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(19) **United States**(12) **Patent Application Publication** (10) **Pub. No.: US 2006/0166738 A1**
Eyestone et al. (43) **Pub. Date: Jul. 27, 2006**(54) **METHOD AND SYSTEM FOR GOLF SWING
ANALYSIS AND TRAINING FOR PUTTERS****Related U.S. Application Data**

- (63) Continuation-in-part of application No. 10/810,168, filed on Mar. 26, 2004.
- (60) Provisional application No. 60/585,461, filed on Jul. 2, 2004. Provisional application No. 60/501,044, filed on Sep. 8, 2003.

- (75) Inventors: **Richard D. Eyestone**, Fernandina Beach, FL (US); **Nathan J. Hood**, Austin, TX (US); **Alessandro U. Gabbi**, Austin, TX (US); **John Farrington**, Georgetown, TX (US); **Eric Cassady**, Austin, TX (US); **Brian Maloney**, Austin, TX (US); **Raymond Deragon**, Austin, TX (US); **John Lupher**, Austin, TX (US); **James Satterwhite**, Austin, TX (US)

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- (52) **U.S. Cl.** **463/36**
- (57) **ABSTRACT**

Techniques for measuring and modeling club-like sports instrument inertial motion sensing signals are disclosed. The disclosed method and system generate corrected output of a motion sensing circuit, which circuit includes an inertial measurement unit and associates with a putting club-like sports instrument. One aspect of the disclosed subject matter includes a method and system for isolating analysis positions of a golf swing, which analysis positions facilitate measuring and modeling the swinging motion. Another aspect of the disclosed subject matter includes a method and system for correcting golf swing measurement errors for more accurately measuring and modeling the swinging motion. Yet another aspect of the disclosed subject matter provides a method and system for determining an impact position of a swinging sports instrument.

Correspondence Address:

HULSEY IP**Intellectual Property Lawyers, P.C.****Suite 610****1250 S. Capital of Texas Highway, Bldg. 3****Austin, TX 78746 (US)**

- (73) Assignee: **SmartSwing, Inc.**

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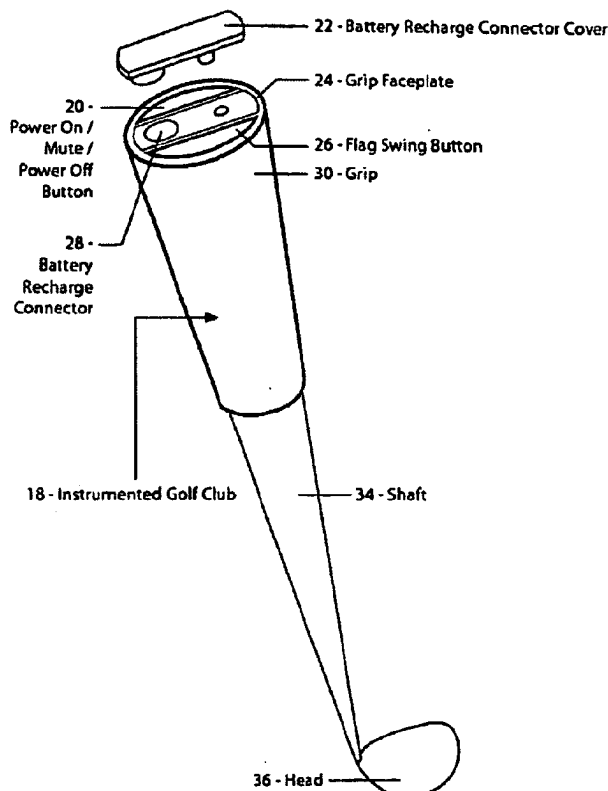


FIGURE 1

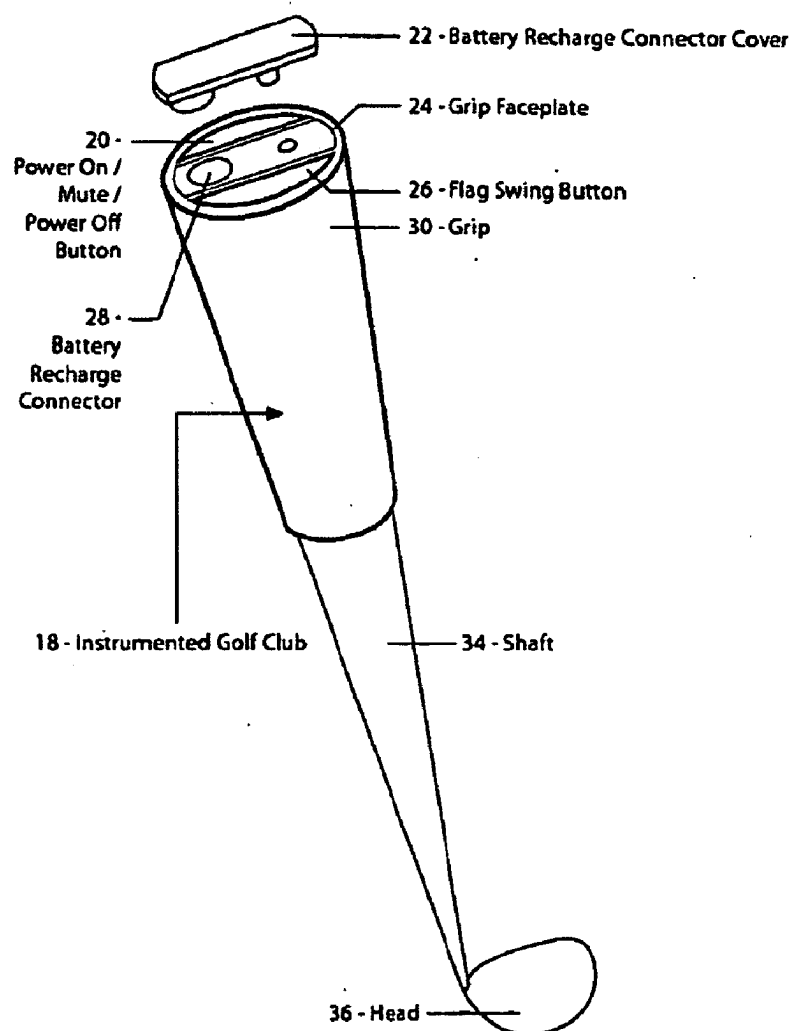


FIGURE 2

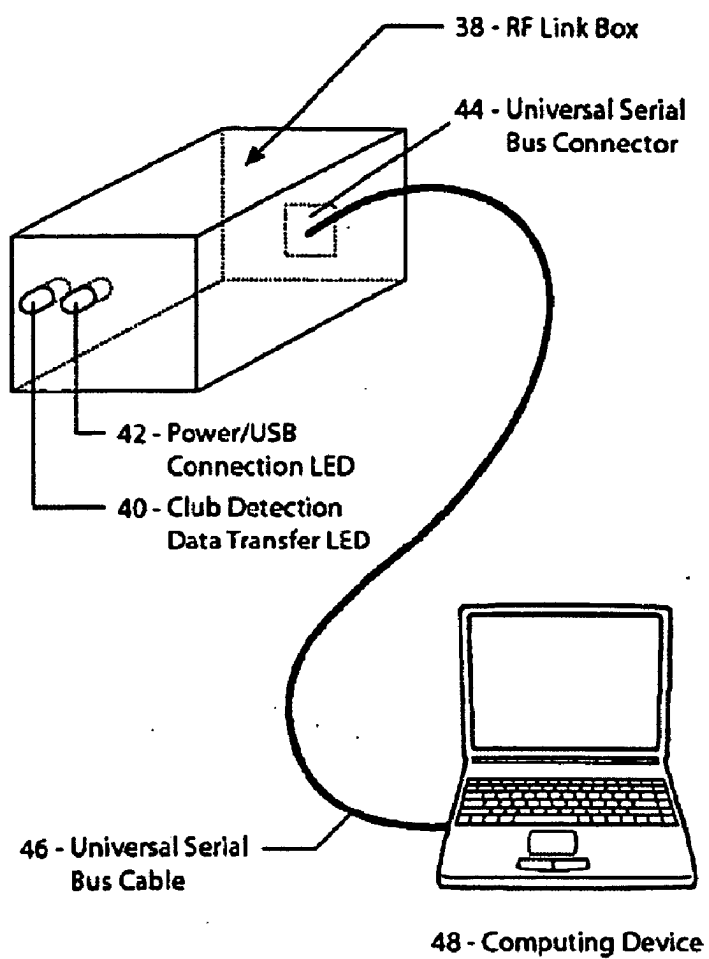


FIGURE 3

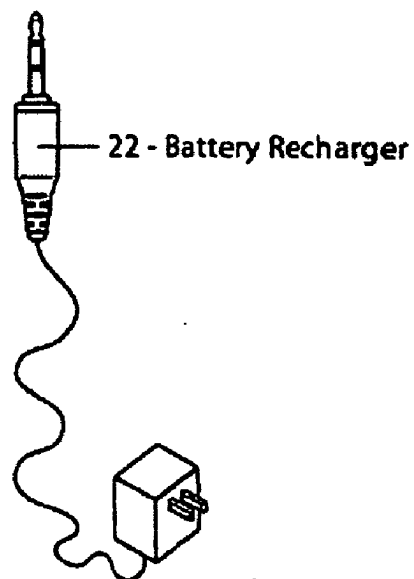


FIGURE 4

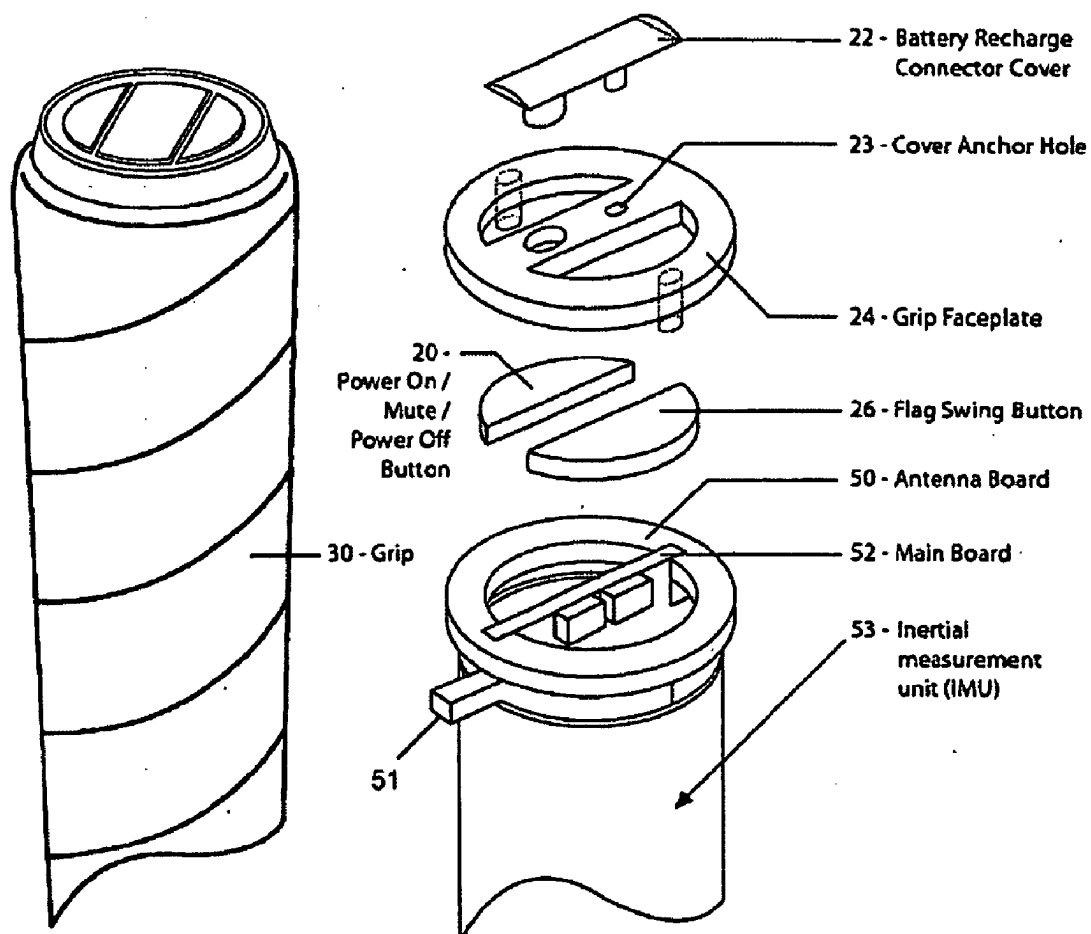


FIGURE 5

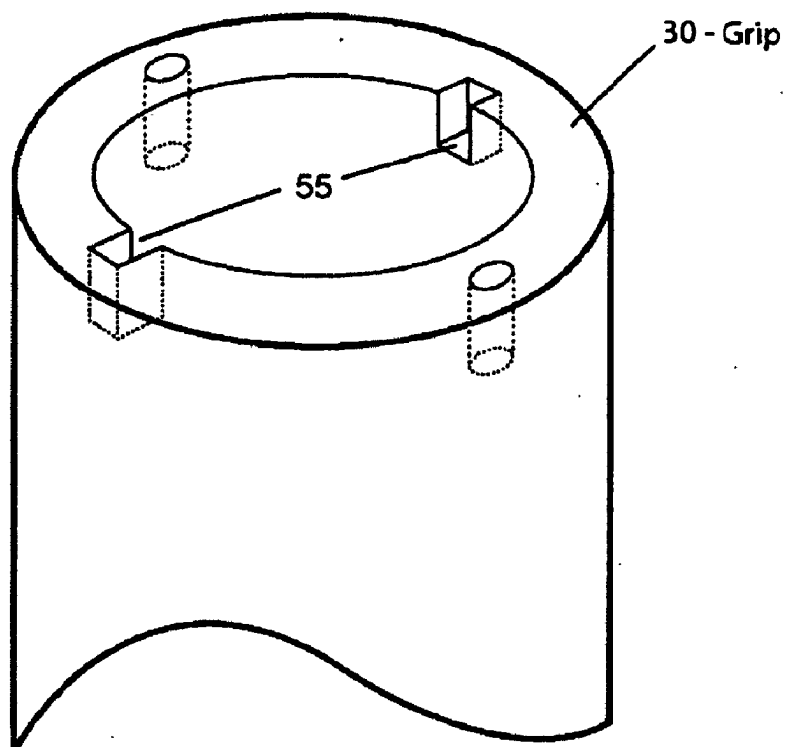


FIGURE 6

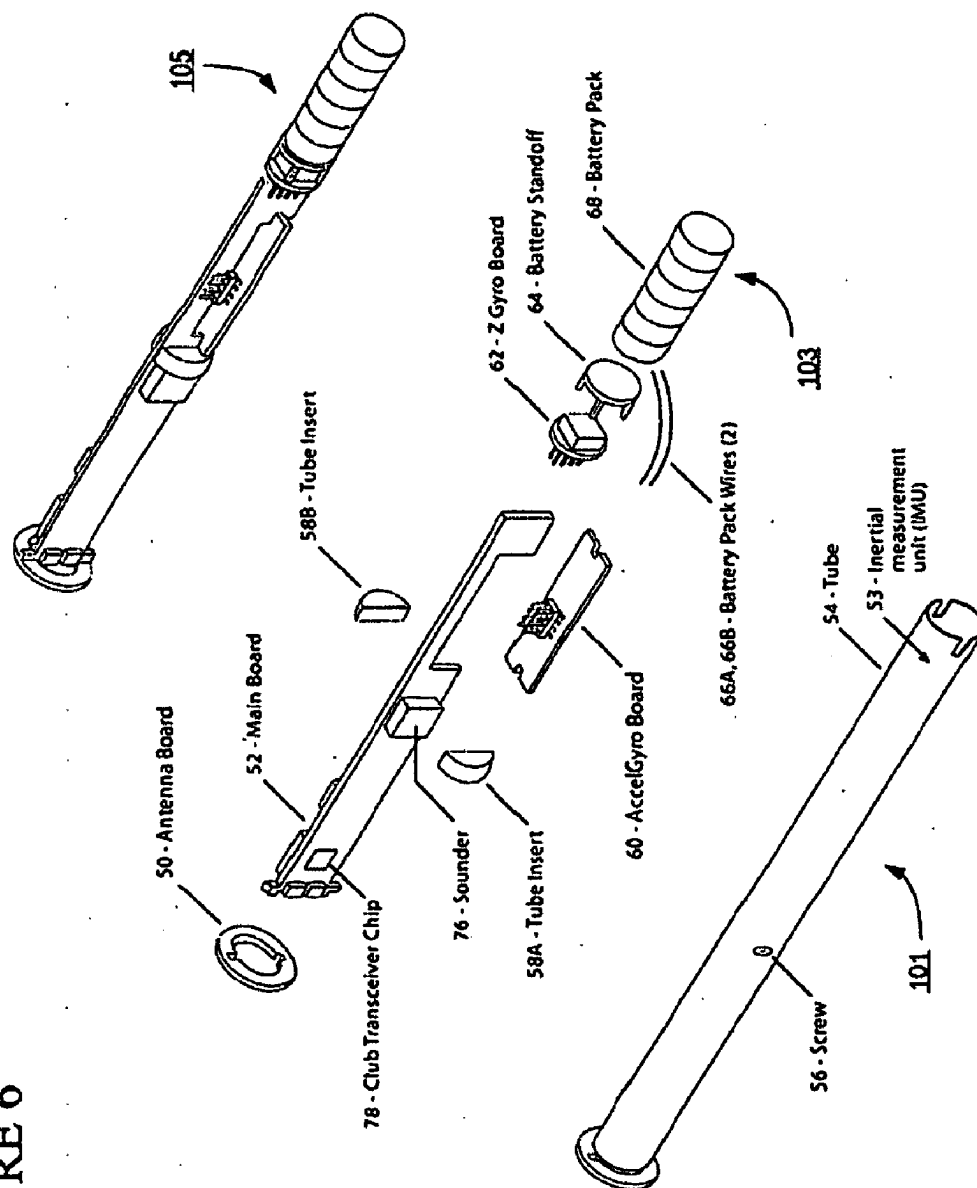


FIGURE 7

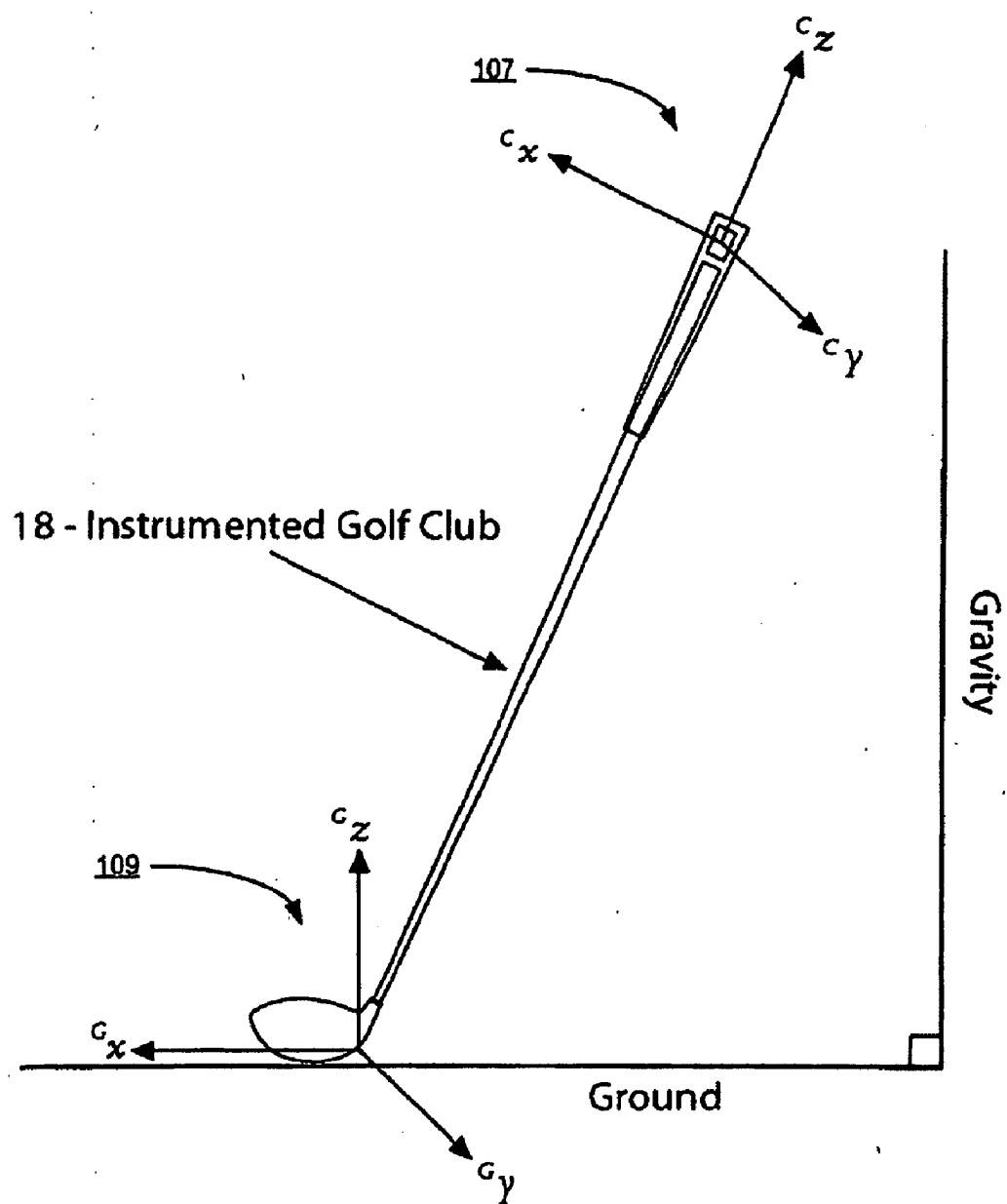


FIGURE 8

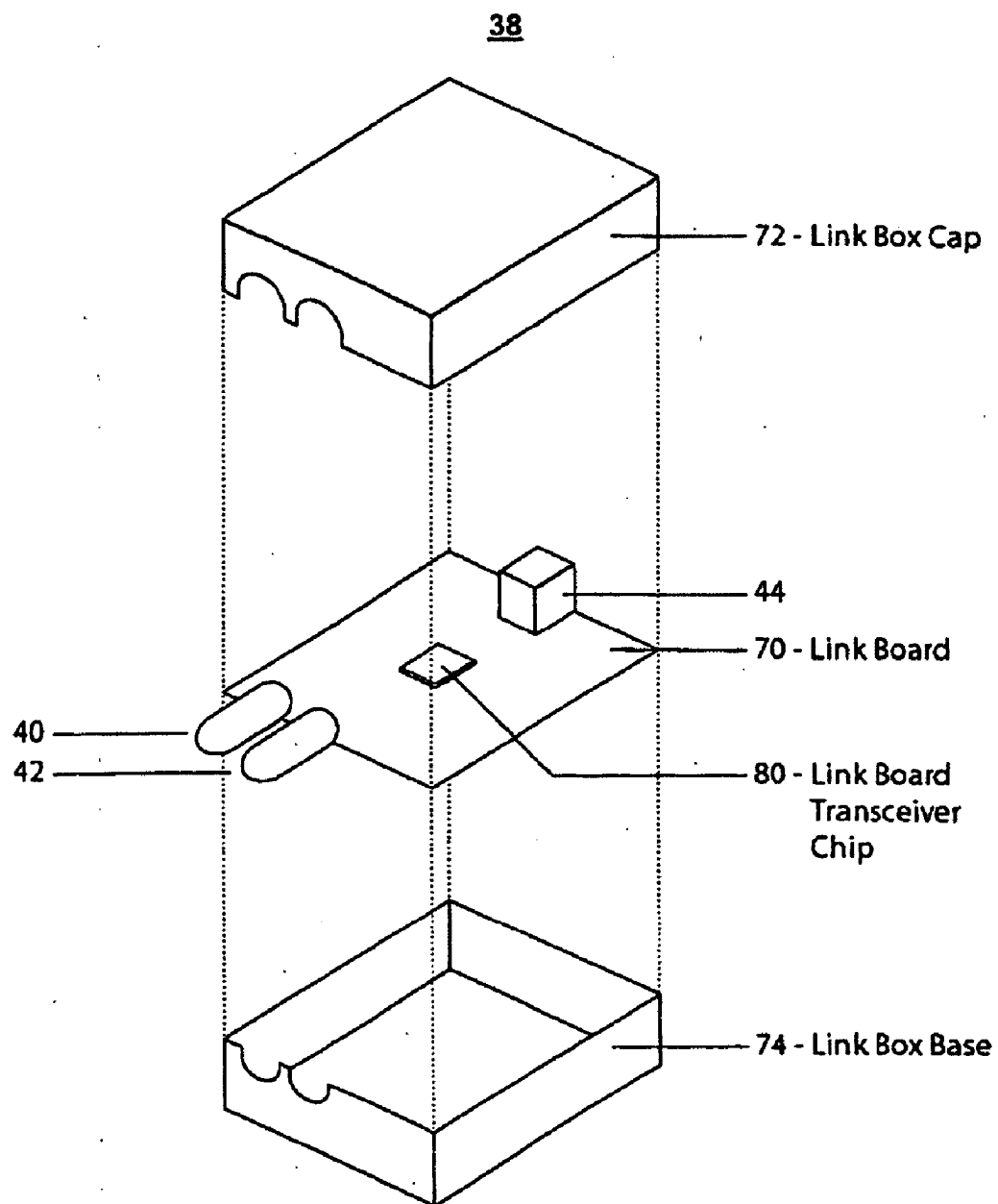


FIGURE 9

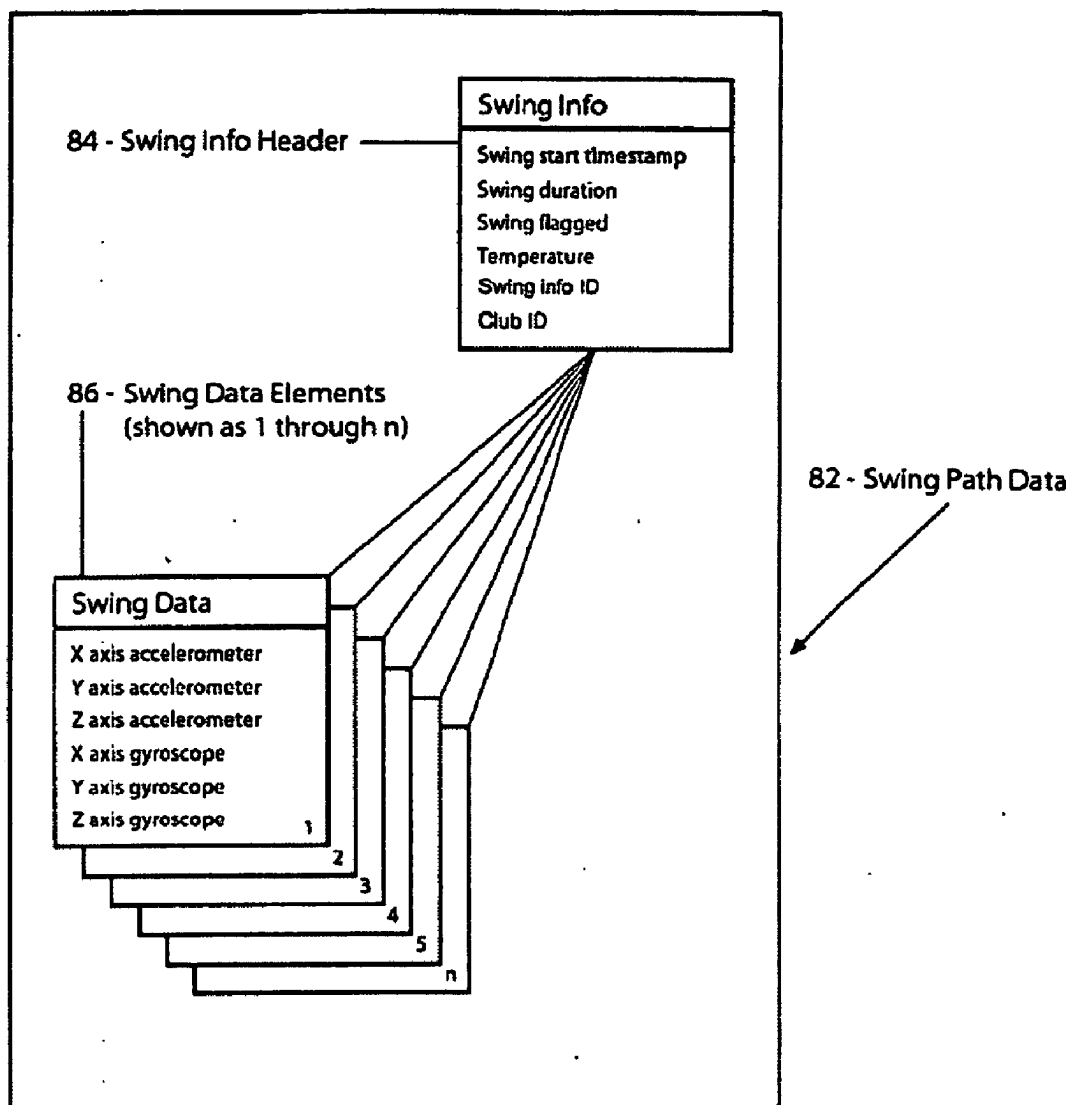


FIGURE 10

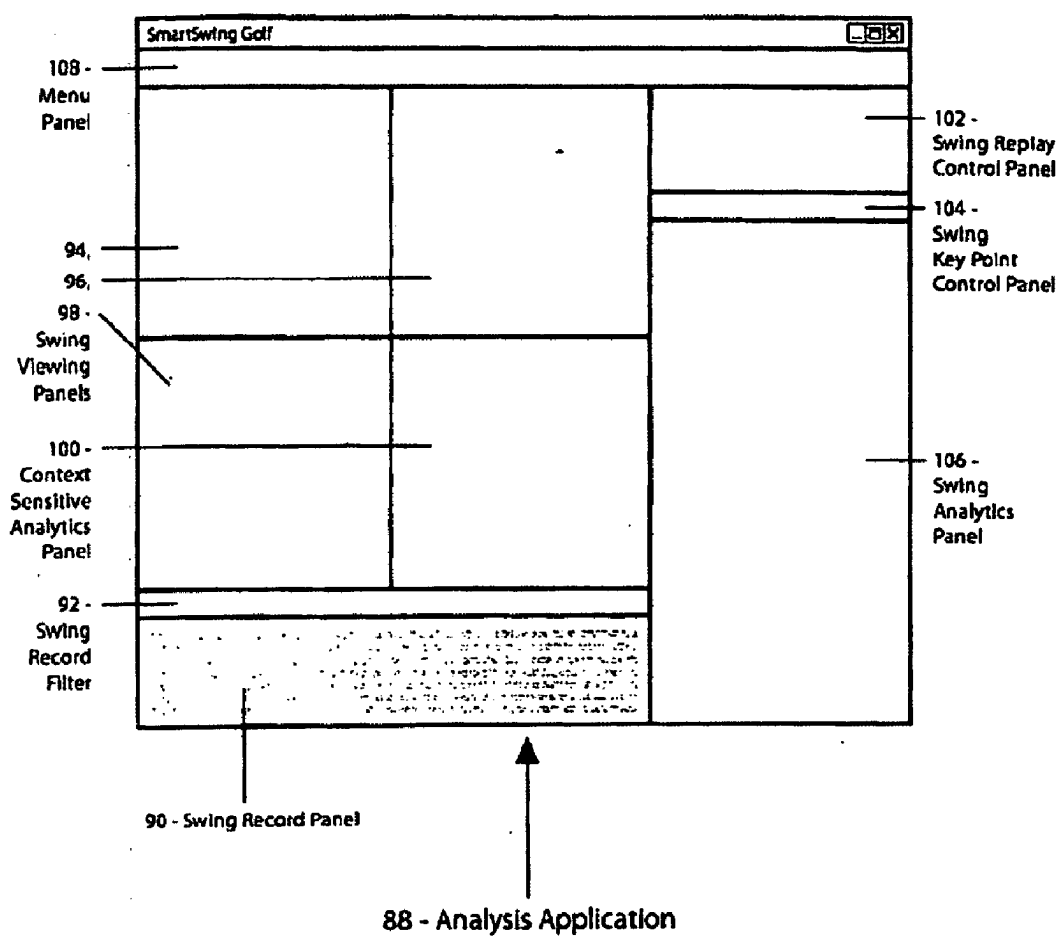


FIGURE 11

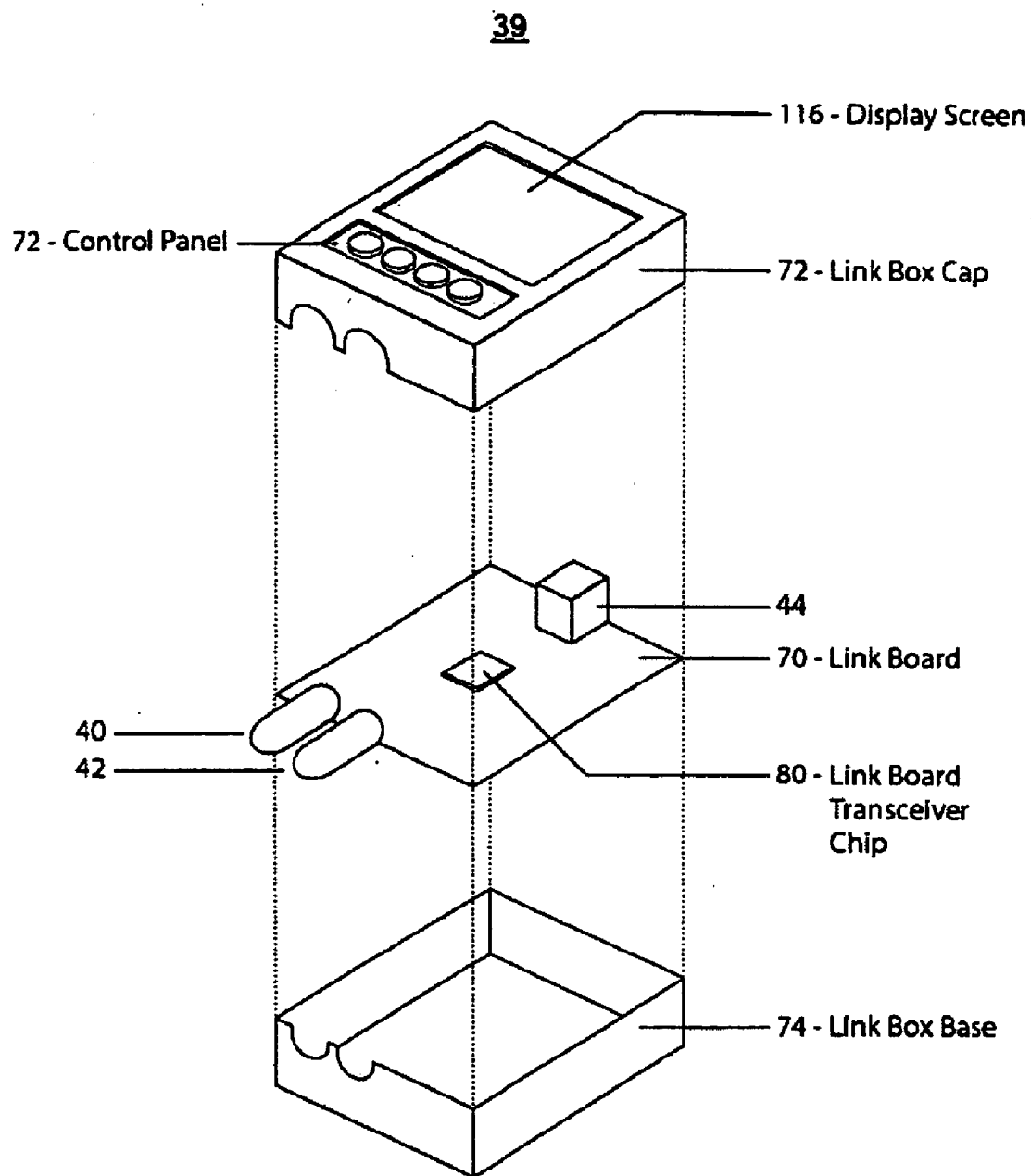


FIGURE 12

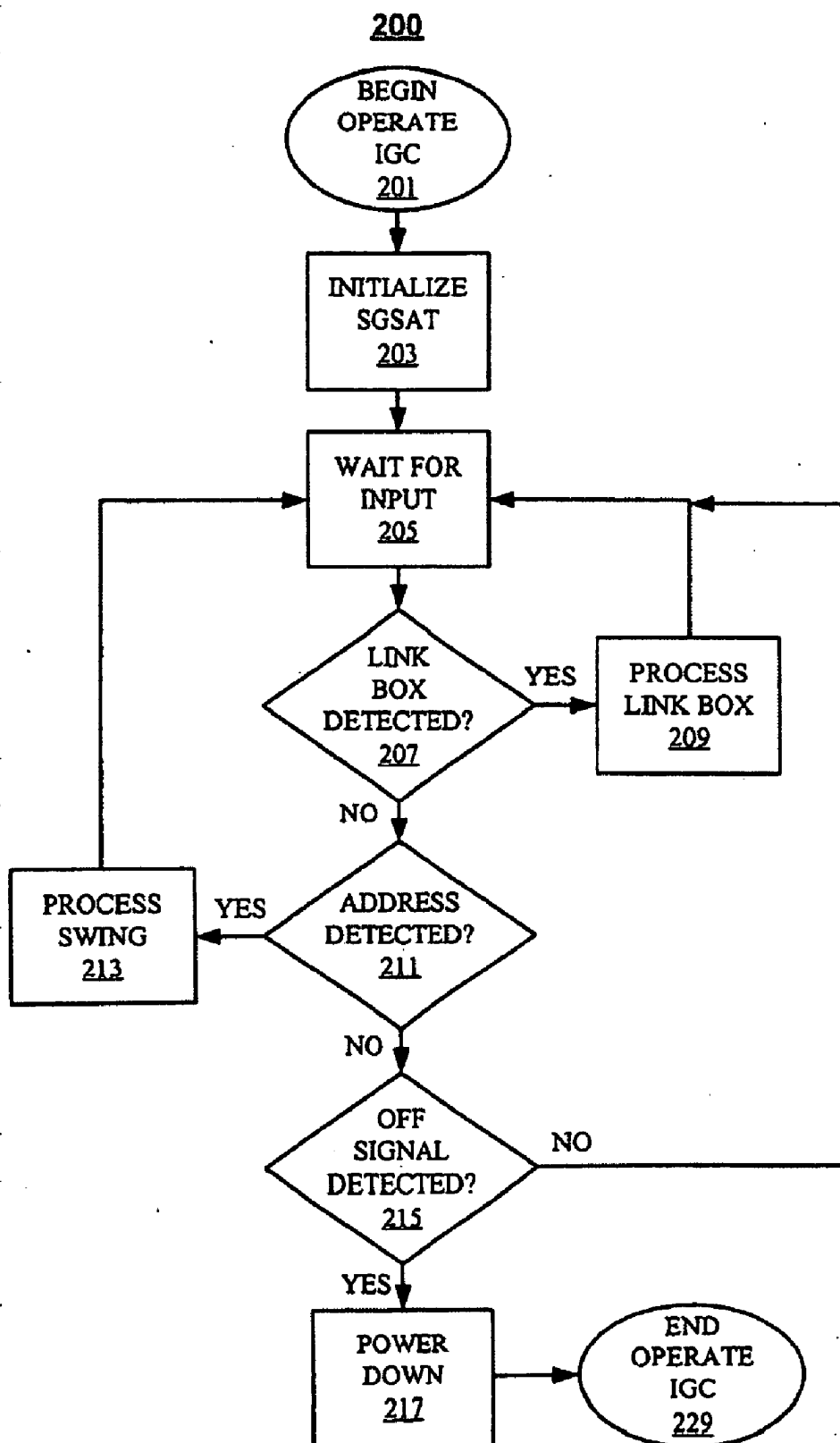


FIGURE 13

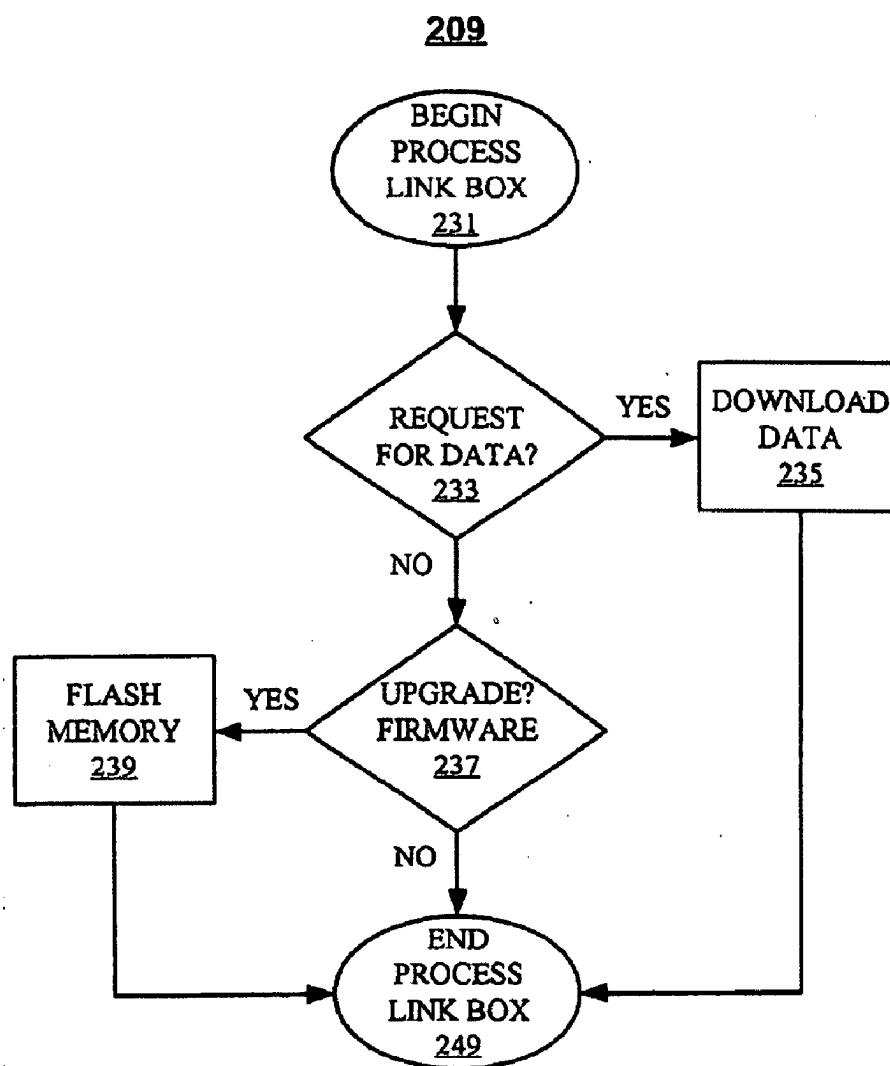


FIGURE 14

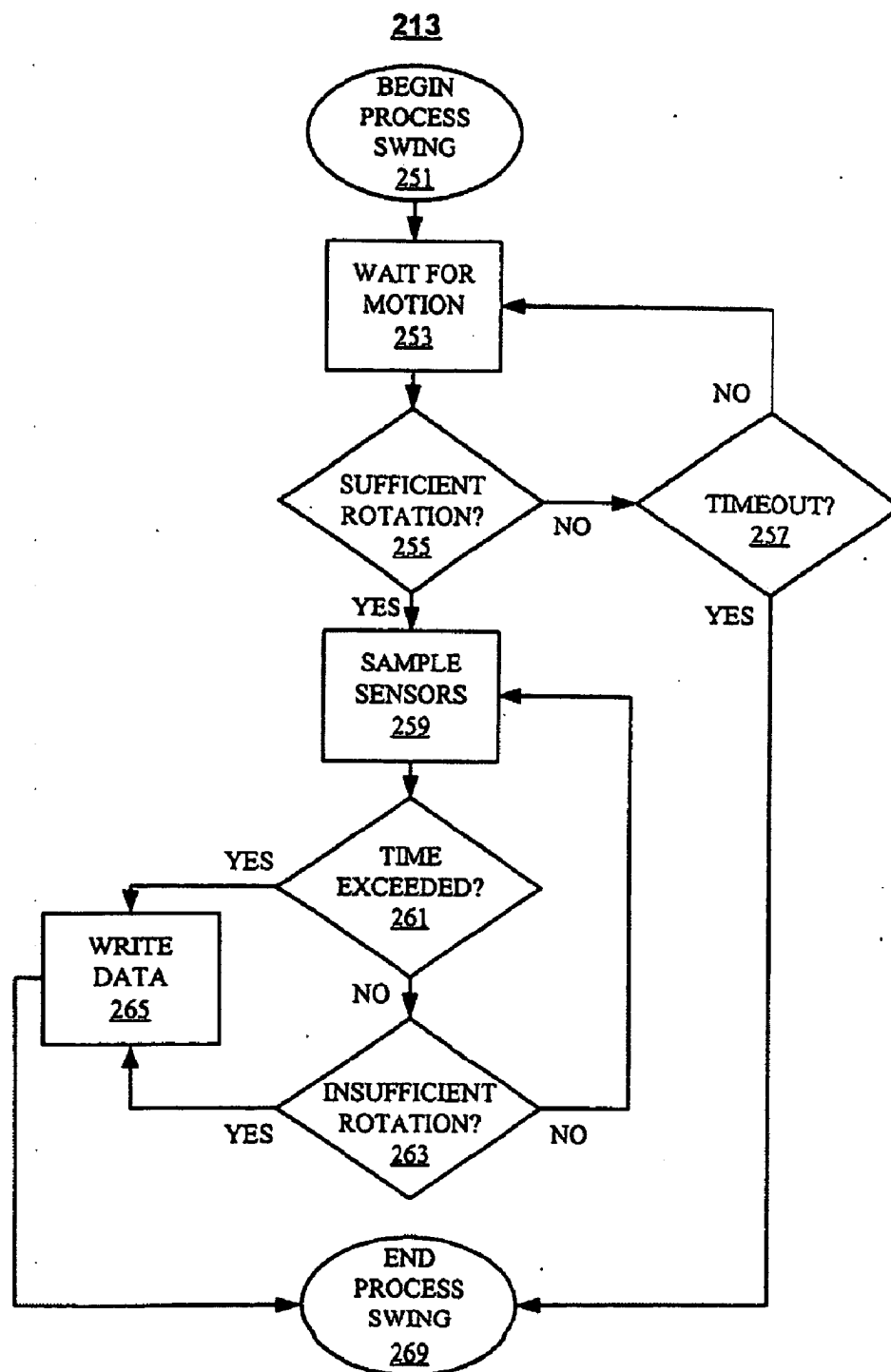
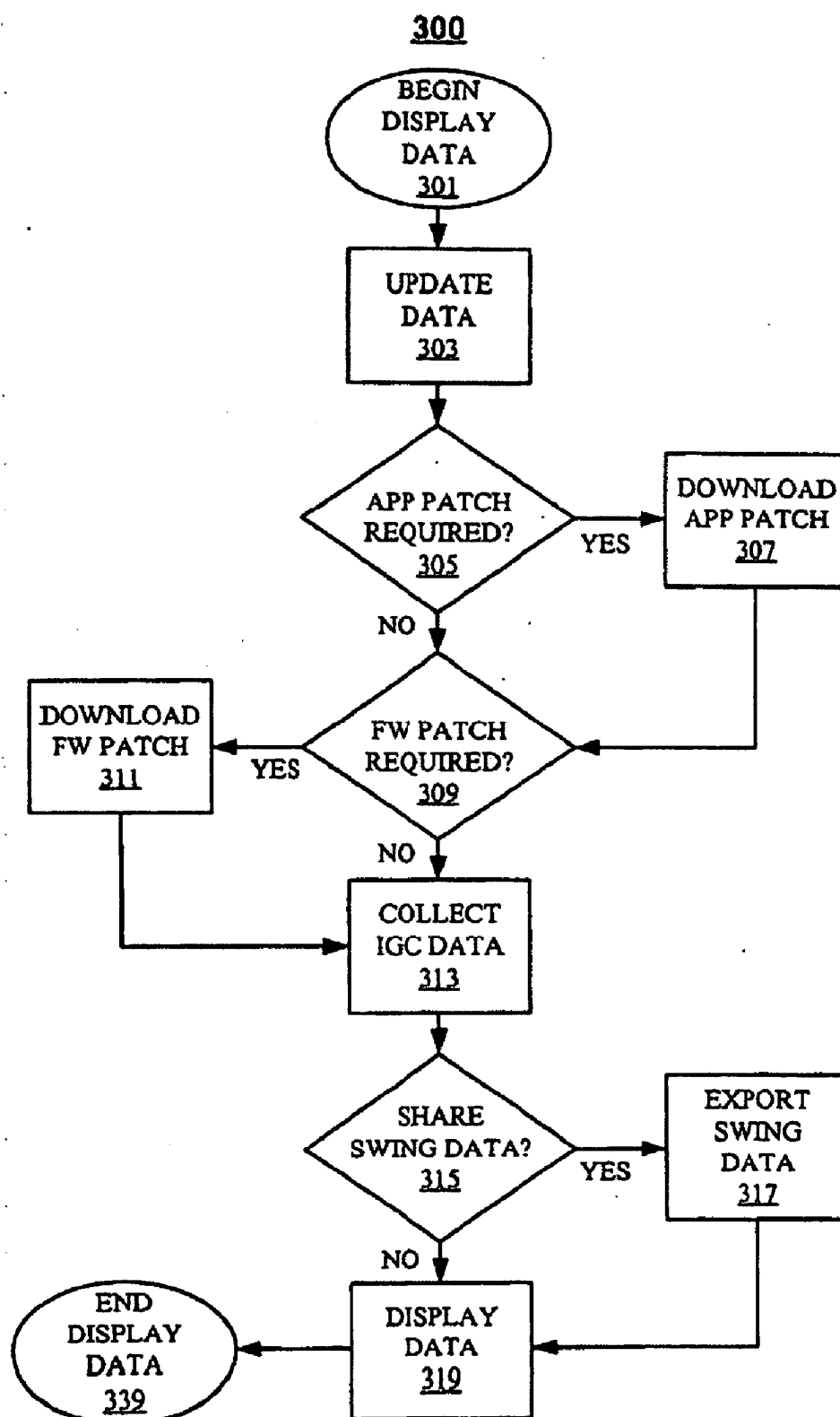


FIGURE 15



METHOD AND SYSTEM FOR GOLF SWING ANALYSIS AND TRAINING FOR PUTTERS

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This patent application is a continuation in part and claims the benefit of U.S. patent application Ser. No. 10/810,168 filed on Mar. 26, 2004, and claims the benefit of U.S. Provisional Patent Applications Ser. Nos. 60/____.

FIELD

[0002] This disclosure pertains generally to a sports training system and, more particularly, to a method and system for measuring and modeling sports instrument inertial motion sensing signals an intelligent sports club, bat or racquet that takes quantitative measurements of a swing for real-time feedback and subsequent analysis and display.

BACKGROUND OF THE DISCLOSED SUBJECT MATTER

[0003] It would seem that simply rolling a golf ball into a hole may not be a difficult task. Those of us that attempt this task will attest to its difficulty. Several elements of the putter stroke are relevant to examine if the golfer is to become a consistent, accurate putter.

[0004] The consistency of the putter stroke, regardless of the type of stroke used, is an important consideration. The ability always to always the same stroke, at the same speed is difficult to achieve. At impact with the golf ball, the 'face' of the putter may be square to the target line. The ability consistently to strike the golf ball on the 'sweet spot' of the putter is also important. The tempo of the putter stroke is important to ensure a consistent relationship between the length of the backstroke and club head speed at impact. The ability to roll the ball a specific distance, under varying green conditions, is key to being a consistent and successful putter. This ability is often referred to as the golfer's 'touch' with the golf ball.

[0005] The putter may always be accelerating at impact with the golf ball.

[0006] Learning to stroke a golf ball with a putter correctly is a seemingly simple act. The difficulty that golfers encounter is that in order to become a good, consistent putter one requires a simple, repeatable stroke and an understanding of the relationships of the various elements of the putting stroke.

[0007] Most of us cannot feel the difference in minor changes to our golf stroke and thus cannot distinguish between a good stroke and a not so good stroke. Further, the present embodiment often obtains incorrect feedback from the results of our putting stroke. the present embodiment can make two errors that offset each other and sink a long putt and think the present embodiment have 'found the answer' to better putting. Even worse, the present embodiment can make a horrible stroke and have the ball find the hole due to imperfections of the putting surface itself. Feedback, based on results is inaccurate!

[0008] Getting good, solid feedback on the various elements of the putting stroke is difficult, if not impossible.

There are many training aids in the market, but they often only work on one of the key elements of putting that the golfer preferably master.

[0009] There is no relative frame of reference to keep the putting stroke "on line" during the back stroke and the down stroke. There is no way of getting immediate feedback w/out a golf pro/trainer. Golf instruction by golf pros is expensive and sometimes unavailable; is perceived to be too slow a process

[0010] Videotaping every stroke on the course is logistically annoying and unlikely to make a huge difference; besides, there is still no frame of reference. It is difficult to visualize what the body and club do as an integrated whole. Improvement comes slowly, if ever, and learning is frustrating. Existing training aids feel and act differently from the clubs typically used. Multiple errors can offset each other providing the golfer with erroneous feedback

[0011] Even good putts often miss due to imperfections on the putting surface

[0012] Accordingly, there is need for a sports training system

SUMMARY

[0013] Techniques for accurately measuring and modeling a sports instrument swinging motion are disclosed.

[0014] The disclosed subject matter, including a method and system for

[0015] These and other aspects of the disclosed subject matter, as well as additional novel features, will be apparent from the description provided herein. The intent of this summary is not to be a comprehensive description of the claimed subject matter, but rather to provide a short overview of some of the subject matter's functionality. Other systems, methods, features, and advantages here provided will become apparent to one with skill in the art upon examination of the following FIGURES and detailed description. It is intended that all such additional systems, methods, features and advantages that are included within this description, be within the scope of the accompanying claims.

BRIEF DESCRIPTION OF THE FIGURES

[0016] For a more complete understanding of the present disclosure, and the advantages thereof, reference is now made to the following brief descriptions taken in conjunction with the accompanying drawings, in which like reference numerals indicate like features.

[0017] FIG. 1 shows selected aspects of an instrumented golf club system which may use the disclosed subject matter;

[0018] FIG. 2 shows a partially exploded view of an instrument golf club (IGC) which may incorporate an inertial measurement unit (IMU) consistent with the teachings of the disclosed subject matter;

[0019] FIG. 3 shows a partially cut-away view of an IGC depicting a printed circuit board (PCB) capable of containing the circuitry and instructions for one embodiment of the disclosed subject matter;

[0020] FIG. 4 shows an exploded view of the top portion of the IGC grip;

[0021] FIG. 5 shows three views of an IMU incorporating the claimed subject matter.

DETAILED DESCRIPTION OF THE FIGURES

[0022] Although described with particular reference to a golf club, the claimed subject matter for measuring and modeling accelerometer measurements and gyroscopic measurements of an inertial measurement unit associated with sports instrument may find beneficial use in many types of devices. FIG. 1 shows selected aspects of an instrumented golf training system 10, which may use the disclosed subject matter. In FIG. 1, instrumented golf training system 10, processes measured golf club swing data 12 on computer 14. A player may control computer 14 using keyboard 16 to communicate with instrumented golf IGC 18 and achieve a highly interactive process that may be formed and may operate as here disclosed.

[0023] An alternative embodiment of the present invention may be used as a golf training aid, a club fitting tool and an add-on module to standard golf putters.

[0024] This embodiment is an instrumented golf putting system consisting of a standard golf putter with either a steel or graphite shaft and a standard putter head, a modified golf club grip, a circuit board that is inserted into the distal (butt) end of the shaft, a mounting system for the circuit board, embedded software in the club mounted circuit board, a means of communication to a standard computational platform, a standard computational platform such as a PC and analytical, control and display software for the PC. For ease of understanding, the invention can be thought of as being comprised of the three major components, a software application, a golf putter containing electronic circuitry and a uni-directional RF device. The circuitry and embedded software in the club are sufficient to track, calculate and store information regarding the trajectory, position, velocity, and acceleration in three-dimensional space of the golf putter during one or more strokes. The circuitry also generates real-time audio or tactile feedback/response to the user during the course of the stroke. Multiple strokes may be stored on the putter and subsequently downloaded to the software application via a wireless or physical connection.

[0025] The software application executes on a personal computer and enables the user to review the downloaded strokes independently or with respect to a known good golf putting stroke, defined as a reference stroke". Furthermore, the software application analyzes the downloaded strokes and provides advice to assist the user in stroke improvement. The uni-directional RF device is used as an alignment aid. The putter is composed of a standard putter head, a standard shaft, and a modified grip. The grip has been modified to include a mounting system for the circuitry and a protective end cap. The circuitry is mounted and encapsulated within the shaft at the distal end of the shaft. All components are contained within approximately the last 7" of the distal end of the shaft. Furthermore, by keeping the weight of all components, mounts, and encapsulant below 2 ounces, the putting experience of the electronic putting club ("EPC") will not differ materially from that of a standard putter. Within the distal end of the shaft, Micro-Electro-Mechanical Systems (MEMS) accelerometers and gyroscopes are

mounted in an orthogonal configuration. This configuration enables the measurement of the club's acceleration in three mutually perpendicular axes and of the club's rate of rotation around these same axes. The MEMS components are coupled with supporting signal acquisition, memory, passive and processing components to calculate the motion and position of the club during the putting stroke. The circuitry includes onboard memory sufficient to store multiple strokes. Furthermore, onboard components support system power, system recharge, and data exchange with the software application. There is a small power switch, actuated by the user with a golf tee or a fingernail, in the distal end of the club. A small LED indicator is located adjacent to the switch for display of on/off/low battery/error system statuses. Finally, the putter contains components required to give audible or tactile feedback to the user during the course of a stroke. The EPC looks, feels, sounds and performs like a standard putter when the circuitry is in the powered-down state and the protective cap is in place on the distal end of the club.

[0026] The embedded software, which is stored on the putter resident circuit board, calculates what are acceptable, virtual 'stroke rails' and 'stroke stops' for the user. The 'stroke rails' are parallel, virtual planes that are perpendicular to the earth's surface. The 'stroke rails' are set by the user some increment wider than the face of the putter in use to enable practicing their stroke and receiving real-time feedback when the stroke contacts a virtual 'stroke rail'. The virtual 'stroke stops' are perpendicular to the 'stroke rails' and are settable by the user to enable practicing strokes of a given length and receiving real-time feedback on the same. If the putter head 'breaks' either of the 'stroke rails', then feedback is provided to the user instantaneously. A stroke is said to 'break' a 'stroke rail' if any part of the club leaves the zone defined by two virtual planes during the backstroke or the following downstroke. Similarly, instant, real-time feedback will be given to the user if the putter head breaks any 'virtual stop' more than a settable amount. This instant, corrective feedback is a significant improvement over prior art. The real-time feedback allows the user to note when their stroke breaks these virtual 'rails' and 'stops' and immediately make corrective adjustments in subsequent swings.

[0027] A small set of the SmartSwing PC software application provides functionality to the user for adjusting application parameter settings and golf putter parameter settings. However, the primary function of the SmartSwing desktop application is the review and analysis of strokes recorded by the EPC and to enable a much better quality practice environment. The logical organization of the application initially focuses the golfer's efforts on learning to stroke the putter within the 'stroke rails' and 'stroke stops'. Next, the golfer is encouraged to work on alignment skills, utilizing the uni-directional RF device on a practice green. This portion of the PC application focuses on applying the improved putting stroke learned by practicing with the 'virtual rails' and 'virtual stops'. Impact analysis is employed to analyze how consistently the golfer is able to stroke the ball with the center or 'sweet spot' of the putter face. Next, the PC software enables the golfer to practice, virtually anywhere, under a variety of simulated conditions. This simulated environment enables the golfer to test and improve all facets of the putting set-up and stroke. Finally, the golfer is assisted with increasing overall stroke consis-

tency. The application allows the user to review and critique strokes by providing three-dimensional stroke visualization and playback features. Furthermore, the application can overlay a user's stroke with a previously stored stroke or with a known good reference stroke. An example of a 'reference stroke' could be the stroke of any of today's PGA or LPGA professionals. A user's performance improvement over time can be analyzed by overlaying multiple strokes or by charting any of the measured or calculated variables. In addition, the application provides information regarding a large number of variables associated with the golf stroke. This information can be used by either the golfer or by a teaching professional to understand the causes of stroke to-stroke performance variation. Finally, the application independently analyzes the strokes and offers advice on ways to improve the user's golf putting stroke.

[0028] Various putter-specific embodiments of the present invention provide a golf putter capable of providing one, some, or all of the following objects:

[0029] instantaneous audible or tactile feedback to the golfer regarding the quality of their putting stroke;

[0030] enable a golfer to gain insight that has not been previously possible into their own stroke by providing the golfer access to information that enables the golfer to understand how his/her stroke differs from a known, good 'reference stroke';

[0031] provide an instrumented golf putter that looks, feels, sounds, and is of similar weight and behavior as a normal golf putter for day-to-day use;

[0032] provide a system that is capable of being used to provide sufficient data on any golfer's stroke to be used for fitting putters specifically to each individual golfer;

[0033] provide a user with a PC-based software solution that allows for detailed analysis of a series of golf putting strokes downloaded from the instrumented club as compared to a known good reference stroke;

[0034] provide a user with a practice environment in which a wide variety of conditions associated with a putting a golf ball can be successfully simulated in order to help the golfer apply their putting skills; and

[0035] provide the golfer with the ability to acquire and view a graphical depiction of their golf putting stroke in three-dimensional space in a PC-based software application for the purposes of obtaining feedback and suggestions from the software on how to improve their stroke and provide a comparison to a known, good reference stroke to enable the golfer to visualize what he/she must do improve their own stroke.

[0036] The EPC will have a wide range of functionality. At its simplest level it will emulate, with greater flexibility and usability, simple mechanical devices in wide use today. At its most sophisticated level it will enable a golfer to simulate putting on a green of infinite size and speed.

[0037] Because many terms will be used throughout this paper, this section will attempt to accurately define the terms to be used, in order to minimize confusion.

[0038] 1. Stroke—Stroke is used to define the 'miniswing' taken by the golfer when putting.

[0039] 2. Consistency of Stroke—A consistent stroke is repeatable and has minimal side-to-side variation during the front-to-back stroke.

[0040] 3. Touch—Touch refers to the golfer's ability to roll the ball the needed distance, consistently. When taking a stroke with a consistent tempo, the length of the golfer's backswing will determine the distance that a ball will roll.

[0041] 4. Impact Point—The point of impact on the face of the putter is a critical variable when putting. Like the 'full swing' clubs each putter has a sweet spot in which the golfer wants to stroke the putt each time.

[0042] 5. Tempo—Tempo refers to the rhythm that the golfer uses to strike each putt. Just as the speed at which different people walk or talk, so does the speed at which one putts a golf ball.

[0043] 6. Alignment—Alignment refers to the relationship of the putter face to the target line. When correctly aligned the face of the putter will be perpendicular to the target line.

[0044] 7. Target Line—Is the line drawn from the ball to the intended target. On a perfectly flat putt the intended target would be the center of the hole.

[0045] 8. Reading a Green—This refers to the golfer's ability to study the contours of a 'non-flat' putting surface and make a determination of where and at what speed to stroke the ball in order to make the putt.

[0046] Three potential EPC embodiments are described. Furthermore, the learning objectives of each of these products is defined below.

[0047] Practice Product:

[0048] 1. Develop consistency of the stroke, minimizing side-to-side motion of the putter during the front-to-back stroke.

[0049] 2. Develop the ability to make the front-to-back stroke a specific distance.

[0050] 3. Develop consistent tempo.

[0051] 'Re-play' Product:

[0052] 1. Develop 'touch' building on the learned ability to make a stroke that is a specific, consistent distance during the backstroke and the subsequent downstroke.

[0053] 2. Develop alignment skills.

[0054] 3. Improve the ability to strike each putt on the sweet spot.

[0055] 4. Develop 'green reading' skills.

[0056] Simulation Product:

[0057] 1. Further develop alignment skills

[0058] 2. Further apply the 'touch' learned previously.

[0059] 3. Develop & apply 'touch' for uphill and downhill putts.

[0060] 4. Practice the newly learned skills in a simulated environment.

[0061] Several putting theories are relevant. Putting a golf ball in a straight line should be a simple task. It is not. One only has to note the nearly infinite varieties of putters

available on the market and the great variety of grips, training aids and other paraphernalia available to golfers to learn this seemingly simple task.

[0062] Most people familiar with the game would agree that be square to the target line at impact. The second is a 'straight back & straight through' stroke in which the golfer attempts to swing the putter like a pendulum on a grandfather clock, keeping the clubface square to the target line during the entire process.

[0063] It is my opinion that the EPC will be able to deal with both scenarios. When the club is taken 'straight back & straight through (SBST)' we will use a simple, mathematical model to determine the golfer's ability to execute this stroke. If the golfer elects to use a stroke other than the SBST stroke we will capture a 'reference there are two kinds of putting strokes. The first is a 'miniswing' in which the clubface opens a bit on the backstroke and closes a bit on the follow through. It is hoped that it will stroke for comparison purposes. More thought and analysis needs to be given to the 'mini-swing' scenario further define this scenario.

[0064] The following hardware will be required to provide the desired functionality of the EPC.

[0065] 1. An instrumented putter.

[0066] 2. Grip based pressure sensors.

[0067] 3. A 'pager-sized' remote transceiver with the ability to receive data in real-time. This device would need voice synthesizer capabilities an earpiece additional memory and other capabilities and features.

[0068] 4. A uni-directional RF device I with a low physical profile, to be used as an alignment tool.

[0069] In order to be able to provide the desired functionality we will need to be able to capture information during each putting stroke. A first pass at what must be captured is listed below. Footnotes will comment on any perceived new functionality or capabilities.

[0070] 1. Clubface position at impact. Is it openly closed or square? If open or closed, how many degrees?

[0071] 2. Length of the backstroke.

[0072] 3. Time of the backstroke.

[0073] 4. Length of the downstroke.

[0074] 5. Time of the downstroke.

[0075] 6. Acceleration at impact.

[0076] 7. Club head speed at impact.

[0077] 8. Acceleration at impact (either positive or negative)

[0078] 9. Impact point on the clubface.

[0079] 10. Grip pressure on the club.

[0080] 11. Alignment to the target line with the clubface.

[0081] As in the full swing club much of the perceived 'value add' comes in our ability to provide the golfer with information that he/she is not currently able to easily capture. This is true of the EPC, as well. See the below list to currently considered 'analytics'.

[0082] 1. Variation from the desired stroke path.

[0083] 2. Variation from the desired stroke length.

[0084] 3. The tempo of the stroke.

[0085] 4. Pattern analysis of a series of strokes.

[0086] 5. Pattern analysis of a set of results.

[0087] 6. Consistency of the stroke.

[0088] 7. Consistency of the results.

[0089] 8. Any variation from square alignment.

[0090] 9. Consistency of the correlation between 'length of backstroke' to 'club head speed' at impact.

[0091] 10. A matrix that computes the result of a putt, when the clubface is not square at distance of 3', 5', 10', 15', 20' & 30' from the hole.

[0092] 11. A matrix that correlates the distance a putt rolls to club head speed.

[0093] 12. 'Probability of make' graphics & analytics.

[0094] At least three 'global analytics' will be required. They are listed below. Exactly how they will calculated is tbd.

[0095] 1. TempoMeter.

[0096] 2. Quality of Stroke.

[0097] 3. Stimpmeter.

[0098] Three basic use modes, or ways, that this EPC will be used by golfers to improve their putting are described herein. These are 'Practice Mode', 'Replay Mode' & 'Simulation Mode'. Each will be discussed separately.

[0099] Practice Mode:

[0100] An EPC with the hardware and software needed to support this mode would be the equivalent of our Visualizer software in combination with the full swing clubs.

[0101] In the 'Practice Mode' the EPC would use a set of 'real-time' tools to provide 'real-time' feedback to him/her on the path of the club head and the length of the backswing. It is worth noting that the intent of most golfers is to swing the putter, like a pendulum and to stroke the ball vs. hitting the ball. In this situation the speed of a putt is varied by varying the length of the backswing. Since this is purely a 'practice mode' the EPC may be used anywhere to hone the golfer is putting stroke.

[0102] 'Virtual Rails' would be employed to help the golfer work on the path of each stroke. These 'virtual rails' roughly correspond to the 'swing planes' in our full swing clubs. The golfer will need to be able to set these 'virtual rails' at some distance apart from each other. This can be best thought of as the distance from the toe and heel of the putter. For example, if the putter a golfer is using is 3" wide, and the golfer wanted a 1" margin of error on each side of the putter, then these 'virtual rails' would be 5" apart and 1" from each side of the putter. These rails would work as follows.

[0103] 1. At address the club would be silent.

[0104] 2. As the stroke is begun, the golfer would hear one of two tones. Each unique tone would represent a direction that the club was moving off line from the 'perfect stroke'.

Some margin of error must be allowed and this margin should be both a default setting and a golfer settable parameter.

[0105] 3. The tone that a golfer hears should be a 'relative tone' that increases or decreases in volume as the stroke varies. An increase in tone volume would occur as the stroke drifted away from the 'perfect stroke' and a corresponding decrease in volume should occur as the stroke moves back toward the midpoint of our 'virtual rails'.

[0106] 4. If the golfer's stroke should stray outside either of our virtual rails, then an additional tone should alert the golfer to this. As an alternative use method the 'relative tones' could be turned off leaving 'break plane' tones as the only feedback.

[0107] 'Virtual Stops' would be employed to provide the golfer feedback on the length of the backstroke. The golfer would be able to define the length of the backstroke that they want to work on. In other words, this would be a 'settable parameter'. Further, each distance that the golfer is working on is actually a set of 'virtual stops'. The first of the 'virtual stops' would be at the desired distance. The second of the 'virtual stops' would be set at default distance, perhaps 1", further from the ball. This distance also needs to be a settable parameter'.

[0108] 1. When working with the 'virtual rails' the 'virtual stops' would function as follows;

[0109] a. If the golfer is successful in making a precise stroke so that the club stops (reaches zero acceleration) in the area between the two 'virtual stops', then a positive tone will be sounded.

[0110] 2. When working exclusively on the length of the backstroke (not focused on the stroke path) a relative tone must be able to be turned on and would function as follows;

[0111] a. As the club approaches the first 'virtual stop' a tone with an increasing volume is heard. This 'relative tone' could be toggled to either on or Off.

[0112] b. In the area between the two 'virtual stops' no tone is heard.

[0113] c. If the golfer is successful in making a precise stroke, as described above, then the same positive tone is heard.

[0114] d. If the golfer is not successful in making a precise stroke and continues the backstroke through the second stop, then a negative tone is heard.

[0115] Re-Play Mode:

[0116] A EPC with re-play mode, in addition to the 'practice mode' is the putter equivalent to the Professional edition of our full swing clubs.

[0117] 'Re-play' mode will require some additional hardware and software capabilities, as described in the previous hardware section. 'Re-play' mode takes place on a practice green where the golfer can easily and safely set-up devices to achieve an excellent practice situation. Use would be as follows.

[0118] 1. The golfer would pick a spot on the practice green that is as flat as possible.

[0119] 2. The golfer would set-up the uni-directional RF device (or other alignment device that we choose to use) down the extended target line beyond the hole. In other words, the golfer is one side of the hole and the uni-directional RF device is on opposite side of the hole.

[0120] 3. Putt a 'reference putt'. On a relatively flat part of the green, stroke a putt of roughly 8'-10'. Put a tee in the ground at the point the ball is putted from and another at the point where the ball stops rolling. This information will be required later for data entry into the PC application. It is possible that more than one 'reference putt' will be required to insure that accurate information is used.

[0121] Once this set-up is complete, the golfer can use the EPC to practice real putts on a real green. The MMI would need to enable the capability to flag a set of putts that are taken from the same distance and to flag putts that are made during the practice session.

[0122] For example, a golfer could go to the practice green and decide to putt 3 sets of 12 3' putts, followed by 3 sets of 12 6' putts, followed by 3 sets of 20' putts & finish up with 1 set of 30' putts, 1 set of 40' putts and a final set of 50' putts.

[0123] Simulation Mode:

[0124] The 'simulation mode' of the EPC would be comparable to the Touring edition of the full swing club. 'Simulation mode', like 'practice mode' is purely a practice exercise and may be set-up and used anywhere space permits.

[0125] The golfer would set-up, as follows.

[0126] 1. At some distance from the golfer, set-up the uni-directional RF device. It seems that a distance of 5'+ should work.

[0127] 2. Select a mode for the simulator on the PC application.

[0128] a. Select a distance and a green speed on the PC application, or

[0129] b. Let the PC pick a distance and green speed.

[0130] 3. Line up, visually, with the RF device and stroke the putt the indicated distance.

[0131] 4. If actually using a ball, set-up something to stop the ball from rolling no more than a few feet. This is an exercise in learning to internalize the stroke required on any given green and at any given green speed and distance.

[0132] 5. Receive visual & audible clues about how good the putt was, via both the PC application and the 'pager size' device. Examples immediately following the stroke include;

[0133] a. The sound of the ball falling into the cup.

[0134] b. Crowd noises

[0135] 6. Immediately following the putt finishing its roll the 'pager size' device would provide immediate feedback about both the distance of the putt from the hole and the direction of the miss. For example, feedback might be "Alignment good, 16 inches past the hole, miss right by 4 inches".

[0136] Drills:

[0137] Each club would arrive with two sets of 'packaged drills' all ready set-up in the club, for use in 'practice mode'

[0138] The first of these would be to have a set of 'virtual rails' and 'virtual stops' set at 3" increments, starting at 3" and progressing up to 36". The second of these is nearly the same except with the stops set in 6" increments, starting at 6" and progressing up to 36".

[0139] Additionally, the user must have the capability to set-up their own 'package' of drills, tailored to meet their own personal stroke training needs.

[0140] A set-up window will be required to enable the golfer to more effectively practice. At least two methods of set-up seem obvious. In the first method the golfer would define the length of backswing they wish to practice (for more such lengths, or either pre-packaged set of drills) and the number of iterations they wish to make at each length. In the second scenario the golfer would identify the length of putt they wish to practice and identify a club whose 'greens' they wish to putt on. SmartSwing would need to refer back to our mini-data base of green speeds by golf course.

[0141] Reporting:

[0142] The EPC lends itself to collecting and analyzing performance improvement in a variety of manners, providing the golfer with real and accurate feedback on the progress they are making through time. Some of these are as follows.

[0143] 1. Stroke improvement. Measure and track the average deviation from a 'perfect stroke' from practice session to practice session.

[0144] 2. Touch improvement. Measure the average deviation from the 'perfect length' from practice session to practice session.

[0145] 3. In 'Re-play Mode' track the percentage of short and medium range putts made and the number of longer putts that roll past the hole but stay within 'makeable range' (often considered to be 18") from 15-25 feet. For very long, lag putts track the number of putts that finish with 10% of the original distance (30' finish within 3', 40' to 4', etc).

[0146] 4. In 'Simulation Mode' track the same statistics.

[0147] Displays:

[0148] The basic display would have the following characteristics.

[0149] 1. Set-up as our current full swing UI.

[0150] 2. Front view of the RP, with and without the user club, in the upper left hand quadrant.

[0151] 3. Top view of the RP, with and without the user club, in the lower left hand quadrant.

[0152] 4. A 'green', complete with a hole and a flagstick, in the upper, right hand quadrant.

[0153] a. As a stroke is made a 'ball' should roll from the front view of the golfer across the 'green' and toward the hole.

[0154] 5. A 'top view' of a set of 'virtual rails' and a set of 'virtual stops' with the stroke path visible.

[0155] 6. Global analytics, as per our current product.

[0156] 7. Some, minimal analytics. Specifics tbd.

[0157] Analytical Displays:

[0158] 1. Stroke analysis display.

[0159] a. A visual display of both stroke path and stroke length vs. the 'perfect stroke'.

[0160] b. A visual display of the clubface at impact.

[0161] 2. Grip pressure vs. time display.

[0162] a. Classic X v. Y graph of grip pressure vs. time with demarcation for address position, end of the back-stroke, impact and end of the stroke.

[0163] 3. A result pattern display.

[0164] a. Display of the 'green' with a hole and a flag, as seen from an angular top view.

[0165] b. A dispersion pattern using 'golf balls' on the green.

[0166] c. Text display;

[0167] i. Length of the putt.

[0168] ii. Number of putts taken.

[0169] iii. Number of putts made.

[0170] iv. 'Typical' miss, if any

[0171] v. Distance of 2nd putt;

[0172] 1. Best, Worst & Average.

[0173] 4. Impact pattern on the clubface display.

[0174] a. A display of the face of the club with

[0175] b. Text display.

[0176] i. Average from the 'sweet spot'.

[0177] ii. Average deviation.

[0178] iii. Worst deviation.

[0179] 5. In one or more of the models or the SmartSwing putter, in the same analytical pane we use for our full swing clubs, we will display the following information.

[0180] a. Clubface Position

[0181] i. Open/Closed & # of degrees

[0182] b. Deviation caused by errant clubface position

[0183] i. How much, in inches, the putt is 'off line' at various distances

[0184] ii. 3', 5', 10', 15', 20' & 30'

[0185] c. Length of backstroke

[0186] d. Length of follow-through

[0187] e. Ratio of the c & d

[0188] f. Acceleration at impact

[0189] i. Yes/No & Amount

[0190] ii. Deceleration shown as a negative number from peak speed

[0191] g. Club head speed at impact

[0192] Simulation Displays:

[0193] The intent here is to let the golfer, as nearly as possible, simulate stroking a putt, of a specific distance on 'greens' of various speeds. Given this the display should be as follows.

[0194] 1. A large 'green' with the RP in the lower left hand corner.

[0195] 2. A hole, complete with flagstick, in the upper right hand corner.

[0196] 3. A 'slider' with indicators for very slow, slow, average, fast & very fast.

[0197] 4. Located just above the 'slider' a digital readout of the Stimpmeter number.

[0198] a. 3 & 4 would be located in the lower right hand corner of the 'green'.

[0199] 5. In the upper left hand corner a 'mini version' of the grip pressure graph, described previously.

[0200] 6. Just below the grip pressure graph, a 'Results Readout' indicating whether the putt was long or short and a digital readout of how much.

[0201] 7. A 'ball' that rolls toward the hole when the RP strokes it toward the hole.

[0202] 8. Sound effects, as discussed previously.

[0203] In 'simulation mode' the golfer would be able to set-up specific drills, as he/she can in the 'practice mode'. For example, the golfer could decide that he/she wants to practice putts inside 10', but at least 3' from the hole, on their home course. The application should select the appropriate green speed from our data base and randomly pick a distance between 3' & 10', advise the golfer of the distance of the selection and provide feedback based on each putt.

[0204] The following discussion relates in more detail certain aspects of making and using the electronic putting club ("EPC") of the disclosed subject matter.

[0205] The electronic putting device (EPC) is a golf learning system that helps a golfer quickly to learn how to become a better putter. The EPC provides golfers with instant feedback and records stroke movements for more in-depth analysis later. An accompanying desktop application allows golfers to perform further analysis of their performance and to adjust settings on the EPC itself. The training aid is built into a commercial, off-the-shelf golf putter and designed with all electronics hardware and embedded software fitting into the handle (shaft grip area) of the golf club. The EPC may be designed to provide instant, audible feedback to the golfer, and may include an alignment device that may be either RF or optical as well as a wireless connection to a personal computer via a wireless protocol.

[0206] For the purposes of the discussions that follow, the present description makes use of certain words in specific ways pertinent to the disclosed subject matter. For example, a "batch" means a group of strokes, either downloaded together from the club or saved manually by the golfer. A "rail" means a small virtual plane that helps the golfer improve his stroke path. A "stop" is a small virtual window that is positioned perpendicular to the virtual rails, both behind and in front of the ball location. The stops are used

to help the golfer make strokes of precise lengths. A "rail tolerance" means a space between the putter heel or toe and the virtual rail. A "touch" relates to the ability to roll a golf ball a specified distance on a green of differing conditions. A "hot point" means the four or five important points in the putting stroke, whereas a "hot spot" relates to the concept of using an indicator, for any type of golf swing or stroke, to indicate a spot that a teaching professional wants a golfer to either avoid or hit with each swing or stroke.

[0207] The EPC will enable golfers to break the stroke down into its component parts so that he can perfect each component. Having gained a comfort level with the component movements of the club, the golfer can then integrate them into a complete, smooth, consistent, repeatable putting stroke.

[0208] This is accomplished by having the putter operate in five 'modes'. These are the Alignment Mode, the Practice Mode, the Re-Play Mode, the Simulation Mode, and the On Course Mode. For Alignment Mode, the golfer goes through his pre-shot routine and sets up to the ball, checking his alignment with the Alignment Device. When the golfer is in practice mode, he is working on perfecting the mechanics of making a good putt. These are a consistent, repeatable stroke path, a square putter face at impact and striking the ball on the sweet spot of the putter Practice Mode. In replay mode, the golfer is actually on a green and begins to focus his efforts on learning touch, in addition to continued work on proper mechanics. Replay Mode. In Simulation Mode, the golfer works on putting everything together plus begins to learn how to modify their stroke based on green conditions, such as speed and slope. Finally, with the On Course mode, the golfer is using the putter out on the course, recording strokes for later download and play back using visualization software.

[0209] The EPC includes positioning electronics and intelligence embedded in the putter itself. This enables us to provide the golfer with instant feedback on every stroke relative to a known, excellent stroke. Combined with personal computer based software, The EPC offers a powerful solution to break the frustrating cycle of long hours of practice with little or no improvement.

[0210] EPCs "know" where they are in three-dimensional space and where they are relative to a known, excellent reference stroke. This enables the EPC to provide the golfer with instant feedback when his or her stroke has strayed from the reference stroke. Stroke data is also captured in memory and may be downloaded, played back for study and intensively analyzed by our personal computer-based software. EPCs are not just passive training devices. You can putt with them on the practice green and put them in your bag to play with every day.

[0211] The EPC's goal is to provide avid golfers with a system that will rapidly improve their golf game through instant feedback and use of analytical tools. There are many training devices on the market, but the EPC is the first that can record stroke movement while simultaneously providing audible feedback. It is also the first device to provide golfers with a comprehensive analytical tool that may be used at home, enabling the golfer to work on his game away from the course.

[0212] While the key audience for the product is the avid golfer and top teaching pros, the product has the potential to

reach a variety of additional markets: the beginner, the local teaching pro, the touring golf pro, etc.

[0213] The present embodiment provides a relative frame of reference to keep the putting stroke “on line” during the back stroke and the down stroke. The disclosed subject matter also provides a way of getting immediate feedback w/out a golf professional or trainer. The disclosed subject matter also avoids the need for videotaping every stroke on the course since there is here provided a frame of reference. As such, it is possible to visualize what the body and club do as an integrated whole. Improvement comes rapidly and frequently and learning is enjoyable.

[0214] The EPC enables golfers to practice putting strokes while receiving instant feedback and recording their performance. At the end of a practice session, golfers can connect the EPC to a personal computer, transfer data, and begin using desktop software that supports a more detailed analysis of each stroke.

[0215] It is anticipated that the EPC are used in one of three modes. Each of these use modes may have different requirements for the hardware, embedded firmware, and personal computer software. Currently, the s under consideration are practice mode, re-play mode & simulation mode.

[0216] The EPC provides the typical end golfer with four main functions. First, the EPC sensing and communications electronics is embedded in normal golf club. Accordingly, the golfer practices his stroke using a putter that looks, feels, sounds, and performs like any other good-quality putter, yet gets training feedback unavailable from any other club.

[0217] The golfer also receives immediate feedback from the EPC. The data storage and transfer functions allow the golfer to record up to/at least 50 strokes from a practice session at the practice green, or anywhere else, without any change to his/her normal golfing behavior, either in a practice environment or on the course; then the golfer can connect the EPC to a personal computer and download his practice session.

[0218] The disclosed subject matter includes personal computer software provides the typical end golfer with two main functions of data transfer and stroke comparison/analysis. The data transfer allows the golfer quickly to download the data from a practice session to view it in the personal computer application as a “batch” and can upload device and personal characteristics. With stroke comparison and analysis, the golfer can view his stroke using a three-dimensional model to superimpose “his” model over that of a known good reference stroke. The golfer can manipulate the video by replaying, looping, viewing in aggregate, etc. so that he may better study his performance. For the putter, reference strokes are most useful when measuring and comparing tempo.

[0219] The software are installed on personal computer computers running Windows 2000, Windows XP Home Edition, or Windows XP Professional (excluding Windows ME) with 256 MB RAM and 100 MB free disk space. The golfer will expect to be able to operate the software himself without outside help or having to ask for email or phone support. Golf trainers wishing to sell a co-branded version of the software will only be to give a digital copy of their logo.

[0220] The disclosed subject matter provides a sampling frequency sufficient to capture changes in motion; initial

estimates put this at 500-1000 Hz while avoiding integration drift and not requiring a large memory footprint of each stroke. The EPC provides the ability to estimate initial inclination around all three axes to calculate the stroke accurately. In one embodiment, the memory may store 50+ strokes, at a data transfer rate of 72.5 K per second. The EPC may include sufficient battery power to last 1-1.5 hours of constant use, e.g., for practice green use, while providing 6 hours of periodic use, e.g., for golf course use.

[0221] The EPC is constructed to withstand storage within an automobile. Golfers typically keep clubs in their automobile for long periods to be prepared for unforeseen golfing opportunities. Accordingly, the EPC preferably withstands jostling and bumping experienced by clubs in a trunk and is able to withstand storage across the temperature ranges experienced in an automobile.

[0222] The disclosed subject provides a “good stroke” path by creating two virtual rails in space. As such, the EPC good stroke path passes between these virtual rails. Since there are many different putting styles, the club and the application may provide feedback with any style. These include the following putting styles. With pendulum style putting, the golfer attempts to take the putter ‘straight back & straight through’. In other words, the center of the putter would correspond exactly with the target line and never vary from it at any point in the stroke. Alternatively, with a ‘mini’ swing putting, in this approach the golfer takes a small version of the full swing. The putter will take a path that is slightly around the golfer’s body with the putter face opening during the backstroke, returning to square at impact and closing slightly on the follow-through. This type of stroke may be either captured or calculated.

[0223] The disclosed subject matter includes the following capture capabilities: A “good stroke” tempo presents the concept of a metronome. For a specific golfer, the stop of the back stroke may correspond to one tick of the metronome, and the completion of the forward stroke may correspond with the next. This speed may remain unchanged regardless of the length of back stroke and forward stroke. However, each different golfer will have his own specific cadence. These typically range from 60 beats/minute to 102 beats/minute.

[0224] The EPC records the following segments: (1) from address to the end of the back stroke, (2) from the start of the down stroke to impact, and (3) from impact to the end of the follow through. The present embodiment keeps all three of these statistics, thus enabling further research and for new metrics for putting tempo.

[0225] The present embodiment makes no assumptions about a golfer’s stance, posture, etc. When not using an alignment device, the present embodiment also assumes that the golfer aligns the putter face correctly. The key assumption is that the golfer has a relatively normal address position.

[0226] The present embodiment is indifferent between a right-handed golfer and a left-handed golfer.

[0227] Description

[0228] Golfers preferably sense no difference between a good-quality putter and the EPC. It preferably feels the same when held, both in weight, grip type, and performance. The

physical hardware that may be added to the exterior of the EPC in order for it to function (PC connection, battery recharge input, on/off switch, feedback speaker, etc.) may be placed so that they do not interfere with the activity of stroking a golf ball with the putter.

[0229] The EPC electronics fits in the top 150 mm of the shaft of a standard steel or graphite golf club. The inner diameter of a standard shaft is approximately 12.7 mm at the top of the shaft. The EPC electronic circuitry weighs less than 2 ounces, including encapsulate, because this weight will not affect the golfer's ability to make a normal putting stroke.

[0230] The EPC is resistant to shock and vibration as experienced by normal golf clubs. These shocks include striking the ball, striking the ground, accidentally dropping the club on a hard surface, and bumping against other clubs in the golf bag during transport. The sensors may be functionally capable for five (5) years.

[0231] The EPC electronic circuitry is immobile within the club shaft such that any shock absorbing material preferably provides the appropriate "give" to prevent data inaccuracy in low frequency acceleration measurement. The shock absorbing material preferably resists high frequency transmission of vibration and impact (for example, a sharp strike to the butt end of the club), and does not interfere with accuracy of sensors during normal operation. Internally generated heat preferably does not force the EPC to reach temperatures over the specified tolerances of included components and encapsulant.

[0232] The method of mounting and encapsulating the circuitry in the club may include a mechanism for pressure equalization between the air volume in the shaft and the outside atmosphere. Allowing for air pressure equalization makes the club robust to non-pressurized airplane cargo holds and to pressure variations caused by temperature and altitude shifts. For example, a thin tube may be inserted to connect the inner shaft air chamber with the outside atmosphere. If necessary, a small hole may be drilled in the shaft immediately below the EPC.

[0233] The mechanical design preferably protects the exposed device components (switches, personal computer connection, etc.) from environmental factors including moisture and dirt. The design may also mitigate impact from golfers dropping the club into the bottom of the golf bag (like a removable rubber stopper or the like).

[0234] The club preferably uses a standard consumer or lightweight grip and may be formed both graphite and steel shafts (nearly 100% of putters use steel shafts.) The club preferably performs the same as a club without instrumentation, with the final weight being preferably no more than 2 oz heavier than a comparable club without circuitry. The club preferably delivers the same sound during ball impact as a comparable club without circuitry. Temperature ranges of club storage and operation to allow golfer to treat the club like a standard golf club without circuitry. Although golfers will not play golf in these temperature ranges, these ranges are conceivable storage conditions in an automobile trunk. If the clubs are moved directly from storage near one of their limits to an acceptable use environment, it is possible that the clubs could initially be near their storage temperature when play begins. The club may be able to withstand storage

and operation across a temperature range of an upper temperature of 160° F. (i.e., approximately the temperature of closed-car heating conditions) and a lower temperature of 0° F. (i.e., a lowest recorded continental US temp is -69.7° F.)

[0235] With one embodiment, a golfer may flag a stroke directly after stroking the golf ball. The golfer will use this flag to identify noteworthy strokes when viewing their stroke batch using the software. The ability to flag a stroke are necessary when the golfer is practicing on a real green, playing on the course, or when performing one of the pre-defined drills. The present embodiment makes no semantic association with a tagged stroke. The golfer can flag any stroke in any mode. It is up to the golfer to remember why the stroke was tagged. This "semantic-less flagging" is something up for discussion in future present embodiments.

[0236] An encapsulant, or mechanical system, may be identified that will act as a shock absorber to mitigate the effects of ball impact and other jarring shocks. Accelerometers and gyroscopes contain moving parts and are vulnerable to physical shocks during manufacturing, device storage, and device usage.

[0237] Golfers may selectively turn on and off the EPC and preferably are able to see when the EPC is on, sleeping, and off. The EPC manages power and after a period of inactivity may automatically turn off. Golfers preferably are able to recharge batteries, and ideally may know when batteries are becoming low.

[0238] A switch or some other method may be available for turning device on and off. If a switch is utilized, it may be positioned at the butt of the club handle. The switch may be very small, as long as it may be easily actuated using a golf tee or object of similar dimensions.

[0239] Indicators may include an On/sleep/off status that is visible to the golfer, and overall system status (Error or Low Power) that may be communicated in some manner. Audible alerts are an acceptable alternative to an LED.

[0240] An error indicator may be triggered when 10% continuous battery usage remains. The EPC may be automatically power down after 1 minute of inactivity and the EPC may include sleep/wake mode or other routines if necessary for power management. In one embodiment, a method of recharging the EPC may be available. If this is a physical connector, it may be positioned at the butt of the club. Recharge also may be available, for example, from a car, wall unit, etc. Battery life may be sufficient to handle either the s of a practice green using 50+ strokes over 1.5 hrs or a full round of golf with 50+ strokes in groups of five or six over six hrs.

[0241] Small amount of handle area greatly limits options for indicators. The present embodiment needs to be very careful to make device communication clear to the average golfer.

[0242] Upon purchase of the disclosed system, golfers preferably are able to connect the EPC to the personal computer running the disclosed application and transfer data from the personal computer application to the onboard application. This data will include the golfer's personal measurements, calibration information and the results of golfer defined putting drills. At any time, the golfer may be

able to update the EPC with upgrades to the firmware or modified personal or calibration data.

[0243] Upon completion of a practice session or a round of golf, golfers may connect the EPC to the personal computer running the disclosed application and transfer data from the EPC to the personal computer application, and upon completion, erase the data that was just transferred from the EPC memory. During use of the EPC in Simulation Mode, data transfer may occur immediately following the 'end of stroke'.

[0244] The EPC preferably supports two-way data transfer with a personal computer, including synchronization of information and hardware management between the personal computer and the EPC, and stroke data transfer from the EPC to the personal computer. Swing data transfer includes transferring swing data from the golf club to the computer. Synchronization of information may be able to complete necessary communications between the golf club and the desktop software to coordinate sharing of sensor-, club- and golfer-specific calibration information, as well as the results of the golfer-defined drills.

[0245] Sensor characteristics—Given the plan specified in the data capture requirements, it may not be necessary to transfer any data associated with sensor characteristics to the desktop application.

[0246] Club characteristics include the ability to transfer fixed club characteristics from the software to the EPC. Fixed data points include, shaft length, Hosel/lie angle, IMU position offset, serial number (preferably indicating type of club, date and location of manufacture, hardware revision number, and other data), and width of the widest part of the putter head (this permits determination of where to situate the rails.) For club performance, the present embodiment includes offsets from where the shaft connects to the putter head to the locations including the sweet spot, the putter toe, and the putter heel. This information may be used as input for drawing the putter head appropriately, determining the quality of the impact point, and determining where to put the rails. Transfer occurs on initialization of golf club in desktop software

[0247] Golfer characteristics may include measurements relating to the way the golfer addresses the ball. A third party may initially enter golfer characteristics incorrectly, so the golfer may be able to update and transfer data after the initial transfer. The golfer characteristics data may include, for example, golfer body measurements, golfer stroke type, such as square-square-square (pendulum) stroke, or mini-swing stroke. In addition, a unique golfer identifier may be included. For example, a single text string may be sufficient, since a single pro will not likely be teaching two "Ted Smith's" at the same time. Even so, with such a text string the present embodiment can always add text to distinguish between the two.

[0248] The disclosed embodiment provides a virtual rail distance between rails as one of three pre-packaged distances. These distances are measured as the distance from the putter toe to the top rail, and from the putter heel to the bottom rail. Note that these distances are the same in that one setting might be "1 inch." In such a case, the toe is 1 inch from the top rail and the heel is 1 inch from the bottom rail.

[0249] The present embodiment provides uses a virtual stop distance from the ball, both directions as well as virtual

stop widths. For example, the distance of each stop from the impact point may be different. Therefore, they are set independently. Usually, the back "stop" distance is shorter than the forward stop distance. the present embodiment will pre-package three sets of stop distances: Back 6" Forward 7"; Back 12" Forward 14", and Back 18", Forward 21". The present embodiment will also supply three out-of-the-box stop window widths: 3", 2", and 1"

[0250] Desktop software tracks whether a club has up-to-date information. Such information may vary according to different golfer characteristics. For example, with certain hardware management aspects, data transfer allows for hardware troubleshooting and firmware upgrading. The desktop software communicates with the DSP/MCU to trigger self-diagnosis routines, and the results of those tests are sent back to the desktop software. In addition, firmware patches and upgrades are sent from the desktop computer via the data transfer mechanism. Hardware troubleshooting operations preferably support back-and forth communication to monitor the status of the hardware

[0251] Various hardware support routines may include power management for tracking the level of charge of the on-board battery and signal when 10% of continuous use remaining power remains (which is about 9 minutes of use). Self-test routines run on all sensors. Battery integrity test recognize an error condition stored on the club and transferring it to the software. Club clock/calendar sync algorithms allow the club to update its onboard clock/calendar with personal computer time and date. Connection sensing algorithms detect when the on-board unit of the club is successfully communicating with the desktop software. An on-board memory status routine detect whether there are strokes stored on the EPC connected to the personal computer. The desktop software may be the launching point for any firmware upgrades that take place. Upgrades may be transferred to the club and executed, and responses may be returned upon success.

[0252] The EPC system provides wireless communications, with wireless connection inside the club. The connectivity solution may be low-impact to the golfer (i.e. not require system configuration that cannot be carried out by the disclosed application).

[0253] Embedded software may be developed to support connectivity with specifications sufficient for development of the personal computer interface. The API may be documented for use by personal computer application developers. The EPC may also store data about the EPC and the golfer, including a unique identifier or serial number, club dimensions and characteristics stored at time of manufacturing, length, IMU position offset, Lie and Loft, and a unique golfer identifier, programmable from the personal computer application. Tolerance parameters for instant feedback, programmable from the personal computer application. At least one embodiment may have no instant feedback, however.

[0254] The EPC includes a number of drills, including a set of pre-defined, out-of-the-box putting drills. The pre-defined drills may include the following a 6-inch drill wherein the backstop is set at 6" and the forward stop is set at 7" for ten putts; a 12-inch drill wherein the backstop is set at 12" and the forward stop is set at 14" for ten putts; and an 18-inch drill (Practice Mode) The backstop is set at 18" and

the forward stop is set at 21" for ten putts. The present embodiment may also provide for golfer-defined drills, defined in a simple manner such as including distance from the hole, number of putts to be attempted, a limit of ten (10) 'Distance/Number of Putts', and combinations thereof.

[0255] During the use of the 'Drills' function, the golfer preferably provides method of denoting whether a putt was successful. Flagging a stroke fulfills this requirement. Again, the golfer may be able to flag a stroke for any reason. There are many reasons a golfer would like to flag a stroke. These may include, but are not limited to, a putt on an actual green being holed, that a putt felt like it was well-struck, but missed the hole, that the result of a putt was terrible, that a putt felt bad in terms of tempo, that a putt felt great in terms of tempo, and other reasons.

[0256] The disclosed embodiment also provides a data transfer rate sufficient to achieve the claimed subject matter. Calculations in the data capture spec suggest that the data footprint for a set of 100 strokes is approximately 4.35 megabytes of data. In order to ensure product usability, the time needed for data transfer may be kept to less than a minute if possible. Given the above requirements, the present embodiment can calculate the rate of transfer for a data solution to be 72.5 kilobytes per second, or 580 kilobits per second. Most USB solutions offer rates significantly higher than this, so meeting this requirement carries little risk.

[0257] The EPC includes an Inertial Measurement Unit (IMU) that accurately calculates and captures position and motion. With the IMU a golfer receives a consistent experience throughout their use of the EPC. In other words, the audible feedback that they hear while completing a stroke translates into visual identification of the same "broken rail or broken stop" in the desktop software. Golfers will rely on the accuracy of the IMU to speed learning, so any failures in the accuracy of the measurement are unacceptable to the golfer.

[0258] Accurate data are provided by three key hardware components, including (a) a biaxial accelerometer, (b) a gyroscope, and (c) a DSP/MCU (1). In addition, an absolute timestamp may be provided either by a separate component or from the DSP/MCU. The use of four (4) biaxial accelerometers assumes that the present embodiment accommodates two (2) sensors, with varying sampling ranges on each axis, to enable an accurate solution. Club head position accuracy occurs within speeds of 2-20 MPH, wherein the EPC position of the club head within +/-2 mm with a 95% confidence interval. Device accuracy may be sufficient to provide a minimum of 2 seconds of accurate data to encompass a "slowest case" stroke in its entirety.

[0259] The IMU will consist of, at minimum, three gyroscopes (one embodiment may use an Analog Devices ADXRS300 BGA) and four dual-axis accelerometers (for which an embodiment uses an Analog Devices ADXL210E) and a time/calendar chip. These devices provide data that allows the position and motion of the club in space to be calculated. Sensors readings derive from accelerometers that may be mounted to measure acceleration along the coordinate axes of the golf club frame-of-reference. The disclosed subject matter contemplates that data be captured from at least three of the four accelerometer sensor channels. For example, unless there is a technical reason preventing read-

ing from all four channels on the accelerometers, the present embodiment may analyze whether capturing a redundant measurement, for an axis will help with accuracy along that axis. If it will, the redundant axis will likely be the x-axis in the club frame-of-reference. This occurs since the redundant axis will often dictate "breaking the rail" for the instant feedback mechanism.

[0260] Three gyroscopes may be mounted to measure angular rate around the three coordinate axes of the golf club frame-of-reference. The gyroscopes capture the sensor readings from each of the three gyroscopes. The sensor offsets capture readings necessary for calculating offsets, as well as capture results from any on-board calibration routines. For such measurements, the face angle to target is +/-1/4 degree to the perpendicular. An external device maybe to achieve this level of accuracy. The present embodiment may achieve this granularity without the use of an external device. In addition, the present embodiment measures the impact point on the face of the putter +/-2 mm.

[0261] In the present embodiment the DSP/MCU processes into discrete units the incoming information about the movement of the EPC provided by the accelerometers and gyroscopes. Continuous data is processed into discrete units covering the same time interval from sensor to sensor. In other words, if information from a gyroscope is captured at the end of one second of gathering information, then information may be captured from all other sensors at that same moment. A golf swing, therefore, will be represented by a set of data points from all sensors for each time interval.

[0262] The DSP/MCU goes through a series of processing steps to convert data from raw voltages into positions. The frequency of data point capture is to be determined. The present embodiment will analyze this decision with respect to signal processing accuracy, data transfer limitations, and mathematical algorithm accuracy. Algorithms currently written in JAVA preferably are ported to whatever embedded language is used by the DSP/MCU. A Kalman filtering algorithm may be written and ported to execute on the EPC, if needed.

[0263] Time/calendar chip may be either in the DSP/MCU or as a stand-alone chip and may be adjustable by the desktop software. During operation, data gathered from the IMU devices may be processed to produce position and attitude data. This data may then be transferred to the personal computer application.

[0264] Memory footprint for a time interval capture processed sensor data (in the form of accelerations, angular rates, and time stamps) to represent a stroke. Memory footprint for a golf stroke, each golf stroke may contain an absolute time stamp (start of swing) and a series of time intervals, consisting of 3-4 accelerations, 3 angular rates. The maximum total memory for a golf stroke has been calculated to be 43.5 kilobytes, given certain assumptions. A minimum of 50+ strokes may be stored in the EPC between downloads to the personal computer application. The memory footprint for a set of 100 strokes calculates to be, in the most conservative case, 4.35 megabytes in size, given certain assumptions.

[0265] The IMU components preferably are oriented so that the sensing axis of each gyroscope may be positioned parallel to its respective club axis. Each accelerometer

provides data on two axes. The accelerometers may be positioned so that three of these sensing axes are parallel to their respective club axes, six if using accelerometers of multiple ranges.

[0266] The IMU may be calibrated at manufacturing. Due to variability in null points and sensitivity of the IMU devices, calibration may be performed during production. The results of calibration may be stored in the EPC for use in data processing. There may be a simple way of allowing golfers to re-calibrate the on club device periodically due to device movement over time. Proper calibration is important, since many of the other face angle and stroke path requirements depend on such calibration.

[0267] With the present embodiment, two, or four, accelerometers are mounted to measure acceleration along the coordinate axes of the golf club frame-of-reference. Because the accelerometers are biaxial, the present embodiment makes four or eight readings available. Preferably a minimum capture of three of the four channels, or six of eight channels for each axis occurs. However, the fourth, or seventh and eighth, channel may be useful in reducing the error due to noise along an axis; this needs to be investigated more closely. Moreover, data from the fourth channel of the accelerometers would be useful in reducing the error due to noise along an axis.

[0268] For various alternative embodiments of the EPC, accelerometers other than the ADXL210 and ADXRS300 may satisfy requirements for detection ranges, sampling rates, and bandwidth. In fact, a lower g accelerometer may improve performance of the EPC.

[0269] The EPC provides an onboard instant feedback that focuses on three items: Address detection, successful stroke detection, and practice stroke detection. The present embodiment needs the ability to compare the last practice stroke with the actual stroke. This will need some technical thought, since the present embodiment has to “work backwards” from the actual putt to the last practice swing.

[0270] In the EPC, address detection occurs in a manner similar to that of the instrumented golf club (“IGC”) of U.S. patent application Ser. No. _____. In fact, the “enter address” detection may function essentially the same as in the IGC. In addition, the “exit address” detection may function essentially the same as in the IGC. Tolerances for all aspects of address detection are changed easily due to various idiosyncrasies in the pre-stroke routines of different golfers. Successful Stroke Detection may function essentially the same as in the IGC.

[0271] An important exception may be, however, that with the EPC, a successful stroke only occurs when striking an actual golf ball. Practice strokes are neither successful strokes nor strokes that hit something such as, for example, a whiffle ball. When a “stroke” occurs that does not strike a real golf ball (nobody putts using whiffle balls), an audible tone (different from that given for “Successful Stroke Detection”) may be sounded.

[0272] One practice stroke (the “last” practice stroke) may be saved in the club’s memory. When a “new” practice stroke is detected, the “old” practice stroke may be purged from the club’s memory. When an actual stroke is detected, the “last” practice stroke is saved along with the actual

stroke. These two strokes are a “pair” and may be kept together for analysis in the user interface.

[0273] The present embodiment includes a user interface capable of distinguishing practice strokes from real strokes. Also, the user interface may provide an easy way for the golfer to compare the last practice stroke to the real stroke. Moreover, the present embodiment preferably takes into account that the golfer might not take a practice stroke prior to hitting a putt.

[0274] The present embodiment preferably determines the all characteristics of what constitutes a “putting stroke,” regardless of whether or not “something” is struck at the perceived impact point. Preferably, this includes determining whether a real golf ball has been struck by the putter at speeds of $(0 \text{ mph} < \text{putter head speed} \leq 20 \text{ mph})$. Using the disclosed subject matter, the golfer may be able to, in “almost” real time, purge the data for an “old” practice stroke when it was determined that a “new” practice stroke has occurred.

[0275] Golfers can more quickly understand flaws in their stroke behavior through immediate feedback. The mechanism the present embodiment uses includes comparison to a set of virtual rails, which are golfer adjustable, on either side of the putter face. Additionally, either in addition to the use of virtual rails, or by themselves each IMU will support a set of golfer definable virtual stops. These stops are set, by the golfer, at some distance behind and in front of the ball. For example, the stop located behind the ball may be set to 8" and the one in front of the ball set to 12". Each time a golfer’s stroke breaks either the virtual rail or virtual stop, they may be given instant feedback so that they may begin to adjust their stance, grip, stroke, etc.

[0276] Define a set of virtual rails for each golfer for use in the feedback mechanism. Determine what, if any, measurements of the golfer are necessary to determine the virtual rails. Beginning golfers will improve a great deal just by keeping the putter between the virtual rails, which may be adjusted to tighter tolerances as the golfer becomes more adept. Golfer may be able to turn audible feedback on and off without affecting whether or not the club is recording.

[0277] Feedback for breaking the inner rail may sound different from feedback for breaking the outer rail. Feedback for breaking the backstop or the forward stop may be the same tone. Since this is supposedly being done in real time, the golfer will know which stop has been broken. Feedback, in the form of a ‘happy tone’, may be given each time the golfer completes a stroke without breaking either a rail or a stop.

[0278] Feedback preferably occurs within 50 ms of a detected error (rail break or stop break) in the golfer’s stroke and may be available for all points from the start of the swing through ball contact and to completion of the follow-through. The mechanism may be able to determine when a swing has been aborted so that the present embodiment prevents false feedback from movements before actual start of stroke (e.g., practice strokes). This mechanism may solve the false-feedback issue described above.

[0279] Real-time feedback for the disclosed subject matter includes almost real-time computations on the DSP/MCU. Stroke-start, stroke-abort, and stroke-end algorithms preferably are determined. Golfers preferably are able to display

a given stroke graphically from a top view with no perspective. If perspective is added, the focal point needs to be directly over the target line directly over, or slightly behind, the ball. For the present embodiment, this is defined as displaying the putter head throughout the stroke.

[0280] Software may be capable of displaying each stroke in “real time” to present more of a video of each stroke. A clock displaying the time during the swing would be a nice feature, as it would allow a golfer to compare tempo between swings. Software may be capable of displaying the complete putting stroke. The software may be able to determine the ending position of the putter, even if some positional information is lost at impact with the golf ball.

[0281] Software preferably displays the presumed location of the golf ball up through impact. After impact, an outline of the location of the ball may remain, or other indicator of the golf ball’s original location, such as a ‘tic mark’. Software may also display a putter stroking a putt.

[0282] Some professional golf instructors maintain that good putters take the same amount of time beginning from the end of their backstroke to the end of their finish stroke (past impact where acceleration reaches zero) regardless of the length of the putt. Such professionals speculate that this pace (backstroke/end of stroke) is based on a specific body rhythm. Using a metronome, all people seem to fall in a range of 60 to 110 beats/minute. Viewed a metronome as going, “tick, tock,” the “tick” corresponds to the end of the back stroke, and “tock” corresponds to the end of the entire putting stroke i.e., the through stroke. Given this, the present embodiment takes an accurate measurement of the time between the end of the golfer’s backstroke and the end of the golfer’s through stroke.

[0283] Another technical advantage of the present embodiment may include a display of a stroke. Such a display forms the basis for analyzing a stroke and see where a stroke needs correction. This functionality also provides the base for other analytics; so failing to provide this would result in other analytics being unavailable or less useful. The display makes use of a determination of the position of the IMU throughout a stroke and the orientation of the IMU throughout a stroke. The EPC calculates the position of the entire club from this information and graphically EPCs this information into a two-dimensional view (plane). The accuracy of data is insufficient to display a close approximation of a stroke.

[0284] A number of physical calculations of how the club behaves will help the golfer to analyze each stroke. This specifically includes accelerations, velocities, and positions of the club at different points of the stroke. The EPC calculates acceleration, velocity, and position throughout a stroke: top of stroke, point of impact (either the theoretical point of contact [for a stroke without the ball] or the actual contact point), and end of stroke. In addition, the EPC calculates orientation of the putter, including shaft angle at address and contact, shaft lean at address and contact, club face orientation at impact. The disclosed subject matter also calculates the present embodiment timing as a qualitative measure of “perfect,” “early,” “very early” and “extremely early.”

[0285] To be able to calculate key time markers defining moments of the swing is an important aspect of the present

embodiment. Calculating any post-impact physics information may be impossible due to the vibrations introduced by contact with the ball. Calculating velocities and accelerations for the club head are non-trivial exercises. The remaining items are trivial calculations given the sensor information and the algorithms necessary to display a stroke. Dependencies with other functions may include calculating all of these functions upon being able to translate angular rate and acceleration readings (sensor readings) into positions and orientations.

[0286] The disclosed subject matter determines the theoretical results of a stroke; in other words, what happens to the ball. The ability to determine how far a golf ball will roll on a green of a given set of conditions is to helping the golfer determine how far to take his back stroke. This provides an important aspect of learning touch in the putting stroke.

[0287] Functional aspects of this technical advantage include determining initial velocity of the ball and the spin imparted to the ball, as well as correlating the club head velocity at impact with the distance the ball will roll on the putting surface. The accuracy of the position and orientation calculations will affect the results such that an error in the orientation will predict an incorrect spin, while a position error when the ball is struck near the edge of the club face could indicate the ball was struck when it is missed, or vice versa. Moreover, the responsiveness of the clubface varies with the contact location. There is a “sweet spot” in the center of the club, and hitting near the edge of the clubface will produce less predictable results.

[0288] The position and orientation calculations will contain some error, so there is some unpredictability in the results. Once the present embodiment determines the attainable accuracy, the present embodiment may better assess the risk of trying to predict the results of individual strokes.

[0289] Another technical feature of the disclosed subject matter includes the ability for a golfer to compare his own strokes with a reference stroke. For example, a golfer may be able to compare directly two strokes-their own actual stroke and a reference stroke, the reference stroke being a nearly ideal stroke shown so that a golfer can more quickly understand what his stroke may look like.

[0290] There are three potential sources for a reference stroke. One of the golfer’s own strokes may serve as a reference stroke for the particular golfer. This is typically an option for the more advanced player, as most golfers will not be able to produce a stroke good enough to use as a reference swing. However, a golfer may move to this version as soon as he can produce one good stroke.

[0291] Another potential reference stroke may be a stroke from another player; typically, a golf pro or tour player. The drawbacks here are the fact that even tour players do not have perfect strokes, and somebody else’s stroke are scaled to match the anatomy of the golfer. A calculated “ideal” stroke. The difficulty here is taking somebody’s measurements and producing a golf stroke. This is an easier proposition if the golfer is employing a ‘straight-back/straight-through’ putting stroke vs. a ‘mini-swing’ putting stroke though this may be calculated, given sufficient information.

[0292] In order for all golfers to have access to a good reference stroke at all times, the present embodiment will

require items (1) and (3) as a minimum requirement. Note: This last sentence has been replaced with the following sentence.

[0293] Because most people use a subtle “mini-swing” putting stroke, one embodiment may use one of the golfer’s own strokes as a reference stroke. This allows comparison of a reference stroke to any of the golfer’s strokes. Such a stroke may be a practice stroke or an actual stroke. In order to quantitatively compare more than one stroke, the present embodiment analyzes what constitutes the best score for each analytic. In addition, the present embodiment combines the information quantitatively to score different elements of a stroke. For example, determining whether a putted ball is a pull or a push is determined by combining the stroke path information and the orientation of the putter face at ball impact. For this purpose, the present embodiment needs to combine information (stroke plane, club face orientation) to determine what falls into which category.

[0294] The disclosed subject matter provides certain analytics, including a tempo-meter, a quality of impact, a quality of stroke, and a quality of putt analytic. The tempo-meter analytic is based on correlating the end of the back stroke and the end of the through stroke to the beats of a metronome. The metric is measured in beats/minute. The quality of impact analytic is a composite analytic that combines information on club face orientation at ball strike, speed of stroke, and location of ball strike on the club face to determine the quality of the impact. The golfer may set tolerances for each of the three analytics to determine the score.

[0295] The quality of stroke analytic provides a composite analytic for scoring each segment of the stroke through the back stroke and the down stroke based upon a weighted sum of discrepancies between the stroke and the selected reference stroke. This, too, would require some tuning of tolerances by the golfer. The quality of putt analytic provides a composite analytic including a global score combining the four elements a putting stroke. Essentially, the quality of putt analytic combines the quality of impact and quality of stroke analytics into another global analytic.

[0296] The present embodiment calculates analytics comparing two strokes, based primarily on the compare a reference stroke to a selected stroke. However, there may be no inherent difference between how the present embodiment represents a reference stroke and a golfer’s stroke. For this technical feature, the present embodiment selects two strokes for side-by-side comparison. With the flexibility to compare any two strokes, without having to designate one as a reference stroke, the disclosed subject matter allows side-by-side comparison of a subset of any analytics. This includes the ability for an individual stroke to have a reasonably defined best and worst score, including composite analytics.

[0297] The EPC, therefore, may compare two strokes over the arcs, possibly including multiple segments to define a series of points from 1 to 10; for each of these segments, thus allowing comparison to highlight where the major discrepancies begin/lie. The EPC may calculate the difference in club positioning, velocity, and acceleration at the beginning of the segment, at the end of the segment, and at the point of maximum difference.

[0298] The EPC provides a variety of personal computer software programs and features. These include a general

golfer interface, first for a basic golfer. However, a professional also may be able to quickly enter and/or reference existing profile information for their students. The golfer may view the software on a laptop while outdoors. All text information may be internationalized and stored in resource files for future translation. Software also provides the ability to load new stroke data from the club, as well as various s. For such cases, the EPC allows to the golfer who has recorded data on the club to download it to the personal computer application for viewing and analysis.

[0299] For downloading data, the EPC connects to a personal computer and the golfer selects the “Download Strokes” item from the file menu and the save batch dialog is displayed. The golfer may be able to load existing stroke data from the club and save that stroke data as a new batch.

[0300] These function are available from the file menu on the main golfer interface. The standard Save Batch dialog is used to save the newly downloaded strokes as a Batch file. The golfer is able to choose a name for the batch or use the application’s suggestion. Batches of Strokes are saved in a database rather than individual golfer files. An option to clear automatically the club’s memory after download is presented via a checkbox on the Save Batch Dialog.

[0301] When the golfer wishes to create a new profile, he may choose to start from default values, or to create the new profile based on an existing profile. In so doing, he steps through a wizard that shows only the minimum settings, but may choose to set advanced options. The golfer loads his profile, causing settings to be loaded and strokes for that golfer to be available. The golfer then saves changes to the profile. Multiple golfer profiles preferably are able to be saved and loaded. All appropriate settings preferably are stored with the golfer’s profile.

[0302] The golfer may load an existing batch of strokes that are added to the stroke summary table by clearing the strokes currently displayed in the stroke summary table and filtering the strokes currently displayed by a variety of criteria. The golfer selects a subset of the displayed strokes by checking the boxes displayed next to each stroke and then sorts the strokes currently displayed by a column of the table. The golfer finally saves the currently displayed strokes.

[0303] Front and back stops can be either the same distance from the ball or different distances from the ball. The user interface considers this, permitting the golfer to select a putting stroke and views a 3D animation of that stroke in comparison to a reference stroke. The stroke may be animated in real-time, slowed, and stepped through. The present embodiment will only support a “top view” for the electronic putting club.

[0304] The currently selected stroke in the stroke summary table is displayed in the visualization panel. The visualization panel allows a three-panel view. This view includes the top view, the visualization of the impact point on the face of the putter, and a tempo “metronome” that matches the golfer’s tempo. The visualization panel allows a single viewpoint view with any of the viewpoints chosen to maximize in the visualization panel.

[0305] The visualization panel displays a golfer’s stroke as a putter head aligned with the target line and allows a golfer to toggle display of pre-defined arcs showing the path of the

putter head during the stroke. Overlay arcs on stroke perspective displays. Support club head arcs, including color-code an arc (possibly including an entire stroke) to represent ranges of an analytic. For example, highlight an arc based upon club head velocity or acceleration.

[0306] The visualization panel also provides a display of an indicator showing the maximum or minimum value for an analytic. For example, a display indicates the point of maximum putter head acceleration or velocity. On the visualization panel, a golfer may insert a note tied to a certain point on a stroke that would display each time the general stroke is displayed. This would allow the golf pro or a golfer to make a key point about a particular stroke that may be referred to later. Allow golfer to toggle display of stroke rails in stroke path view.

[0307] Stroke rails may be semi-transparent and of a consistent color on the visualization panel. The stroke rails may turn and remain a darker shade of the same color at any point that the putter affects the stroke rails. This allows a golfer to toggle display of stroke stops in stroke path view. Stroke stops may be semi-transparent and of a consistent color that is different from the color chosen for stroke rails.

[0308] The visualization display may provide, for example, ten hot-points, scaled in favor of more important sections of the stroke. Hot-points 1-5 may be from (1) the "at-address" position to (5) the "at zero acceleration" point, which occurs the end of the backstroke. Points between may be from point (2) to point (4), which may be scaled equidistant between point (1) and (5). Hot-points (6) through (8) may be set with (8) to be the "at-impact" point with the ball, and points (6) and (7) to be equidistant between points (5) and (8). Hot-point (10) may be at the point of zero acceleration in the follow-through with point (9) to be equidistant between points (8) and (10). Regardless of the animation mode of the stroke, the face angle display may show the relative position the putter face throughout the stroke, in real-time. Animation of putter to include multiple putter head shapes

[0309] Display leader board learning focus portion of the visualization panel allows the golfer to view qualitative, "at a glance" measurements of the selected stroke. Displayed on the leader board tab of the analysis panel, each analytic on this panel will initially be displayed as a single value. A graphical display option allows the golfer to see a bar chart representation of the values.

[0310] A "view details" option allows the golfer to see the data used in the calculation and additional information. A display tempo-meter analytic includes a backstroke duration, which may be calculated as time from swing start to zero acceleration point at transition to the down stroke. For now, this value is not used in computing putting tempo. However, the present embodiment may add its use in the future. A through-stroke duration is provided, which is calculated as time from point of zero acceleration at transition from backstroke to point zero acceleration at the completion of the entire putting stroke.

[0311] The visualization panel also may provide a display quality-of-impact analytic as a numeric score following a formula such as the following: (face angle score)+(clubface impact location score)+(acceleration score). Also, a clubface impact location score may be calculated as follows: impact

within sweet-spot=5; within 0.25 cm of sweet-spot=4; within 0.5 cm of sweet-spot=3; within 0.75 cm of sweet spot=2; and other=1. A face angle score may be calculated as follows: square to ¼ degree open or closed=3; ¼ to 1 degree open or closed=2; 1 to 2 degrees open or closed=1; and other=0. Acceleration score calculated as follows: If putter is accelerating=2; if not=0. The sweet spot diameter adjustable in golfer settings detail view will show putter head speed at impact, initial velocity of the ball in feet/sec, as well as clubface impact location score. Using the 10 hot-points, previously defined, may measure the divergence from the reference stroke at each hot-point, from 3" down to ⅛ of an inch.

[0312] Using a scale of 0 to 'total available divergence' assign a score to each swing with 0" of total divergence equaling a score of 10 and a score equal to the 'total available divergence' of divergence equaling a score of 0. Scale proportionally between these two extremes. Score range 0 (Very bad) to 10 (Perfect). Upper scale factor in inches adjustable in golfer settings. The golfer wishes to view analytics related to the three variables that determine the golf balls direction upon being struck. These variables are the path of the stroke itself, the angle of the face of the putter at impact, and whether or not the ball was struck with the 'sweet spot' of the putter face.

[0313] The present embodiment also provides a "round notes" function, which is a scorecard template for allow a golfer to track his rounds. Part of the collateral that came with the EPC software would be tips on how to track a round. This may include how to track putts, fairways hit, greens hit, lost balls, etc. The golfer could spend a few moments defining a course, and would then be able to enter his results quickly into what looks like a golf scorecard for the course. This would allow a golfer to compare his results at a course over time, and lends to some statistical analysis of a golfer's overall game.

[0314] The disclosed subject matter furthermore includes a tips function that displays golf tips upon desktop software start-up and/or having tips available for browsing in the software. These tips could come from one of two sources. Customizable tips may be entered after a golf lesson (possibly as part of lesson notes) or whenever the golfer encounters a tip he likes. Alternatively, a third-party professional or other source may provide some tips that the present embodiment could use within a software program.

[0315] The present embodiment may also provide a 'hot spot' capability to enable a teaching professional to set a 'hot spot' at any point in space and use the hot spot to train the golfer to either hit or avoid the hot spot.

[0316] For each time interval of a swing, the DSP/MCU will process raw sensor inputs into voltages, convert the voltages into accelerations and angular rates, and then convert these data points into orientations and positions. It is possible to pass along any of the three data sets to the desktop unit, as the present embodiment can easily mimic the data processing capabilities on a desktop machine. Therefore, the main criteria for selecting which data set to transfer are desktop software usability, data accuracy, streamlining the data transfer, and overall development implications.

[0317] An important desktop software usability issue is the re-processing that may take place for each stroke. The

DSP/MCU processes the data all the way from voltages to positions and orientations, so processing that takes place on the desktop unit are redundant if the fully processed information is not transferred. However, given that the DSP/MCU will have slower than a desktop computer processor, and that on-board processing happens in less than the time of a golf stroke (less than three seconds), re-processing of information may not be a significant concern. This is especially true because the desktop software can process the information just one time, and store information for future use.

[0318] Data accuracy may depend upon the point at which the EPC chooses to transfer data. The EPC may use simplified orientation or position algorithms on-board to reduce processing time for instant feedback purposes. Since DSPs are designed for signal processing, it is less likely that conciliations are made in the processing of raw sensor signals into accelerations and angular rates, and more likely that the simplifications are made later in the process.

[0319] Streamlining the transferred data set will reduce the time of transfer and the minimum connection speed for one embodiment. A streamlined set will promote the smallest memory footprint for storing data for a swing, either reducing memory requirements or allowing the golfer to store extra strokes.

[0320] Here are the three most logical points to transfer data, including before any processing of sensor readings takes place, after processing of sensor readings from voltages to accelerations and angular rates, and after all processing has taken place. The information that may be transferred includes, for all three scenarios (assuming four accelerometer readings) raw sensor data of accelerometer voltages, gyroscope voltages, changes to dynamic offsets, and time information. Sensor offsets may be stored in the desktop software or be available in the data transfer. Processed data may include angular rates and accelerations, and time information

[0321] A preferred embodiment transfers the processed sensor data to both streamline data transfer and minimize risk and development time. Therefore, each swing may consist of, for example, at most 8 data points for each time interval. Assuming that the present embodiment capture time offsets in milliseconds and assuming a maximum necessary precision of 16 bits for each acceleration and angular rate, this implies a footprint of 14.5 bytes per time interval.

[0322] Having defined the necessary information for a time interval, the present embodiment makes use of specific data for each stroke. The first piece of data for a given stroke is a time stamp denoting the beginning of the stroke. Because this is just one data point, this piece of data is not included in calculation of the memory footprint size. By this same logic, any additional "one-time" pieces of information will have very little impact on the overall size of the memory footprint, as the most precise number carries a cost of about 2 bytes.

[0323] The remaining data are the series of readings for each time intervals. Each time interval will consist of 3 to 8 accelerations and 3 angular rates. In addition, if the present embodiment is unable to standardize the length of each time interval, the present embodiment will transfer a count of the milliseconds elapsed since the previous time interval.

[0324] The claimed subject matter for modeling the golf club swinging motion and performing the measurement corrections here claimed applies to all types of golf clubs, including irons, fairway woods, wedges, and putters. Another type of sports device that may benefit from the claimed subject matter is a racquet. All racquet sports include tennis, racquetball, squash, and badminton racquet. With minor software modifications to the disclosed embodiment, the advantages of real-time swing feedback, swing data storage, transmission, and advanced analysis can be extended to the players of racquet sports. Further, additional embodiments may include bats such as those used in baseball, softball, t-ball, cricket, polo, hockey, etc. Yet more generally, the disclosed subject matter may apply to any sport using an instrument to strike another instrument, which may even include a leg (e.g., as in kicking a soccer ball or football) or an arm (e.g., as in boxing or playing handball). With minor software modifications to the disclosed embodiment, the advantages of real-time swing feedback, swing data storage, transmission, and advanced analysis could be extended to the players of bat sports.

[0325] An additional embodiment of the present correction process may be adapted for use with a video game controller or computer game controller. Real time data transmission from an instrumented game controller allows for real-life swing data to be directly fed into any sports video or computer game. In addition, the portions of the disclosed subject matter can be instrumented in software, hardware, or a combination of software and hardware. The hardware portion can be instrumented using specialized logic; the software portion can be stored in a memory and executed by a suitable instruction execution system such as a microprocessor, tablet personal computer (PC), or desktop PC.

[0326] In addition, the concepts of an IMU may also be employed in a system associated with a telecommunications system for the purpose of communicating between the sports instrument and a remote site. As such, the remote site may receive data relating to the movement of the sports instrument. Such data may be used to provide a more accurate evaluation and a more timely player coaching from the remote location. For example, remote viewing could be used for evaluation/coaching, as well as for displaying the swing. In particular, applications such as viewing a golf shot where there are no cameras exist on the golf course, or with computer game applications, such as displaying an actual swing to a remote viewer/competitor. Moreover, a coach may produce a make a demonstration swing for use by a student using the method and system of the disclosed subject matter

[0327] Several exemplary objects and advantages of an electronic sports instrument with which the measurement correction and modeling process and associated system of present embodiment may cooperate are described in U.S. patent application Ser. No. 10/810,168 filed on Mar. 26, 2004, which is entitled "METHOD AND SYSTEM FOR GOLF SWING ANALYSIS AND TRAINING" and is commonly assigned with this present application. Such objects and related features and benefits are here expressly incorporated by reference. Other aspects, objectives, and advantages of the claimed subject matter will become more

apparent from the remainder of the detailed description when taken in conjunction with the accompanying FIGURES.

[0328] The following terms and definitions are herein provided for the purpose of illustration and not for limitation. There may be other equivalent definitions for the terms herein provided and any used for explanatory or demonstrative purposes. Accordingly, it is only by reference to appended claims that the scope of the present disclosure and the various embodiments herein is and can be limited. However, because of their beneficial ability to establish the novel concepts of the present disclosure they are here provided.

[0329] For purposes of the disclosed subject matter, the term “inertial measurement unit” or “IMU” ascribes to one or more sensor groupings of nominally three accelerometers and nominally three gyroscopes. Each of such groupings align along the same set of mutually perpendicular axes, however, such sensors may align to one of the three sensors along an axis that is not mutually perpendicular or may align along a different set of coordinate axes. Ultimately, the groupings of accelerometers, gyroscopes, or other sensors all cooperate to provide appropriate sensor readings to establish IMU movement detection in a three-dimensional coordinate axis system.

[0330] Moreover, devices different from accelerometers and/or gyroscopes may be used to obtain the desired measurements of acceleration and changes in inertial measurements. The disclosed subject matter, therefore, provides an IMU for use in measuring movement of a sports instrument, which movement measurements include analyzing a stroking motion of the sports instrument, determining the point at which the sports instrument contacts an object, and correcting for differences between measured signals and actual signals. In one embodiment, the IMU may be classified as a six-degree-of-freedom measurement unit, and may include six sensors. However, any number of sensors may be used to achieve the IMU measurements. For example, more than six sensor readings may be beneficial for certain applications to improve accuracy, which measurements may use redundant sensors to reduce noise or capture high speed motion versus low speed motion.

[0331] The term “Frame-of-reference” or “FoR” relates to a system within a system. For example, when a golfer rides in a car, the player is motionless in the player’s frame of reference, while the world appears to move around the player. In an IMU for use with the disclosed subject matter, a FoR has its own coordinate system, so the IMU FoR has a set of coordinate axes fixed relative to IMU.

[0332] In the golfing application of the disclosed subject matter, the term “square clubface” describes a situation that occurs when a vector normal to the sweet spot of the face lies in the vertical plane along the target line. In other words, in such an orientation, a target line runs along the ground, and a normal vector may point into the ground or up in the air. The “neutral at-address position” occurs when a club is positioned so that the sports instrument face is square and the shaft is leaning neither towards the target nor away from the target. In contrast, the “at-address” position means the golfer has positioned the club face square to the target line and has ceased human-perceptible motion for a period of time.

[0333] In such applications, this description provides definitions for various frames of reference as beneficial for illustrative purposes only and not for limitation in any manner. For instance, a “world FoR” or “world frame of reference” has a set of coordinate axes where the X-axis is the direction a right-handed player faces, the Y-axis is the target line of the golf shot, and the Z-axis is up. Referring briefly to **FIG. 6**, in the world FoR, the origin is at the center of the golf ball. The “club FoR” or “club frame of reference” includes the coordinate axes given a neutral at-address position for the sports instrument, where the Z-axis is up center of club shaft, the X-axis is the “top” of the sports instrument grip and should lie in world XZ plane in a neutral at-address position, and further where the Y-axis—positions towards target and should be parallel to world Y-axis is a neutral at-address position. In the sports instrument FoR, the origin is fixed distance from top of board.

[0334] With the above terms and definitions as a basis and with a focus on the correction process of the disclosed subject matter, **FIG. 2** shows a partially exploded view of an instrument golf club (IGC) **18** which may incorporate an inertial measurement unit (IMU) consistent with the teachings of the disclosed subject matter. IGC **18** includes a head **20** and a shaft **22**, both of which are similar to shafts and heads on a typical golf club. Although illustrated as a driver, head **20** can be any type of golf club, including but not limited to, an iron, a wedge, a wood, and a putter. As mentioned above, the claimed subject matter is not limited to golf clubs but can be applied to many types of bats, racquets, and game controllers. Attached to the top of shaft **22** is a grip **24**, into which the claimed subject matter is incorporated. Grip **24** includes a Power On/Mute/Power Off button **26**, a battery recharge connector **28**, a battery recharge connector cover **30**, a grip faceplate **32** and a Flag Swing button **34**.

[0335] Power On/Mute/Power Off button **26** is pushed once to power on the IGC **18**. Once the IGC **18** is powered on, off button **26** is pushed to toggle on and off an audio feedback signal that indicates to a player when a particular swing has broken a plane representing a correct swing. Note that such audio feedback is not a necessary, but rather a possible feature of the disclosed embodiment. Other forms of feedback and other modes of communication may occur with similar embodiments of the disclosed subject matter.

[0336] To power off the IGC **18**, off button **26** is pushed in and held for four or more seconds. In addition, one embodiment of IGC **18** may turn off when held upside down and stationary for five seconds. Battery recharge connector **28** is a socket into which a battery recharger may be inserted to charge a battery pack within IGC **18**. Flag swing button **34** is pushed when a player desires to mark the data corresponding to a particular swing of IGC **18** for future investigation using an analysis application on an associated computing device. A saved swing can also become a benchmark, or reference swing, against which subsequent swings can be compared, including setting a reference for the breaking planes sounds.

[0337] Grip **24** includes a Power On/Mute/Power Off button **26**, a battery recharge connector **28**, a battery recharge connector cover **30**, a grip faceplate **32** and a Flag Swing button **34**. Power On/Mute/Power Off button **26** is pushed once to power on IMU **44**. Once IMU **44** is powered

on, off button 26 is pushed to toggle on and off an audio feedback signal that indicates to a player when a particular swing has broken a plane representing a correct swing. To power off the IMU 44, off button 26 is pushed in and held for four or more seconds.

[0338] Battery recharge connector 28 is a socket into which a battery recharger is inserted to charge a battery pack within IMU 44. Battery recharge connector cover 30 is a plastic cover that has two protruding posts, post 36 plugs into the connector 28 and keeps moisture and dirt from entering connector 28 when battery recharger is not connected to IMU 44. Post 38 plugs into anchor hole 40 to retain cover 30 after retracting post 36 from connector 28. When IMU 44 requires recharge, cover 30 is lifted and rotated around the second protruding post to expose connector 28 and a battery recharger is inserted into connector 28. Grip faceplate 32 is a finishing piece for IMU 44 that fits within grip 24.

[0339] FIG. 3 shows a partially cut-away view of IGC 18 depicting printed circuit board (PCB) or main board 42 to illustrate the dimensions of the disclosed subject matter as making IGC 18 capable of fitting within grip 24. FIG. 4 shows club grip 24 and an expanded view of a top portion of IMU 44, which fits within IGC 18. Battery recharge connector cover 30, grip faceplate 32, power on/mute/power off button 26 and flag swing button 34 were introduced above in conjunction with FIG. 1. Below grip faceplate 32 is an antenna board 46 that is employed in wireless communication between IGC 18 and an associated RF link box as described in U.S. patent application Ser. No. 10/810,168. Tab 48 extends from main board 42 and serves to secure IMU 44 in a fixed position relative to grip 24. A second, opposing tab (not shown) protrudes from the other side of main board 42 and also serves to secure IMU 44 in position relative to grip 24.

[0340] A microprocessor on main board 42 serves as a central processing unit for IGC 18. The microprocessor controls the other components of main board 42, collects sensor data, monitors system temperature, corrects sensor data for temperature related distortion, processes the corrected sensor data into position, velocity, and acceleration vectors, stores the corrected sensor data in flash memory (not shown) for later download, and performs real-time collision detection of IGC 18 with respect to the swing planes.

[0341] FIG. 5 shows three views of IMU 44. In particular, an outer view 60, an inner, exploded view 62, and an inner, assembled view, or assembly 64. Outer view 60 shows a tube 66 into which assembly 64 fits. Also shown is a screw 68 that secures assembly 64 to tube 66. Exploded view 62 includes antenna board 46 and a full view of main board 42, both of which were introduced above in conjunction with FIG. 3. Antenna board 46 is coupled both mechanically and electrically to main board 42. Also coupled mechanically and electrically to main board 42 are a club transceiver chip 70, a sounder 72, an accel/gyro board 84 and a Z-gyro board 78.

[0342] Club transceiver chip 70, which in this example is a 2.4 GHz transceiver, is responsible for wireless communication between IGC 18 and the associated RF link box. Transceiver chip 70 employs a quarter wave monopole antenna (not shown) located on antenna board 46. Sounder 72 provides an audio feedback signal to a player of IGC 18

when a particular swing falls outside of acceptable parameters. Screw 68 extends through one wall of tube 66, through one tube insert 76, through main board 42, through second tube insert 76 and through the opposite wall of tube 66. Screw 68 serves as a main position of structural integrity within IMU 44. In other words, screw 68 and tube inserts 76 prevent the various components of assembly 64 from vibrating within tube 66.

[0343] IMU 44 employs three solid-state gyroscopes, such as Analog Devices' ADXRS160, to measure angular rates around axes C_x , C_y , and C_z . A gyroscope located on accel/gyro board 84 measures the angular rate of rotation around C_x , a gyroscope located on main board 42 measures the angular rate of rotation around C_y , and a gyroscope located on the Z-gyro board 78 measures the angular rate of rotation around C_z .

[0344] IMU 44 makes possible corrected output from the gyroscope sensor measurements from accel/gyro board 84. These gyroscopes are configured with a bandwidth of 1320 degrees per second in order to record a typical golf swing, although other bandwidths are possible depending upon the particular application. Additional signal conditioning and analog to digital conversion circuitry (not shown) supports the three gyroscope sensors.

[0345] IMU 44 also provides two dual-axis accelerometers, such as Analog Devices ADXL210e, to measure linear acceleration along axes C_x , C_y , and C_z . An accelerometer on main board 42 measures linear acceleration along C_x and C_z axes. An accelerometer on accel/gyro board 84 measures linear acceleration along C_y axis and duplicated data along the C_z axis. Although one embodiment uses only one channel of the C_z data, another embodiment may compare both channels of C_z data for such benefits as increased accuracy and/or signal noise reduction. It should be noted that accelerometers can measure both linear acceleration and forces due to gravity. The ability to measure the effects of gravity allows for the resolution of a gravity vector that in effect tells IGC 18 which direction is down with respect to the surrounding world.

[0346] Swing data is stored on 8 MB of serial flash memory (not shown) on main board 42. One embodiment of the claimed subject matter employs approximately 72 kB of memory per recorded swing therefore allowing over 100 swings to be stored on the flash memory before the flash memory is consumed. Another embodiment of the claimed subject matter may use higher quantities of memory that would allow for data captured for a higher number of swings. For example, additional memory may store additional sensor readings, if additional sensors or groups of sensors are used for performing the disclosed movement measurements.

[0347] In addition, other embodiments may sample fewer data positions per swing, thereby allowing for data to be captured from a higher number of swings. Furthermore, other embodiments may employ data compression algorithms to allow for more data to be captured from a higher number of swings. For completeness, exploded view 62 further shows tube inserts 76, battery standoff 80, battery pack 82, and battery pack wires 84.

[0348] The disclosed subject matter provides a comprehensive system for accurately measuring and modeling a

swing sports instrument, such as IGC 18. For such accurate measurements and swing modeling, a coordinately set of analysis points, impact points, corrections and calibrations are necessary. One aspect of the disclosed subject matter, therefore, includes a method and system for isolating analysis positions of a golf swing. Another aspect of the disclosed subject matter provides a method and system for determining an impact position of a swinging sports instrument. Another aspect of the disclosed subject matter includes a method and system for correcting golf swing measurement errors for more accurately measuring and modeling the swinging motion. U.S. patent application Ser. No. _____, entitled "METHOD AND SYSTEM FOR CALIBRATING SPORTS IMPLEMENT INERTIAL MOTION SENSING SIGNALS," having commonly inventorship and assignment to the present disclosure describes the relevant calibrations.

[0349] In addition to the acceleration and orientation corrections of the disclosed subject matter, IMU 44 provides for highly accurate determination of accelerometer measurements and gyroscopic measurements using a calibration process. The calibration process takes into consideration the property that IMU 44 operates as though all accelerometer and gyroscopic measurements occur with reference to a single geometric position. Because this cannot occur in practice, measurement calibrations must take place. The calibration process of the disclosed subject matter, therefore, accounts for both position and orientation measurements that actually occur and that differ from measurements that may occur were it possible for them to occur in ideal circumstances. The calibrations associated with the disclosed subject matter are described and claimed in U.S. patent application No. _____, entitled "METHOD AND SYSTEM FOR CALIBRATING SPORTS INSTRUMENT INERTIAL MOTION SENSING SIGNALS, by Eric A. Cassady, et al. and commonly assigned with the present disclosure.

[0350] The use of the terms "a" and "an" and "the" and similar referents in the context of describing embodiments of the disclosure (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms "comprising," "having," "including," and "containing" are to be construed as open-ended terms (i.e., meaning "including, but not limited to,") unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein.

[0351] All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any examples, or exemplary language (e.g., "such as") provided herein, is intended merely to better illuminate embodiments

of the disclosure and does not pose a limitation on the scope of the disclosure unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the disclosure.

[0352] Preferred embodiments of this disclosure are described herein, including the best mode known to the inventors for carrying out the disclosure. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the disclosure to be practiced otherwise than as specifically described herein. Accordingly, this disclosure includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the disclosure unless otherwise indicated herein or otherwise clearly contradicted by context.

1. An intelligent golf putting system for improving of putting performance, comprising:

- a golf putting club head;
- a shaft of a dimension, weight, and tensile properties essentially similar to a standard golf putting club;
- a grip handle associated with said shaft of a dimension and weight essentially similar to a standard golf putting club;
- electronic components inserted into said grip handle, the electronic components comprising:
 - a plurality of accelerometers capable of producing linear acceleration measurements of the sports device in three (3) axes during a swing of the sport device;
 - a plurality of gyroscopes capable of producing angular rate measurements of the sports device in three (3) axes during the swing of the sport device; and
 - an RF transmitter for transmitting the linear acceleration measurements and the angular rate measurements;
- a radio frequency link box for receiving the transmissions of the linear acceleration measurements and the angular rate measurements from the radio frequency transmitter;
- logic coupled to the radio frequency link box for transforming the linear acceleration measurements and the angular rate measurements into swing information corresponding to the swing of the sport device; and
- a display for displaying the swing information.

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