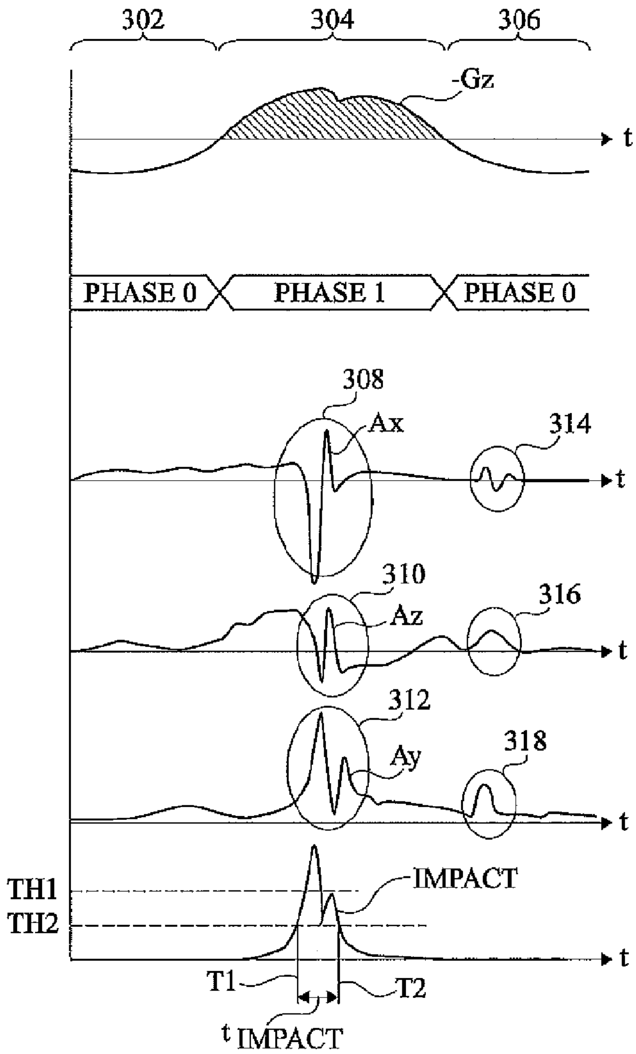
Fig 2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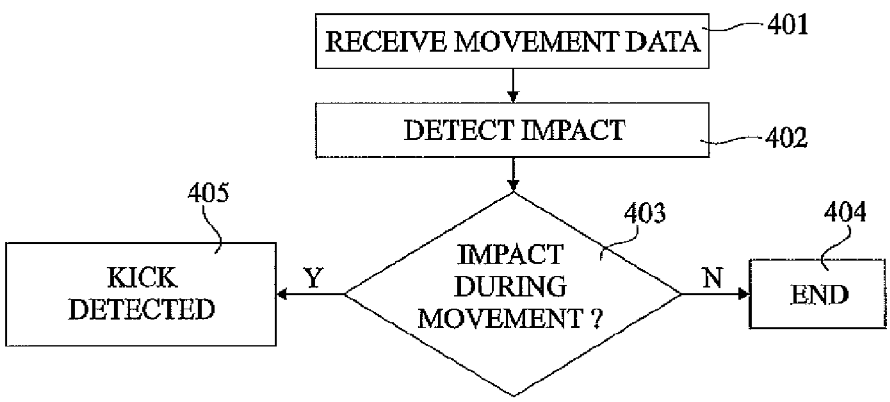
T1
T2
t IMPACT

Fig 3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405
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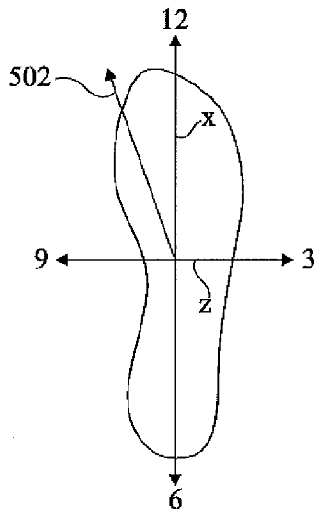
END

Fig 4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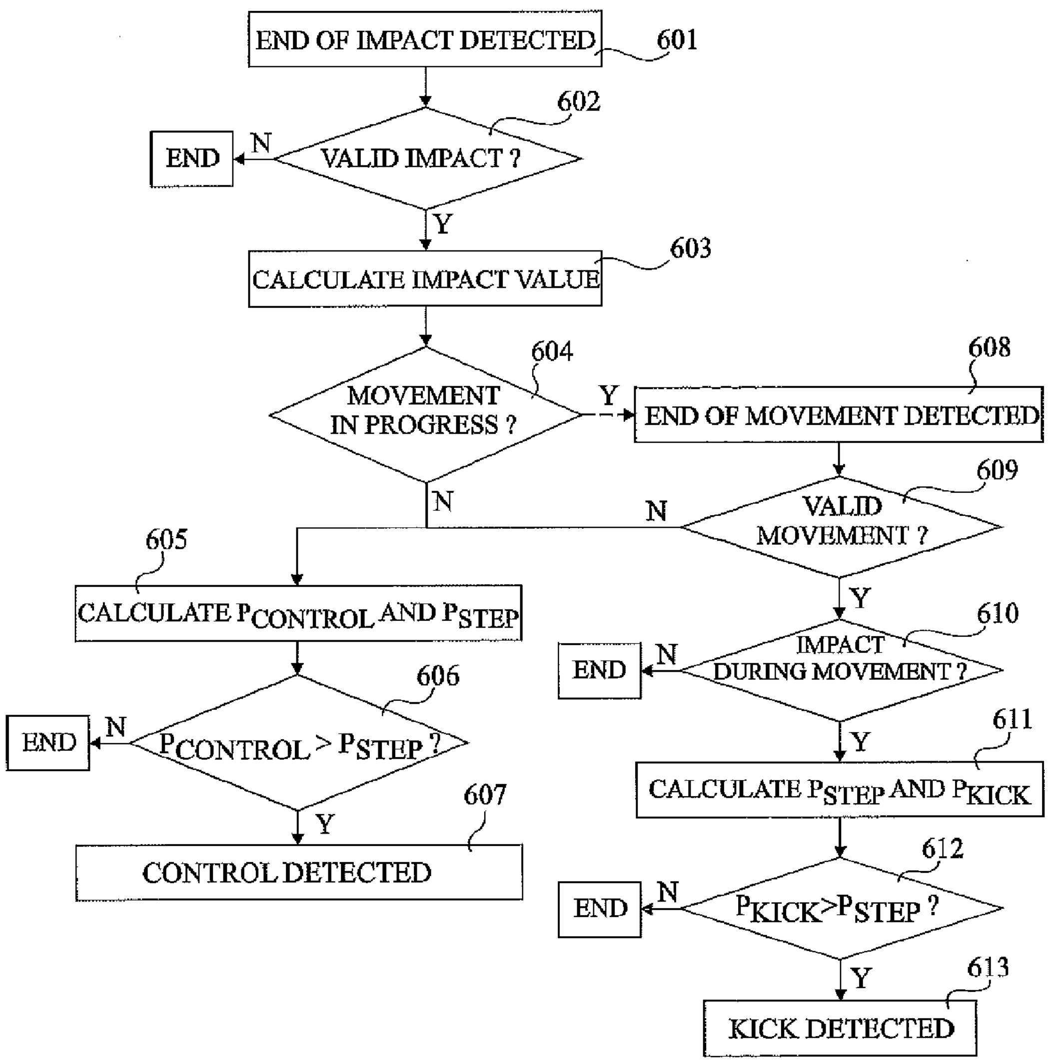
x
9
3
z
6

Fig 5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604
608
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END OF MOVEMENT DETECTED
609
N
N
VALID MOVEMENT ?
605
CALCULATE PCONTROL AND PSTEP
Y
610
END
N
IMPACT DURING MOVEMENT ?
606
Y
611
END
N
PCONTROL > PSTEP ?
CALCULATE PSTEP AND PKICK
607
Y
612
CONTROL DETECTED
END
N
PKICK>PSTEP ?
Y
613
KICK DETECTED

Fig 6

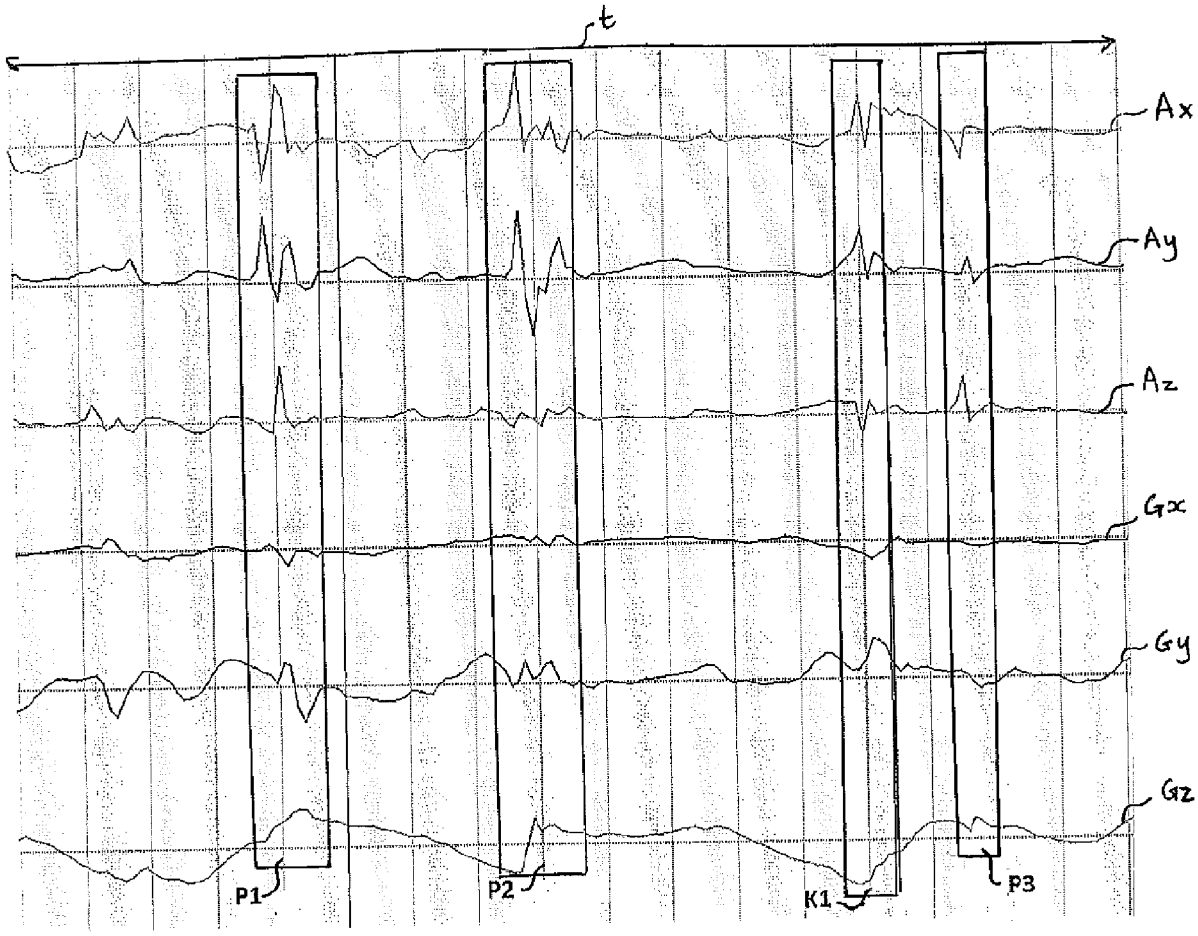


Fig 7

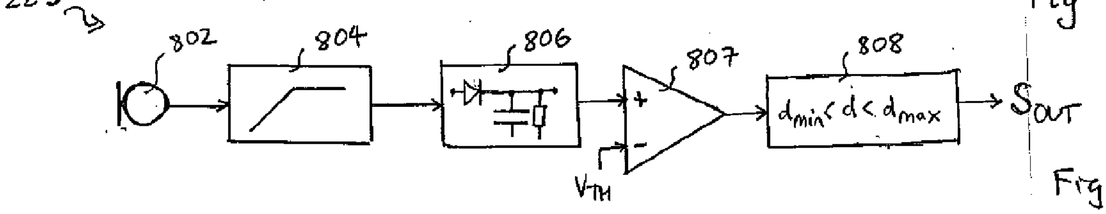


Fig 8

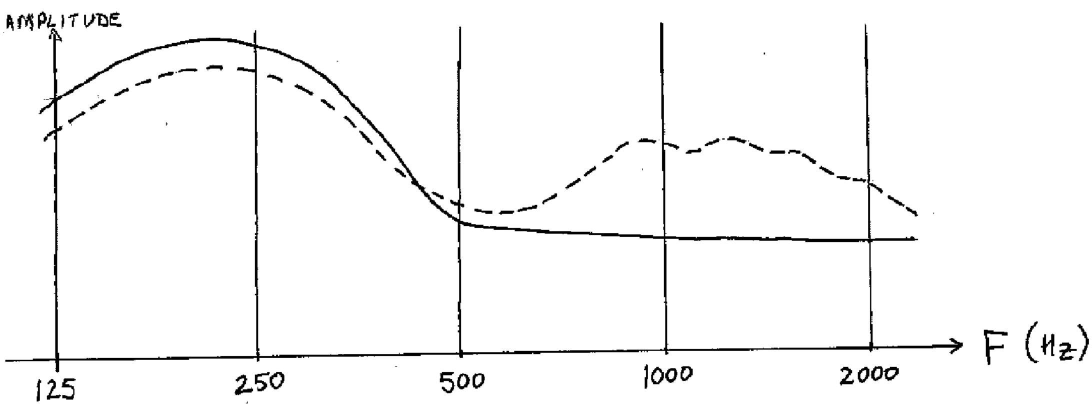


Fig 9

# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/060092

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. A61B5/11
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data, BIOSIS, EMBASE

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | WO 2014/066779 A2 (NIKE INTERNATIONAL LTD [US]; NIKE INC [US]) 1 May 2014 (2014-05-01) | 1-6, 10-15 |
| Y | paragraphs [0066], [0070], [0120], [0137], [0188], [0190], [0195], [0205], [0419], [0427] - [0431] | 7-9 |
| | ----- | |
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☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Clevorn, Jens |

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# INTERNATIONAL SEARCH REPORT

**Information on patent family members**

International application No
PCT/EP2015/060092

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
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