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(54) **SYSTEM AND METHODS FOR PROVIDING PERFORMANCE FEEDBACK**

(71) Applicant: **ISOLYNX, LLC**, HAVERHILL, MA (US)

(72) Inventors: **Douglas J. DeAngelis**, Ipswich, MA (US); **Edward G. Evansen**, West Newbury, MA (US)

(57) **ABSTRACT**

Systems and methods provide feedback to at least one participant in a field of play. A performance analysis device determines performance information of each participant in the field of play, where the performance information is based upon at least one of determined location, speed, path, acceleration and biometrics of said each participant. At least one output device provides real-time feedback to the at least one participant based upon the performance information. The real-time feedback comprises performance information of the at least one participant and/or performance informa- tion of one or more other participants in the field of play.

100

108

110(2)

110(3)

110(1)

106(1) ⬜ 112(1)

144

106(4) 112(4)

112(2)

106(2)

112(3)

106(3)

110(4)

110(5)

119

126

| OBJECT TRACKING DEVICE 102 | → | CAMERA CONTROL DEVICE 104 |

126

127

RECORDING DEVICE 120

105

HH DEVICE 142

140

DISPLAY DEVICE 130

FIG. 1

FIG. 2

300

FIG. 3

400

FIG. 4

500

300

400

FIG. 5

600

608

609

606(1) 612(1) 606(2) 606(3) 606(4)

644(1) 646(1)

646(5) 612(5)

HH DEVICE
642

644(5)

606(8)

606(7) 606(6) 606(5)

652

PERFORMANCE ANALYSIS DEVICE 602

640

PERFORMANCE
MONITOR 622

STRATEGY
MANAGER 626

FEEDBACK
GENERATOR 624

RECORDING DEVICE 620

PROFILE DATA
621

STRATEGY
DATA 627

DISPLAY DEVICE 630

FIG. 6

SYSTEM AND METHODS FOR PROVIDING PERFORMANCE FEEDBACK

RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 15/386,265, filed Dec. 21, 2016, which is a continuation of U.S. patent application Ser. No. 13/231, 802, filed Sep. 13, 2011, now U.S. Pat. No. 9,566,471, which is a continuation of International Patent Application No. 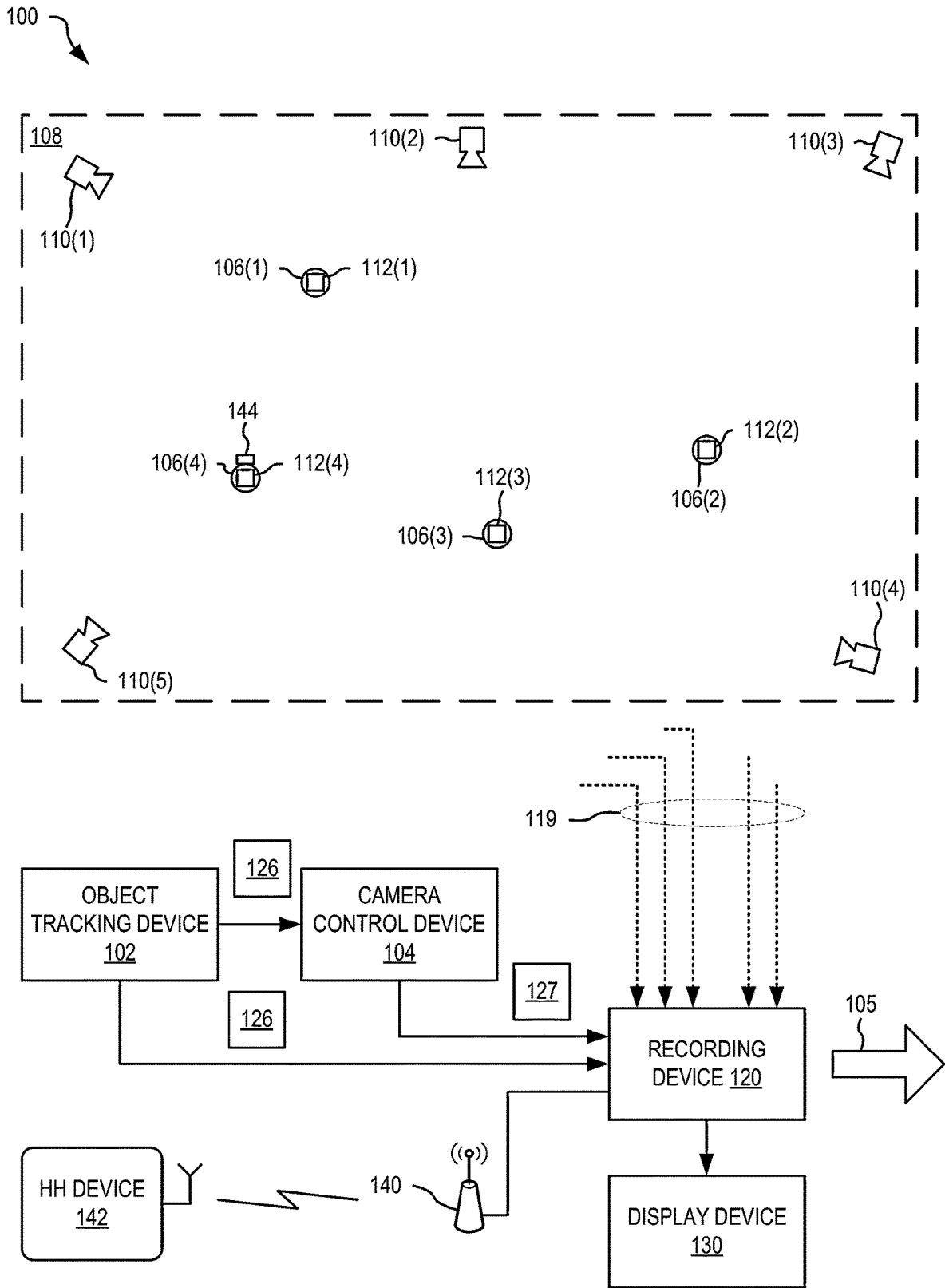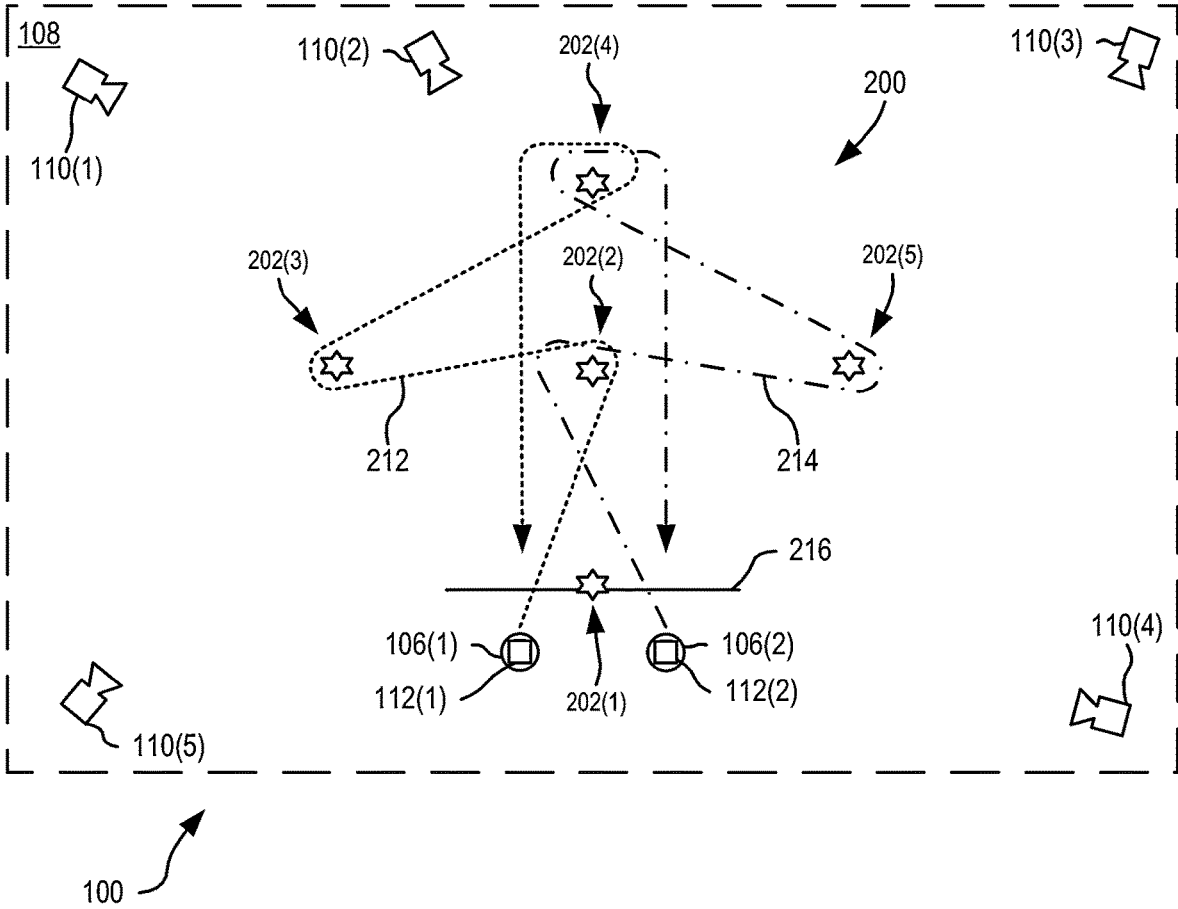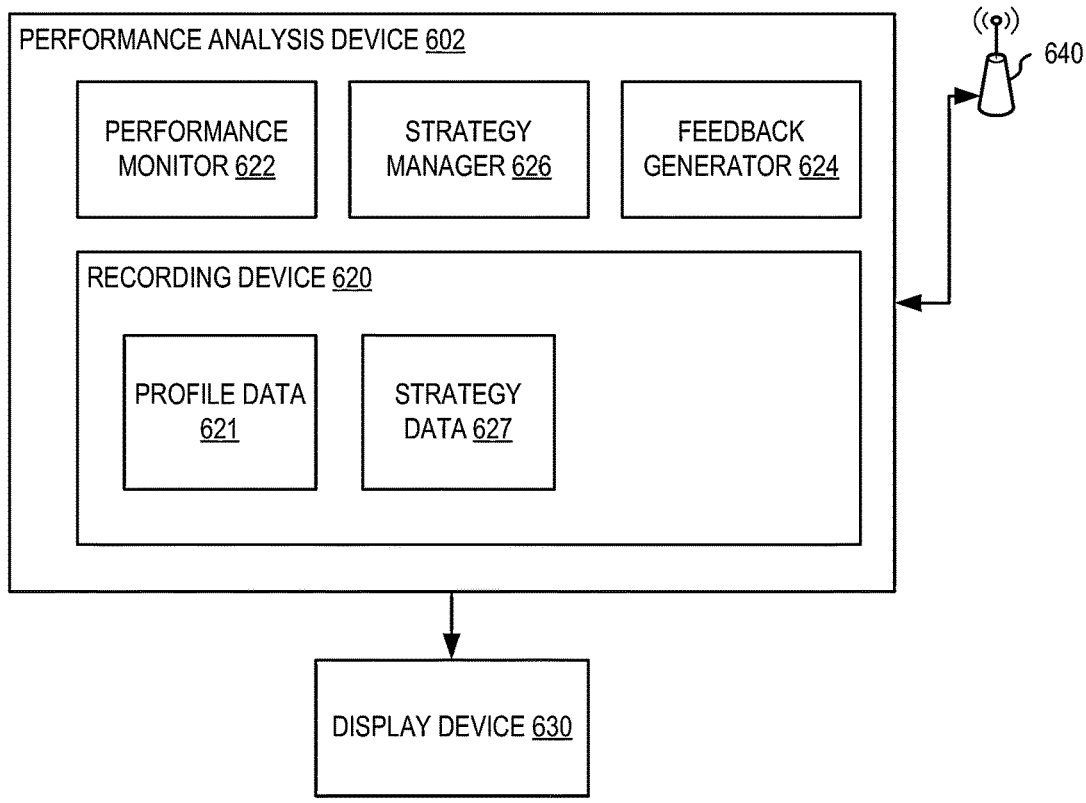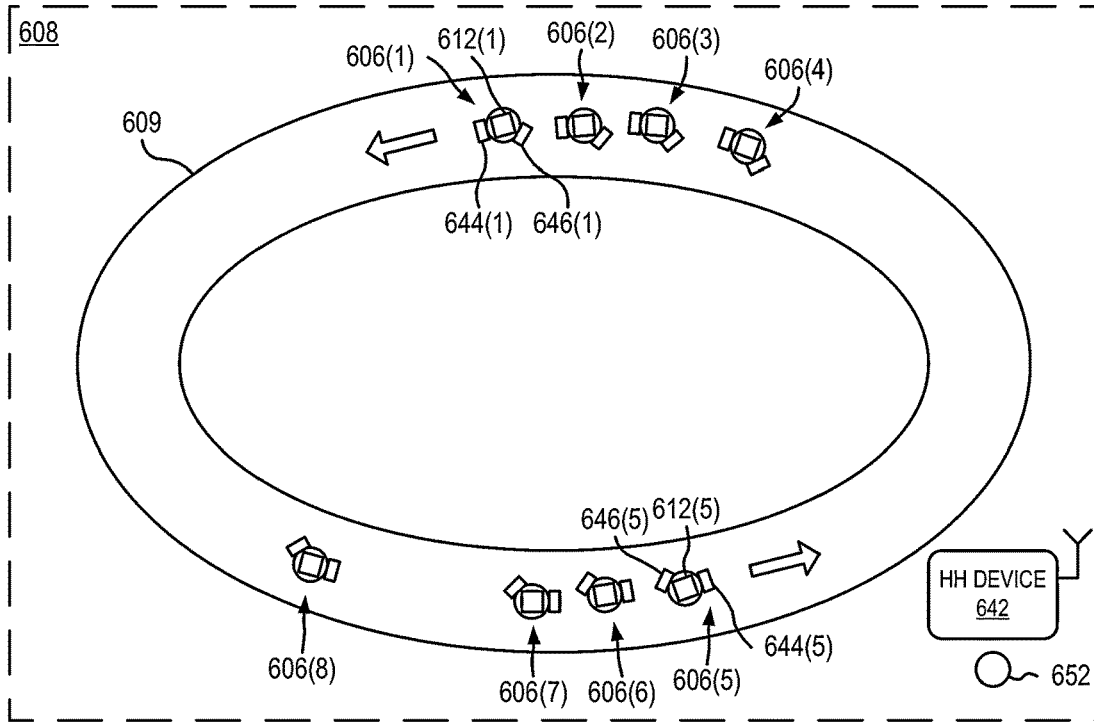PCT/US2010/027349, filed Mar. 15, 2010, which claims priority to U.S. Patent Application No. 61/160,141, filed Mar. 13, 2009. Each of these applications is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Traditionally, video and still images of a live event (i.e., video content and still image content) are created by a team of professionals. In the case of video content, highly trained camera persons operate one or more cameras and highly trained production staff operate production equipment (e.g., within a production van at a sporting event) to select camera shots and combine graphics into a production feed. In the case of still image content, highly skilled camera persons operate still cameras to capture still images of an event and submit these still images to one or more editors who select shots for use in magazines, for example.

[0003] The cost of producing video and still image content defines the market size required to cover this cost. Thus, only events having a sufficient market justify the cost of producing video and still image content. Although technology has reduced the cost of production, the cost of skilled human operators remains high.

[0004] Images from a camera may be used to visually track an object (e.g., a golf ball) within the camera's field of view. The camera may be motorized to allow it to move so as to maintain the moving object within its field of view. However, such systems fail when the camera 'loses sight' of the object; for example, the camera may lose sight of the object if the object becomes visually obscured by another object.

[0005] For certain sporting events, cameras may be motorized to facilitate tracking of competitors and are operated by remote camera operator. These cameras still require the skill of a person.

[0006] Many systems have been developed to track objects by attaching a sensor to the object and then using the sensor to determine the location of the object. Such object tracking provides data (e.g., speed) to computer systems but is not known to facilitate real image production.

SUMMARY OF THE EMBODIMENTS

[0007] In an embodiment, a system provides feedback to one or more participants in a field of play. The system includes a performance analysis device for determining performance information of each participant in the field of play. The performance information is based upon at least one of determined location, speed, path, acceleration and biometrics of the participant. The system also includes at least one output device for providing real-time feedback to the participants based upon the performance information.

[0008] In another embodiment, a system provides feedback to a leader of one or more participants in a field of play. The system includes a performance analysis device for determining performance information of each of the participants, where the performance information is based upon at least one of determined location, speed, path, acceleration and biometrics of said each participant. The system also includes an output device for providing real-time feedback to the leader based upon the performance information.

[0009] In another embodiment, a method provides feedback to at least one participant in a field of play. Successive locations of the participant within an operational field are determined. Performance of the participant is determined based upon the successive locations, real-time feedback is provided to the participant based upon the determined performance.

[0010] In another embodiment, a system provides feedback to at least one participant in a field of play. The system includes a performance analysis device for determining performance information of each participant in the field of play, where the performance information is based upon at least one of determined location, speed, path, acceleration and biometrics of said each participant. The system also includes at least one output device for providing real-time feedback to the at least one participant based upon the performance information.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 shows one exemplary system for capturing performance data of tracked objects moving within an operational field, in an embodiment.

[0012] FIG. 2 illustrates use of the system of FIG. 1 for measuring skill and performance of training athletes performing a drill.

[0013] FIG. 3 shows one exemplary Perfect Execution template.

[0014] FIG. 4 shows one exemplary plot of data captured during a play.

[0015] FIG. 5 shows one exemplary overlay of the plot of FIG. 4 and the template of FIG. 3.

[0016] FIG. 6 shows one exemplary system for providing performance feedback, in an embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0017] FIG. 1 shows one exemplary use of a system 100 for capturing performance data of tracked objects 106 moving within an operational field 108. Objects 106 for example represent runners, football players, speed skaters, race cars or horses and/or jockeys, and field 108 represents a running track, a football field, an ice rink, a race track or a horse track, respectively.

[0018] System 100 is shown with an object tracking device 102, a recording device 120, a display device 130, an optional camera control device 104 and five optional motorized cameras 110. If included, cameras 110 may be situated within or around operational field 108. Four exemplary objects 106 are shown within field 108, each object having a location unit 112.

[0019] Object tracking device 102 utilizes location units 112 to determine location information (e.g., coordinate data) for objects 106 within operational field 108. Object tracking device 102 sends this location information to recording device 120 and optionally to camera control device 104. Camera control device 104 may include a model of operational field 108, with coordinates of each camera 110.

Camera control device **104** receives coordinate data of objects **106** from object tracking device **102**, determines a possible field of view from each camera **110** to each object **106**, and assigns cameras **110** to the objects based upon optimum field of view selection. For example, for each camera **110** and for each object **106**, camera control device **106** determines a possible field of view from the camera to the object. Then, by selecting an optimum field of view for each object (e.g., based upon the distance from the camera to the object, the objects position within field **108** and whether all objects are assigned to a camera), control device **104** determines which camera **110** to assign to each object **106**. Where the number of objects is less that the number of cameras, camera control device **104** may assign more than one camera **110** to an object **106**. Where the number of objects is more than the number of cameras, camera control device **104** may assign one or more select cameras **110** to a more important object **106** (e.g., the leader in a race). Each object **106** is for example prioritized such that cameras assignment is also prioritized for that object—in a race, the leader is assigned a higher priority to ensure best camera assignment.

[0020] As objects **106** move within field **108**, object tracking device **102** may provide, for each object **106**, velocity and position information **126** to recording device **120** and to camera control device **104**. Camera control device **104** uses this velocity and position information for optimal camera assignment to each object **106**. Thus, camera control device **104** may be made aware of movement characteristics (e.g., direction of movement) of objects **106**, and accordingly assigns or re-assigns cameras based upon camera fields of view that include the front of object **106**. Further, camera control device **104** for example assumes that the front of object **106** faces forward as it moves, or it may instead be programmed to identify the front of object **106** as the aspect facing the general direction of movement of an event. Camera control device **104** accordingly assigns and controls cameras **110** to capture frontal and side image data of object **106**, in preference to rear images.

[0021] Recording device **120** records velocity and positional information **126** received from object tracking device **102** and may record and/or convert image data **119** from each camera **110**. Camera control device **104** may also provide annotation data **127** to recording device **120** such that recording device **120** may record relevant camera information (e.g., zoom, direction and azimuth) with velocity and positional information **126**.

[0022] In one embodiment, recording device **120** simultaneously records image data **119** from each camera **110**, velocity and position information **126** and annotation data **127**. Image data **119** is a signal or signals representing data bits captured by each camera **110**. Recording device **120** includes processing software for converting the received signal into a data stream and interpreting the data stream as a series of images, which are then recorded as video, for example. System **100** is thus suitable for use in autonomous still or moving picture production.

[0023] Camera control device **104** sends annotation data **127** to recording device **120** for recording with image data **119**. Annotation data **127** includes identification of tracked objects of image data **119**. For example, if camera **110(1)** is selected to maintain object **106(1)** within its field of view, as the image data from camera **110(1)** is recorded by recording device **120**, camera control device **104** may include identi-

fication of object **106(1)** within annotation data **127** that is recorded with the image data.

[0024] Recording device **120** may generate a live feed **105** (optionally including annotation data and performance characteristics of displayed objects) and allow interaction with a user through display device **130**.

[0025] Recording device **120** may display images from selected cameras **110** on display device **130** together with measured performance statistics.

[0026] Recording device **120** may include additional functionality for determining performance statistics and movements of objects **106**. In one example, recording device **120** shows a plan view of at least part of field **108** on display **130** and plots movement of objects **106** over select periods. Recording device **120** may also determine performance data for objects **106** and include this performance data, e.g., as a video overlay, when recording image streams of object **106** and/or when displaying select image streams on device **130** and/or live feed **105**. This video overlay is for example formatted as tabulated figures that include the performance statistics and/or a graphical representation of the performance of object **106**.

[0027] In another embodiment, recording device **120** replays recorded image data **119**, velocity and position information **126** and annotation data **127** as feed **105** featuring one or more objects **106**. Where system **100** is utilized as a training device by a sports team, recording device **120** may be operated to generate output for image feed **105** and/or display device **130** by overlaying velocity and position information **126** and annotation data **127** onto image data **119** for one or more selected athletes. Thus, recording device **120** automatically displays recorded image streams and performance information of the selected athlete. The video overlay and performance information included therein is variable according to sport and/or preference or selection of a user of recording device **120**. In one example, live feed **105** may drive a large stadium display during practice to highlight training performance.

[0028] In one embodiment, recording device **120** delivers instant replay images or video streams that include overlaid performance information determined from velocity and position information **126** and/or annotation data **127** for the object(s) **106** associated with the selected image data **119**.

[0029] In another embodiment, recording device **120** generates live image feed **105** by combining a video overlay of performance information selected from velocity and position information **126** and/or annotation data **127** and image data **119**. In particular, recording device **120** of this embodiment matches performance information from annotation data **127** to image data **119** for each object **106** to which a camera **110** is assigned.

[0030] Recording device **120** may also connect to (or include) a wireless transceiver **140** that communicates with a hand held display and control device **142** to allow a coach to utilize system **100** while on a practice field. Further, transceiver **140** may communicate wirelessly with one or more head-up-display devices, such as glasses **144**, worn by athletes to provide real-time display of performance related information and other training aids. Glasses **144** may utilize, for example, Light-guide Optical Element (LOE) technology, such as that employed in Video Eyeglasses manufactured by Lumus Ltd.

[0031] Skill Evaluation and Improvement

[0032] Real time position data may be used to measure, evaluate and compare athlete skill parameters such as velocity, acceleration and change of direction agility on predefined drill paths. In addition, using velocity and position information **126** to control cameras **110** to track objects **106** within field **108**, skill and performance of athletes represented by objects **106** may be evaluated when performing these predefined drills, such that mechanics of the athlete may be evaluated and corrections made to the athlete's techniques to improve future performance.

[0033] Data Only: Performance Evaluation

[0034] FIG. **2** shows use of system **100**, FIG. **1**, for measuring skill and performance of training athletes performing an arrowhead drill **200** within field **108**. Arrowhead drill **200** involves two athletes (represented as objects **106(1)** and **106(2)**), five cones **202(1)-202(5)** placed five yards apart as depicted in FIG. **2**, and two discrete paths **212** and **214**.

[0035] The first athlete (object **206(1)**) starts out from a start/finish line **216** on path **212** and the second athlete (object **206(2)**) starts on path **214** once the first athlete has reached cone **202(2)**. By continually or periodically monitoring velocity and position of objects **206** while performing arrowhead drill **200**, system **100** may determine agility of each athlete. For example, determining speed, acceleration and change of direction for each athlete may be measured as a continuous function over one or more predefined drill paths to provide significantly more detailed information on the athletes' agility and skill level than by evaluating speed and acceleration as average values between discrete points using fixed measurement devices (such as stop watches, touch pads and photocells), as previously done. The collection of velocity and positional information (i.e., velocity and positional information **126**) eliminates the need for mechanical measurement devices along the drill path and allows velocity and acceleration data to be determined at any point along the path(s).

[0036] Performance drills are intended to predict the eventual success level of an athlete in real world situations. In the most primitive form, a stop watch collects time from start of the drill to completion to provide a gross measure of overall performance and may be useful as a first pass selection of athletes. However, this simple timing measurement gives no indication of how the athlete performed each element of the drill. Discrete measurement points along the path may be added to provide additional information, but since they are limited to discrete points along the path, this additional information is still limited to average performance measurements of the drill elements.

[0037] The collection of continuous data by system **100** provides complete performance measurements, such as velocity and acceleration, at all points along each element of the drill. In football drills, such as arrowhead drill **200** of FIG. **2**, these parameters are particularly critical at turning (cutting) points. Continuous data collection allows fine distinction between the performances of multiple athletes. This distinction may be critical in determining how well an athlete should perform in a real world situation. For instance, a first and second athlete may have the same overall time when performing a drill; however, the first athlete may be achieving this time by an ability to cut right and accelerate exceptionally well, while being slow in cutting and accelerating left. In contrast, the second athlete may cut and accelerate equally well to both the right and the left. In real world situations of a football game, the second athlete with balanced ability should consistently outperform the first athlete who is unbalanced, since defenders facing the second athlete will not be able to predict which way the second athlete will choose to cut as the second athlete has equal ability in both directions, whereas the first athlete would typically favor his fastest cut direction.

[0038] Thus, by monitoring velocity and position information continually (or periodically) for each athlete, weaknesses and strengths of each athlete may be easily measured.

[0039] In the simplest form, continuous real time position data collection may be employed on a 40 yard dash. Although existing systems provide total time and split times at discrete points along the path, from which the average velocity and acceleration between the split points can be calculated, these average values are limited by the positions of the discrete points. Since system **100** may collect position information in real time, velocity and acceleration values may be determined as a continuous function, allowing plots of instantaneous velocity and acceleration at any point along the 40 yard path.

[0040] The 40 yard dash and arrowhead drill **200** are used as examples and should not be used to limit the scope hereof. The advantages of real time data collection over existing discrete measurement systems hold true for all practice drills in all sports.

[0041] Data and Camera Integration: Performance Evaluation and Improvement

[0042] Camera control device **104**, FIG. **1**, may use velocity and position information **126** from object tracking device **102** to automatically aim one or more cameras on one or more athletes performing a drill path such that recording device **120** may record video of the athlete's motion and performance data. For example, recording device **130** may generate one or more displays (e.g., on display **130**, video feed **105**, handheld device **142** and/or heads-up-display device/glasses **144**) showing direction vectors and/or acceleration plots overlaid onto video of the athlete performing the drill to allow a coach to evaluate the athlete's mechanics and performance at specific points on the drill path. The coach may replay this video and data overlay to make determinations between athletes and in coaching methods for athletes to improve their individual performance.

[0043] Practice Field: Evaluation and Productivity

[0044] Data Only and Camera Integration: Keep Practice Productive

[0045] On a practice field it is often difficult, if not impossible, to know where all players are at all times. This is especially true when players have assignments on multiple squads such as offense, defense and any one of the special teams. If the coach cannot find an athlete, that athlete may miss important coaching advice and training. Further, one athlete missing from a training session may prevent training of ten other players on a squad until the missing athlete is found. Much valuable practice time is often lost due to players not being in the right location.

[0046] Since system **100** collects real time position information for all objects **106** continually, a coach may determine the location of any athlete by identifying the player (e.g., entering the player's number) to system **100** such that recording device **120** may display the current location of the player to the coach. In one example of operation, a coach enters a player's number into handheld device **142** and recording device **120** displays a plan of field **108** showing

the location of the selected player. Optionally, system **100** may be configured and/or operated to display live video imagery of the player's activity to the coach on handheld device **142** by activating one or more cameras **110** to image the current location of the selected player. Thus, through the use of system **100**, the coach learns the location of the selected player and can see the activity of that player, thereby allowing an instantaneous decision as to whether to call on him, wait for him or select a substitute.

[0047] Data Only: Assignment Verification

[0048] Collected, real time position data of an athlete(s) continuous position during a play can be used to determine whether the athlete correctly performed his specific assignment. As an example, consider an offense practicing plays where the receiver routes are of particular interest.

[0049] Assignment Verification Operation:

[0050] "Perfect Execution" Capture:

[0051] Eleven players may be outfitted with positioning tags so that their exact positions can be recorded as a play is executed. After diagramming the play, the players may walk through the play exactly as it is supposed to be executed. The data from all eleven players is plotted and saved in a play library as a template, such as Perfect Execution template **300**, FIG. **3**, for later comparison against subsequent executions. For simplicity, only the receiver paths are shown in template **300**; however, in most cases the paths of all eleven players would be captured, plotted and stored. This can be done for all plays in a playbook and the "Perfect Execution" need only be captured once for each play.

[0052] "Practice Execution" Capture:

[0053] The players are told to run a specific play. This play may be executed at walk through speed, half speed or full speed. The real time continuous position of each player is captured as the play unfolds Immediately following the play, the data for each player is plotted. An example of such a plot is shown in FIG. **4**. For ease of illustration, Practice Execution plot **400** shows only the receiver paths; however, in most cases the paths of all eleven players would be captured and plotted.

[0054] Assignment Verification:

[0055] The Practice Execution plot **400** is then overlaid on the Perfect Execution template **300** for immediate evaluation by coaches on the field. An example of such an overlay is shown by overlay **500**, FIG. **5**. The solid lines represent perfect execution template **300** and the dashed lines represent practice execution plot **400**. From this example, it is immediately obvious that the tight end and wide receivers ran their assigned routes reasonably close to design while the tailback clearly deviated from his assigned route.

[0056] Overlay Automation:

[0057] For practical implementation, Perfect Execution template **300** and Practice Execution plot **400** overlay automatically. Furthermore, the overlay may be independent from where the data for each was collected. For example, Perfect Execution template **300** may be collected in a gym while Practice Execution plot **400** may be collected on a practice field days or even years later. In addition, successive plays may originate from different points on the practice field, and they could be moving in either direction.

[0058] Automatic overlay is accomplished by selecting two stable reference points whose relative starting positions to each other are known. For instance, in both Perfect Execution template **300** and Practice Execution plot **400**, the position of the right tackle is known and stable relative to the position of the left tackle. Therefore, this relationship can be used in establishing the overlay starting point.

[0059] Data and Camera Integration: Mechanics and Performance Evaluation:

[0060] Real time position data is used to aim a camera(s) automatically at specific athletes of interest during a practice play execution to record video of the execution. The number of athletes videoed is limited only by the number of cameras. The video can be viewed in real time, while the play is being executed, or saved and reviewed later.

[0061] Real-Time Video and Performance Data:

[0062] The video stream from the camera is transmitted to a handheld or tablet computer being held by a coach on the field. The coach selects the player of interest on the screen before the play is executed. While the play is being executed, the camera isolates on this player and the video is streamed to the handheld for the coach to view in real time. As the player moves on the field a yellow line indicating the path traveled is laid down on the image of the field. A data window on the screen also indicates the current velocity and acceleration of the player.

[0063] Replay of Video and Performance Data:

[0064] In addition to streaming the video to the handheld, the video is also streamed to disk. The stored video can be used on the field by the coach for instant replay, which can be used in coaching the player. The replay video can be stopped at any point to freeze the action and highlight specific situations. The coach can also access the velocity and acceleration of the player at any point by touching the screen on the yellow path indication line.

[0065] Post Analysis of Video and Performance Data:

[0066] All continuous position, velocity, acceleration and path data, as well as video, from a practice session can be stored for post analysis. Successive plays can be compared to isolate what performance elements contributed to the success or failure of a particular play execution. For instance, in the case of a wide receiver running a route and being covered by a defender.

[0067] Post Analysis Use of Video:

[0068] Video can be used to analyze the receiver's body motion while running his route and distinguish between moves that are "fakes" (i.e., moves which are successful in confusing a defender), resulting in a successful play, from moves which did not confuse the defender, resulting in an unsuccessful play.

[0069] Post Analysis Use of Data Parameters:

[0070] Data such as velocity and acceleration at any point along the path traveled can be compared to identify the precise point at which burst of acceleration is particularly successful in getting distance between the receiver and the defender.

[0071] While the examples above involve an offensive play, identical situations exist for defensive plays as well as all special teams plays.

[0072] Integration of Real Time Data with Audio Feedback: Training and Task Execution

[0073] The collection of continuous real-time position data can be used in conjunction with an "in helmet" audio system to assist players in learning and perfecting new tasks. The audio system is mounted in the player's helmet in stereo fashion with a miniature speaker at the left and right ears. The speakers operate independently allowing specific information to be communicated to the player, in real time,

through variations in tone and volume. The following are examples of how this might be used to train various player positions but the same principles could be applied to all positions in learning and perfecting new tasks.

[0074] Audio Feedback: Quarterback Example

[0075] To be an effective passer, a quarterback must know how much time he has in "the pocket" before he must get rid of the ball or run. The most basic parameter is time, which is measured in seconds (typically 3.5 or less). Failure to wait as long as possible could mean making a bad decision or throwing before a receiver has had time to get open. However, waiting 1 ms too long could result in a sack or career-ending injury.

[0076] Continuous real time data in conjunction with audio feedback can be used in helping a quarterback to learn the optimal time in the pocket. Real time position data is used to determine when the quarterback is located in the pocket. As soon as he is in position a timer start and a beeping sound is sent to the speakers in his helmet. This beeping increases in frequency as time expires. The frequency continues to increase until the maximum time has elapsed and the beeping becomes a steady tone.

[0077] In the real world, the maximum amount of time a quarterback has in the pocket may be cut short by defenders reaching him more quickly than anticipated. To be effective in this situation a quarterback must learn to "feel" the pressure of defenders. Defensive pressure usually comes from the left or right side and in this case the quarterback must sense the pressure through peripheral vision. Since he is focused down field looking for potential receivers this can be a difficult skill to master. By tracking the real time position of the defenders their proximity to the quarterback is easily determined. To aid the quarterback in learning to "feel" this pressure the beeping frequency can be increased more rapidly to reflect the decreasing available time in the pocket and the volume of the right or left speaker can be increased to indicate the specific direction the pressure is coming from.

[0078] Audio Feedback: Receiver Example

[0079] For a receiver to be effective, he must be where the quarterback expects him to be. The most basic element of this is running the proper route. Continuous real time position data in conjunction with audio feedback can be used to help the receiver learn his routes quickly and accurately so that he runs them the same every time.

[0080] When the receiver first begins his route, there is tone of equal volume in both speakers. As he moves along the path, the system senses his position and slowly increases the volume in the ear on the side to which he will eventually cut. Upon arriving at the cut point, the volume in the speaker on the side of the cut hits a peak and the speaker on the opposing side shuts down completely.

[0081] The second element of being in the right place, and eluding defenders, involves running the various legs of the route at different speeds. In this instance, the tone in the example above would be replaced by a beeping sound. The frequency of the beeping indicates the speed at which the receiver should be running. In a simple case, a low frequency would represent a jogging speed, a medium frequency would represent a medium speed run and a high frequency beeping would present full speed. The system controls the beeping frequency by sensing what leg of a route the receiver was on and delivering the preprogrammed speed message. In an alternate embodiment, the beeping

may have a frequency based upon a desired cadence for the athlete, thereby indicating the desired running speed.

[0082] Both messages (speed and direction) can be delivered to the receiver by employing the volume and beeping frequency described above simultaneously. The beeping frequency indicates the speed to run and the volume of the beeping in the right or left ear indicates the direction to turn.

[0083] Integration of Real Time Data with Visual "Heads-up" Feedback: Training and Task Execution

[0084] The collection of continuous real-time position data can be used in conjunction with "heads up" technology to assist players in learning and perfecting new tasks. The heads-up technology consists of a pair of transparent glasses 144 (FIG. 1), worn by the player, which have the capability to accept wireless data and project this data in the form of images, which appear to the player to be at some distance in front of the glasses.

[0085] PATENT Attorney Docket No. 614755

[0086] Visual Heads-up Feedback: Quarterback Example

[0087] Time in the Pocket:

[0088] To be an effective passer, a quarterback must know how much time he has in 'the pocket' before he must get rid of the ball or run. The most basic parameter is time, which is measured in seconds (typically 3.5 or less). Failure to wait as long as possible could mean making a bad decision or throwing before a receiver has had time to get open. However, waiting 1 ms too long could result in a sack or career ending injury.

[0089] Continuous real time data in conjunction with heads-up technology can be used in helping a quarterback to learn the optimal time in the pocket. Real time position data is used to determine when the quarterback is located in the pocket. As soon as he is in position, a timer starts and bar graphs located in both the far right and left corners of his vision begin growing. When there is 0.5 seconds remaining the graphs begin blinking and when time has expired, they turn solid red.

[0090] In the real world, the maximum amount of time a quarterback has in the pocket may be cut short by defenders reaching him more quickly than anticipated. To be effective in this situation a quarterback must learn to "feel" the pressure of defenders. Defensive pressure usually comes from the left or right side and in this case, the quarterback must sense the pressure through peripheral vision. Since he is focused down field looking for potential receivers this can be a difficult skill to master. By tracking the real time position of the defenders, their proximity to the quarterback is easily determined. To aid the quarterback in learning to "feel" this pressure the bar graphs can be increased more rapidly to reflect the decreasing available time in the pocket. In addition, the system can sense the specific position of the defenders and they can be represented by dots that start out at the far most sides of the glasses and move toward the center as the defenders get closer. When the defender dot reaches the center of the vision area, the defender has reached the quarterback.

[0091] Receiver Looks:

[0092] In any passing play, a quarterback has multiple receivers to select from and a limited time to make the best selection. The process of deciding which receiver to throw to is referred to as "receiver looks". The most effective quarterbacks are those who methodically move through these looks to find the best receiver to throw to. Typically, there will be a primary look, the receiver the ball is intended

to go to, a secondary look, the receiver the quarterback will consider if the primary is tightly covered and a safety valve. The safety valve is a receiver positioned such that the quarterback can dump the ball off when he has reached his maximum time in the pocket (described above). Note that a quarterback typically only has 1.2 to 1.5 seconds to evaluate each of his receivers so this is not an easy skill to perfect, especially under defensive pressure.

[0093] Continuous real time data in conjunction with heads-up technology can be used in helping a quarterback learn to rotate methodically through his available receivers. As the quarterback drops back into the pocket, the dynamic position of the primary receiver appears as a dot in his vision. Since the system is sensing the actual position of the primary receiver this dot represents the actual, relative position of the receiver. If the receiver starts out on the left side and runs straight up the field, then the dot will start in the bottom left hand side of the vision and move up the left side of the vision. If the receiver runs across the middle then the dot will start out in the bottom left and move up and left to right through the vision. As an aide to help the quarterback rotate at the right time, the receiver dot begins to blink at programmed time (say 1 second). At a preprogrammed time (say 1.5 seconds) the primary receiver dot turns off and the secondary receiver dot turns on and functions in the same manner as the primary receiver dot. Following the second interval (say 1.5 seconds or total of 3 seconds), the safety receiver dot turns on. Optionally, dots corresponding to multiple potential receivers are shown simultaneously in the quarterback's vision, allowing the quarterback to select the best receiver (e.g., the receiver in a most desired position) to throw to, from multiple options.

[0094] Team Position Reads:

[0095] Real time position of all or select members of a team may also be represented with heads-up technology, enabling a player (e.g., the quarterback) to determine when other players are in or approaching a desired position. For example, position of players involved in a predetermined play may appear as dots in the quarterback's vision. When the dots achieve or approach a desired formation, indicating that players are in position for or moving into position for the play, the quarterback may initiate the play.

[0096] Combining Time in the Pocket and Receiver Reads:

[0097] As a quarterback's training progresses the time in pocket feedback and receiver look elements can be integrated to provide the quarterback with maximum real-time feedback to become a more effective and efficient passer.

[0098] Simulated Use of Heads-up Feedback:

[0099] Once data has been captured while using this system in practice with real receivers and real defenders, it can be replayed at any time. This allows the quarterback to practice and experience the live situation without all of the other players being present thus allowing them to work on perfecting their own individual roles. This is essentially a video game where the quarterback is an active participant and the actions of the receivers and defenders are derived from data of his actual teammates. This allows players in skill positions, such as quarterbacks, to maximize the amount of time they spend perfecting their role, under life like conditions, without requiring the other 21 players to be present. This video game like ability yields an unprecedented advance in the training of skill position players.

[0100] Visual Heads-up Feedback: Receiver Example

[0101] Route Definition:

[0102] In this situation the heads-up glasses display is used much like the display on a GPS. The receiver is able to look right through the transparent glasses but a line indicating the specified route would be projected in front of him. The system continuously senses the receiver's position and as he traveled down each leg of the route, the path would get shorter and shorter until he reached a turning, or cutting, point. As soon as he made his cut, the next leg of the route would turn upward indicating forward motion in that direction.

[0103] Route Speed:

[0104] Each leg of a route may have a different ideal speed and in some cases, there may even be multiple speeds per leg. As the receiver moves along the path, specified by the route definition method described above, the ideal speed in feet/second is projected in his field of view. The system continuously monitors his current speed and displays this next to the ideal speed. The system monitors the athlete's performance in real time and may provide visual indications to the athlete when the athlete meets certain desired criteria, or when those criteria are not being met by the athlete. For example, if the athlete needs to speed up then his actual speed may be projected in green and if he needs to slow down then it may be projected in red.

[0105] Game Time: Coaching

[0106] Data Only: Assignment Verification

[0107] Assignment verification can be employed in a game situation in exactly the same way it is employed during practice sessions. This provides coaches with real time feedback as to which players are performing their assignments accurately and consistently.

[0108] Data Only: Fatigue Analysis

[0109] Various parameters such as time on the field and distance traveled may be tabulated and used to determine when a player's effectiveness may be diminishing.

[0110] Time on the Field

[0111] The total amount of time a player is on the field during a quarter, half or game can be determined by accumulating time when the player is located in the region of play defined by the playing field and both end zones. This parameter can be made even more relevant by associating the time accumulation with the playing clock such that time on the field is only accumulated when the game clock is running.

[0112] Distance Traveled

[0113] In many skill positions, such as running backs, defensive backs and receivers, total distance traveled by the athlete may be a more accurate determinant of fatigue than time on the field. The total distance traveled by an athlete during a quarter, half or game can be determined by accumulating distance traveled when the player is located in the region of play defined by the playing field and both end zones.

[0114] Data and Camera Integration: Opposition Evaluation

[0115] Real time position data is used to aim a camera(s) automatically at the area "around" a specific athlete of interest. By aiming a camera at the area around a specific athlete it is possible to determine how the opposition is responding to specific actions of the athlete of interest. For instance, by aiming a camera at the area around a wide receiver the defensive backfield rotations and/or assignments of the opposition can easily be determined.

[0116] FIG. 6 shows one exemplary system 600 for providing performance feedback. For purposes of example, system 600 is described below with respect to athletes.

However, it will be appreciated that system **600** is not limited to use by athletes or an athletic team (including a coach), but may provide beneficial performance feedback to any participant in a field of play.

[0117] System **600** includes a performance analysis device **602** that determines a location of each of a plurality of athletes **606** within an operational field **608**. In the example of FIG. **6**, athletes **606** are formed into two pursuit teams that include athletes **606**(1-4) and athletes **606**(5-8), respectively, that race around circuit **609** in a direction indicated by arrows. Each athlete **606** wears a location device **612** that is used by performance analysis device **602** to determine the location of the athlete, a biometric sensing unit **646** that senses biometric information of the athlete, and a feedback device **644** that provides feedback from performance analysis device **602** to the athlete. The biometric information sensed by biometric sensing unit **646** may include one or more of: body temperature at one or more locations, heart rate, blood oxygen levels, hydration level, respiratory rate, perspiration salinity level, blood sugar levels, and other blood analysis results. For example, Cygnus Inc.'s GlucoWatch checks glucose levels every 20 minutes by sending tiny electric currents through the skin. Biometric sensing unit **646** may sense other biometric information without departing from the scope hereof.

[0118] Feedback device **644** may represent one or more of a visual display, such as a liquid crystal display (e.g., a watch and a bicycle handlebar display unit) and a HUD incorporated within glasses (e.g., glasses **144**, FIG. **1**) and/or a helmet, an audio output unit that generates audio signals such as beeps, tones and verbal information, and an actuator that provides movement (tactile) feedback. Where the athlete is taking part in a sport that utilizes equipment that is ridden, such as a bicycle, feedback device **644** may be attached to the equipment or the athlete. Performance analysis device **602** utilizes a wireless transceiver **640** to send feedback information to each feedback device **644**, to receive biometric information from biometric sensing units **646**, and to receive location information from location units **612**.

[0119] Performance analysis device **602** includes a performance monitor **622** that utilizes real time location information from location units **612** and biometric feedback information from biometric sensing units **646** to determine, for each athlete **606**, performance that includes one or more of location, velocity, stress level, and fatigue level. Performance monitor **622** may also generate and maintain profile data for each athlete, shown as profile data **621** stored within recording device **620** of performance analysis device **602**. Profile data **621** may include, for each athlete, historical performance such that current and future performance of the athlete may be predicted. For example, if a particular athlete finished a four-thousand meter training race in the morning, a lighter level of afternoon training may be expected for that athlete and performance analysis device **602** may not push the athlete as hard as another athlete who was resting that morning.

[0120] Recording device **620** may generate a live feed and allow interaction with a user through a display device **630**.

[0121] In the example of FIG. **6**, each athlete **606** receives feedback for his team. For example, each athlete **606**(1-4) receives feedback including location, stress and fatigue levels, for themselves and each other. Similarly, each athlete **606**(5-8) receives feedback including location, stress and

fatigue levels, for themselves and each other. Feedback generator **624** may also provide feedback defining each team performance with respect to the other. For example, in the pursuit illustrated in FIG. **6**, timing between each last athlete of each team (i.e., athletes **606**(4) and **606**(8)) may be provided to each athlete **606**. As the order of each team changes through rotation, performance analysis device **602** automatically identifies the 'last' man of the team. Performance monitor **622** and feedback generator **624** may also provide each team with relative position information of each team member, such that a current leader of the team becomes aware when the last member begins to fall too far behind. For example, feedback device **644** displays four green dots or blips to indicate team members in position, and a red dot or blip to indicate a team member falling behind. In one aspect, the leader of a track cycling team becomes aware (via performance monitor **622** and feedback generator **624**) that the last man of the team is struggling to keep pace and may thus modify the team's pace to prevent exhaustion of the last man, in hopes of bettering the team's collective race result.

[0122] In another example, a quarterback receives feedback, indicating a projected fatigue level for potential receivers, allowing an informed choice as to which receiver to select for a particular play. Similarly, the quarterback may receive fatigue information for defenders such that potential weaknesses may be reduced or at least identified at the last second prior to the snap of the football.

[0123] Each athlete **606** may receive feedback indicating the location of other athletes relative to himself, particularly athletes not directly in his current field of view. Further, each athlete may receive feedback relating to their entire team, based upon processing of data by performance analysis device **602**. For example, where a player in a football team is recovering from high impact in a previous play, other team members will be aware of this through feedback from performance analysis device **602**.

[0124] Biometric sensing units **646** may include one or more accelerometers that measure impact to athlete **606** and movement of the athlete. In one example, these biometric sensors measure cadence of the athlete running such that performance monitor **622** may determine stride length (e.g., based upon measured cadence and speed determined from location information).

[0125] Performance analysis device **602** may also monitor athletes **606** while resting between training exercises, such that profile data **621** for each athlete includes recovery rates.

[0126] Performance analysis device **602** may include a strategy manager **626** that creates and/or utilizes strategy data **627** stored within recording device **620**. In one example, strategy data **627** represents plays (e.g., Perfect Execution Template **300**, FIG. **3**) in an American football game, or practice session. Strategy manager **626** may define criteria (e.g., paths and speeds) for one or more players in the play and feedback generator **624** sends these criteria to feedback devices **644** of relevant players. Performance monitor **622** may monitor movement of each player (e.g., using location units **612**) and provide feedback, via feedback generator **624**, indicating how well, or not, each player conforms to the suggested path and speed. Feedback generator **624** may also provide, in real-time, corrective moves and instructions to players that do not maintain the desired criteria.

[0127] FIG. 6 also shows a coach 652 of athletes 606 utilizing a hand held device 642 that wirelessly interacts, via transceiver 640, with performance analysis device 602. Hand held device 642 may include a processor, a memory, an input device and a display, such as found in an Apple™ iPad. Device 642 allows coach 652 to view live performance information determined by performance analysis device 602 for athletes 606, and feedback that is sent automatically to the athletes from feedback generator 624. Coach 652 may provide input to object tracking device, via hand held device 642 and transceiver 640, to adjust the level of feedback provided by performance analysis device 602.

[0128] In an embodiment, coach 652 receives 'alarm' messages from performance analysis device 602, via wireless transceiver 640 and hand held device 642, indicating athletes that have one or more of: high stress levels, high fatigue levels, high temperatures, and other abnormal biometric information. Coach 652 may then make informed decisions to rest athletes prior to potential injuries or life threatening conditions.

[0129] Changes may be made in the above methods and systems without departing from the scope hereof. For example, the athletes referenced above may represent any type of participant within an operational field or field of play. Performance analysis device 602 for example provides biometric information to and of any "team". By tracking and reporting biometric data of team members, performance analysis device 602 allows team members to monitor one another, and/or allows an instructor, coach or supervisor to monitor each team member. In one aspect, performance analysis device 602 allows commercial divers, astronauts or fighter pilots to monitor one another for signs of panic (e.g., increased respiration and heart rate) or distress even when out of sight. It should thus be noted that the matter contained in the above description or shown in the accompanying drawings should be interpreted as illustrative and not in a limiting sense. The following claims are intended to cover all generic and specific features described herein, as well as all statements of the scope of the present method and system, which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A system for providing real-time audio feedback to an athlete, comprising:
   one or more audio speakers configured to be co-located with the athlete and play the real-time audio feedback to the athlete; and
   a performance analysis device configured to:
      continuously determine a location of the athlete from a location device worn by the athlete,
      determine an audio signal, based on the continuously-determined location of the athlete, that indicates how well, or not, the athlete conforms to one or both of a path and a speed, and
      direct the one or more audio speakers to play the audio signal as the real-time audio feedback.

2. The audio feedback system of claim 1, the one or more audio speakers including left and right speakers for left and right ears, respectively, of the athlete.

3. The audio feedback system of claim 2, the left and right speakers being mounted to a helmet worn by the athlete.

4. The audio feedback system of claim 2, the audio signal indicating the real-time audio feedback to the athlete via a

beeping frequency of a beeping sound, a tone, a volume of one or both of the left and right speakers, and a verbal message.

5. The audio feedback system of claim 2, the audio signal being configured to indicate how well the athlete conforms to the speed via a beeping frequency of a beeping sound.

6. The audio feedback system of claim 2, the audio signal being configured to indicate how well the athlete conforms to the path via a volume of one or both of the left and right speakers.

7. A method for providing real-time audio feedback to an athlete, comprising: continuously determining a location of the athlete from a location device worn by the athlete;
   determining an audio signal, based on the continuously-determined location of the athlete, that indicates how well, or not, the athlete conforms to one or both of a path and a speed; and
   directing one or more audio speakers, co-located with the athlete, to play the audio signal as the real-time audio feedback.

8. The method of claim 7, the one or more speakers including left and right speakers for left and right ears, respectively, of the athlete.

9. The method of claim 8, the left and right speakers being mounted to a helmet worn by the athlete.

10. The method of claim 8, wherein said determining the audio signal includes determining the audio signal such that the audio signal, when played on the left and right speakers, indicates the real-time audio feedback to the athlete via a beeping frequency of a beeping sound, a tone, a volume of one or both of the left and right speakers, and a verbal message.

11. The method of claim 8, wherein said determining the audio signal includes determining the audio signal such that the audio signal, when played on the left and right speakers, indicates to the athlete how well the athlete conforms to the speed via a beeping frequency of a beeping sound.

12. The method of claim 8, wherein said determining the audio signal includes determining the audio signal such that the audio signal, when played on the left and right speakers, indicates to the athlete how well the athlete conforms to the path via a volume of one or both of the left and right speakers.

13. A system for providing real-time audio feedback to an athlete in a field of play, comprising:
   one or more audio speakers configured to be co-located with the athlete and play the real-time audio feedback to the athlete; and
   a performance analysis device configured to:
      continuously determine a location of the athlete from a location device worn by the athlete,
      continuously determine, from a location device worn by each of one or more other athletes in the field of play, a location of said each of the one or more other athletes,
      determine an audio signal based on the continuously-determined location of the athlete and the continuously-determined location of said each of the one or more other athletes, and
      direct the one or more audio speakers to play the audio signal as the real-time audio feedback.

14. The audio feedback system of claim 13, the one or more audio speakers including left and right speakers for left and right ears, respectively, of the athlete.

15. The audio feedback system of claim **14**, the left and right speakers being mounted to a helmet worn by the athlete.

16. The system of claim **14**, the performance analysis device being further configured to:

determine a direction from which situational pressure is coming toward the athlete, the situational pressure being based on proximity of the athlete to each of the one or more other athletes; and

indicate the direction to the athlete via the real-time audio feedback by controlling a volume of one or both of the left and right speakers.

17. The audio feedback system of claim **16**, the performance analysis device being further configured to determine the proximity of the athlete to said each of the one or more other athletes based on the continuously-determined location of the athlete and the continuously-determined location of said each of the one or more other athletes.

18. The audio feedback system of claim **17**, wherein the athlete is a quarterback in an American football game, and the one or more other athletes are defenders of the quarterback.

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