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(54) **GOLF SWING ANALYSIS METHOD AND APPARATUS**

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(60) Provisional application No. 61/668,090, filed on Jul. 5, 2012.

(57) **ABSTRACT**

This invention relates to a method and apparatus for analyzing a golf swing. In particular, the invention relates to a method and apparatus for analyzing a golf swing utilizing a portable computing device such as a smart phone, wherein a golfer can wear the device and the device uses sensors to monitor swing motion, and more particularly monitor a golfer's hip mechanics during a golf swing.

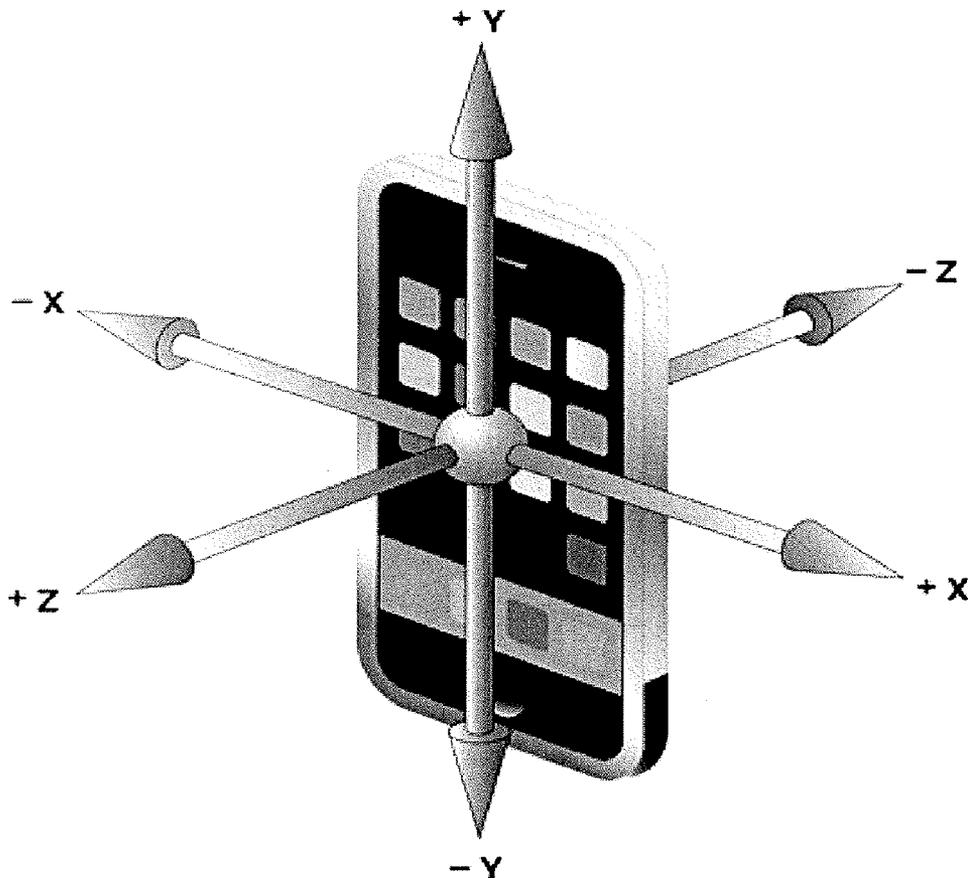


Figure 1

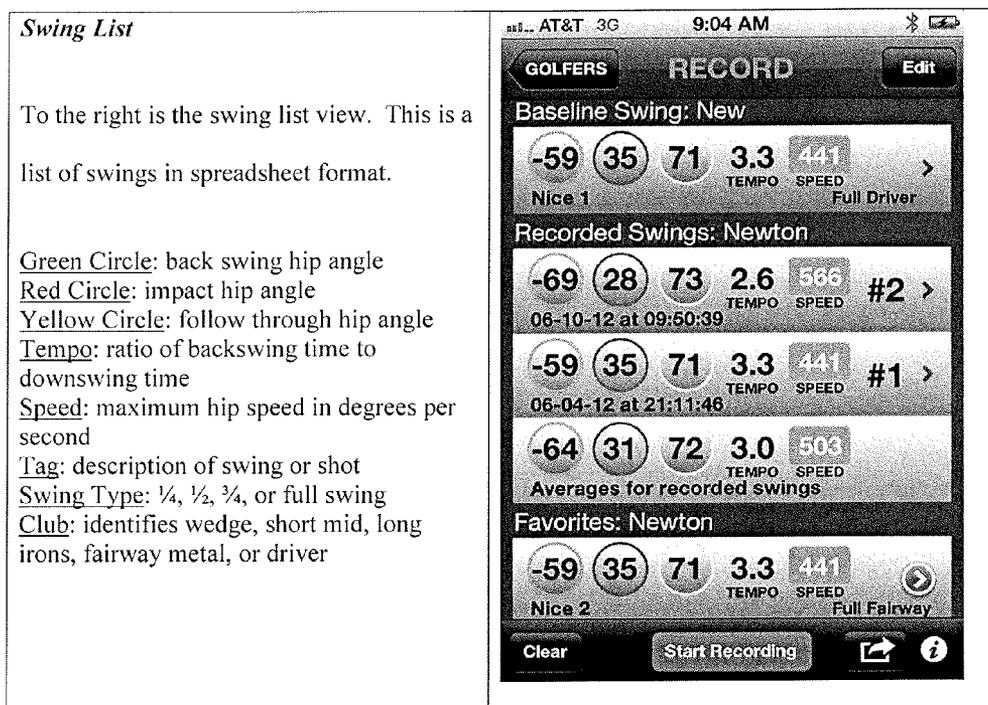


Figure 2

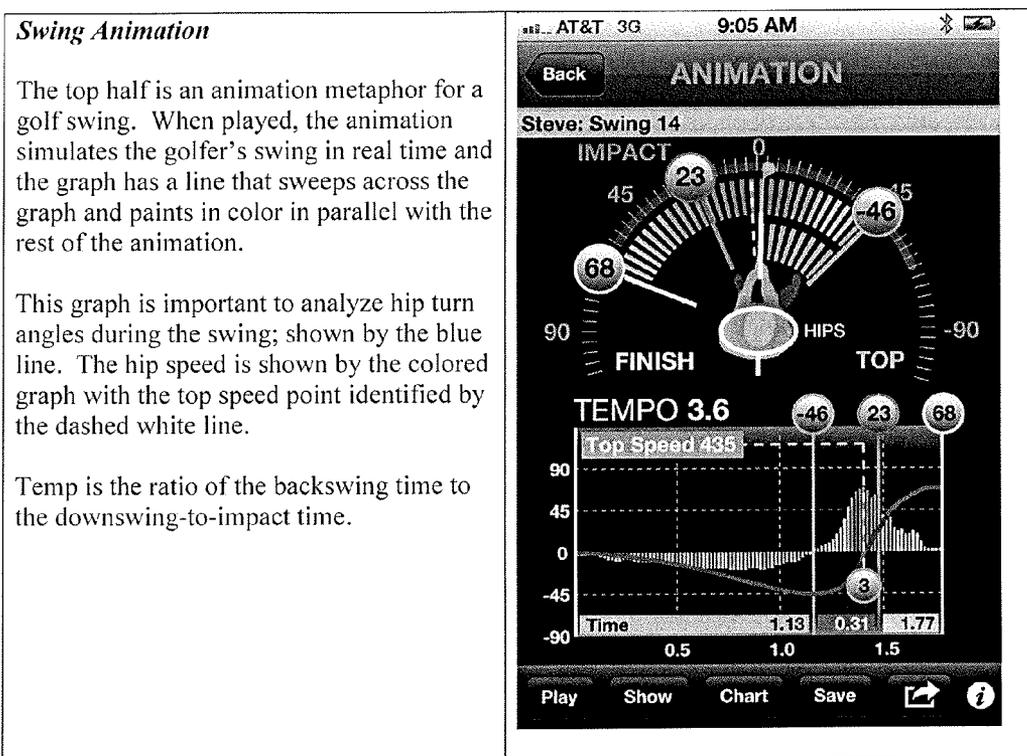


Figure 3

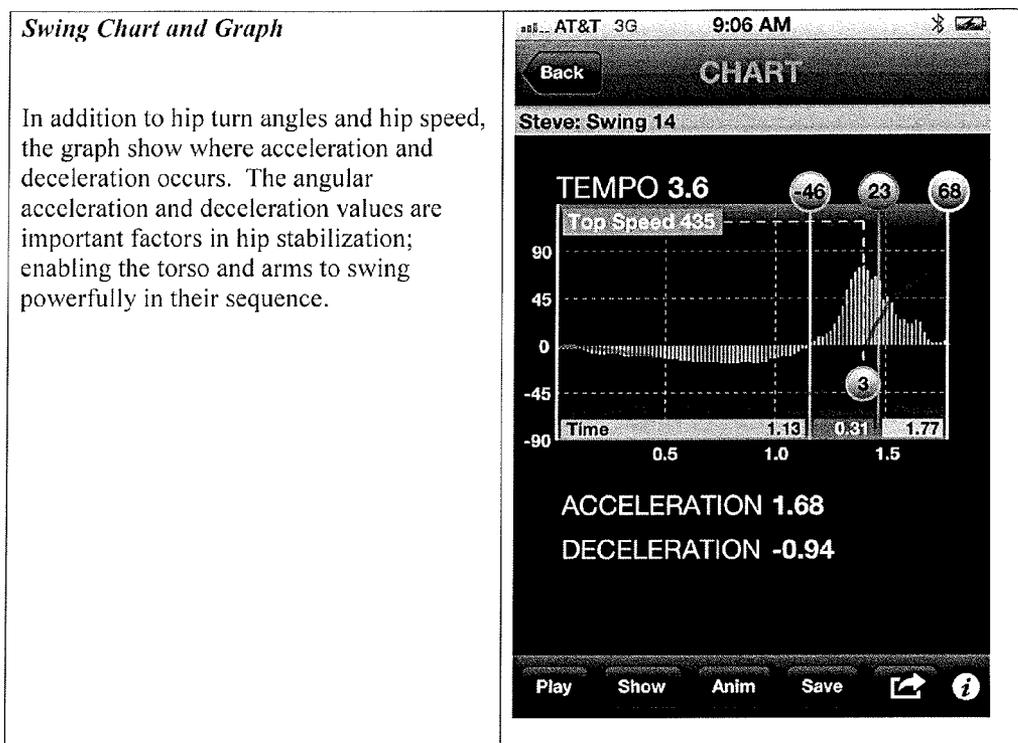


Figure 4

Swing Animation Comparison to Baseline

The animation can be compared to a baseline swing animation so the golfer can see the differences between the two swings. If the baseline is recorded from a solid golf shot, then duplication of the hip turns and tempo during practice can help improve a golfer's swing.

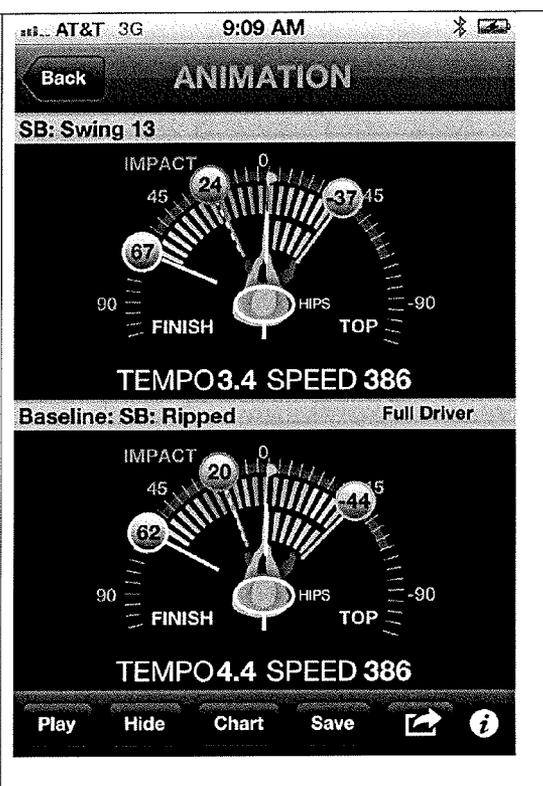


Figure 5

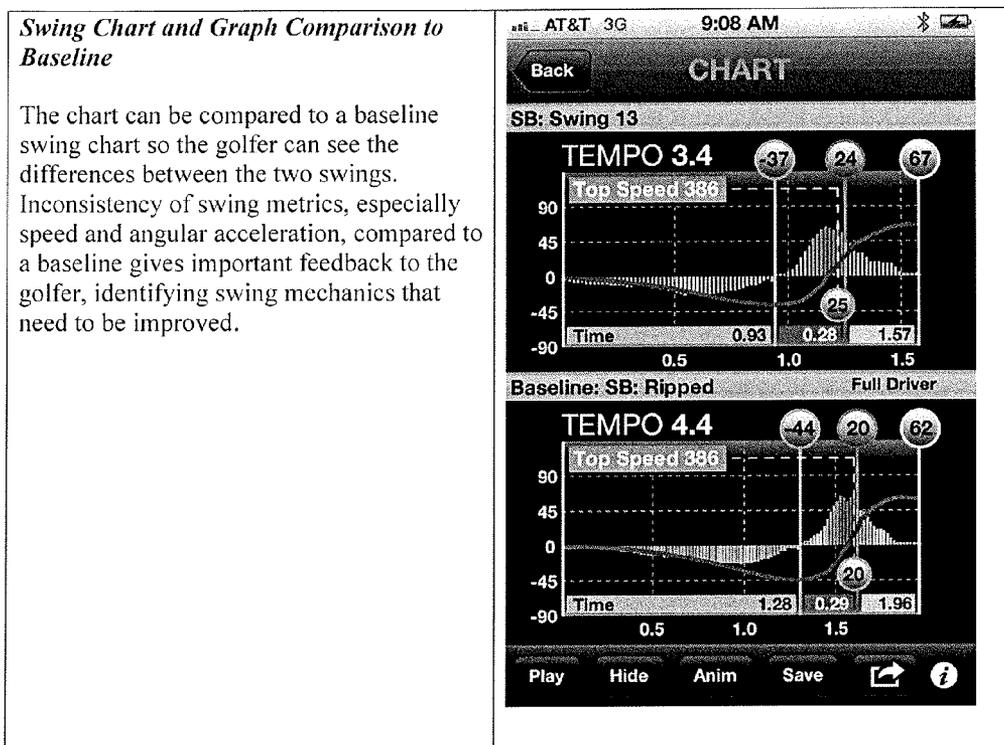


Figure 6 Decision model for practice and education

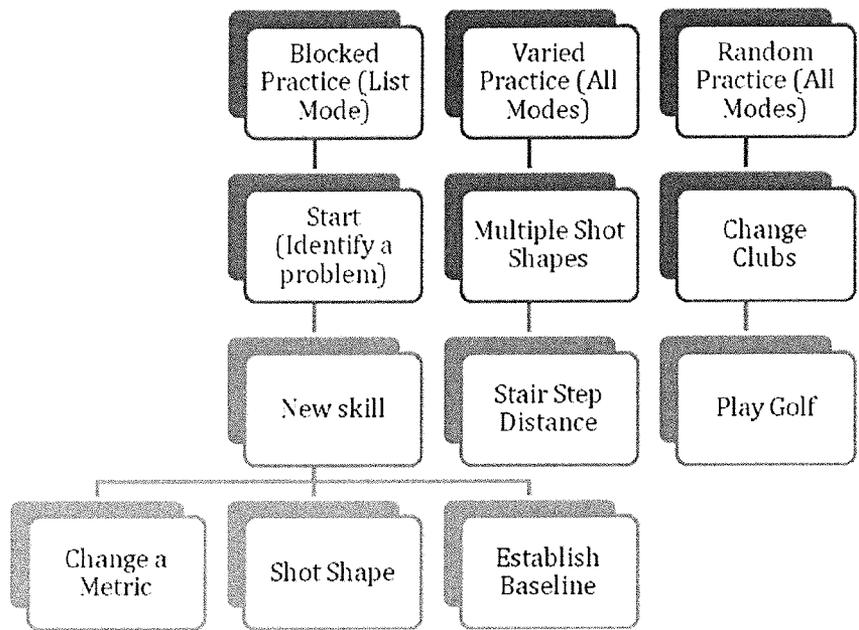


Figure 7 Motion sensor X, Y, and Z axis rotations

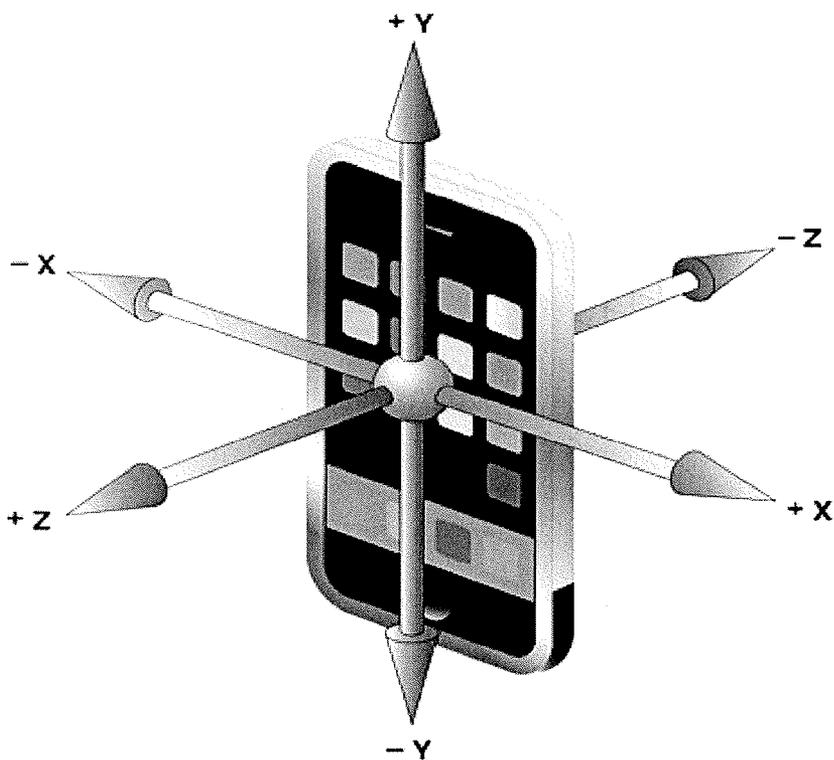


Figure 8 Golf swing segments: Address #1, Top of backswing #5, Impact #9, Finish #12

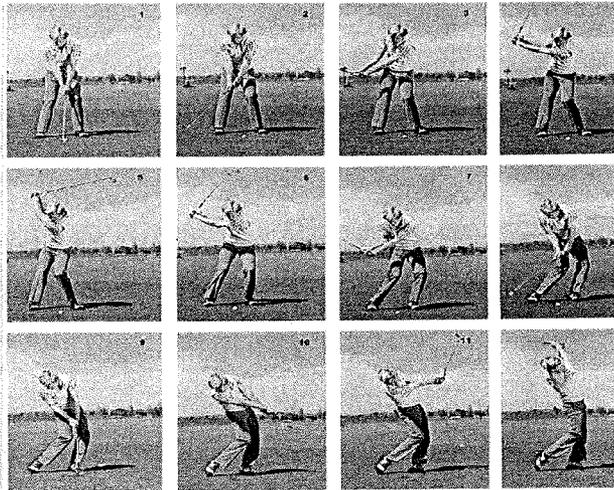


Figure 9 Flow diagram of Address segment algorithm

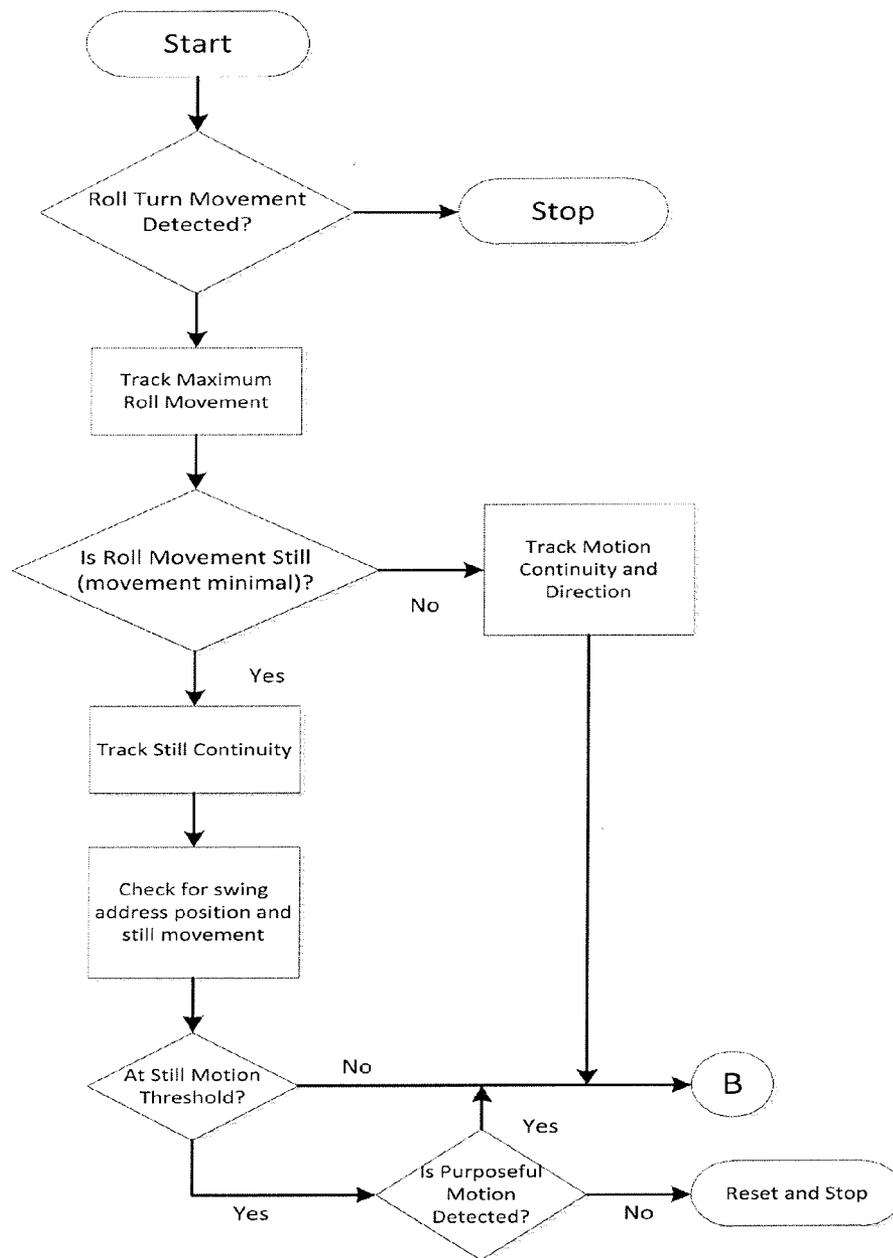


Figure 10 Flow Diagram of Backswing segment algorithm (Backswing and Forward swing algorithms are identical)

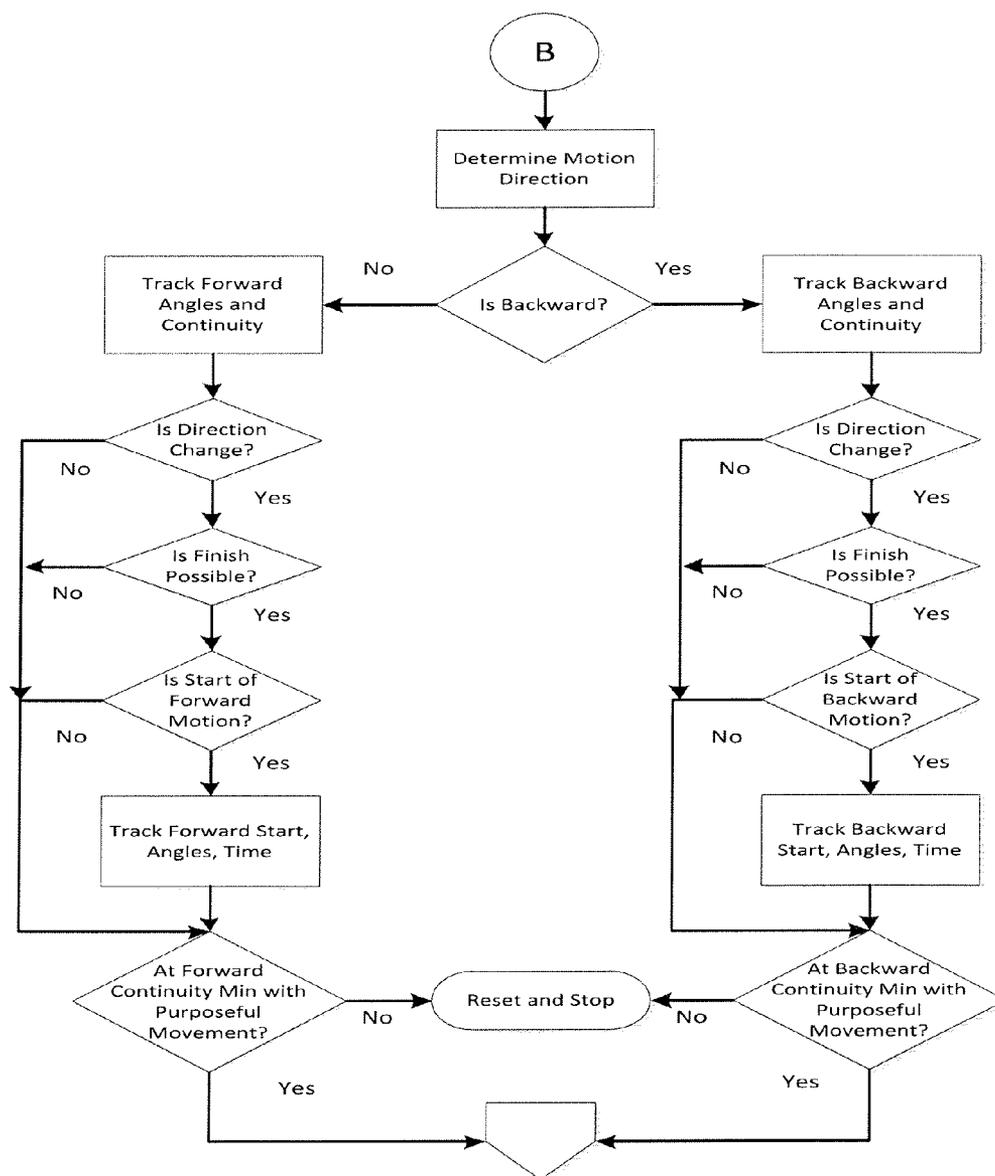


Figure 11a Flow Diagram of swing disqualification checks

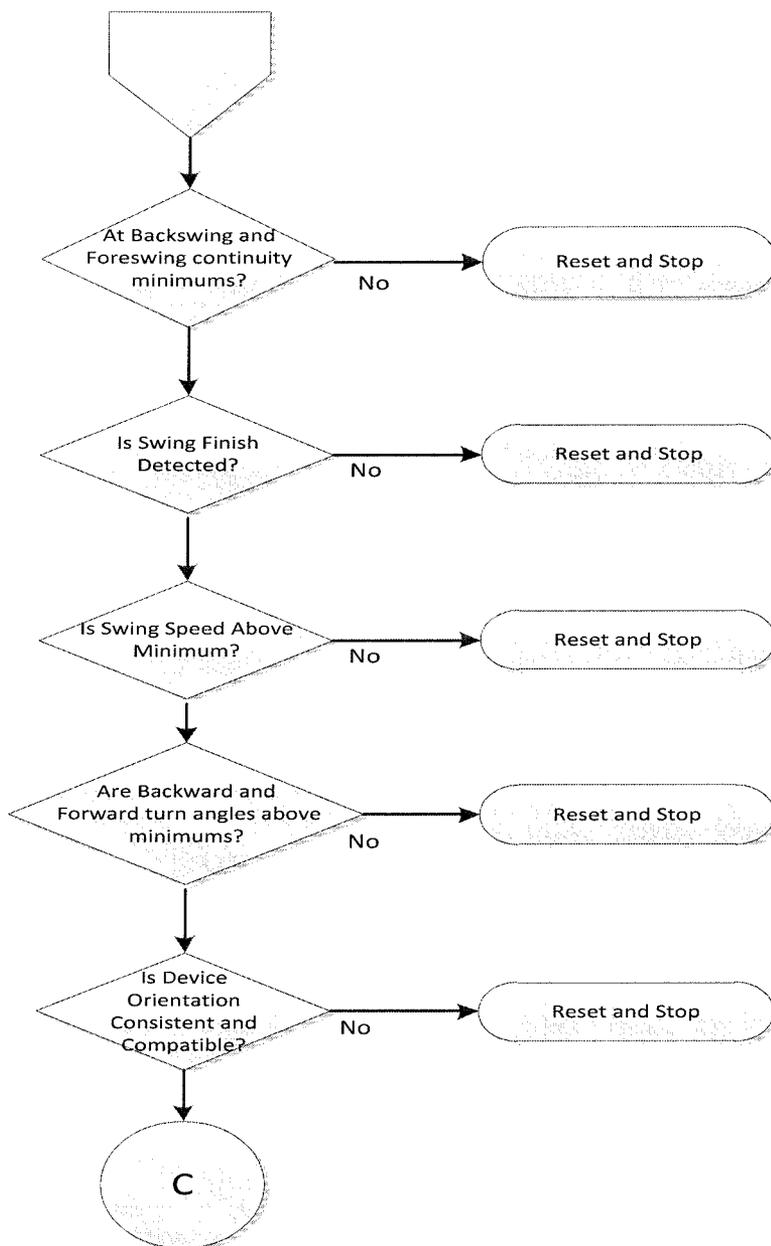
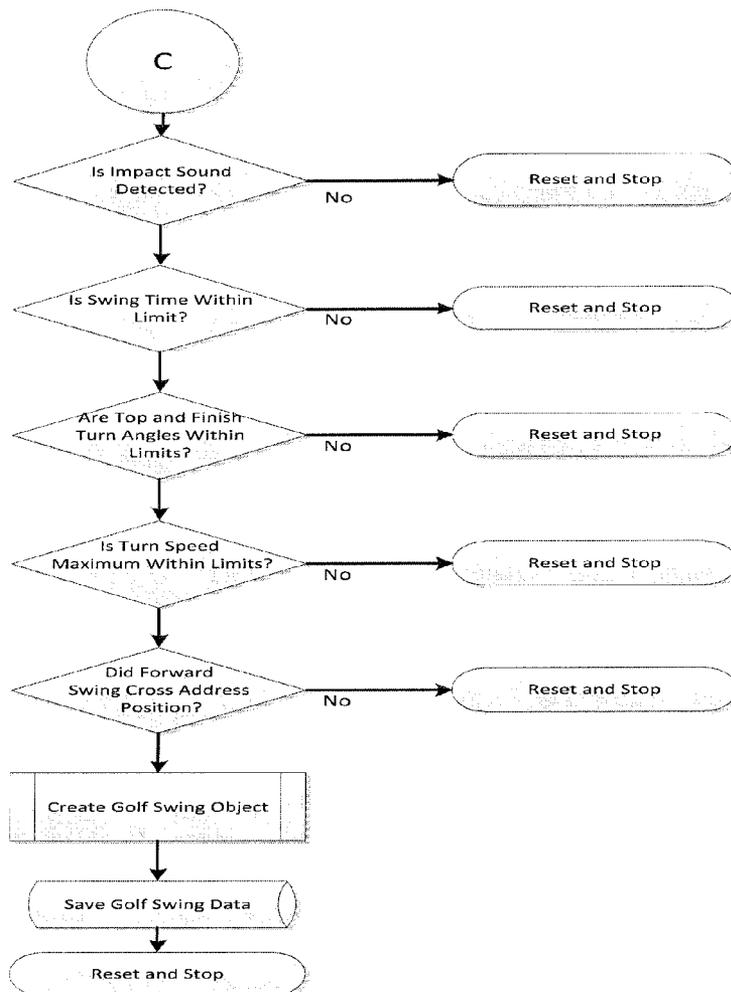


Figure 11b Flow Diagram of swing disqualification checks



GOLF SWING ANALYSIS METHOD AND APPARATUS

RELATED APPLICATIONS

[0001] The present application claims priority to and incorporates by reference U.S. Provisional Application No. 61/668,090 filed on Jul. 5, 2012.

BACKGROUND

[0002] 1. Field of the Invention

[0003] This invention relates to a method and apparatus for analyzing a golf swing. In particular, the invention relates to a method and apparatus for analyzing a golf swing utilizing a portable computing device such as a smart phone, wherein a golfer can wear the device and the device uses sensors to monitor swing motion, and more particularly monitor a golfer's hip mechanics during a golf swing. Of course, a person of ordinary skill in the art will understand that the invention is not necessarily so limited.

[0004] 2. Background of the Invention

[0005] Golf is an extremely popular sport worldwide. The popularity stems from a variety of reasons, including the difficulty of the game. Golfers of all levels enjoy the challenge of the game, which requires development of both athletic ability and mental acuity.

[0006] Improvement in golf requires some sort of a feedback mechanism. The golfer has to have a way to evaluate whether changes to the swing cause a positive or negative impact. Feedback can take many forms, but any feedback system that relies solely on a golfer's subjective evaluation of the swing is inherently flawed. A golfer cannot see their swing, and so has no real way to be sure what they are doing.

[0007] For this and other reasons, golf instruction is very helpful. Not only can a professional instructor more easily spot flaws in a golfer's swing, they can visually evaluate progress toward correction. The drawback of this approach is that the feedback ends when the lesson ends.

[0008] Once the instruction period has ended, the golfer is generally on their own again in terms of evaluating progress, which of course forces the golfer to rely on mostly subjective evaluation criteria.

[0009] Video swing analysis is similarly useful in the feedback progress, and video systems exist that can be used to evaluate swing mechanics in outdoor real-time environments. Modern smart phones, and the like, can be used to photograph or take video of a golf swing, and the player can then use the results to gauge performance.

[0010] This approach, however, still suffers from a number of drawbacks. It normally requires two people to utilize these tools—one to hold and operate the device, and the other to be the subject of the analysis. Most golfers practice by themselves and therefore do not have the ability to easily use video. Secondly, video is a purely visual evaluation tool, which has to be interpreted by the golfer—thereby reintroducing subjectivity into the process. Video allows the golfer to see what they are doing, but it does not necessarily help them understand what they are doing. In other words, it is one thing to see something it is entirely another thing to appreciate the significance of what you are seeing.

[0011] Video does not provide objective feedback, because the results still need to be subjectively evaluated. The feedback loop has still not been closed.

[0012] Accordingly, a need exists for an improved apparatus and method to provide a golfer with an objective means to evaluate their golf swing.

SUMMARY OF THE INVENTION

[0013] An object of the present invention is to provide an improved apparatus and method for a golfer to objectively evaluate their golf swing.

[0014] These and other objects of the present invention will become apparent to those skilled in the art upon reference to the following specification, drawings, and claims. To that end, the present invention comprises a method and apparatus read the break in a surface and adjust aim accordingly. The method utilizes a mobile computing device positioned near a golfer's hips, wherein the mobile computing device has internal accelerometers that measure acceleration in three perpendicular axes. The golfer takes a swing at a golf ball. The mobile computing device's microphone listens for the sound of the impact of the golf ball and the golf club. The mobile computing device's accelerometers and internal logic to determine one or more of the following: a backswing hip angle; the point in time at which the back swing hip angle is reached; an impact hip angle taken at the time of impact of the golf ball; and the golf club as determined by the mobile computing device's microphone; the point in time at which the impact hip angle is reached; a follow through hip angle; the point in time at which the follow through hip angle is reached; and hip acceleration and deceleration through the golf swing.

BRIEF DESCRIPTION OF DRAWINGS

- [0015] FIG. 1 shows a swing list screen shot.
- [0016] FIG. 2 shows a swing animation screen shot.
- [0017] FIG. 3 shows a swing chart and graph screen shot.
- [0018] FIG. 4 shows a swing animation and comparison screen shot.
- [0019] FIG. 5 shows a swing chart and graph comparison screen shot.
- [0020] FIG. 6 shows a decision model block diagram
- [0021] FIG. 7 shows an axis motion diagram.
- [0022] FIG. 8 shows composite view of a golf swing.
- [0023] FIG. 9 shows an address detection algorithm.
- [0024] FIG. 10 shows a backswing detection algorithm.
- [0025] FIG. 11 shows a swing disqualification check diagram.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0026] In the Figures, is shown a mobile device application that measures a golfer's hip mechanics during a golf swing to provide precise and relevant information back to the golfer. In particular, the device is a smart phone and more particular a smart phone running the Apple OS or Android operating system, or other similar systems and related devices. Of course, the invention is not necessarily so limited.

[0027] The swing analysis and resulting feedback and metrics information substantially overcomes the limitations of prior art device applications that rely on video or detached wireless sensors to record swing motion because of the following advantages:

[0028] The present invention determines the impact point of the club and ball via sound detection using the

device microphone. Specifically, the following swing metrics are dependent on measuring the point of ball impact:

[0029] Impact hip angle

[0030] Tempo

[0031] Hip acceleration and deceleration

[0032] Lateral motion

[0033] Real time swing recognition is continuous requiring no prompts or countdown sequences to tell a golfer when to swing.

[0034] Address position can change to allow the golfer to aim at various targets without affecting alignment, resulting turn angle metrics, or requiring any manipulation of the device.

[0035] Only valid swings that meet motion, timing, impact, and acceleration rules are recorded, and validity is determined by the device.

[0036] Uses device hardware capabilities of sound, vibration, and visual display to provide immediate feedback for each recorded swing.

[0037] Uses the mobile device motion sensors and gyroscope to measure the following aspects of a golf swing:

[0038] Back swing turn hip angle

[0039] Ball impact hip angle

[0040] Follow through hip angle

[0041] Max hip speed

[0042] Tempo: ratio of timing from start to top and top to impact

[0043] Hip angular velocity

[0044] Hip acceleration and deceleration

[0045] Lateral motion

[0046] Tilt

[0047] Analysis of recorded swings is presented through three different visual displays using bright color contrasts to be visible outdoors

[0048] Swing Animation—The swing animation displays the 3 hip angles listed above through an animated model.

[0049] Swing Graph—The graph displays hip speed over time and reveals hip angular acceleration and deceleration, timing at top, impact, and finish, and the top speed point during the swing

[0050] Swing List—This resembles a spreadsheet by listing the data associated with multiple swings to allow a user to quickly compare the numbers. The swing list is a mechanism to determine consistency and identify outliers.

[0051] Provides meaningful objective metrics and measurements for golfers of all skill levels.

[0052] Support for rapid experimentation of different hip motions and tempo and their resulting affect on shot shape (straight, fade, draw, push, pull, slice, hook).

[0053] Allows golfer to save swings to a Favorites list and using these swings for future reference.

[0054] Allows golfer to save a swing as a Baseline for use as a future comparison to other swings. The ability to save swing metrics for good and bad shots is key to the golfer's ability to later adjust hip mechanics to achieve desired results.

[0055] Tag recorded swings with descriptions, club selection, swing type, and shot shape.

The following describes the operation of the device software in performing various tasks.

[0056] Recording Swings

Recording Swings is achieved by:

1. Pressing the record button to begin motion sensor sampling and start the swing recognition algorithm.

2. Placing the device firmly and securely on or near the hips

[0057] a. In a front or back pocket

[0058] b. By tucking it between the pant waistband or belt and the waist

[0059] c. In a holder that clips on the pant waistband or belt

[0060] d. Using a waist strap designed to hold the device

3. Taking one or more swings

[0061] Device holders that clip on a belt and straps that go around a waist are generally available from a number of retailers.

[0062] Analysis and Resulting Feedback

[0063] Each recorded swing can be analyzed through the application views that show a swing list spreadsheet, an animation, a chart and graph, and in comparison to another recorded swing used as a baseline. The swing list view is depicted in FIG. 1. This view allows the golfer to view the analytic information in a list. The view shows a previously captured baseline swing displaying (from left to right) the back swing hip angle, impact hip angle, follow through hip angle, tempo ratio, and maximum hip speed in degrees per second. Also, displayed are comments included a tagline (“Nice 1”), swing type (“Full”), and club (“Driver”).

[0064] Below the baseline entry is the same information for three recorded swings, which can be easily viewed in comparison to the baseline swing analytics. The list view also allows you to view any favorite swings that have been stored in the system. At the bottom of the screen, options are available to clear the entries, record new swings, post the information to email or social media, and an information icon.

[0065] FIG. 2 shows the swing animation view for any particular view selected by the golfer. This view shows a 360° top down view of the golfer to view an animation of the swing from start to finish. The view also shows a two dimensional graph of the swing where the x-axis represents time, and the y-axis hip rotation angle (0° line represents the address position, negative angles represent the back swing and the beginning portion of the down swing, and positive angles represent the remainder of the down swing and follow through). In FIG. 2, the back swing hip angle is shown (“-46°”), the impact hip angle (“23°”), follow through hip angle (“68°”), and the hip angle at the point of maximum hip speed (“3°”). The impact point is shown with the dotted line.

[0066] FIG. 3 shows the swing chart and graph view, which in addition to the information shown in the other views shows the with the additional graph line the acceleration and deceleration profile, as well as the points in time acceleration and deceleration peak.

[0067] FIG. 4 show the swing animation comparison screen, which allows the golfer to select two swings to compare in the animation view.

[0068] When a swing is animated, the primary animation is played in parallel with the swing graph. The purpose is to align the two aspects of the data to enable a user to properly analyze a swing. The graph animation is important because it reveals the point of hip stabilization and deceleration where kinetic energy is transferred from the hips to the upper torso and arms, which ultimately effects club head speed. This

transfer of energy represents provides great insight into a user's ability to generate swing power.

[0069] The golf coach can use the application during the lesson to identify and tag a baseline swing. This allows the coach to prescribe motion and the type of practice that a student should be doing. A coach would want to save both a student's best shot to aspire to and poor shots that exemplify common pitfalls and errors. Identifying both good and bad shots will enable the student to recognize what types of movements impact the quality of the shot during practice.

[0070] FIG. 5 shows the swing chart and graph comparison, which compares two swings using the chart view format.

[0071] The present invention supports the use of social media. Once a golfer has constructed a list of swings, he has the ability email or post the swings on Facebook natively in the application through a button click (see the rectangle/arrow icon at the bottom right of FIGS. 1-5). There are two different things that a user can post—an individual swing animation, and the swing list. The place that these elements are posted will vary based on whether the golfer has identified a coach. If a coach has not been identified, the element will be posted on the user's Facebook wall. If a coach has been identified, the element will be posted on the coach's wall. In both circumstances, the user will be tagged in the swing to ensure it shows up in various news feeds for others to see. This aspect benefits both the golfer and the golf coach, by further closing the feedback loop.

[0072] For the golfer, posting an element on Facebook is the primary mechanism in which to close the feedback loop with the golf coach between lessons. When a new golfer is going through a series of lessons to improve swing mechanics, the golfer will typically see an initial degradation in consistency, which results in frustration. During this phase of retooling swing mechanics, it is critically important to keep the new golfer actively engaged with the golf coach to ensure proper practice techniques and the likelihood of the golfer returning for another lesson, and to prevent the golfer from misinterpreting the negative results and making unrelated changes that compound the problems. Both win in this scenario because the golfer has increased odds of improving their swing mechanics, and the golf coach is awarded with continued business. Not only can a user post swings on Facebook but they can also be emailed to a coach as well.

[0073] There is also an embedded feature inside the application that enables a user to seek out certified instructors from a list provided from a competent source. If a user is having problems with his swing, there will be a button inside the application that enables a user to send the swing to a nearby certified coach for analysis. A coach who is trying to develop additional business can then elect to respond to a request as a new business development mechanism. Certified instructors are searchable in the application and associated to the user account as their instructor. This enables easy posting of swings to the coach's Facebook wall. When posted, the swing will show the coaches name in the animation/swing fingerprint picture. When a swing is posted to a coach's wall, the user will be automatically tagged in the swing to get the swing to show up in the user's newsfeed.

[0074] Accompanying the application are education resources to aid a user with the journey of swing improvements. An important topic is, a "now what?" feature. It is one thing when a trained golf professional is using the application to walk a user through the interpretation of the data; it is another thing to draw a user into the application without the

presence of a golf professional. When a first time user uses the application, they will need assistance in understanding and applying the information provided, therefore, it will be important to guide them through what to do next. The first step toward this end is intuitive design; the next step is education resources. This all is designed to convert the application objective analytical data into the golfers' personal swing knowledge. In FIG. 6, is a practice and decision model that will translate the data to an actionable practice method.

[0075] Another benefit of the present invention is its ability to objectively and automatically perform swing recognition, through in particular the use of device hardware. The swing recognition algorithm makes use of mobile device hardware including the motion sensor and accelerometer, the system clock and its timer capabilities, and the system audio microphone and speaker components.

[0076] As shown in FIG. 7, the swing recognition algorithm uses the motion sensor to obtain 3-axis motion data that includes

[0077] Pitch—rotation around the X axis

[0078] Roll—rotation around the Y axis

[0079] Yaw—rotation around the Z axis

[0080] These angles are also known as Euler angles and each represents degrees of rotation around an axis. From a selected reference angle set, subsequent angle data defines the number of degrees and direction the device has moved along each axis.

[0081] The swing recognition algorithm detects the impact point using the device microphone and sampling for a spike in peak volume. The recognizer must be able to choose the correct impact point from multiple possible sounds from various sources such as other golfers hitting balls nearby, a loud voice, or a car horn in the background.

[0082] The device speaker is used to signal the successful swing recognition to the golfer by playing a short sound like a beep or ping.

[0083] When the device is secured to a golfer's hip, motion changes are sampled up to 60 times per second by accessing the system clock a timer components. As the hips turn and tilt during a golf swing, the motion data is used to detect the following distinct motion segments of a golf swing (all described in reference to the panels shown in FIG. 8):

[0084] 1. A swing always starts with an address position during which motion is still or minimal (FIG. 8 panel #1)

[0085] 2. The backswing starts with a backward turn motion that continues its direction until the top or transition point at the start of the down swing. Turn speed and acceleration during the backswing segment are relatively slow compared with speed and acceleration of the downswing. (FIG. 8 panel #5)

[0086] 3. The downswing is the start of forward motion from the top of the backswing. Turn speed and acceleration increase rapidly. Impact of the club head with the golf ball happens during the downswing, normally just after the hips pass their position at address. (FIG. 8 panel #9)

[0087] 4. The swing finish is a continuation of the downswing past impact. Turn speed and acceleration slow from their downswing peak. At the finish, motion is still or minimal. (FIG. 8 panel #12)

[0088] Swing recognition by the application relies on key device hardware components available on most presently available smart phones, as well as other similarly enabled computing devices such as small tablet computers.

[0089] The swing recognition algorithm samples motion data from the device up to 60 times per second. For each timer interval, the new motion data is compared to the last data. The changes, or deltas, in degrees and direction around each axis can determine the motion direction, speed, acceleration, tilt, and sway, which allows for identification of swing segments.

[0090] The application makes defines reference angles to allow for detection of swing segments. From a selected reference angle set, subsequent angle data defines the number of degrees and direction the device has moved along each axis. The swing algorithm sets reference angles at the start of the motion sampling. During swing recognition, reference angles are reset frequently when periods of still motion are detected.

[0091] The motion data must be modified depending on the device orientation. The swing recognizer works properly regardless of orientation. The device can be in portrait mode with it top up or down. It can also be in landscape mode on its right or left side. The recognizer does not work when the device is face up or face down.

[0092] In portrait orientations, the recognizer uses the Y axis roll angles to track motion. With the device on either side in landscape orientation, the recognizer uses the X axis pitch angles.

[0093] FIG. 9 depicts a flow diagram for the address segment of the swing. A swing always starts with an address position during which motion is still or minimal. The golfer can change alignment to a target without affect on the algorithm or the resulting swing metric data. This is possible because the algorithm resets the reference angles whenever a sequence of still motion samples are detected. Movements in either direction, forward or backward, are determined to be still if the change of motion is less than a threshold of about 0.5 degrees. About 25 continuous still motion samplings will cause a reset of the reference angles. The number of still motions and the threshold are configurable, and can be varied based on experimentation.

[0094] The golf swing is considered to be in the address segment whenever continuous motion sampling is still or the reference angles have just been reset. The exception is if still motion is showing contiguous movements in the same direction, this is purposeful motion as opposed to random motion, which changes direction in no discernable pattern. Purposeful motion is allowed to continue past the still motion threshold and the angles are not reset. This allows the swing recognizer to accurately calculate the start of the backswing segment.

[0095] The Backswing Segment flow diagram is shown in FIG. 10. The backswing starts with a backward turn motion that continues its direction until the top or transition point at the start of the down swing. Turn speed and acceleration during the backswing segment are relatively slow compared with speed and acceleration of the downswing.

[0096] Every motion sample during each timer interval is tested for direction. Backswing direction is opposite for left or right-handed swings. The swing recognizer determines left or right swings by the direction of the backswing segment indicated by positive or negative angle data from the motion sensor. The backswing segment directional recognition algorithm is the same for either backward or forward direction.

[0097] If the direction is the same as the previous motion sample then the directional continuity counter is incremented. A valid backswing segment will have a minimum number of continuous directional motions. The directional continuity minimum threshold is tested. There must also be purposeful continuous motion that has minimal still motion

samplings. Too much still motion will cause a reset of the reference angles, which stops the current swing recognition and starts it over from the beginning. Directional movement that reaches the minimum continuity threshold with purposeful motion qualifies as a backswing segment. Turn speed, direction change counts, maximum speed, segment time, and total turn angles are among the metrics variables tracked.

[0098] Once the backswing segment is valid, further backward motions add to its length. Subsequent forward motions do not invalidate the backswing segment. This allows for some sway at the top of the backswing.

[0099] If the direction has changed, directions from the previous forward motion sample:

[0100] 1. A possible swing finish is determined if both a valid backswing and downswing (forward swing) segments.

[0101] 2. A new backswing start is begun if preceding backward motions did not establish a valid backswing segment.

[0102] Variables that track directional continuity, possible finish segment position, new backswing segment start, speed, angles, tilt, sway, and time are all updated.

[0103] A valid backswing segment can become invalid if its continuity is too long so a check is performed to see if the continuity is below the maximum.

[0104] Another step in the process is the swing qualification processing, which is valid for the back swing and the down swing segments. Every motion sample is also tested for the existence of both a valid backward and forward segment; the two key motion segments that form the swing. Once these are in place, a short series of backward motions that are still (movement below the still motion threshold), constitute the swing finish segment. At this point, with all four swing segments identified, the swing is qualified and the algorithm proceeds to a series of checks that might yet disqualify it. These checks are described below in the Swing Recognition Disqualifiers section (also shown in FIG. 11).

[0105] The down swing segment is not described. The downswing is the start of forward motion from the top of the backswing. Turn speed and acceleration increase rapidly. Impact of the club head with the golf ball happens during the downswing, normally just after the hips pass their original position at address.

[0106] The recognition algorithm for Motion Direction Processing as well as Swing Qualification Processing for the downswing segment is identical to that of the backswing segment. The motion data can start in either direction depending on the golfer swinging right or left handed. The right-handed backswing motion data is the same direction as the left-handed downswing, and vice versa. Refer to The Backswing Segment section for the algorithm.

[0107] The downswing segment must have one important attribute not present in the backswing segment: an impact point when the club hits the golf ball. This processing is described in the next section.

[0108] The swing recognition algorithm detects all possible impact points using the device microphone and sampling for a spike in peak volume. The recognizer must be able to choose the correct impact point from multiple possible sounds from various sources such as other golfers hitting balls nearby, a loud voice, or a car horn in the background.

[0109] The microphone is sampled up to four times during each motion sampling. At 60 motion samplings per second and 4 sound samplings per motion, the sound level is checked up to 240 times per second. This is important to ensure accu-

racy of the impact point since it is key to determining the impact hip turn angle, the impact timing and swing tempo, and deceleration at impact.

[0110] Impact points are analyzed and validated during the motion sampling. Impact points during the address, backswing, and finish segments are not valid. Only impact points that occur during the downswing segment are valid. All valid impact points are saved in an array. Placement position in the array is done so that the most qualified and likely impact point is in the array's first position. Placement is determined by these factors:

[0111] 1. A new impact point does not replace an existing point if it is within four motion sampling intervals of the existing point. The sound of an impact can register a peak sound level over several motion samples.

[0112] 2. If the peak sound (loudness) of a new impact point is greater than an existing point, the new point can replace the existing point.

[0113] 3. If a new impact point is in a valid expected hip turn range of 10 to 40 degrees, the new point can replace an existing point that is not in the expected range.

[0114] The finish segment is now described. The swing finish is a continuation of the downswing past impact. Turn speed and acceleration slow from their downswing peak. At the finish, motion is still or minimal. The finish segment begins when the downswing segment reaches its end and changes direction or becomes still for a short series of motion sampling intervals, around eight such intervals. This allows for either a smooth finish that just slows to a stop or a finish that slows but then quickly changes direction into a recoiling motion.

[0115] Detection of the finish segment ensures only that all four swing segments have been identified. The swing is qualified such that it has motion that forms the four segments. However, motion alone does not determine a valid swing. For example, a swing in very slow motion can produce the four motion segments, but it would lack sufficient speed, acceleration, and timing to be recognized as a valid swing. Additionally, a practice swing might otherwise qualify, but it lack impact.

[0116] To achieve qualification as a valid swing, the algorithm proceeds to a series of checks that might disqualify it. These checks are described below.

[0117] Once all four swing segments have been identified, the swing recognizer makes a series of tests that all valid golf swings must pass. Failure of any one of these tests disqualifies the potential swing and restarts the swing recognition algorithm to the start. Each disqualification test is described below (see also FIG. 11).

[0118] 1. Did the swing achieve the minimum required speed? This rules out very slow motion swings that had no real speed or significant acceleration. This also eliminates random motion the golfer might make between swings.

[0119] 2. Did the swing achieve the minimum required turn angle? A valid swing must have a backward turn then a forward turn. The sum of these turns must be a minimum number of degrees. This rules out small swings like chips or putts, or just random motion between swings; waggles, half turns, and small back and forth motions.

[0120] 3. Did the device orientation stay consistent during the swing? The orientation when the reference angles are set must stay the same through the swing finish. Otherwise, motion data angles for pitch and roll may be confused.

[0121] 4. Did the swing complete within a time limit? Most golf swings take about 2 seconds from start to finish. Any time more than 4.5 seconds indicates random motion that could be going on after the four motion segments have been completed.

[0122] 5. Did the swing contain at least one impact point? A valid swing without impact is just a practice swing.

[0123] 6. Did the backswing turn and downswing turn both complete within their turn limits?

[0124] A real golf swing has normal and reasonable turns in both directions. Excessive turns, full circles, and other wild turn movement disqualify the swing.

[0125] 7. Did the downswing pass or cross the position at address? A valid swing must turn back then forward past the address position facing the ball.

[0126] 8. Did the swing achieve top speed during the downswing? Top speed is normally just before or after impact. A swing that has its top speed during the backswing is not a real golf swing.

[0127] A valid swing that has passed all the disqualification tests is ready to be processed as a real recorded swing. Steps to create the recorded swing follow.

[0128] Recording is suspended while the swing is created and saved. This stops the motion sensor time interval samplings and analysis.

[0129] The golfer is notified that a swing has been recorded via sound and vibration.

[0130] A golf swing object is created

[0131] The reference angle data and all other motion data points that construct the swing motion segments are transferred from an internal buffer to an array property of the golf swing object. Each data point contains the Euler angles for pitch, roll, and yaw, a timestamp, speed or roll motion, and indication of whether the data point is before or after impact.

[0132] Speed values of each data point are adjusted based on actual time rather than the timer interval constant, since the system does not always invoke the timer on exact timer intervals. Devices such as smart phones are not dedicated real-time devices and are subject to interruptions and delays from other applications running in the background. Phone calls and other types of alerts also affect the timer interval.

[0133] The impact angle is adjusted two ways:

[0134] To allow for the time variance for the sound to travel from the club and ball to the device. This reduces the impact angle slightly.

[0135] To allow for which of the four sound samplings taken during the impact motion sensor interval actually recorded the impact. These happen at different times during the interval. This reduces the impact angle slightly if the first sound sample found impact, and increases the impact angle slightly if the 2nd, 3rd, or 4th sound sample detected the impact.

[0136] The swing is saved with the golfer's profile and written to the disk.

[0137] Recording is resumed which begins the motion sensor time interval samplings and analysis.

[0138] The swing recognition algorithm resets the reference angles and begins analyzing motion samples to define address, backswing, downswing, and finish segments for the next swing.

[0139] Features in the application offer the student multiple options when capturing and analyzing data at any point in the

learning process. For example if a student is a beginner or a scratch golfer, learning a new motor skill, there are specific functions built in to the application to guide efficient learning and practice. There are also different modes that give feedback based on learning styles and preferences. The animation mode gives the student multiple layers of data using color and design. The data is displayed with an animated diagram that can be slowed or paused to analyze any element in the swing. Data like speed, acceleration, deceleration, rotation, tempo, hip angles can be compared against other swings in multiple formats in a side-by-side mode. The chart mode shows the data in an animated graph format. The spreadsheet mode not only shows hip data it can also display pattern recognition, timestamps, notes, tags and give an efficiency rating for most of the data. Each mode will serve a specific purpose for the user depending on their individual intentions. When a student is practicing a new motor skill and is using repetition to train the skill using the spreadsheet mode will give the best feedback at a glance. When a student is just looking for feedback on a specific swing or metric that animated modes will offer just the right amount of feedback. The animated mode is good for a small number of swings in a tight feedback loop and the spreadsheet mode is good for a large number of repetitive swings with a broad range of feedback.

[0140] The info menu offers access to videos, articles, and diagrams to explain or troubleshoot any details that may need to be understood by the user. The videos are in a storytelling structure so the user can build the best possible memories to assist in the experience. The graphic animations, charts, graphs and the layout of the user interface have been design to offer multiple levels of information displayed in a very intuitive manner so the student can focus on what is relevant for their learning and not get distracted with unnecessary feedback.

[0141] The invention has been described in reference to golf, but it is not so limited. In particular, the invention can be applied to motion analysis for other sports. With modifications to the definition of motion segments and disqualification rules, the swing can be used to detect key movements in other sports and activities, such as:

[0142] The tennis serve has address, backward, forward and finish segments, and impact of the racket with the ball. Hip action plays an important part in the power and flight of the serve.

[0143] The baseball and softball swing has address, slight backward, forward and finish segments, and impact of the bat with the ball. Hip action plays an important part in the power and flight of the ball.

[0144] The hockey slap shot has address, backward, forward and finish segments, and impact of the stick with the puck. Hip action plays an important part in the power and flight of the shot.

[0145] Football punting and placekicking both have address, backward, forward and finish segments, and impact of the foot with the ball. Hip action plays an important part in the power and flight of the ball.

[0146] Soccer has address, backward, forward and finish segments, and impact of the foot with the ball. Hip action plays an important part in the power and flight of the ball.

[0147] Martial arts, boxing, punching, kicking actions all involve sequencing of the hips to produce power. These actions can be recognized with the golf swing recognizer.

[0148] Fitness, training, cross fit, and gymnastic activities all have motion that requires proper turns, flexibility, stabilization, and other movements that can be detected and monitored with recognition algorithms similar the golf swing recognizer.

[0149] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials similar to or equivalent to those described herein can be used in the practice or testing of the present invention, suitable methods, and materials are described below. All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety to the extent allowed by applicable law and regulations. In case of conflict, the present specification, including definitions, will control.

[0150] The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof, and it is therefore desired that the present embodiment be considered in all respects as illustrative and not restrictive, reference being made to the appended claims rather than to the foregoing description to indicate the scope of the invention. Those of ordinary skill in the art that have the disclosure before them will be able to make modifications and variations therein without departing from the scope of the invention.

1. A method of analyzing a golfer's swing, comprising:

- (a) positioning a mobile computing device near a golfer's hips, wherein the mobile computing device has internal accelerometers that measure acceleration in three perpendicular axes;
- (b) having the golfer take a swing at a golf ball;
- (c) having the mobile computing device's microphone listen for the sound of the impact of the golf ball and the golf club;
- (d) using the mobile computing device's accelerometers and internal logic to determine:
 - (i) a backswing hip angle;
 - (ii) the point in time at which the back swing hip angle is reached;
 - (iii) an impact hip angle taken at the time of impact of the golf ball and the golf club as determined by the mobile computing device's microphone;
 - (iv) the point in time at which the impact hip angle is reached;
 - (v) a follow through hip angle;
 - (vi) the point in time at which the follow through hip angle is reached; and
 - (vii) hip acceleration and deceleration through the golf swing.

2. The method of claim 1, further comprising:

- (e) having the mobile computing device's display screen display one or both of:
 - (i) the backswing, impact and follow through hip angles during the golf swing; or
 - (ii) a continuous plot of the changing hip angle through the swing together with hip acceleration and deceleration through the swing.

3. The method of claim 1, wherein the mobile computing device is an iPhone.

4. The method of claim 2, further comprising:

- (i) having the mobile computing device determine the tempo of the swing, wherein the tempo of the swing is the ratio of backswing time to downswing time; and

- (ii) displaying the tempo of the swing on the mobile computing device's display screen.
- 5. The method of claim 2, wherein (e)(i) and (e)(ii) are simultaneously displayed together on the display screen of the mobile computing device.
- 6. The method of claim 2, further comprising:
 - (i) having the mobile computing device determine the point of maximum swing speed through the swing; and
 - (ii) displaying the point of maximum swing speed on the mobile computing device's display screen.
- 7. The method of claim 2, wherein the backswing, impact, and follow through hip angles are displayed on an animated model.
- 8. The method of claim 1, wherein positioning a mobile computing device near a golfer's hips comprises placing the mobile computing device in the user's pants pocket.
- 9. The method of claim 2, further comprising:
 - (i) repeating the method of claim 1 for a second golf swing; and
 - (ii) displaying the swing information as set forth in claim 2 for the first and second golf swings simultaneously on the mobile computing device screen, thus allowing the golfer to compare the first and second swings.
- 10. A mobile computing device-based system for analyzing a golfer's swing, comprising:
 - (a) a mobile computing device;
 - (b) a microphone in the mobile computing device;
 - (c) internal accelerometers in the mobile computing device that measure acceleration in three perpendicular axes;
 - (d) a computer-based system in the mobile computing device for using the microphone to listen for the sound of the impact of a golf ball and a golf club; and
 - (e) a computer-based system in the mobile computing device for using the accelerometers and internal logic to determine:
 - (i) a backswing hip angle;
 - (ii) the point in time at which the back swing hip angle is reached;
 - (iii) an impact hip angle taken at the time of impact of the golf ball and the golf club as determined by the mobile computing device's microphone;
 - (iv) the point in time at which the impact hip angle is reached;
 - (v) a follow through hip angle;
 - (vi) the point in time at which the follow through hip angle is reached; and

- (vii) hip acceleration and deceleration through the golf swing.
- 11. The system of claim 10, further comprising:
 - (a) a computer-based system in the smart phone for displaying one or both of:
 - (i) the backswing, impact and follow through hip angles during the golf swing; or
 - (ii) a continuous plot of the changing hip angle through the swing together with hip acceleration and deceleration through the swing.
- 12. The system of claim 10, wherein the mobile computing device is an iPhone.
- 13. The system of claim 10, further comprising:
 - (a) a computer-based system in the mobile computing device for:
 - (i) determining the tempo of the swing, wherein the tempo of the swing is the ratio of backswing time to downswing time; and
 - (ii) displaying the tempo of the swing on the mobile computing device's display screen.
- 14. The system of claim 10, further comprising:
 - (a) a computer-based system in the mobile computing device for:
 - (i) determining the point of maximum swing speed through the swing; and
 - (ii) displaying the point of maximum swing speed on the mobile computing device's display screen.
- 15. The system of claim 10, further comprising:
 - (a) a computer-based system in the mobile computing device for:
 - (i) recording the information as set forth in claim 10 for first and second golf swings; and
 - (ii) displaying the information as described in claim 10 for the first and second golf swings simultaneously on the mobile computing device screen, thus allowing the golfer to compare first and second swings.
- 16. A mobile computing device-based system for analyzing a golfer's swing, comprising:
 - a. mobile computing device;
 - b. internal accelerometers in the mobile computing device that measure acceleration in a plurality of axes
 - c. a computer-based system in the mobile computing device for using the accelerometers and internal logic to determine an objective measure of a golf swing.

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