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(54) SYSTEM, METHOD AND COMPUTER PROGRAM PRODUCT FOR ESTIMATING CLUB SWING CONDITION(S) FROM BALL LAUNCH MEASUREMENTS

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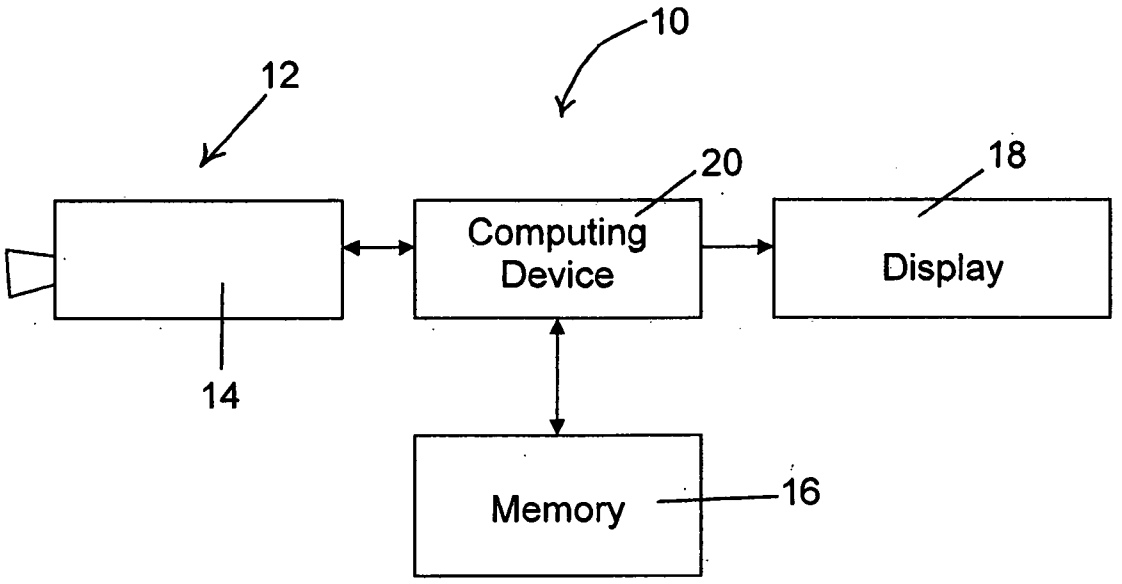
(57) **ABSTRACT**

A method, system and computer program product are provided to permit golf swing conditions, such as spin loft, club speed, angle of attack and club path, to be determined without direct measurements of the club swing and, instead, to be based upon the launch conditions of the ball. Initially, a plurality of launch conditions of a ball may be determined, such as by means of a launch monitor. Based upon the launch conditions of the ball, components of momentum 1 P_N normal and tangential to the colliding surfaces of the club and the ball may be determined, such as by means of a computing device. At least one club swing parameter may then be determined based upon the normal and tangential components of momentum P_N and P_T. In this regard, the club swing condition may be spin loft, club speed, angle of attack and/or club path.



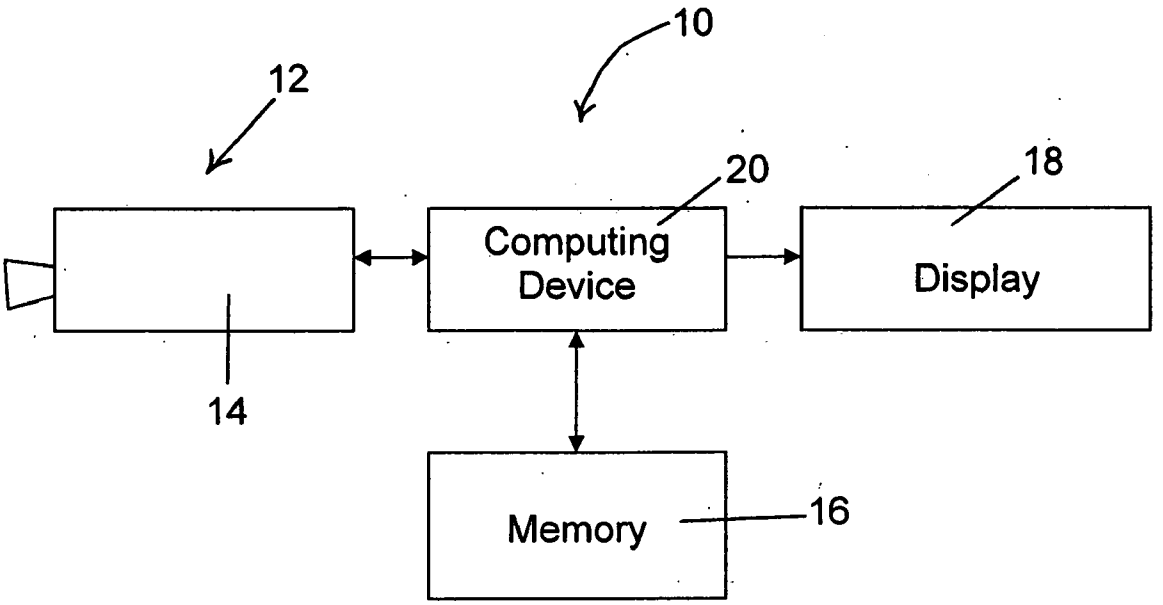


FIGURE 1

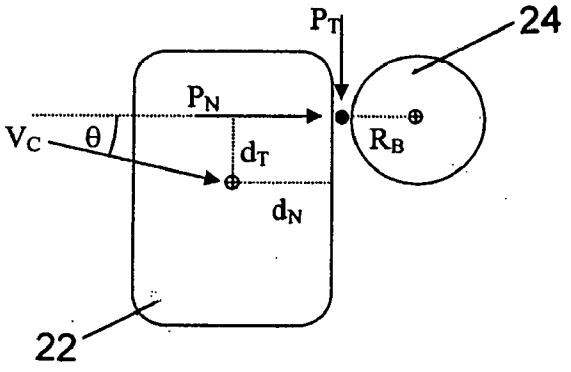


FIGURE 2

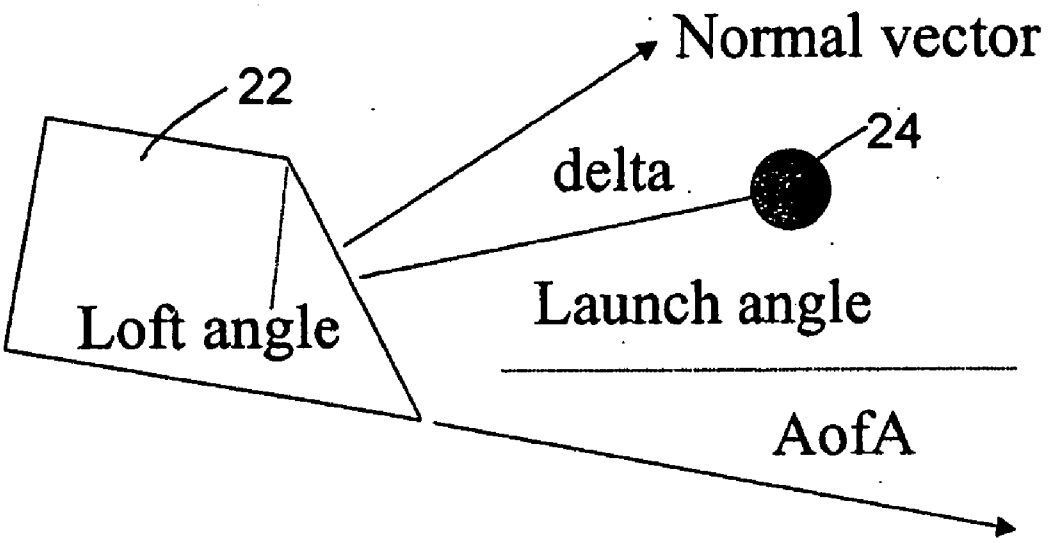


FIGURE 3

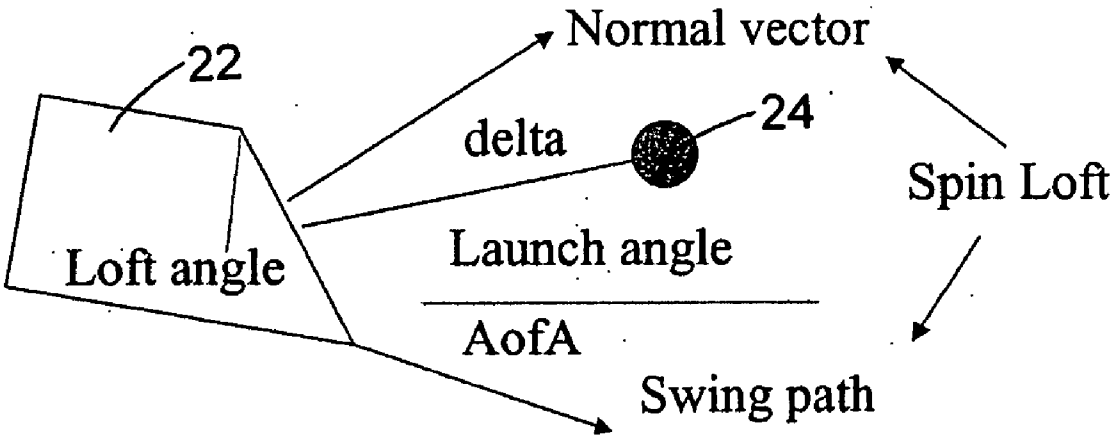


FIGURE 4

SYSTEM, METHOD AND COMPUTER PROGRAM PRODUCT FOR ESTIMATING CLUB SWING CONDITION(S) FROM BALL LAUNCH MEASUREMENTS

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] The present application claims priority from U.S. Provisional Application No. 60/606,254, filed Sep. 1, 2004 and entitled System and Method for Estimating Club Swing Conditions From Ball Launch Measurements, the contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The embodiments of the present invention relate generally to techniques for estimating one or more golf swing conditions and, more particularly, to techniques for estimating one or more of the spin loft, the club speed, the angle of the attack and the club path.

BACKGROUND OF THE INVENTION

[0003] Many golfers work consistently to improve their game. One tool that has been developed to assist golfers in analyzing their golf shots is a golf ball launch monitor. Golf ball launch monitors are used extensively to provide detailed information regarding the velocity of the ball, the launch angle of the ball, the side spin of the ball and the like. As such, golf ball launch monitors are quite useful in training sessions to evidence the manner in which swing changes affect the resulting golf shots. Similarly, launch monitors are quite useful in club fitting to provide feedback on the golf shots hit by a golfer with different clubs such that the golfer can more intelligently select the most suitable set of clubs for their game. Further details regarding launch monitors are provided in the U.S. patent application Ser. No. 10/360,196, filed Feb. 7, 2003, entitled "Methods, Apparatus and Computer Program Products for Processing Images of a Golf Ball", the contents of which are incorporated herein in their entirety.

[0004] However, golf ball launch monitors generally only provide information regarding the golf ball following the impact of the club head with the golf ball. Since the swing of the golf club up to and including impact with the golf ball dictates the manner in which the golf ball will be launched, it is also commonly desirable to obtain information regarding the golf swing itself. In this regard, information regarding those golf swings that result in poor golf shots could be analyzed in relation to those golf swings that result in better golf shots in an attempt to identify the characteristics of the golf swing that led to the different results so as to provide feedback on aspects on the golf swing that should be corrected to more consistently hit good shots in the future.

[0005] Accordingly, it would desirable to provide an apparatus and method that is capable of providing information regarding a golf swing without requiring golfers or golf professionals to purchase additional training equipment. If information regarding the golf swing could be gathered, however, the attributes of the golf swing that lead to good and bad golf shots could be determined in order to provide a golfer with valuable information that identifies those characteristics of their golf swing that need to be monitored in order to consistently produce good golf shots.

SUMMARY OF THE INVENTION

[0006] A method, system and computer program product are provided according to embodiments of the invention which address at least some of the needs and shortcomings identified above. In this regard, the method, system and computer program product may be capable of determining a plurality of launch conditions of a ball, such as by means of a launch monitor. Based upon the launch conditions of the ball, the method, system and computer program product may also be capable of determining, such as by means of a computing device, a component of momentum P_N normal to the colliding surfaces of the club and the ball as well as a component of momentum P_T tangential to the colliding surfaces of the club and the ball. Further, the method, system and computer program product may be capable of determining at least one club swing parameter based upon the normal and tangential components of momentum P_N and P_T. In this regard, the club swing condition may be spin loft, club speed, angle of attack and/or club path. As such, in one embodiment, a golf ball launch monitor may be employed to determine a number of launch conditions of a ball and then to process those measured launch conditions to determine one or more club swing conditions. As such, the club swing parameters of one embodiment can be determined in a manner that is independent of any direct measurements of the club swing. Once determined, the club swing conditions may then be utilized by a golfer to determine the impact of various club swing conditions upon the resulting golf shots.

[0007] In one aspect, the determination of the tangential component of momentum P_T may be based upon the radius of the ball, the spin of the ball and the moment of inertia of the ball. Additionally, the determination of the normal component of momentum P_N may be based upon the mass of the ball, the velocity of the ball and the tangential component of the momentum P_T.

[0008] According to another aspect, the determination of the spin loft may be based upon the normal and tangential components of momentum P_N and P_T, the respective masses of the club head and the ball, the radius of the ball, the respective moments of inertia of the ball and the club head, the velocity of the ball and the distance in a tangential direction between the center of gravity of the club head and the location of impact between the club head and the ball. Additionally, the determination of the club speed may be based upon the normal and tangential components of momentum P_N and P_T, the respective masses of the club head and the ball, and the spin loft.

[0009] According to a further aspect of the present invention, the determination of the tangential component of momentum P_T and the spin loft is based upon the back spin of the ball without consideration of other spin components of the ball. Additionally, the determination of the angle of attack may be based upon the normal and tangential components of momentum P_N and P_T, the launch angle of the ball and either the loft angle of the club or the spin loft.

[0010] Still further, the determination of the tangential component of momentum P_T and the spin loft may be based upon the side spin of the ball without consideration of other spin components of the ball. In addition, the determination of the club path may be based upon the normal and tangential components of momentum P_N and P_T, the launch angle of the ball, and the spin loft.

[0011] Accordingly, methods, systems and computer program products are provided according to the various embodiments of the present invention to permit golf swing conditions, such as spin loft, club speed, angle of attack and club path, to be determined without direct measurements of the club swing and, instead, to be based upon the launch conditions of the ball. As a result, a launch monitor can be utilized to capture the launch conditions of the ball such that the club swing conditions can then be determined. The golfers are accordingly provided meaningful information regarding their club swing conditions that will assist the golfer in improving their game without having to invest in additional training equipment.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0012] Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

[0013] **FIG. 1** is a block diagram of a system according to one embodiment of the present invention;

[0014] **FIG. 2** is a schematic representation of a club head and ball upon impact;

[0015] **FIG. 3** is a schematic representation of the angle of attack of a golf club relative to the launch angle of the golf ball and the vector normal to the face of the golf club; and

[0016] **FIG. 4** is a schematic representation of the angle of attack of a golf club relative to the launch angle of the golf ball and the spin loft of the golf club.

DETAILED DESCRIPTION OF THE INVENTION

[0017] The present inventions now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, these inventions may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

[0018] A system **10** for estimating for at least one club swing condition according to embodiments of the present invention is shown in **FIG. 1**. The system typically includes a launch monitor **12** for determining the plurality of launch conditions of a ball. While the system, method and computer program product of the embodiments of the present invention will generally be described hereinafter in conjunction with the swing of the golf club, the system, the method and computer program product of other embodiments in the present invention may be employed in conjunction with other types of balls, such as baseballs, softballs, etc., and in conjunction with other types of clubs, such as baseball and softball bats, etc.

[0019] In the embodiment in which the launch monitor **12** is monitoring the launch of golf ball, the launch monitor may be of the type generally described by the above referenced U.S. patent application Ser. No. 10/360,193. In this regard, the launch monitor generally includes a sensor **14** positioned, typically in front of or to the side of the golfer, to measure a plurality of initial launch conditions. The initial launch conditions may include initial ball velocity, vertical launch angle, lateral launch angle, dispersion angle, back spin and side spin and potentially a number of other launch parameters. The sensor can advantageously include an image sensor and, more particularly, one or more camera(s) for capturing at least two images of the ball immediately after launch from which the foregoing initial launch conditions can be measured.

[0020] The system **10** of the illustrated embodiment also includes a computing device **20**, such as a processor, a personal computer or the like, that operated under control of a computer program stored in memory **16** as well as any other combination of hardware, such as an electronic circuit, an ASIC or the like, software or firmware, for thereafter estimating at least one club swing condition based upon the launch conditions of the ball. As is shown, this system can also optionally include a display **18** for depicting the launch conditions of the ball and/or the club swing conditions determined therefrom.

[0021] The computing device **20** generally models the collision between the club head and the ball using the guiding principles relating to the conservation of momentum of rigid bodies. The relevant parameters associated with this modeling process are shown in **FIG. 2** in which the impact of the club head **22** with the ball **24** is shown from a top view looking downward onto the club head and ball. As illustrated in **FIG. 2**, the club has a swing speed V_C at the time of impact and impacts the ball at an angle θ, termed the spin loft, which is the angle between the velocity vector and the vector normal to the ball at the impact location. The impact location can be defined relative to the center of gravity of the club head by d_N which is the distance component in the normal direction, e.g., in the direction normal to the ball at the impact location, and d_T which is the distance component in the tangential direction (the direction tangential to the ball at the impact location). The impact location can also be defined relative to the center of gravity of the ball by the radius R_B of the ball.

[0022] The momentum that is involved in the collision between the club head and the ball has two components. The normal component of momentum P_N acts in the direction normal to the colliding surfaces of the clubhead and ball, while the tangential component of momentum P_T acts in the direction tangential to the colliding surfaces, as also shown in **FIG. 2**.

[0023] As described above, the launch monitor **12** determines a number of launch conditions of the ball and, based upon these launch conditions and principles relating to the conservation of momentum, the computing device **20** determines one or more club swing conditions. In this regard, assuming the club head is not spinning prior to impact and neglecting smaller terms that involve the product of both d_N and d_T, the normal component of momentum P_N can be defined as follows:

$$P_N = (1+e)V_C\cos\theta\left(\frac{1}{m_C}+\frac{1}{m_B}+\frac{d_T^2}{I_C}\right)^{-1} \quad (1)$$

where m_C is mass of the club head, m_B is mass of the ball, I_C is the moment of inertia of the club head in the plane containing P_N and P_T, and e is the coefficient of restitution which, in turn, is defined as the velocity of separation divided by the velocity of approach of the club head and ball in the normal direction. While m_C, m_B and I_C may be defined in advance and d_T can be measured by the launch monitor **12** (or assumed to be equal to 0 for impact locations at or near the sweetspot of the club head), it is noted that a number of the other parameters are club swing conditions or otherwise cannot be directly measured by the launch monitor **12**.

[0024] Assuming there is no relative velocity or sliding in the tangential direction when contact ceases and by making the same assumptions and simplification as in equation (1), the tangential component of momentum P_T can be similarly defined as follows:

$$P_T = V_C \sin\theta \left(\frac{1}{m_C} + \frac{1}{m_B} + \frac{R_B^2}{I_B} \right)^{-1} \tag{2}$$

where I_B is the moment of inertia of the ball. As noted above, while m_C, m_B, I_B and R_B may be defined in advance, it is noted that a number of the other parameters are club swing conditions or otherwise cannot be directly measured by the launch monitor.

[0025] In reality, different ball types have different spin characteristics due to the different material properties and the different types of layered constructions. The foregoing expressions are not intended to model the velocity and spin characteristics of different ball types, but are intended to relate the spin change and velocity change of a given ball for different club head swing speeds and spin lofts.

[0026] Based upon the normal and tangential components of momentum P_N and P_T, the post-impact velocity V_B of the ball and spin ω_B on the ball can then be defined as follows:

$$V_B = m_B^{-1} \sqrt{P_N^2 + P_T^2} \text{ and } \omega_B = I_B^{-1}(R_B P_T) \tag{3, 4}$$

[0027] It should be noted that the spin ω_B represents the total spin and θ represents the total spin loft. The spin ω_B can be further defined to be comprised of sidespin ω_S and backspin ω_{BS}. Similarly, the total spin loft θ of the ball can be further defined to be comprised of θ_s representing the effective open and close angle of the face at impact and θ_L representing the effective loft at impact.

[0028] Based upon equations (1) and (2), the club speed V_C can be defined in terms of the normal and tangential components of momentum as follows:

$$V_C = \frac{P_T \left(\frac{1}{m_C} + \frac{1}{m_B} + \frac{R_B^2}{I_B} \right)}{\sin\theta} = \frac{P_N \left(\frac{1}{m_C} + \frac{1}{m_B} + \frac{d_T^2}{I_C} \right)}{(1+e)\cos\theta} \tag{5, 6}$$

[0029] Based upon equations (3) and (4), the normal and tangential components of momentum P_N and P_T can then be defined as and determined by the computing device **20** as follows:

$$P_T = \frac{\omega_B I_B}{R_B} \tag{7}$$

$$P_N = \sqrt{(m_B V_B)^2 - P_T^2} \tag{8}$$

[0030] As will be noted, the computing device **20** can determine the tangential component of momentum P_T based upon the measurements of the launch conditions provided by the launch monitor **12** since the launch monitor can measure the spin ω_B as well as the parameters which define the moment of inertia of the ball, while the radius of the ball R_B is predefined. Once the tangential component of momentum P_T has been determined, the computing device can determine the normal component of momentum P_N since the velocity of the ball V_B is measured by the launch monitor and the mass of the ball m_B is predefined.

[0031] It is also noted that equations (5) and (6) include spin loft θ. The spin loft θ can be defined from the normal and tangential components of momentum defined by equations (1) and (2) as follows:

$$\theta = a\sin\left[\frac{P_T \left(\frac{1}{m_C} + \frac{1}{m_B} + \frac{R_B^2}{I_B} \right)}{V_C} \right] = a\cos\left[\frac{P_N \left(\frac{1}{m_C} + \frac{1}{m_B} + \frac{d_T^2}{I_C} \right)}{V_C(1+e)} \right] \tag{9, 10}$$

[0032] However, these expressions contain the clubspeed V_C and therefore the computing device **20** cannot directly determine the spin loft θ from the launch conditions measured by the launch monitor **12** utilizing equations (9) and (10). However, equations (9) and (10) can be rearranged to arrive at the following equation for spin loft that is independent of the club speed V_C:

$$\theta = a\tan\left[\frac{(1+e)P_T \left(\frac{1}{m_C} + \frac{1}{m_B} + \frac{R_B^2}{I_B} \right)}{P_N \left(\frac{1}{m_C} + \frac{1}{m_B} + \frac{d_T^2}{I_C} \right)} \right] \tag{11}$$

[0033] It should be noted that equation (11) includes e which is usually related as a function of club speed. In general terms, e varies in an inverse relationship to club speed such that swings having a faster club speed have an e with a lower value, and vice versa. However, the computing device **20** can employ an approximation for e such that equation (11) no longer has any dependence upon the club speed. In this regard, e may be approximated as a predefined value, such as 0.83. Alternatively, e may be defined as a function of the velocity of the ball V_B since the velocity of the ball is almost linearly proportional to the club speed. In any event, equation (11) is not particularly sensitive to the value of e such that an approximation of e still yields accurate values of spin loft. Moreover, as the remainder of the terms of equation (11) can either be measured by the

launch monitor (d_T) or computed by the computing device from the launch conditions measured by the launch monitor (P_T and P_N) or are predefined (m_C, m_B, I_C, $I_B$and R_B), the computing device can now determine spin loft θ without having to directly measure any club swing parameter. Furthermore, it is noted that since the mass terms m_C and m_B are both in the numerator and denominator and since R_B and I_B dominate relative to the mass terms, spin loft θ as defined by equation (11) is not sensitive to the mass terms.

[0034] After determining the normal and tangential components of momentum P_N and PT and the spin loft θ in accordance with equations (7), (8), and (11), respectively, the computing device **20** can determine the club speed V_C utilizing equations (5) or (6) above. As will be noted, the computing device can advantageously determine the club speed V_C based, directly or indirectly, on measurements of the launch conditions of the ball as obtained by the launch monitor **12** as well as predefined values without any direct measurement of the club swing or club swing parameters. Thus, the system **10**, method and computer program product of exemplary embodiments of the present invention can indirectly determine club swing parameters, such as the club speed V_C and the loft angle θ, in a manner independent of any direct measurement of the club swing.

[0035] The angle of attack (AofA) of the club head relative to a ball also provides useful information to the golfer and gives quantifiable information on how his/her swing affects launch conditions. AofA can also be calculated by the computing device **20** from the measured launch conditions, and the predefined loft angle of the clubhead. In this regard, **FIG. 3** depicts an exemplary AofA and its relationship to the launch conditions of the ball. It should be noted that **FIG. 3** is a side view and shows the club and ball in the vertical plane and that AofA is negative.

[0036] The face of the club head has a loft angle as shown which is an inherent and predefined property of the club and the normal vector of the club head, that is, the vector normal to the face of the club, at the impact location is shown. The AofA is defined as the orientation of the clubhead relative to the horizontal axis at impact and may be defined as $AofA_1$ as follows:

$$AofA_1 = \text{Launch Angle} + \text{delta} - \text{Loft Angle} \tag{12}$$

where delta is given by

$$\text{delta} = \arctan\left(\frac{P_{TBS}}{P_N}\right) \tag{13}$$

[0037] Unlike the foregoing description of the tangential component of momentum P_T which was based upon the total spin ω_B of the ball, the tangential component of momentum P_{TBS} utilized in the equations (12) and (13) utilizes only the backspin ω_{BS} of the ball and not the sidespin ω_S or other spin components. In other words, the computing device **20** determines the tangential component of momentum P_{TBS} utilizing only the backspin ω_{BS} of the ball as follows:

$$P_{TBS} = \frac{\omega_{BS} I_B}{R_B} \tag{14}$$

[0038] However, the computing device **20** determines the normal component of momentum P_N in the same manner as described above. Thus, the computing device can determine delta based upon launch conditions of the ball that have been measured by the launch monitor **12** as well as predefined values. Once delta has been determined, the computing device can determine AofA, as defined above by equation (12) with the launch angle also being determined by the launch monitor as a launch condition of the ball and the loft angle being a predefined property of the club face. Thus, the system **10**, method and computer program product of the foregoing embodiment of the present invention can also determine the angle of attack, another club swing condition, based upon measurements of the launch conditions of the ball and predefined values associated with the ball and the club without any direct measurement of the club swing.

[0039] Another way to define AofA is to be the angle the swing path makes with the horizontal axis at the time of impact as shown in **FIG. 4**. As with **FIG. 3**, the AofA is shown to be negative in **FIG. 4** as the AofA extends below the horizontal axis.

[0040] As indicated by **FIG. 4**, spin loft is defined as the angle θ_L in the vertical plane between the swing path and the normal vector, that is, the vector normal to the club face at the impact location. Unlike the definition of spin loft θ described above and set forth in equation (11) which is based upon the total spin COB of the ball, the definition of spin loft θ_L utilized to determine the AofA is premised upon a tangential component of momentum P_{TBS} that is based only upon the backspin ω_{BS} of the ball and not the sidespin ω_S or other spin components. As such, the computing device **20** determines the tangential component of momentum P_{TBS} as set forth by equation (14) above and, in turn, determines the spin loft in the vertical plane θ_L in accordance with equation (11), albeit utilizing P_{TBS} as opposed to P_T.

[0041] As shown schematically by **FIG. 4**, the $AofA_2$ may be determined by the computing device **20** as follows:

$$AofA_2 = \text{Launch Angle} + \text{delta} - \text{Spin Loft} \tag{15}$$

which takes into account the swing path (through the spin loft component) and not just the orientation of the club face to a horizontal axis as In this regard, spin loft θ_L in the vertical plane and delta can be determined as described above with reference to equation (13) in regards to delta and the launch angle can be measured as a launch condition by the launch monitor **12**. As such, the system **10**, method and computer program product of the foregoing embodiment of the present invention can also determine $AofA_2$, another club swing condition, based upon measurements of the launch conditions of the ball and predefined values associated with the ball and the club without any direct measurement of the club swing. This expression takes into account the swing path and not just the orientation of the clubface relative to the horizon as in equation (12).

[0042] Another club swing parameter is club path which is defined as the path of the club head in the horizontal plane

prior to impact. The clubpath is usually referred to as being "in to out" or "out to in" meaning that a component of the path traveled by the club head was moving in directions generally away from the golfer and toward the golfer, respectively. The computing device can determine club path in a comparable manner to that described above in conjunction with AofA. In this regard, the club path may be defined as follow:

$$\text{Club path} = \text{Spin Loft} - \text{Launch Angle} - \text{delta} \quad (16)$$

[0043] Because the club path is in the horizontal plane, the tangential component of momentum P_{TS} utilized to determine delta and the spin loft utilizes only the sidespin ω_S of the ball and not the backspin ω_{BS} or other spin components. In other words, the computing device **20** determines the tangential component of momentum P_{TS} utilizing only the sidespin ω_S of the ball as follows:

$$P_{TS} = \frac{\omega_S I_B}{R_B} \quad (17)$$

[0044] The computing device **20** then determines delta and spin loft (actually the component of spin loft that defines how open or closed the clubface is at impact) utilizing equations (7) and (11), respectively, albeit with P_{TS} as opposed to P_T. Since the launch angle is a launch condition of the ball that has been measured by the launch monitor **12**, the computing device can determine the club path in accordance with equation (16). As with the other club swing conditions that have been described above to be determined by the computing device, the system **10**, method and computer program product of the foregoing embodiment of the present invention can also determine the club path based upon measurements of the launch conditions of the ball and predefined values associated with the ball and the club without any direct measurement of the club swing.

[0045] Accordingly, methods, systems and computer program products are provided according to the various embodiments of the present invention to permit golf swing conditions, such as spin loft, club speed, angle of attack and club path, to be determined without direct measurements of the club swing and, instead, to be based upon the launch conditions of the ball. As a result, a launch monitor can be utilized to capture the launch conditions of the ball such that the club swing conditions can then be determined. The golfers are accordingly provided meaningful information regarding their club swing conditions that will assist the golfer in improving their game without having to invest in additional training equipment.

[0046] Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

That which is claimed:

1. A method of estimating at least one club swing condition comprising:

determining a plurality of launch conditions of a ball;

determining a component of momentum P_N normal to colliding surfaces of the club and the ball and a component of momentum P_T tangent to the colliding surfaces of the club and the ball based upon the launch conditions of the ball; and

determining at least one club swing condition based upon the normal and tangential components of momentum P_N and P_T, wherein the at least one club swing condition is selected from the group consisting of spin loft, club speed, angle of attack and club path.

2. A method according to claim 1 wherein determining at least one club swing parameter comprises determining at least one club swing parameter in a manner independent of direct measurements of the club swing.

3. A method according to claim 1 wherein determining the tangential component of momentum P_T comprises determining the tangential component of momentum P_T based upon a radius of the ball, spin of the ball and a moment of inertia of the ball, and wherein determining the normal component of momentum P_N comprises determining the normal component of momentum P_N based upon a mass of the ball, a velocity of the ball and the tangential component of momentum P_T.

4. A method according to claim 1 wherein determining at least one club swing condition comprises determining spin loft based upon the normal and tangential components of momentum P_N and P_T, respective masses of the club head and the ball, a radius of the ball, respective moments of inertia of the ball and the club head, a velocity of the ball, and a distance in a tangential direction between a center of gravity of a club head and a location of impact between the club and the ball.

5. A method according to claim 1 wherein determining at least one club swing condition comprises determining club speed based upon the normal and tangential components of momentum P_N and P_T, respective masses of the club head and the ball and the spin loft.

6. A method according to claim 1 wherein determining the tangential component of momentum P_T and the spin loft comprises determining the tangential component of momentum P_T and the spin loft based upon backspin of the ball without consideration of other spin components of the ball, and wherein determining at least one club swing condition comprises determining the angle of attack based upon the normal and tangential components of momentum P_N and P_T, a launch angle of the ball and at least one of a loft angle of the club and the spin loft.

7. A method according to claim 1 wherein determining the tangential component of momentum P_T and the spin loft comprises determining the tangential component of momentum P_T and the spin loft based upon sidespin of the ball without consideration of other spin components of the ball, and wherein determining at least one club swing condition comprises determining the club path based upon the normal and tangential components of momentum P_N and P_T, a launch angle of the ball and the spin loft.

8. A system for estimating at least one club swing condition comprising:

a launch monitor capable of determining a plurality of launch conditions of a ball; and

a computing device capable of determining a component of momentum P_N normal to colliding surfaces of the club and the ball and a component of momentum P_T tangent to the colliding surfaces of the club and the ball based upon the launch conditions of the ball, said computing device being further capable of determining at least one club swing condition based upon the normal and tangential components of momentum P_N and P_T, wherein the at least one club swing condition is selected from the group consisting of spin loft, club speed, angle of attack and club path.

9. A system according to claim 8 wherein said computing device is capable of determining at least one club swing parameter in a manner independent of direct measurements of the club swing.

10. A system according to claim 8 wherein said computing device is capable of determining the tangential component of momentum P_T based upon a radius of the ball, spin of the ball and a moment of inertia of the ball, and wherein said computing device is further capable of determining the normal component of momentum P_N based upon a mass of the ball, a velocity of the ball and the tangential component of momentum P_T.

11. A system according to claim 8 wherein said computing device is capable of determining spin loft based upon the normal and tangential components of momentum P_N and P_T, respective masses of the club head and the ball, a radius of the ball, respective moments of inertia of the ball and the club head, a velocity of the ball, and a distance in a tangential direction between a center of gravity of a club head and a location of impact between the club and the ball.

12. A system according to claim 8 wherein said computing device is capable of determining club speed based upon the normal and tangential components of momentum P_N and P_T, respective masses of the club head and the ball and the spin loft.

13. A system according to claim 8 wherein said computing device is capable of determining the tangential component of momentum P_T and the spin loft based upon backspin of the ball without consideration of other spin components of the ball, and wherein said computing device is further capable of determining the angle of attack based upon the normal and tangential components of momentum P_N and P_T, a launch angle of the ball and at least one of a loft angle of the club and the spin loft.

14. A system according to claim 8 wherein said computing device is capable of determining the tangential component of momentum P_T and the spin loft based upon sidespin of the ball without consideration of other spin components of the ball, and wherein said computing device is further capable of determining the club path based upon the normal and tangential components of momentum P_N and P_T, a launch angle of the ball and the spin loft.

15. A system according to claim 8 wherein said launch monitor comprises said computing device.

16. A computer program product capable of estimating at least one club swing condition, the computer program product comprising a computer readable storage medium having computer readable code embodied in said medium, the computer readable code comprising:

a first executable portion adapted to receive a plurality of launch conditions of a ball;

a second executable portion adapted to determine a component of momentum P_N normal to colliding surfaces of the club and the ball and a component of momentum P_T tangent to the colliding surfaces of the club and the ball based upon the launch conditions of the ball; and

a third executable portion adapted to determine at least one club swing condition based upon the normal and tangential components of momentum P_N and P_T, wherein the at least one club swing condition is selected from the group consisting of spin loft, club speed, angle of attack and club path.

17. A computer program product according to claim 16 wherein said third executable portion is further adapted to determine at least one club swing parameter in a manner independent of direct measurements of the club swing.

18. A computer program product according to claim 16 wherein said second executable portion is adapted to determine the tangential component of momentum P_T based upon a radius of the ball, spin of the ball and a moment of inertia of the ball, and wherein said third executable portion is further adapted to determine the normal component of momentum P_N based upon a mass of the ball, a velocity of the ball and the tangential component of momentum P_T.

19. A computer program product according to claim 16 wherein said third executable portion is further adapted to determine spin loft based upon the normal and tangential components of momentum P_N and P_T, respective masses of the club head and the ball, a radius of the ball, respective moments of inertia of the ball and the club head, a velocity of the ball, and a distance in a tangential direction between a center of gravity of a club head and a location of impact between the club and the ball.

20. A computer program product according to claim 16 wherein said third executable portion is further adapted to determine club speed based upon the normal and tangential components of momentum P_N and P_T, respective masses of the club head and the ball and the spin loft.

21. A computer program product according to claim 16 wherein said second and third executable portions are further adapted to determine the tangential component of momentum P_T and the spin loft based upon backspin of the ball without consideration of other spin components of the ball, and wherein said third executable portion is further adapted to determine the angle of attack based upon the normal and tangential components of momentum P_N and P_T, a launch angle of the ball and at least one of a loft angle of the club and the spin loft.

22. A computer program product according to claim 16 wherein said second and third executable portions are further adapted to determine the tangential component of momentum P_T and the spin loft based upon sidespin of the ball without consideration of other spin components of the ball, and wherein said third executable portion is further adapted to determine the club path based upon the normal and tangential components of momentum P_N and P_T, a launch angle of the ball and the spin loft.

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