



(12) **PATENTTIJULKAISU  
PATENTSKRIFT**

(10) **FI 123772 B**

(45) Patentti myönnetty - Patent beviljats

31.10.2013

(51) Kv.lk. - Int.kl.

**A63B 69/36** (2006.01)  
**A63B 24/00** (2006.01)  
**G01P 15/18** (2006.01)

**SUOMI – FINLAND**

**(FI)**

**PATENTTI- JA REKISTERIHALLITUS  
PATENT- OCH REGISTERSTYRELSEN**

(21) Patentihakemus - Patentansökning

20116262

(22) Saapumispäivä - Ankomstdag

13.12.2011

(24) Tekemispäivä - Ingivningsdag

13.12.2011

(41) Tullut julkiseksi - Blivit offentlig

14.06.2013

(73) Haltija - Innehavare

**1 •Vihario Technologies Oy**, Teknologiantie 1, 90590 Oulu, SUOMI - FINLAND, (FI)  
**2 •Vibsolas Oy**, Sammonkatu 6, 90570 OULU, SUOMI - FINLAND, (FI)

(72) Keksijä - Uppfinnare

**1 •Marjanen, Ykä**, OULU, SUOMI - FINLAND, (FI)  
**2 •Pärkkä, Timo**, Oulu, SUOMI - FINLAND, (FI)

(74) Asiamies - Ombud

**Kolster Oy Ab**, Iso Roobertinkatu 21 - 23, 00120 Helsinki

(54) Keksinnön nimitys - Uppfinningens benämning

**Menetelmä, laite ja tietokoneohjelmistotuote golf-lyönnin laadun elektronista määrittämistä varten  
Metod, apparat och dataprogram för bestämning av kvaliteten på ett golfslag**

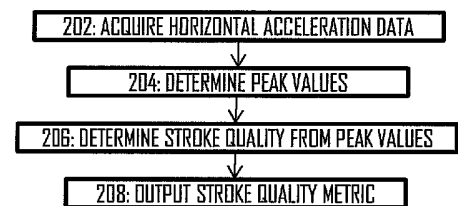
(56) Viitejulkaisut - Anförda publikationer

DE 102006008333 A1, US 2003207718 A1, US 5688183 A, US 5209483 A

(57) Tiivistelmä - Sammandrag

A method, apparatus, and computer program for determining electronically a quality of a golf stroke are disclosed herein. The method comprises: acquiring horizontal acceleration data measured with at least one accelerometer attached to a golf club during a stroke with the golf club, the horizontal acceleration data representing acceleration in a direction parallel to a ground plane and perpendicular to a motion vector of a club head of the golf club during the stroke; determining a maximum peak value and a minimum peak value of the horizontal acceleration data; and determining at least one quality metric representing the quality of the stroke from at least the maximum peak value and the minimum peak value of the horizontal acceleration data.

Tässä kuvataan menetelmä, laite ja tietokoneohjelmisto golf-lyönnin laadun elektronista määrittämistä varten. Menetelmä käsittää: hankitaan golf-mailaan kiinnitettyllä ainakin yhdellä kiihtyvyyssanturilla mitattua horisontaalista kiihtyvyydataa golf-mailalla tehdyn lyönnin aikana, joka horisontaalinen kiihtyvyydata kuvaa kiihtyvyyttä suunnassa, joka on samansuuntainen maaton kanssa ja kohtisuorassa golf-mailan kärjen lyönnin aikaiseen liikevektoriin nähden; määritetään horisontaalisen kiihtyvyydataan maksimihuippuarvo ja minimihuippuarvo; ja määritetään ainakin yksi laatumitta, joka kuvaa lyönnin laatua, horisontaalisen kiihtyvyydataan ainakin maksimihuippuarvosta ja minimihuippuarvosta.



## **Method, apparatus, and Computer Program Product for Determining Electronically the Quality of Golf Stroke**

### **Field**

The invention relates to the field of performance analysis in sports  
5 and, particularly, to estimating a stroke quality when a person strokes with a  
play tool, e.g. a golf club.

### **Background**

Several stroke performance analysis tools have been developed for  
analysing the quality of a golf stroke. Some tools are based on visual  
10 perception using video cameras. Such arrangements are very cumbersome  
and prone to human errors. Other conventional solutions attempt to use  
accelerometers but with unreliable results.

### **Brief description**

According to an aspect of the present invention, there is provided a  
15 method as specified in claim 1.

According to another aspect of the present invention, there is  
provided an apparatus as specified in claim 8.

According to yet another aspect of the present invention, there is  
provided a computer program product embodied on a computer readable  
20 distribution medium as specified in claim 9.

Embodiments of the invention are defined in the dependent claims.

### **List of drawings**

Embodiments of the present invention are described below, by way  
of example only, with reference to the accompanying drawings, in which

25 Figure 1 illustrates an arrangement to which embodiments of the  
invention may be applied;

Figure 2 is a flow diagram of a process for determining a stroke  
quality electronically according to an embodiment of the invention;

30 Figures 3A to 5 relate to an embodiment for analysing peak values  
when evaluating the stroke quality electronically according to some  
embodiments of the invention;

Figures 6 and 7 illustrate acceleration data associated with different  
strokes;

Figures 8 and 9 are flow diagrams related to embodiments for determining stroke quality electronically according to other embodiments of the invention;

Figure 10 illustrates a diagram related to mapping parameters  
5 computed from the acceleration data to stroke quality according to an embodiment of the invention;

Figure 11 is a flow diagram related to a process for determining the stroke quality electronically according to yet another embodiment of the invention; and

10 Figures 12 and 13 illustrate embodiments of an apparatus for determining the stroke quality according to some embodiments of the invention.

### **Description of embodiments**

The following embodiments are exemplary. Although the  
15 specification may refer to “an”, “one”, or “some” embodiment(s) in several locations, this does not necessarily mean that each such reference is to the same embodiment(s), or that the feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments. Furthermore, words “comprising” and “including” should  
20 be understood as not limiting the described embodiments to consist of only those features that have been mentioned and such embodiments may contain also features/structures that have not been specifically mentioned.

Figure 1 illustrates an arrangement for use in connection with training strokes by a golf player. The arrangement comprises a measurement  
25 device 100 attached to a golf club 102, e.g. a golf putter club, in order to measure and evaluate the quality of strokes made by the player. As shown in Figure 1, the measurement device 100 may be attached to the shaft of the golf club 102 just below a grip portion. A casing of the measurement device 100 may be attached to the shaft by using glue or another adhesive, or the  
30 attachment may be realized by grip forcing the casing into tight contact with the club 102. An advantage in placing the measurement device 100 as close to the grip as possible is that the weight of the measurement device 100 has a minimal effect on the balance of the golf club 102. The measurement device 100 may be attached to the club for the training purposes, and it may be

removed from the club when the training is complete, e.g. for the duration of a game on a golf course.

In addition to the shaft, the golf club 102 comprises a club head 104. The right hand side of Figure 1 illustrates the club head 104 and a golf ball 106. When the ball 106 is hit with the golf club 102, the impact of the club head 104 on the golf ball 106 determines the trajectory of the golf ball and, thus, the quality of the stroke. The club head 104 typically has a sweet spot which is an optimal hit location, and the player attempts to hit the ball 106 with the sweet spot. The sweet spot is typically in a centre of gravity of the golf club 102. Hitting the golf ball 106 with the sweet spot causes the ball to follow the trajectory of the club head 104 during the stroke, provided that a face of the club head is perpendicular to the trajectory of the club head at the moment of impact with the ball 106. As a consequence, one way to determine the stroke quality is to determine whether or not the player hit the ball with the sweet spot.

Performing a perfect hit in golf is difficult, and there exist several methods for coaching a player to make better strokes. Some schemes utilize visual analysis in the form of human or video analysis, but these methods are based on human perception and are thus prone to errors. Furthermore, at least some of such methods require "laboratory conditions", e.g. setup of a camera system and they cannot be realized during a real golf game. An embodiment of the present invention utilizes one or more accelerometers attached to the golf club 102 so as to determine the quality of the stroke electronically from acceleration data measured by said one or more accelerometers. The accelerometer may be attached to the golf club during practice or game and, therefore, they enable performance measurements in real situations. Figure 2 illustrates a flow diagram of a process for determining the quality of the stroke electronically in an apparatus comprising at least one processor and at least one memory storing computer program instructions causing the apparatus to execute the process. In an embodiment, the apparatus is the measurement device 100. In another embodiment, the apparatus is a personal electronic device 120 communicating with the measurement device 100 over a wireless or wired connection. The personal electronic device 120 may be a laptop, a generic palm device, a palm device dedicated for use with golf applications, or a mobile communication device such as a cellular phone equipped with suitable hardware and software to communicate with the measurement device 100 and to process any data received from the measurement device 100.

Referring to Figure 2, horizontal acceleration data measured with at least one accelerometer attached to a golf club during a stroke with the golf club is acquired in block 202. In an embodiment, block 202 comprises the at least one processor retrieving the acceleration data from the at least one memory unit. In another embodiment, block 202 comprises also measuring the acceleration data by at least one accelerometer provided in the measurement device 100 and applying the measured acceleration data to the at least one processor. The horizontal acceleration data represents acceleration in a direction parallel to a ground plane and perpendicular to a motion vector of a club head 104 of the golf club 102 during the stroke. In other words, the horizontal direction corresponds to the direction the player faces when carrying out the stroke with a conventional technique. While the horizontal direction may be referred to as a front-back direction from the viewpoint of the player, let us denote the horizontal direction as Y direction in this description. Let us also denote the direction of the shaft of the golf club (up-down direction) as X direction which is perpendicular to the ground plane, and the direction of motion of the golf club during the stroke as Z direction. X, Y, and Z direction are all perpendicular with respect to each other, so they may be understood as forming orthogonal axes of a three-dimensional diagram.

In block 204, a maximum peak value and a minimum peak value of the horizontal acceleration data of the stroke are determined. As a consequence, the maximum acceleration value and the minimum acceleration value are searched for from the acceleration data in block 204. These peak values contain information that enables the determination of the stroke quality, as will be described in several embodiments below. In block 206, at least the maximum peak value and the minimum peak value of the horizontal acceleration data are used to derive at least one quality metric representing the quality of the stroke. The quality metric may be a value that defines the quality of the stroke on a determined scale, or it may provide more detailed information on the sub-optimality of the stroke, as will be described below. In block 208, the quality metric is output. In an embodiment, block 208 comprises transmitting the quality metric from the measurement device 100 to the personal electronic device 120, while in another embodiment block 208 comprises displaying or playing back the quality metric in the personal electronic device 120.

Let us now describe an embodiment for determining a hit or impact location between the club head 104 and the ball 106 in the stroke. As background, let us note that a perfect stroke contains no acceleration in the Y direction. However, such a stroke occurs very rarely, if ever. Typically, the Y directional acceleration component is present, and the Y directional component is illustrated in Figures 3A and 3B. Figures 3A and 3B represent the behaviour of the horizontal acceleration signal as a function of time. While the Figures show the signal as a continuous signal, the signal may equally be a discrete signal that has been digitized. Figure 3A illustrates an acceleration signal in which the maximum peak A1 precedes the minimum peak A2, i.e. timing T1 associated with the maximum peak A1 is lower than timing T2 associated with the minimum peak T2. Figure 3B illustrates an acceleration signal in which the maximum peak A1 follows the minimum peak A2, i.e. the timing T1 associated with the maximum peak A1 is higher than the timing T2 associated with the minimum peak T2.

It has been discovered that the quality of the stroke may be determined from the order of occurrence of the peaks A1 and A2. Figure 4 illustrates a flow diagram of a process for determining the location of the club head 104 hitting the ball 106 in the stroke. The flow diagram of Figure 4 may be understood as an embodiment of blocks 206 and 208 of Figure 2. Referring to Figure 4, the process proceeds to block 400 from block 204 of Figure 2. In block 400, the order of occurrence of the maximum peak value and the minimum peak value of the horizontal acceleration data is analysed. This may be carried out by comparing a timing T1 of the maximum peak A1 with the timing T2 of the minimum peak A2 to determine which one of them occurs first. In block 402, the hit location of the golf ball 106 in the club head 104 with respect to an optimal hit location (the sweet spot) of the club head 104 is determined from the order of occurrence of the peak values A1 and A2. In block 404, the stroke quality metric is derived on the basis of the hit location, and it may be output, as described above. In an embodiment, the stroke quality metric is configured in block 404 to represent the determined hit location with respect to the optimal hit location.

Figure 5 illustrates an embodiment of deriving the quality metric, and the process of Figure 5 may be seen as an embodiment of block 402. Referring to Figure 5, the order of occurrence of the peaks A1 and A2 is determined in block 500. If the minimum peak A2 precedes the maximum peak

A1, the process proceeds to block 502 in which it is determined that the hit point is located between the sweet spot of the club head 104 and the body of the player. As a consequence, block 404 may comprise forming an indicator that indicates that the hit point is located between the sweet spot of the club head 104 and the body of the player. The indicator may be a determined value, word, or any visual indicator to be output. On the other hand, if the maximum peak A1 precedes the minimum peak A2, the process proceeds to block 504 in which it is determined that the sweet spot is located between the hit point and the body of the player. As a consequence, block 404 may comprise forming an indicator that indicates that the hit point is located away from the sweet spot of the club head 104 and the body of the player.

In some embodiments, the measurement device 100 comprises an accelerometer arrangement that is configured to measure the acceleration in the X, Y, and Z direction. Figure 6 illustrates an example of measured acceleration data in the X, Y, and Z direction during a stroke. The stroke illustrated in Figure 6 is an example of a poor stroke, and the low quality of the stroke may be determined from the measured acceleration data. Figure 7, on the other hand, shows the acceleration data in the X, Y, and Z direction for a good stroke. Figure 8 illustrates an embodiment for determining the quality of the stroke from the acceleration data of Figure 6 and/or 7. According to this embodiment, the quality of the stroke is determined from the horizontal acceleration data (Y direction). As can be seen in Figures 6 and 7, the range of the acceleration signal in the amplitude domain is lower for the better quality stroke. Referring to Figure 8, a peak-to-peak value is computed for the horizontal acceleration data of one stroke in block 800. In general, the peak-to-peak value may be computed by subtracting the minimum peak value from the maximum peak value. The maximum peak value may be defined as the highest value in the sample set of one stroke, while the minimum peak value may be defined as the lowest value in the sample set of one stroke. Block 800 may be repeated for a plurality of strokes. In block 802, the peak-to-peak value(s) is/are mapped to the quality metrics according to a determined criterion. The rules for mapping may be defined by a scale, and the scale may be determined through a calibration process or according to the distribution of the set of peak-to-peak values. In an embodiment using the calibration process, a reference stroke is carried out by an expert golf player, for example. The acceleration data is then measured during the reference stroke, and block

800 is executed to derive the peak-to-peak value for the reference stroke. This reference peak-to-peak value may then be mapped to a stroke quality metric value indicating the best stroke quality, and any peak-to-peak value exceeding the reference peak-to-peak value is then mapped to a stroke quality metric value indicating a stroke quality lower than the best stroke quality. The scale of degrading the stroke quality metric according to the peak-to-peak values in the scale may be determined according to the design and, thus, it is possible to derive the mapping between the peak-to-peak values and the stroke quality metric values. In this embodiment, the apparatus may output the stroke quality metric immediately after each stroke, as the apparatus has the scale available so as to map the peak-to-peak value to the stroke quality metric.

In another embodiment, the apparatus may carry out block 800 for a plurality of times so as to derive the peak-to-peak values for a plurality of strokes. Then, the apparatus may map the lowest peak-to-peak value to the highest stroke quality metric, and the highest peak-to-peak value to the lowest stroke quality metric, and provide a linear or non-linear scale between the highest value and the lowest value for the rest of the peak-to-peak values so as to derive the mapping scale. In this embodiment, the apparatus may output the stroke quality metrics after the training has been completed.

The embodiment of Figure 8 may be improved by using at least one of the X and Z directional acceleration data in connection with the Y directional acceleration data. Figure 9 illustrates an embodiment for utilizing at least one of X and Z directional acceleration data. Referring to Figure 9, at least one acceleration data representing direction perpendicular to the horizontal acceleration data is acquired in block 900. In block 902, a maximum peak value and a minimum peak value of the at least one other acceleration data is determined, and the peak-to-peak values of the horizontal acceleration data and the at least one other acceleration data are determined from the maximum peak values and the minimum peak values in block 904. In block 906, the relation between the peak-to-peak values computed in block 904 is analysed, and the at least one quality metric is determined from a relation between the peak-to-peak values of the horizontal acceleration data and the at least one other acceleration data. In an embodiment, the stroke quality is determined to be better if the peak-to-peak value of the other acceleration data is higher than the peak-to-peak value of the horizontal acceleration data, and the higher is the peak-to-peak value of the other acceleration data with respect to the peak-

to-peak value of the horizontal acceleration data the better is the stroke quality. On the other hand, the stroke quality is determined to be poorer if the peak-to-peak value of the other acceleration data is roughly equal to or lower than the peak-to-peak value of the horizontal acceleration data or, in other words, the lower is the peak-to-peak value of the other acceleration data with respect to the peak-to-peak value of the horizontal acceleration data the poorer is the stroke quality. This applies to both the X and Z directional acceleration data, when compared with the Y directional acceleration data. The mapping between the relation and the stroke quality metric may be determined in the above-described manner, e.g. through the calibration process or by using the statistical distribution obtained from the set of strokes.

In an embodiment, the relation between the peak-to-peak value of the other acceleration data and the peak-to-peak value of the horizontal acceleration data is determined by dividing the peak-to-peak value of the other acceleration data by the peak-to-peak value of the horizontal acceleration data, and the result of the division is then mapped to the stroke quality metric. Instead of using the division operation, another comparative operation may be used, e.g. comparing the absolute values of the horizontal acceleration data and the other acceleration data or computing a subtraction between them.

In another embodiment, X, Y, and Z directional acceleration data is used in evaluating the stroke quality. In more detail, the peak-to-peak values of both X and Z directional acceleration data may be divided by the peak-to-peak value of Y directional acceleration data, and the two division results in combination may be mapped to a scale to determine the stroke quality metric. As the amount of data available for determining the stroke quality is increased, the accuracy is improved. Figure 10 illustrates a distribution of thus obtained division results for a plurality of strokes, wherein each star represents a single stroke. The horizontal axis represents the division result obtained by dividing the peak-to-peak value of the X directional acceleration data by the peak-to-peak value of Y directional acceleration data, and the vertical axis represents the division result obtained by dividing the peak-to-peak value of the Z directional acceleration data by the peak-to-peak value of Y directional acceleration data. It has been discovered that the highest quality strokes are located in the graph of Figure 10 in the top-right portion, while the lowest quality strokes are located in the graph of Figure 10 in the bottom-left portion of the Figure. From that behaviour, it may be derived that the Y directional

acceleration component is low for a high quality stroke, which shows that the stroke quality may be estimated from the Y directional component alone, as described above.

Figure 11 illustrates an embodiment utilizing the above-described behaviour for estimating the stroke quality. Referring to Figure 11, X and Z directional acceleration data are acquired in addition to the Y directional acceleration data in block 1100, and the peak-to-peak values are computed for the X, Y, and Z directional acceleration data in block 1102. It should be noted that the X, Y, and Z directional acceleration data relate to the same stroke, as in the previous embodiments. In block 1104, the peak-to-peak value of the X directional acceleration data is divided by the peak-to-peak value of the Y acceleration data, thus obtaining a first division value, and the peak-to-peak value of the Z directional acceleration data is divided by the peak-to-peak value of the Y directional acceleration data, thus obtaining a second division value. In block 1106, the first division value in combination with the second division value is mapped to a scale to obtain the quality metric. The mapping between the quality metric and the combination of the first division value and the second division value may be determined according to the design. Referring to Figure 10, the mapping may be configured to provide a quality metric indicating a high quality stroke to combinations having a high first division value and a high second division value, and to provide a quality metric indicating a poor quality stroke to combinations having a low first division value and a low second division value. The quality metric may have a numeric value, for example, and the scale is a design-specific factor, e.g. from one to ten. The mapping of a high first division value and a low second division value or a low first division value and a high second division value to the corresponding quality metrics is also design-specific. In an embodiment, an average between the first division value and the second division value is computed, and the resulting average value is mapped to the quality metric according to a determined scale. In another embodiment, the average is a weighted average in which either the first division value or the second division value is given a higher weight, depending on which one of them is considered to represent the stroke quality more reliably. The weighting may be fixed and determined beforehand.

Figures 12 and 13 illustrate embodiments of an apparatus for carrying out any one of the above-described stroke quality estimation

processes. Figure 12 illustrates an embodiment where the measurement device 100 is configured to carry out the stroke quality estimation process. The measurement device 100 may comprise at least one accelerometer 10 configured to measure translational motion of the golf club 102 in at least one direction and, in some embodiments, in a plurality of perpendicular directions. The accelerometer(s) 10 may be any state-of-the art accelerometer(s), either analog or digital. The accelerometers 10 may be triggered to start measuring the acceleration when the measurement device 100 is powered up, or upon reception of a user input through a user interface 54 of the measurement device 100. The accelerometer(s) 10 may output the measured acceleration signal(s) to an acceleration data processor 12 comprised as a sub-circuitry in a processor 30 of the measurement device 100. Any sub-circuitry 12 to 18 of the processor 30 may be understood as a separate physical circuitry or as a separate sub-routine or computer program executed by the same physical processor 30. An interface between the accelerometer 10 and the processor 30 may be any internal interface or, if the accelerometer 10 and the processor 30 are in separate casings, the interface may be any known wired or wireless interface known in the art. The acceleration data processor 12 may process the received acceleration signal according to a determined criterion. For example, in case of analog accelerometer(s), the acceleration data processor 12 may convert an analog acceleration signal into a digital acceleration signal. In an embodiment, the acceleration data processor 12 is be configured to identify acceleration data related to one stroke, e.g. from raw acceleration data received from the accelerometer(s). The acceleration data processor 12 may comprise a signal detector configured to detect and store acceleration data associated with the one and the same stroke. The detection may be based on threshold detection, e.g. detecting only accelerations exceeding a given threshold level, or detecting gradients in the acceleration signal, etc. The acceleration data processor 12 may keep the acceleration data associated with different directions as separated. The acceleration data processor 12 may output the acceleration data associated with the stroke to a peak value computer 14. The outputting may comprise storing the acceleration data in a memory 20 and outputting a triggering signal to the peak value computer 14, thereby activating the peak value computer.

The peak value computer 14 is configured to compute at least one peak value or, in some embodiments, at least one peak-to-peak value of the

acceleration data and output the peak value(s) to a quality estimator circuitry 16. The quality estimator circuitry 16 may be configured to carry out the above-described mapping between the peak value(s) and the quality metric(s). The quality estimator circuitry 16 may output at least one quality metric per stroke.

5 In an embodiment using the calibration phase, the quality estimator circuitry 16 is configured during the calibration phase to identify the mapping rules on the basis of calibration acceleration data. For example, when the calibration acceleration data represents a reference stroke, the quality estimator circuitry 16 may assign a quality metric indicating perfect stroke quality to the peak

10 value(s) received during the calibration phase and, during the actual evaluation, map any peak value(s) to the quality metrics according to a determined scale. In the embodiments using the distribution of the peak value(s) of the plurality of strokes as the scaling parameter, the quality estimator circuitry may assign the highest quality metric to the peak value representing

15 the best stroke in the stroke set and the lowest quality metric to the peak value representing the poorest stroke in the stroke set. Then, the quality estimator circuitry 16 may map the remaining peak value(s) to between these two values according to the determined scale. The quality estimator circuitry 16 may determine the scale, for example, on the basis of a variance or dispersion of

20 the peak values. For example, if there is low variance amongst the peak value(s), the quality estimator circuitry 16 may use a scale comprising less possible values of the quality metric than in a case where the variance is high. The quality estimator circuitry 16 may also output a quality metric representing the variance, thereby indicating the consistency of the stroke quality for the

25 player. The quality estimator circuitry 16 may output the quality metrics to a communication circuitry 18 configured to process the received quality metrics for transmission to the personal electronic device 120. The communication circuitry 18 may be configured to support any known wired or wireless communication technology, comprising Universal Serial Bus (USB) and/or

30 Bluetooth®, for example. The personal electronic device 120 may comprise a corresponding communication circuitry so as to enable the communication. The communication circuitry 18 may comprise components comprised as a sub-circuitry of the processor 30, e.g. digital signal processing parts of the communication circuitry 18, and it may also comprise other components that

35 are external to the processor, e.g. analog circuitries such as an analog amplifier, filter, frequency converter, and antenna. Any data measured or

computed by the measurement device 100 may be output to the personal electronic device for the analysis of the performance of the player. The data may comprise at least the quality metrics.

Figure 13 illustrates another embodiment where the quality estimation is carried out in the personal electronic device 120. In such a case, the personal electronic device comprises an apparatus according to an embodiment of the invention. Referring to Figure 13, the measurement device may now comprise one or more processors 40 comprising at least the acceleration data processor 12 and the communication circuitry 18. The peak value computer 14 may be comprised either in the measurement device 100 or in the personal electronic device 120. In the former case, the measurement device computes the peak values and outputs them to the communication circuitry 18 for transmission to a communication circuitry 52 of the personal electronic device 120. The communication circuitry then applies the received peak values to the quality estimator circuitry 16. In the latter embodiment, the acceleration data processor outputs the processed acceleration data to the communication circuitry 18, and the communication circuitry 52 of the personal electronic device applies the received acceleration data to the peak value computer 14. The personal electronic device may comprise one or more processors 50 comprising the circuitries 52 and 16 and optionally 14 as sub-circuitries. The quality estimator 16 may output the computed quality metrics to a user interface 54 which may comprise a display or any other output means. A memory 60 of the personal electronic device 120 and the memory 20 of the measurement device may comprise computer programs configuring the operations of the devices and any parameter and rules used in the stroke quality estimation process.

In summary, an embodiment provides an apparatus comprising at least one processor and at least one memory including a computer program code, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to carry out the method described above in connection with any one of Figures 2 to 11.

As used in this application, the term 'circuitry' refers to all of the following: (a) hardware-only circuit implementations, such as implementations in only analog and/or digital circuitry, and (b) to combinations of circuits and software (and/or firmware), such as (as applicable): (i) a combination of processor(s) or (ii) portions of processor(s)/software including digital signal

processor(s), software, and memory(ies) that work together to cause an apparatus to perform various functions, and (c) to circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present.

This definition of 'circuitry' applies to all uses of this term in this application. As a further example, as used in this application, the term "circuitry" would also cover an implementation of merely a processor (or multiple processors) or portion of a processor and its (or their) accompanying software and/or firmware. The term "circuitry" would also cover, for example and if applicable to the particular element, a baseband integrated circuit or applications processor integrated circuit for a mobile phone or a similar integrated circuit in server, a cellular network device, or other network device.

Referring to the embodiments described above, the stroke quality estimation processes may be used in connection with training the golf strokes. In particular, the processes may be used when the player repeatedly practices the same stroke, e.g. a putt. As described above, the mapping between the peak values of the acceleration data and the quality metrics may be defined by using a scale or a mapping function that may be derived through the calibration procedure or, after a plurality of strokes, from the distribution of at least one parameter of the measured acceleration data, e.g. peak or peak-to-peak values of the strokes. In the embodiment utilizing the distribution of the at least one parameter of the measured acceleration data, there is necessarily no need for the predetermined reference values, but the quality of a single stroke may be evaluated with respect to the distribution of the at least one parameter, as described herein. In an embodiment, the quality metrics are computed by using one mapping function and, then, a new mapping function is determined on the basis of the distribution of the quality metrics and mapping at least some of the quality metrics. It may be envisaged that the stroke quality may be estimated from any parameter by using the distribution of the parameter derived from said plurality of strokes. Such a method for determining electronically the quality of a golf stroke may comprise: acquiring acceleration data measured with at least one accelerometer attached to a golf club during a stroke with the golf club; computing at least one parameter of the acceleration data; repeating the acquiring and the computing for a plurality of strokes, thereby acquiring a plurality of computed parameters; and mapping each parameter to a quality

metric according to the distribution of the plurality of parameters. The parameter may in practice be any parameter that may be used to evaluate the stroke quality, e.g. a parameter representing the acceleration of the golf club about its vertical axis (the axis formed by the shaft of the golf club). This method may be executed by an apparatus comprising means for carrying out the method. Such means may comprise one or more processors and a memory unit storing program instructions, e.g. a computer program product, executable by the one or more processors. The program instructions configure the one or more processors to carry out the method. Another aspect provides the computer program product stored on a distribution medium and comprising the program instructions configuring a processor executing the computer program product to carry out the method.

The processes or methods described in connection with Figures 2 to 11 may also be carried out in the form of a computer process defined by a computer program. The computer program may be in source code form, object code form, or in some intermediate form, and it may be stored in some sort of carrier, which may be any entity or device capable of carrying the program. Such carriers include a record medium, computer memory, read-only memory, electrical carrier signal, telecommunications signal, and software distribution package, for example. Depending on the processing power needed, the computer program may be executed in a single electronic digital processing unit or it may be distributed amongst a number of processing units. It will be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

## Claims

1. A method for determining electronically the quality of a golf stroke, the method comprising:

5 acquiring (202) horizontal acceleration data measured with at least one accelerometer attached to a golf club during a stroke with the golf club, the horizontal acceleration data representing acceleration in a direction parallel to a ground plane and perpendicular to a motion vector of a club head of the golf club during the stroke;

10 determining (204) a maximum peak value and a minimum peak value of the horizontal acceleration data;

**characterized** by the method further comprising: determining (400, 402) a hit location of a golf ball in the club head with respect to an optimal hit location of the club head by analysing the order of occurrence of the maximum peak value and the minimum peak value of the horizontal acceleration data;

15 and

configuring (404) the at least one quality metric to represent the determined hit location with respect to the optimal hit location.

2. The method of claim 1, further comprising:

20 computing (800) a peak-to-peak value for the horizontal acceleration data; and

mapping (802) the computed peak-to-peak value to the at least one quality metric such that a low peak-to-peak value is mapped to a quality metric indicating high quality of the stroke and a high peak-to-peak value is mapped to a quality metric indicating poor quality of the stroke.

25

3. The method of any preceding claim, further comprising:

acquiring (900) and at least one other acceleration data representing direction perpendicular to the horizontal acceleration data;

30 determining a maximum peak value and a minimum peak value of the at least one other acceleration data;

determining (902) a peak-to-peak value for the horizontal acceleration data and the at least one other acceleration data from the maximum peak values and the minimum peak values; and

determining the at least one quality metric from a relation between the peak-to-peak values of the horizontal acceleration data and the at least one other acceleration data.

4. The method of claim 3, further comprising:

5 determining the at least one quality metric by mapping the relation to a scale where the scale provides a better stroke quality for decreasing peak-to-peak value of the horizontal acceleration data with respect to the peak-to-peak value of the at least one other acceleration data and a poorer stroke quality for an increasing peak-to-peak value of the acceleration data with  
10 respect to the peak-to-peak value of the at least one other horizontal acceleration data.

5. The method of claim 3 or 4, wherein the other acceleration data comprises vertical acceleration data and lateral acceleration data, the vertical acceleration data representing acceleration in the direction of a shaft of the golf club, and the lateral acceleration data representing acceleration in the direction  
15 of the motion of the club head of the golf club during the stroke, the method further comprising:

dividing (1104) the peak-to-peak value of the vertical acceleration data by the peak-to-peak value of the horizontal acceleration data, thus  
20 obtaining a first division value;

dividing (1104) the peak-to-peak value of the lateral acceleration data by the peak-to-peak value of the horizontal acceleration data, thus obtaining a second division value; and

25 mapping (1106) the first division value in combination with the second division value to said scale to obtain the quality metric.

6. The method of any preceding claim, further comprising:

acquiring a plurality of parameter values derived from said acceleration data associated with a plurality of strokes; and

30 forming a mapping function between the parameter values and the quality metrics according to the distribution of the plurality of parameter values; and

mapping at least some of the plurality of parameter values into the quality metrics according to the mapping function.

7. The method of any preceding claim 1 to 6, further comprising:

performing a calibration procedure before the measurement of the acceleration data, thus obtaining a scale for use in mapping a parameter computed from the acceleration data to the quality metric; and

5 computing said at least one quality metric by mapping at least one parameter computed from the acceleration data to the quality metric according to the scale obtained during the calibration procedure.

8. An apparatus, comprising means (30, 12, 14, 16) configuring the apparatus to carry out the method according to any preceding claim 1 to 7.

9. A computer program product embodied on a distribution medium  
10 readable by a computer and comprising program instructions which, when loaded into an apparatus, execute the method according to any preceding claim 1 to 7.

### Patenttivaatimukset

1. Menetelmä golf-lyönnin laadun elektronista määrittämistä varten, joka menetelmä käsittää:

5 hankitaan (202) golf-mailaan kiinnitetyllä ainakin yhdellä kiihtyvyyssanturilla mitattua horisontaalista kiihtyvyydataa golf-mailalla tehdyn lyönnin aikana, joka horisontaalinen kiihtyvyydata kuvaa kiihtyvyyttä suunnassa, joka on samansuuntainen maaton kanssa ja kohtisuorassa golf-mailan kärjen lyönnin aikaiseen liikevektoriin nähden;

10

määritetään (204) horisontaalisen kiihtyvyydataan maksimihuippuarvo ja minimihuippuarvo;

**tunnettu** siitä, että menetelmä käsittää lisäksi: määritetään (400, 402) golf-  
15 pallon osumakohta mailan kärjessä suhteessa mailan kärjen optimiosumakohtaan analysoimalla horisontaalisen kiihtyvyydataan maksimihuippuarvon ja minimihuippuarvon esiintymisjärjestys; ja

20 konfiguroidaan (404) mainittu ainakin yksi laatumitta kuvaamaan määritettyä osumakohtaa suhteessa optimiosumakohtaan.

2. Patenttivaatimuksen 1 menetelmä, joka käsittää lisäksi:

lasketaan (800) huipusta huippuun arvo horisontaaliselle kiihtyvyydataalle;

25

linkitetään (802) laskettu huipusta huippuun arvo ainakin yhteen laatumittaan siten, että pieni huipusta huippuun arvo linkitetään laatumittaan, joka osoittaa lyönnin korkeaa laatua, ja suuri huipusta huippuun arvo linkitetään laatumittaan, joka osoittaa lyönnin heikkoa laatua.

30

3. Jonkin edellisistä patenttivaatimuksista mukainen menetelmä, joka käsittää lisäksi:

35 hankitaan (900) ainakin yhtä muuta kiihtyvyydataa, joka edustaa suuntaa, joka on kohtisuorassa horisontaaliseen kiihtyvyydataan nähden;

määritetään tämän ainakin yhden muun kiihtyvyyssdatan maksimihuippuarvo ja minimihuippuarvo;

- 5 määritetään (902) huipusta huippuun arvo horisontaaliselle kiihtyvyyssdatalle ja tälle ainakin yhdelle muulle kiihtyvyyssdatalle maksimihuippuarvoista ja minimihuippuarvoista; ja

- määritetään (904, 906) ainakin yksi laatumitta horisontaalisen kiihtyvyyssdatan ja tämän ainakin yhden muun kiihtyvyyssdatan huipusta huippuun arvojen välisestä suhteesta.

4. Patenttivaatimuksen 3 mukainen menetelmä, joka käsittää lisäksi:

- 15 määritetään ainakin yksi laatumitta linkittämällä tämä suhde asteikkoon, joka asteikko tarjoaa paremman lyönnin laadun horisontaalisen kiihtyvyyssdatan pienenevälle huipusta huippuun arvolle suhteessa ainakin yhden muun kiihtyvyyssdatan huipusta huippuun arvolle, ja heikomman lyönnin laadun horisontaalisen kiihtyvyyssdatan kasvavalle huipusta huippuun arvolle  
20 suhteessa ainakin yhden muun kiihtyvyyssdatan huipusta huippuun arvolle.

5. Patenttivaatimuksen 3 tai 4 mukainen menetelmä, jossa ainakin yksi muu kiihtyvyyssdata käsittää pystysuuntaista kiihtyvyyssdataa ja sivusuuntaista kiihtyvyyssdataa, joka pystysuuntainen kiihtyvyyssdata kuvaa kiihtyvyyttä golf-  
25 mailan varren suunnassa, ja sivusuuntainen kiihtyvyyssdata kuvaa kiihtyvyyttä golf-mailan kärjen liikkeen suunnassa lyönnin aikana, joka menetelmä käsittää lisäksi:

- jaetaan (1104) pystysuuntaisen kiihtyvyyssdatan huipusta huippuun arvo  
30 horisontaalisen kiihtyvyyssdatan huipusta huippuun arvolla, saaden näin ensimmäisen jakamisarvon;

- jaetaan (1104) sivusuuntaisen kiihtyvyyssdatan huipusta huippuun arvo  
horisontaalisen kiihtyvyyssdatan huipusta huippuun arvolla, saaden näin toisen  
35 jakamisarvon;

linkitetään (1106) ensimmäinen jakamisarvo yhdessä toisen jakamisarvon kanssa mainittuun asteikkoon laatumitan saamiseksi.

6. Jonkin edellisistä patenttivaatimuksista mukainen menetelmä, joka  
5 käsittää lisäksi:

hankitaan useita parametriarvoja, jotka on johdettu useisiin lyönteihin yhdistetystä mainitusta kiihtyvyydsdatasta; ja

10 muodostetaan linkitysfunktio parametriarvojen ja laatumittojen välille näiden useiden parametriarvojen jakauman mukaisesti; ja

linkitetään ainakin osa useista parametriarvoista laatumittoihin linkitysfunktion mukaisesti.

15

7. Jonkin patenttivaatimuksista 1 – 6 mukainen menetelmä, joka käsittää lisäksi:

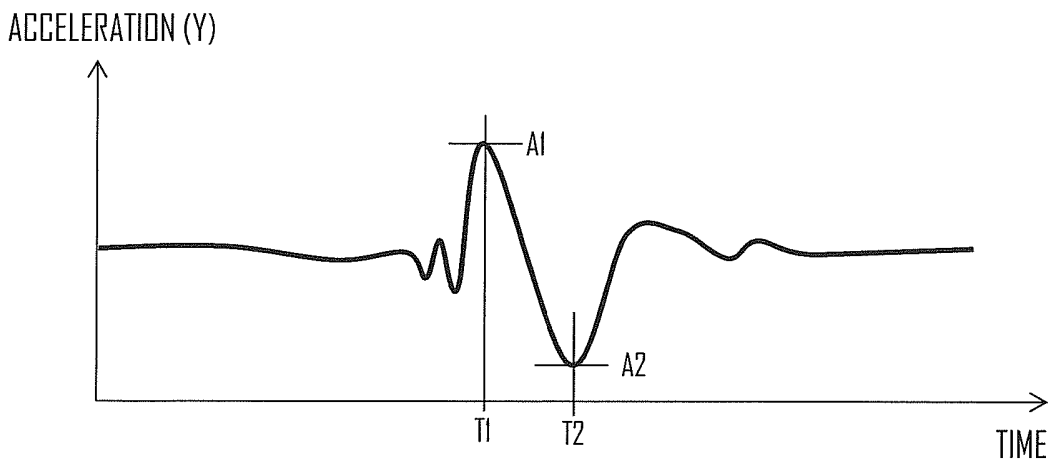
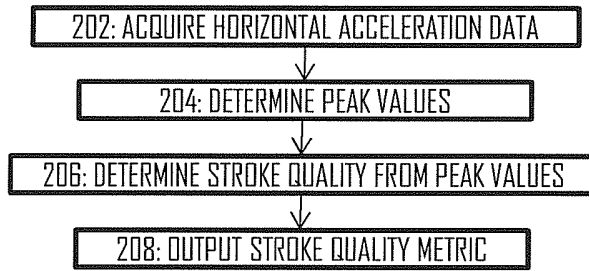
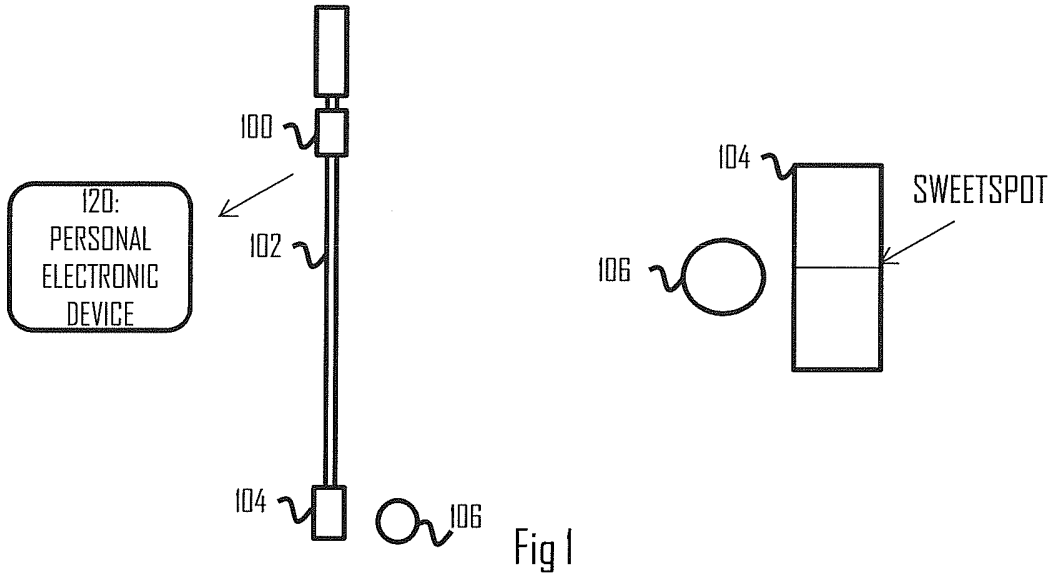
20 suoritetaan kalibrintiproseduuri ennen kiihtyvyydsdatan mittausta, ja näin saadaan asteikko käytettäväksi linkitettäessä kiihtyvyydsdatasta laskettu parametri laatumittaan; ja

25 lasketaan mainittu ainakin yksi laatumitta linkittämällä kiihtyvyydsdatasta laskettu ainakin yksi parametri laatumittaan kalibrintiproseduurin aikana saadun asteikon mukaisesti.

8. Laite, joka käsittää välineet (30, 12, 14, 16), jotka konfiguroivat laitteen suorittamaan jonkin edellisistä patenttivaatimuksista 1 – 7 mukaisen menetelmän.

30

9. Tietokoneohjelmistotuote toteutettuna tietokoneella luettavalla jakeluvälineellä ja käsittäen ohjelmistokomentoja, jotka laitteeseen ladattuina suorittavat jonkin patenttivaatimuksista 1 – 7 mukaisen menetelmän.



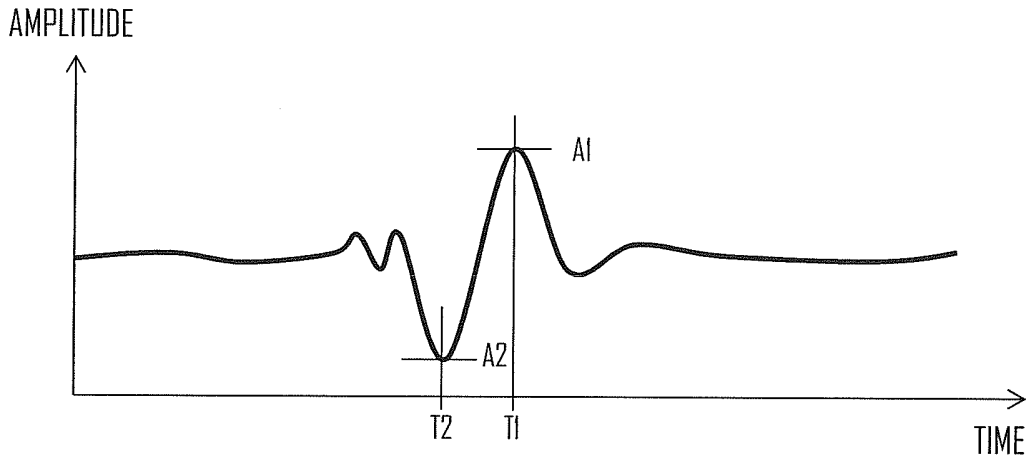


Fig 3B

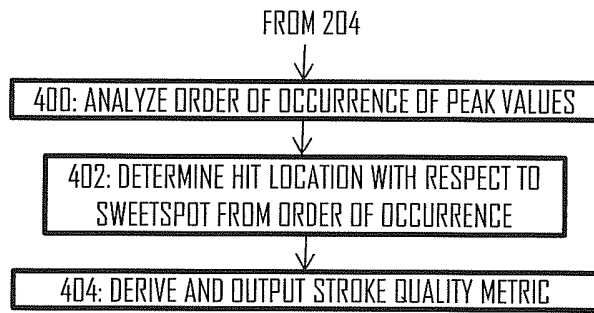


Fig 4

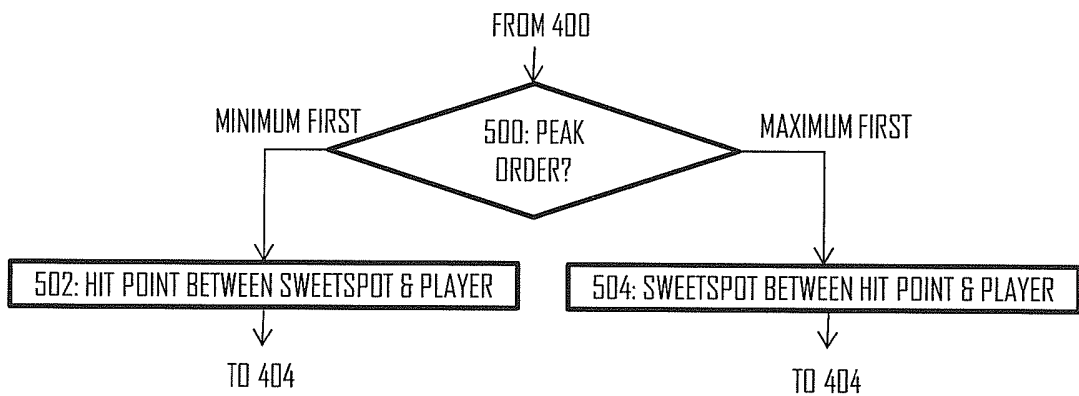


Fig 5

EXAMPLE OF LOW QUALITY STROKE

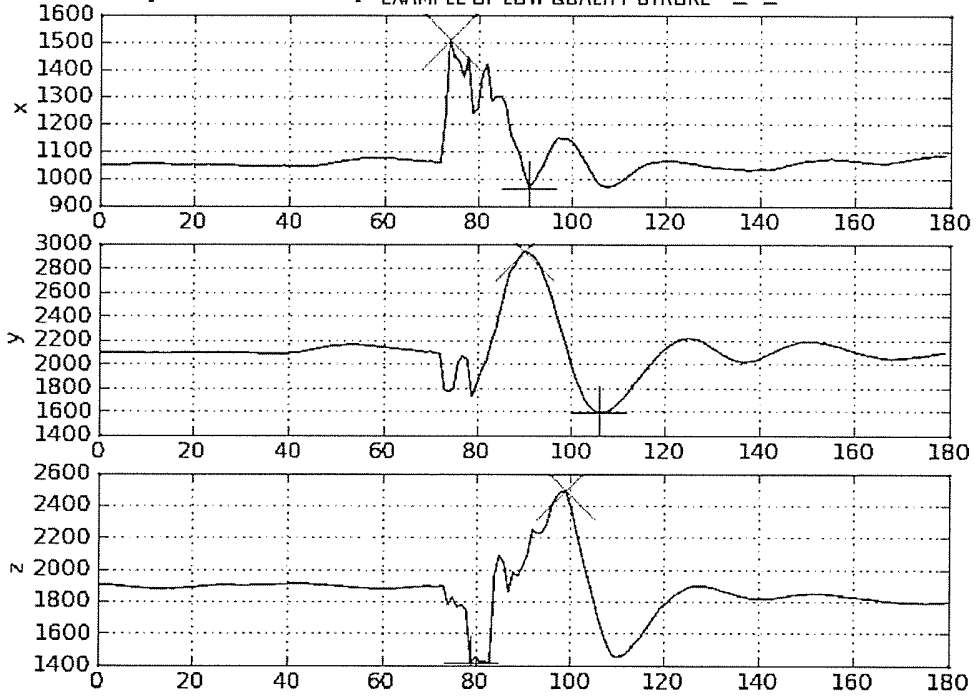


Fig 6

EXAMPLE OF HIGH QUALITY STROKE

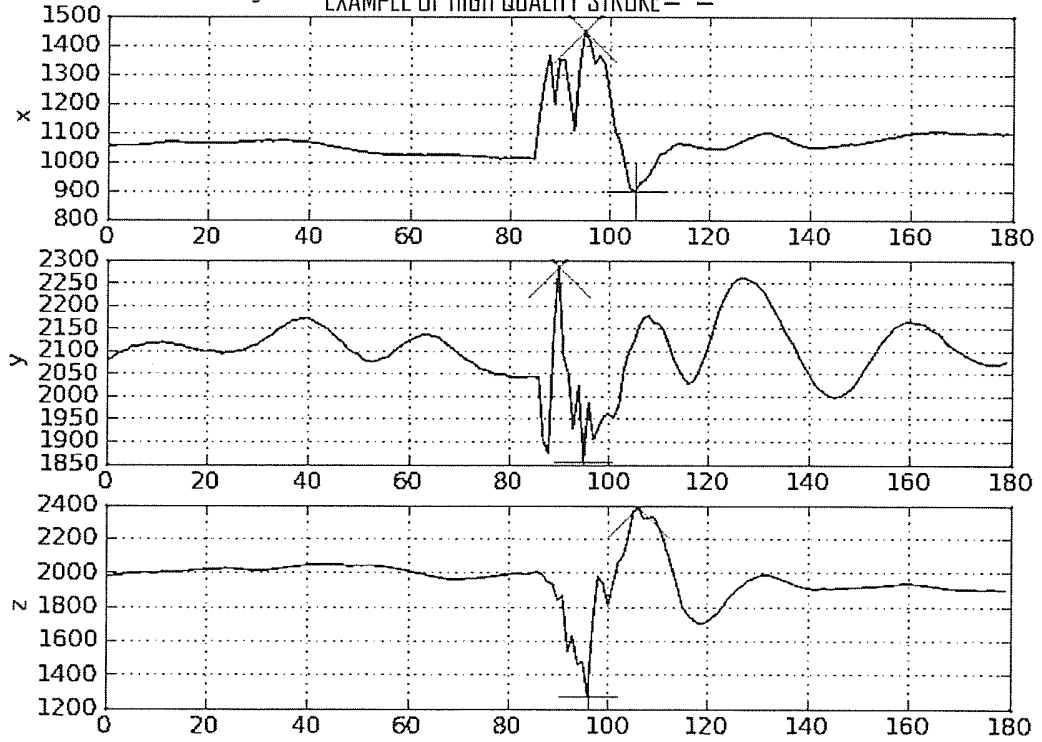


Fig 7

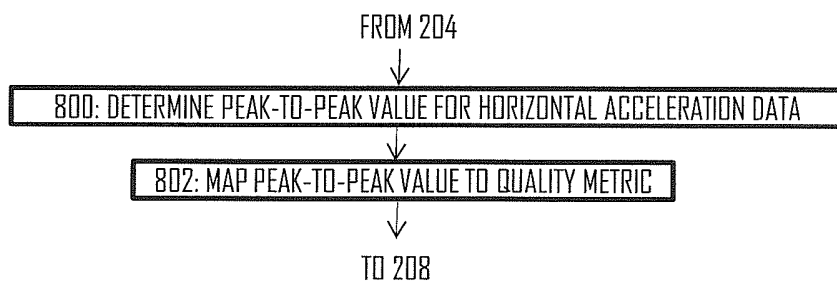


Fig 8

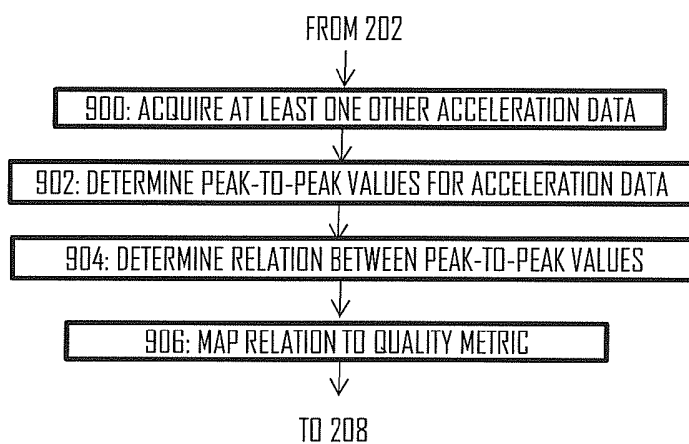


Fig 9

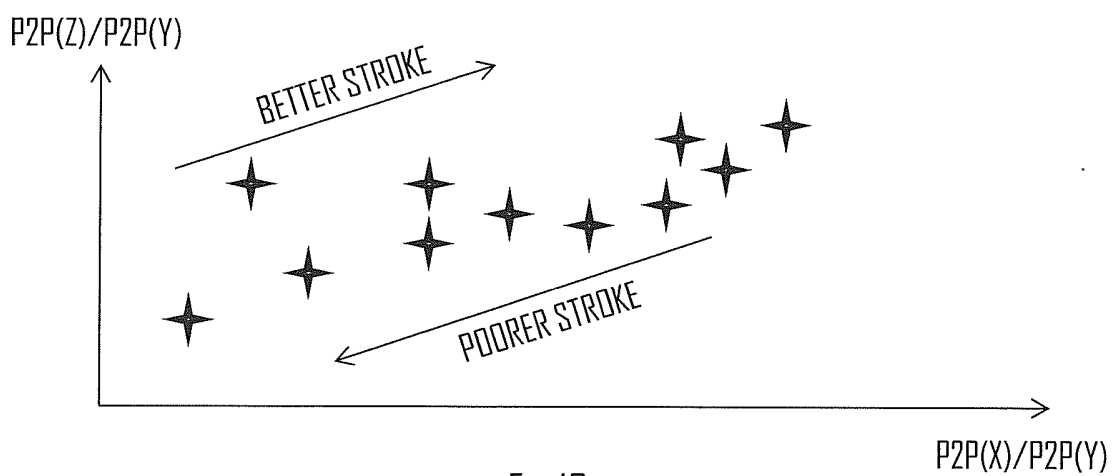


Fig 10

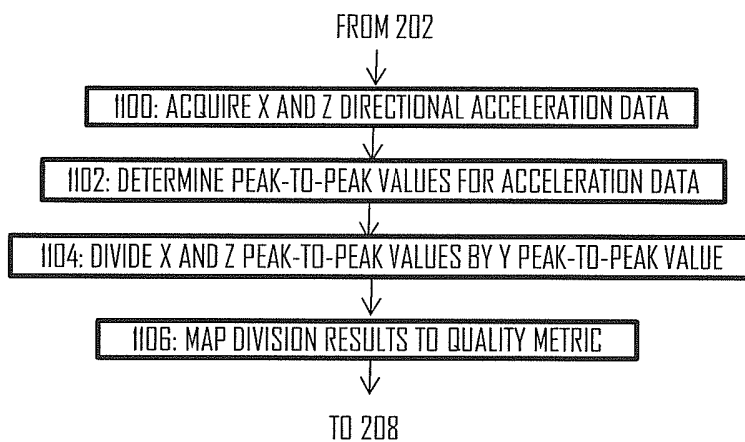


Fig 11

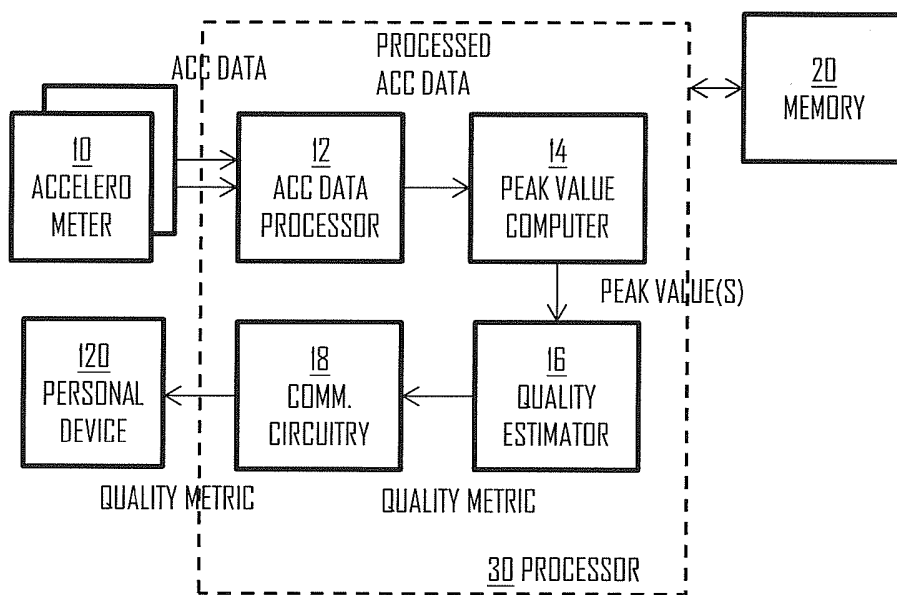


Fig 12

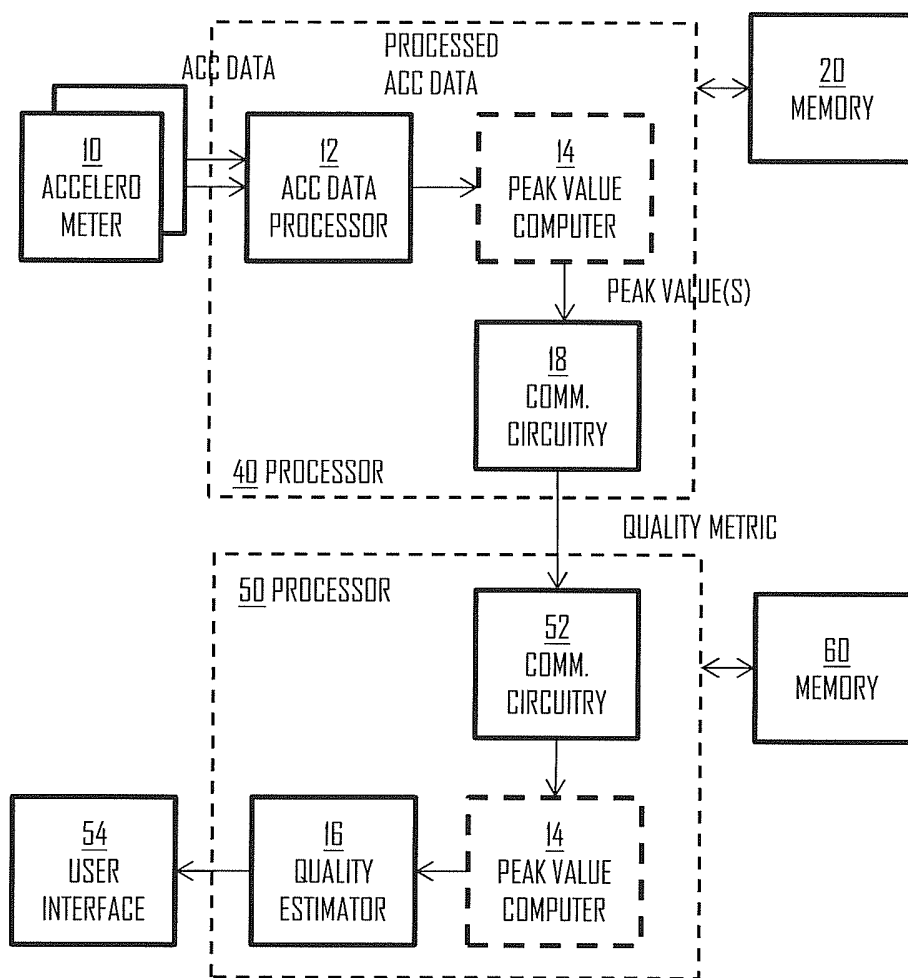


Fig 13