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(54) APPARATUS FOR THE IMPROVEMENT OF ROWING TECHNIQUE

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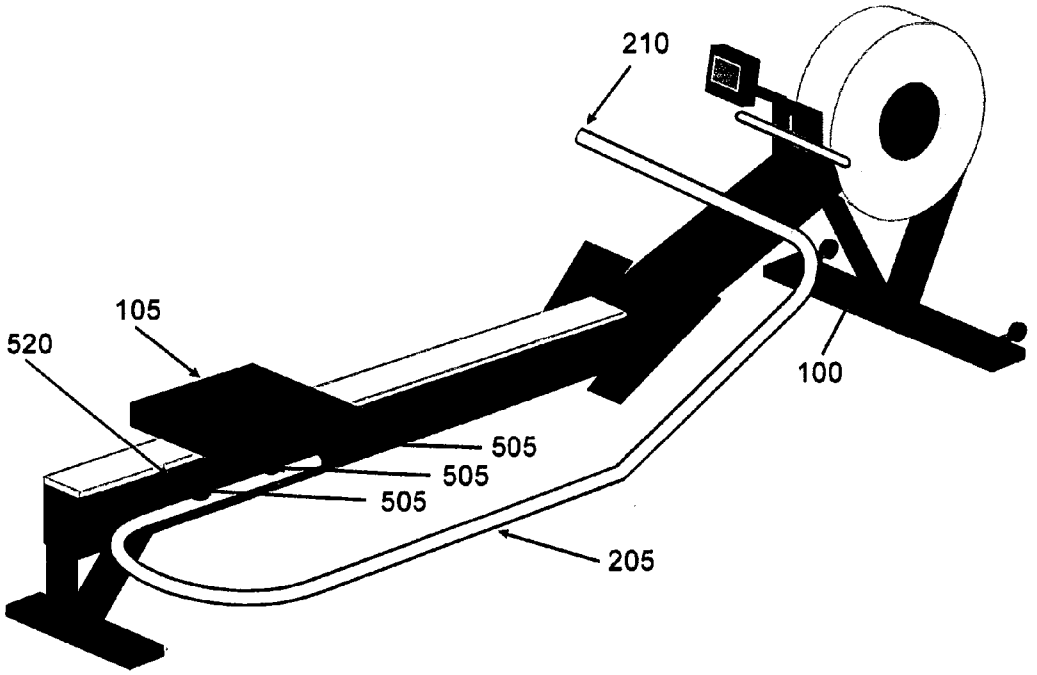
(57) **ABSTRACT**

A position reference device for rowing indicates the relative hip and hand positions of the rower over the course of each rowing stroke. The position reference device provides a reference for kinesthetic learning through constant feedback about torso and hand position. Embodiments of the feedback device can be used on either a boat or on a rowing machine. The embodiments for boats in particular provide the immediate on-water feedback that enables a rower to improve technique in a way that conventional feedback devices generally do not. The rowing machine embodiments enable rowers to improve skill while off the water thus enabling the rower to learn better technique even when it is not possible to row on water.



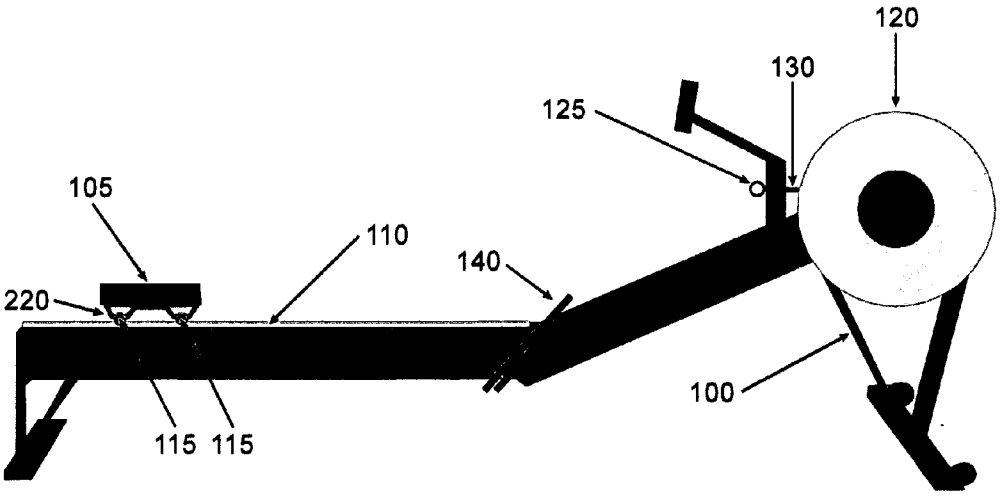


FIGURE 1 (PRIOR ART)

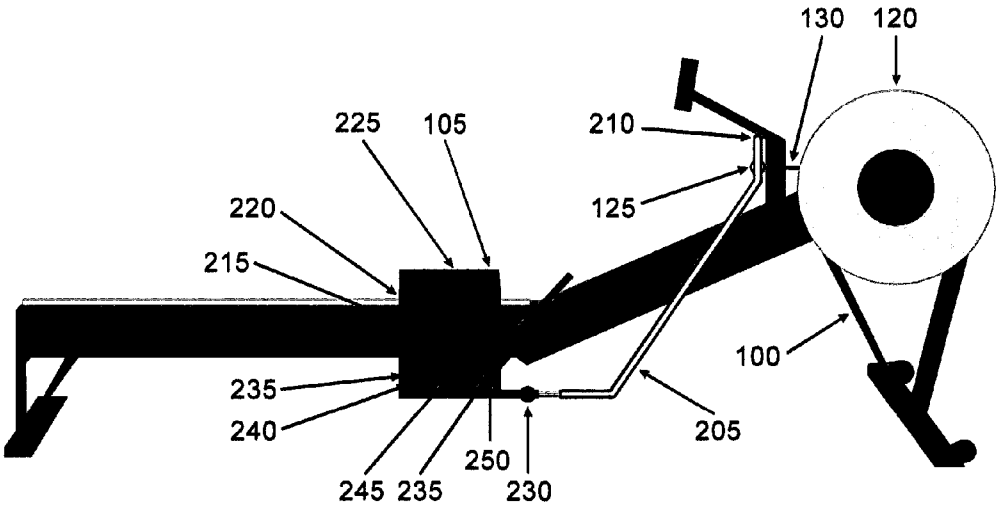


FIGURE 2

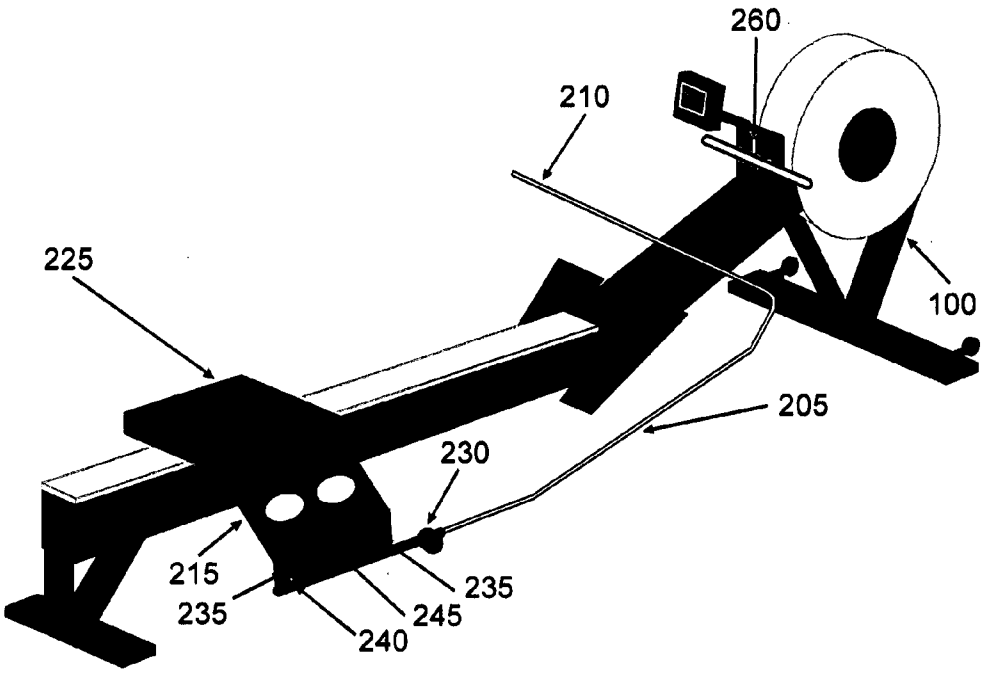


FIGURE 3

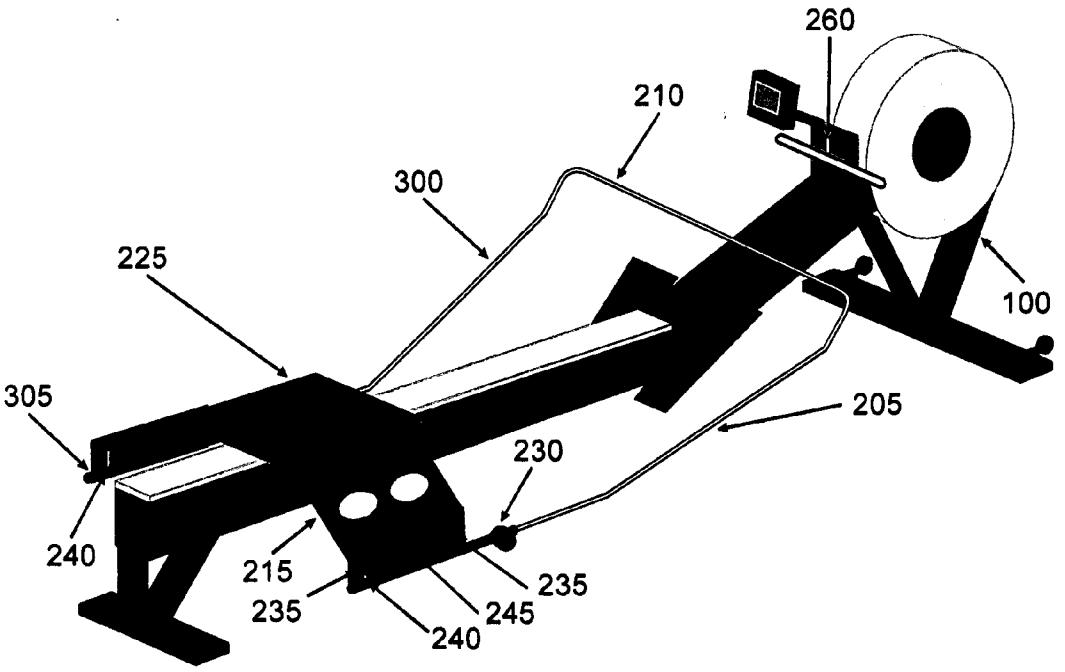


FIGURE 4

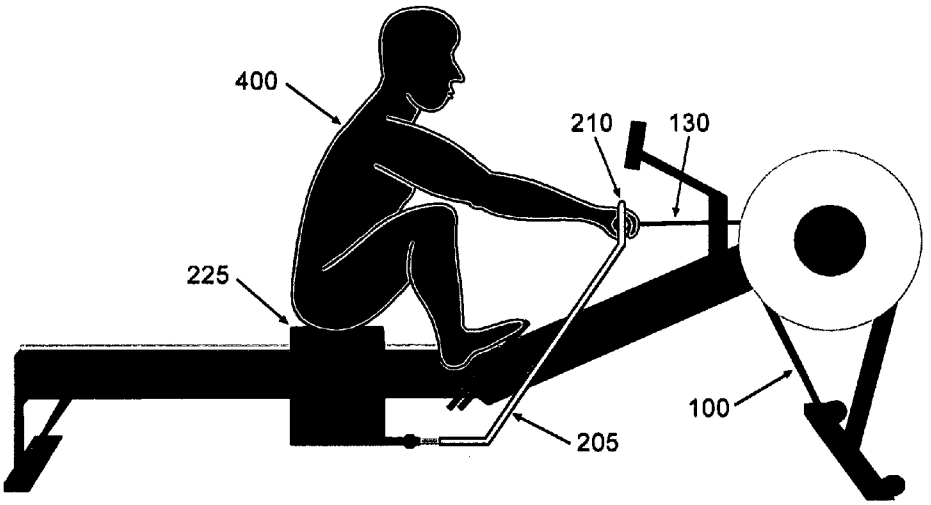


FIGURE 5

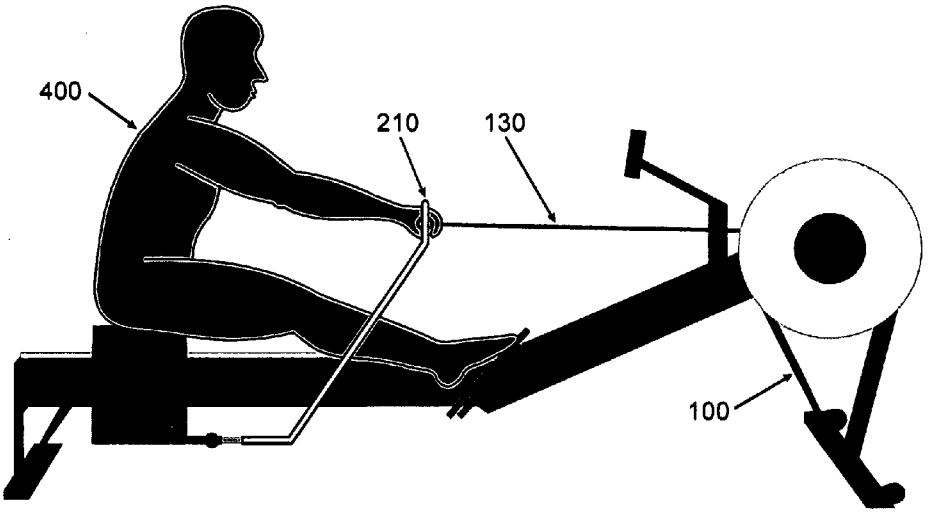
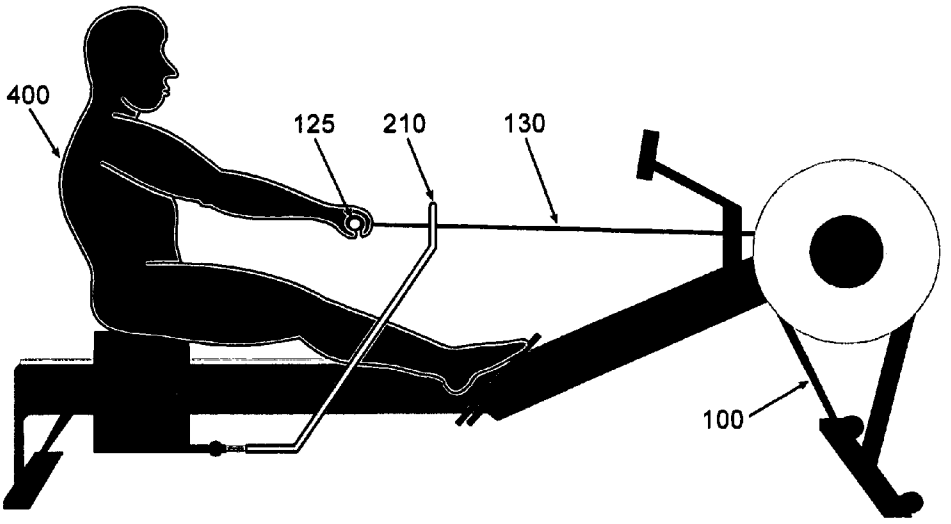


FIGURE 6



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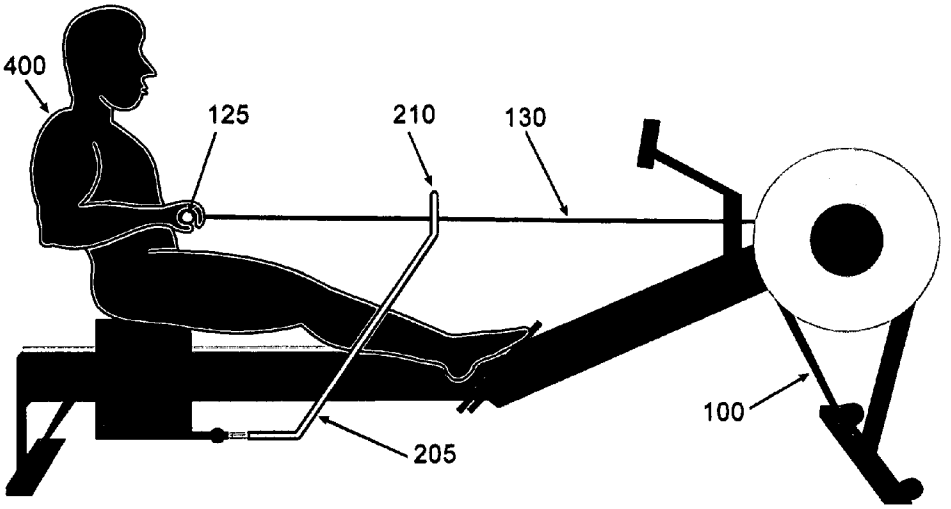
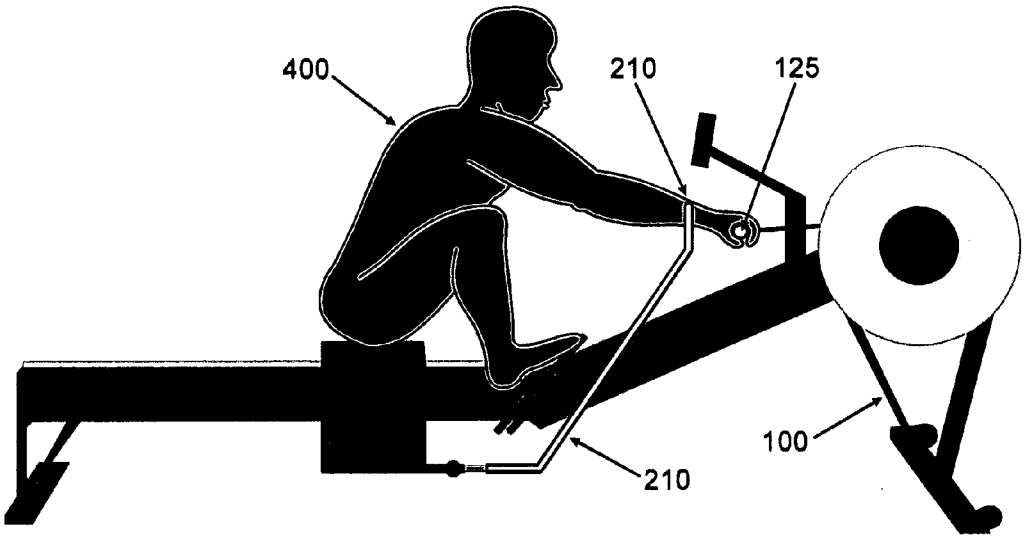


FIGURE 8



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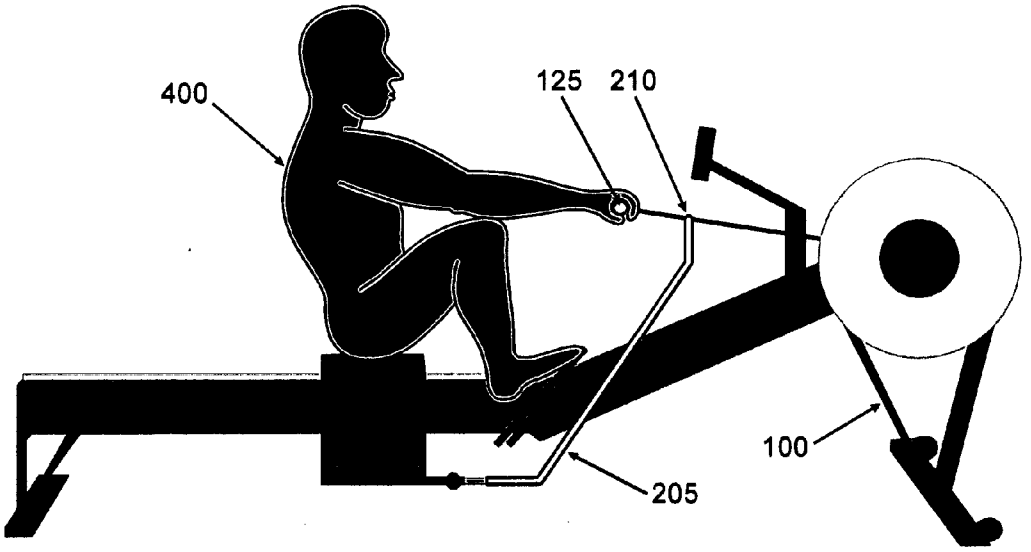

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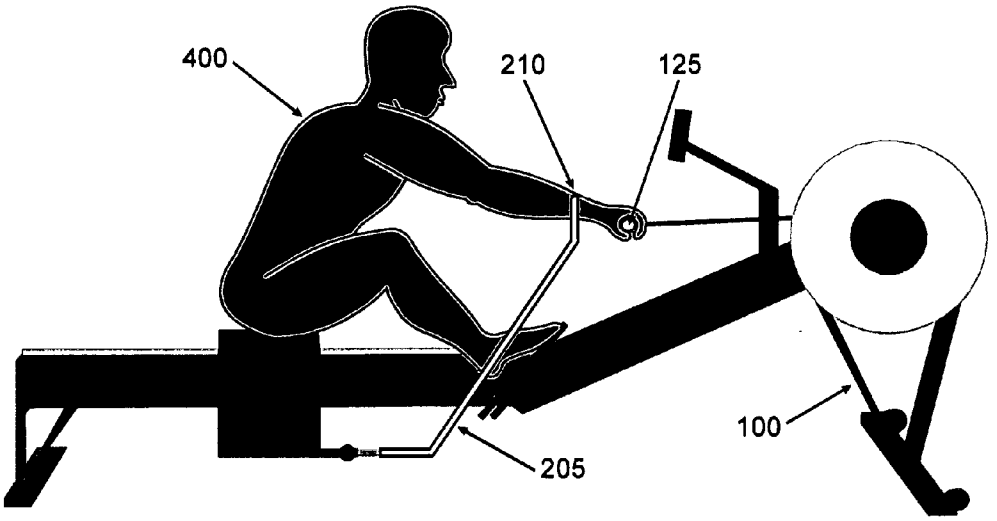

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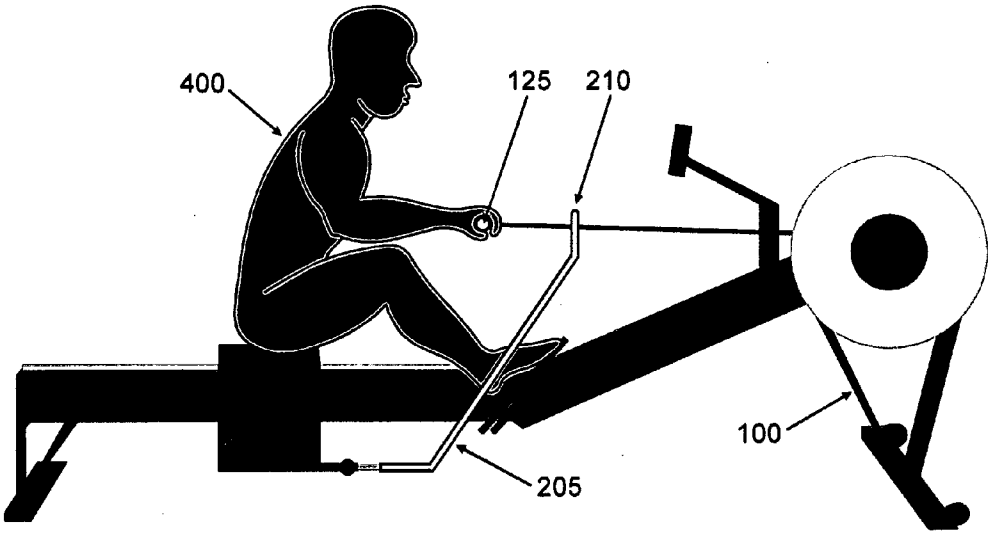
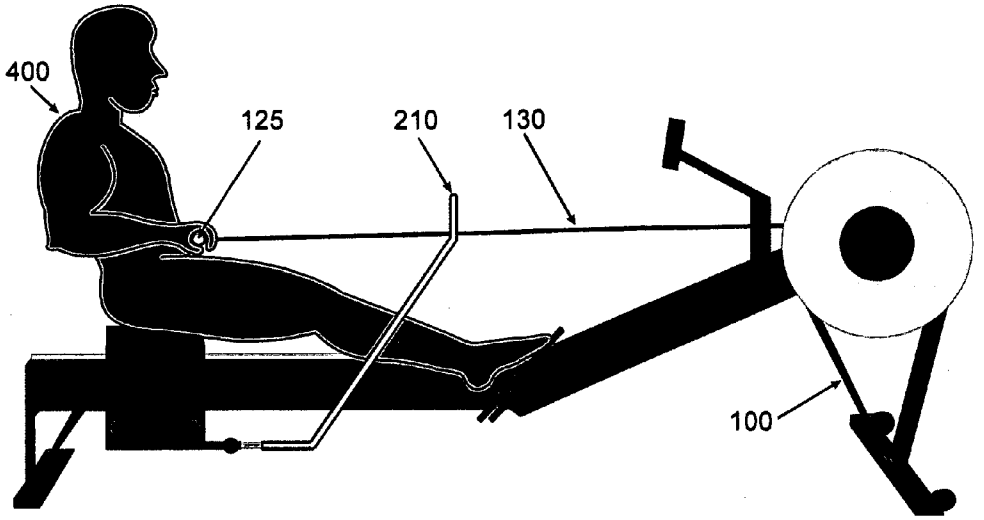


FIGURE 12



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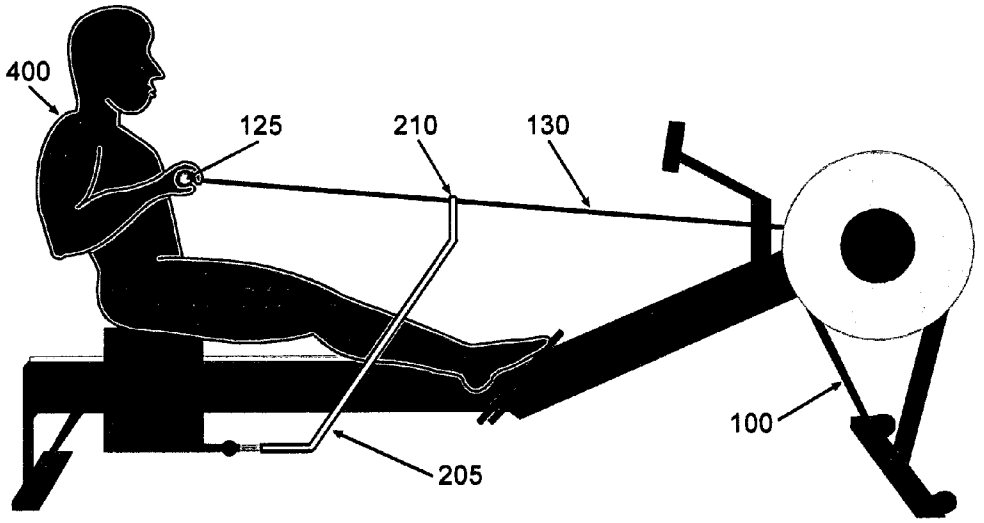

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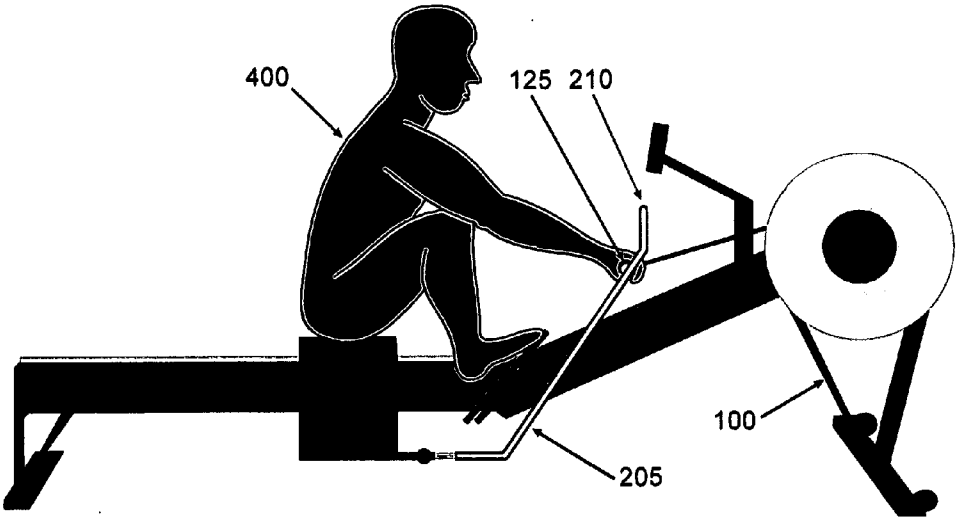

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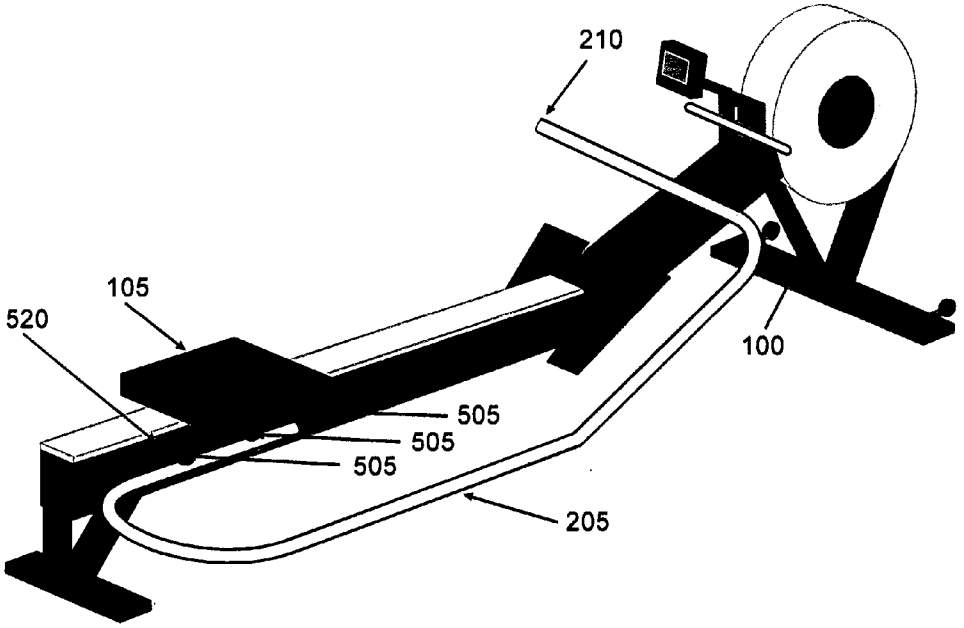

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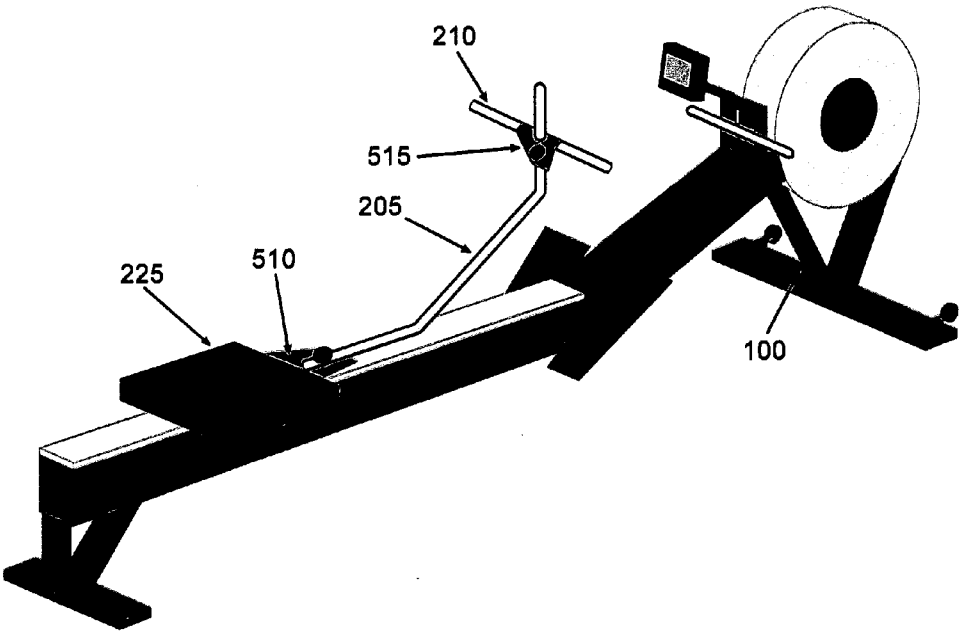
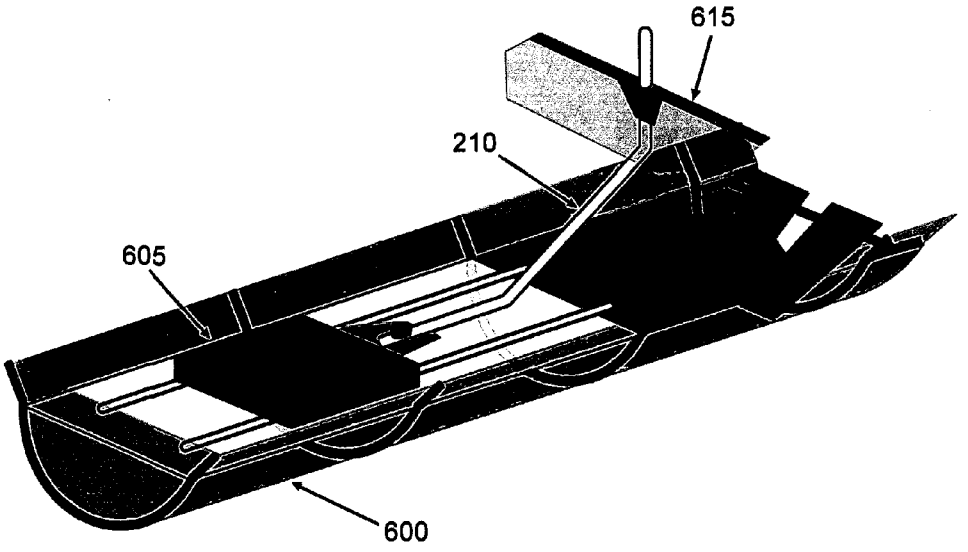


FIGURE 17



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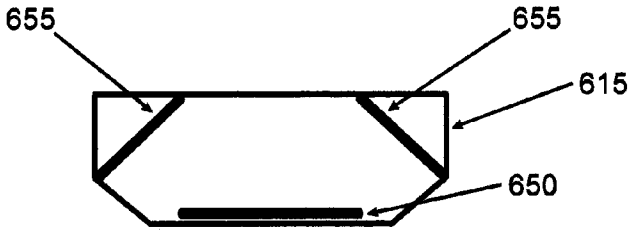


FIGURE 19A

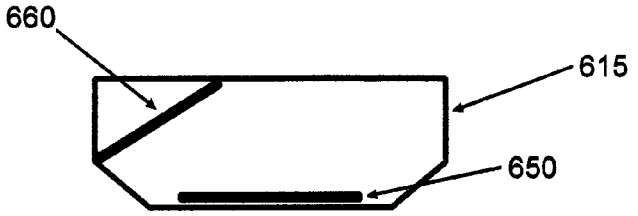


FIGURE 19B

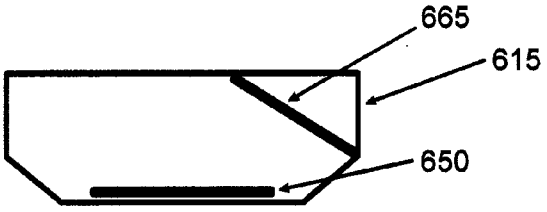
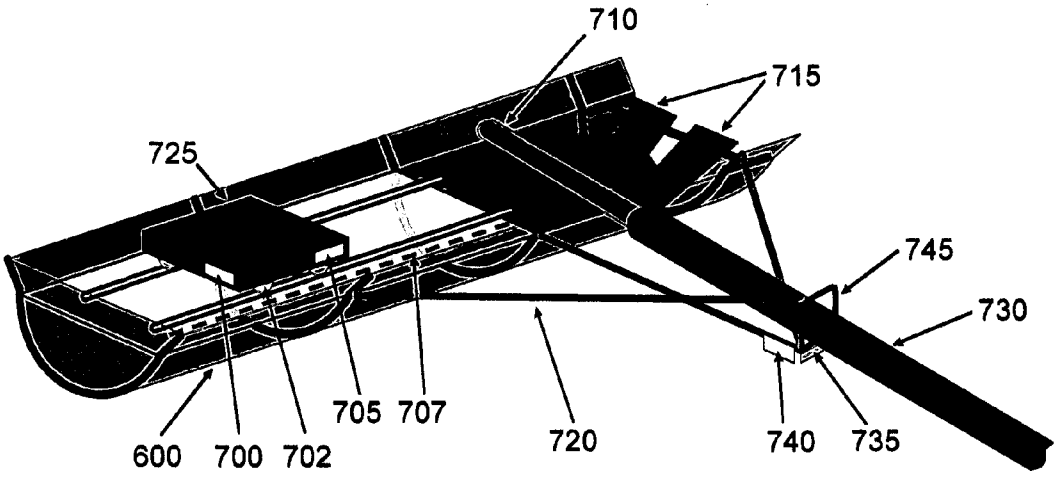


FIGURE 19C



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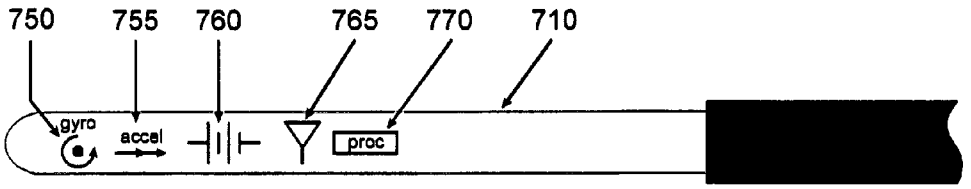

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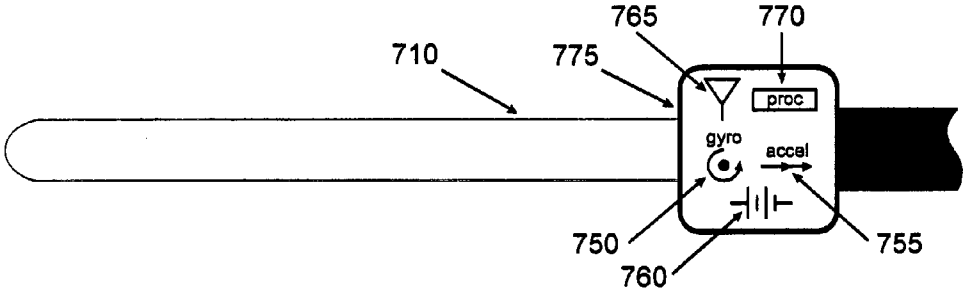

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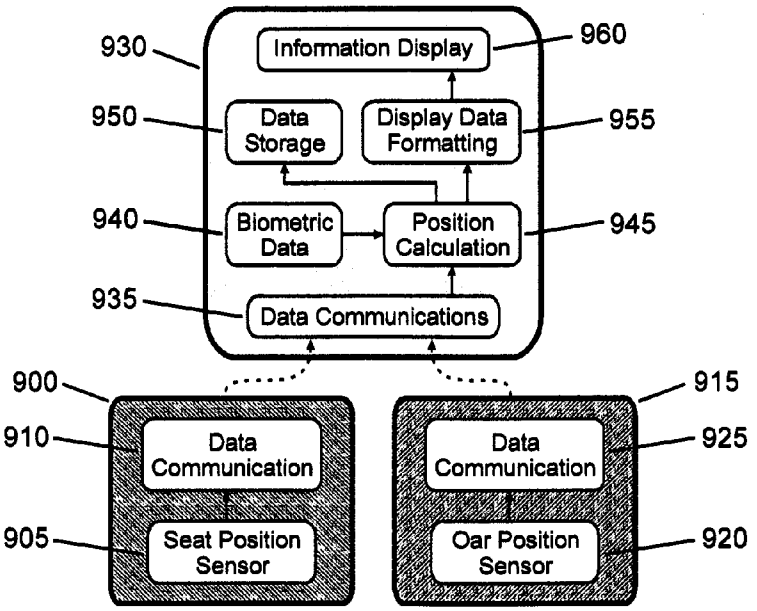

FIGURE 23

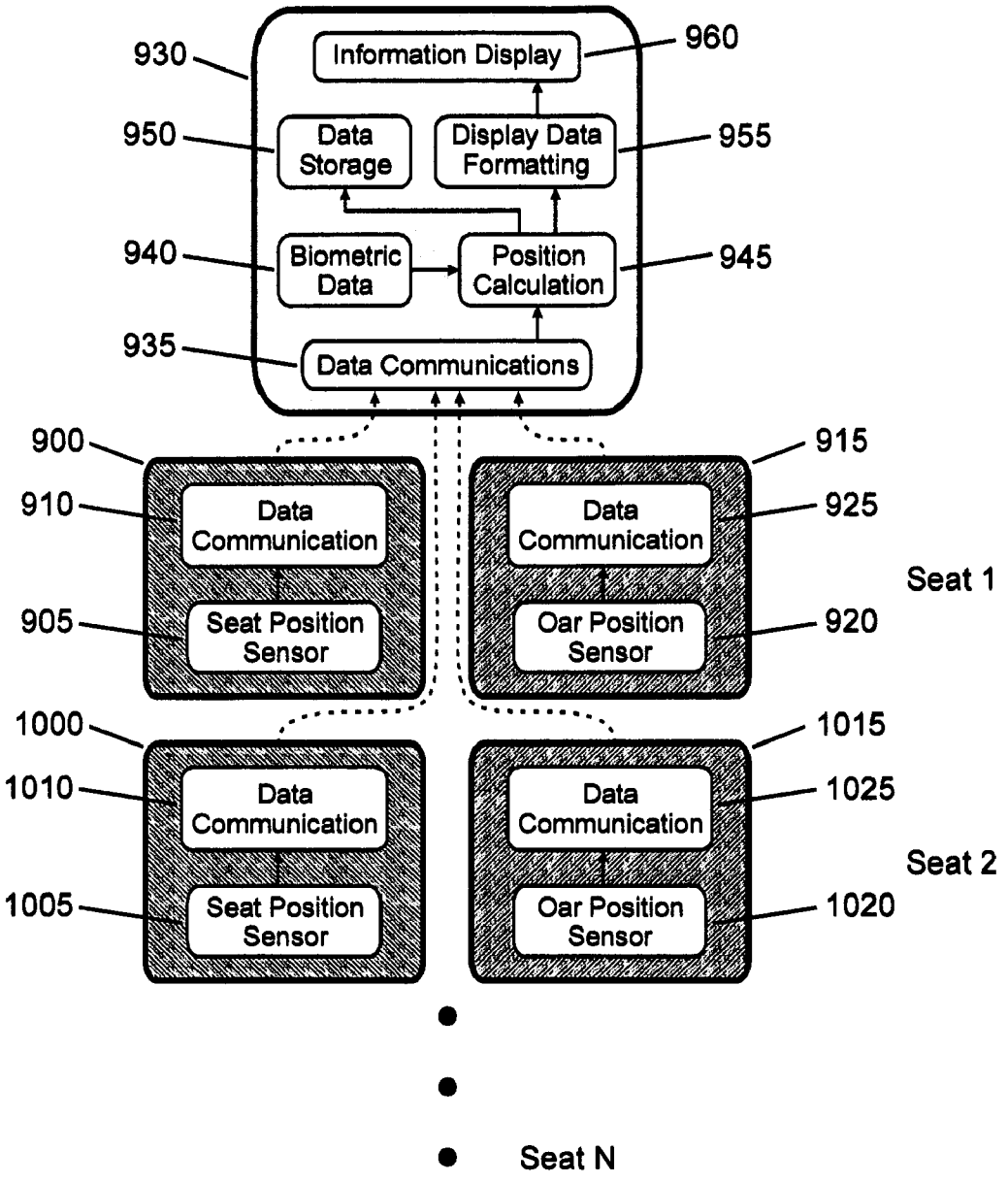
930
Information Display
960
950
Data Storage
Display Data Formatting
955
940
Biometric Data
Position Calculation
945
935
Data Communications
900
915
910
Data Communication
Data Communication
925
Seat 1
905
Seat Position Sensor
Oar Position Sensor
920
1000
1015
1010
Data Communication
Data Communication
1025
Seat 2
1005
Seat Position Sensor
Oar Position Sensor
1020
Seat N

FIGURE 24

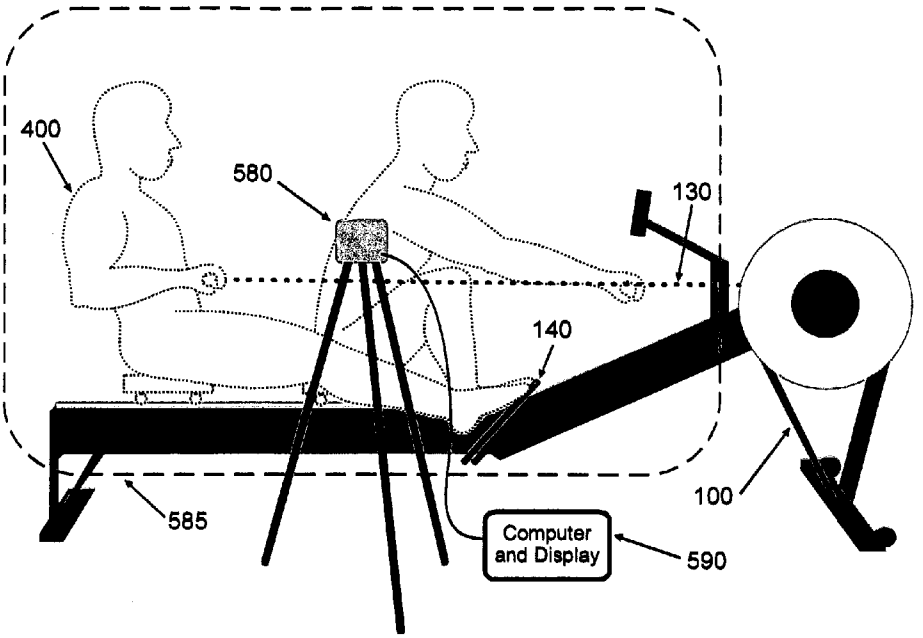

FIGURE 25

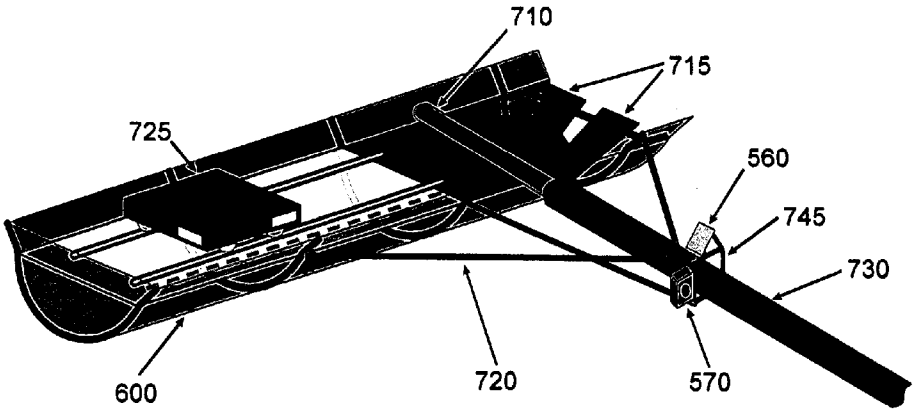

FIGURE 26

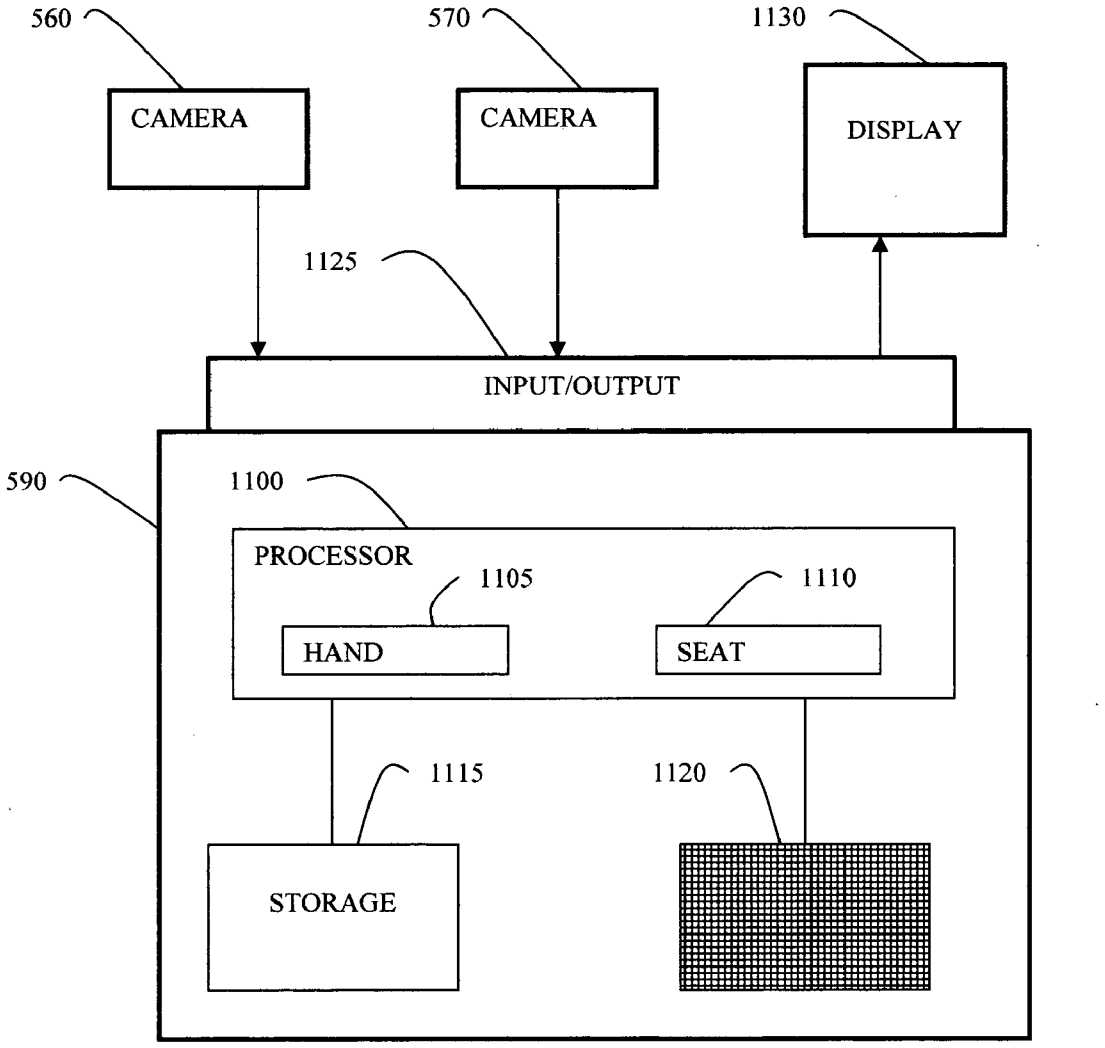
560
570
1130
CAMERA
CAMERA
DISPLAY
1125
INPUT/OUTPUT
590
1100
PROCESSOR
1105
1110
HAND
SEAT
1115
1120
STORAGE

FIGURE 27

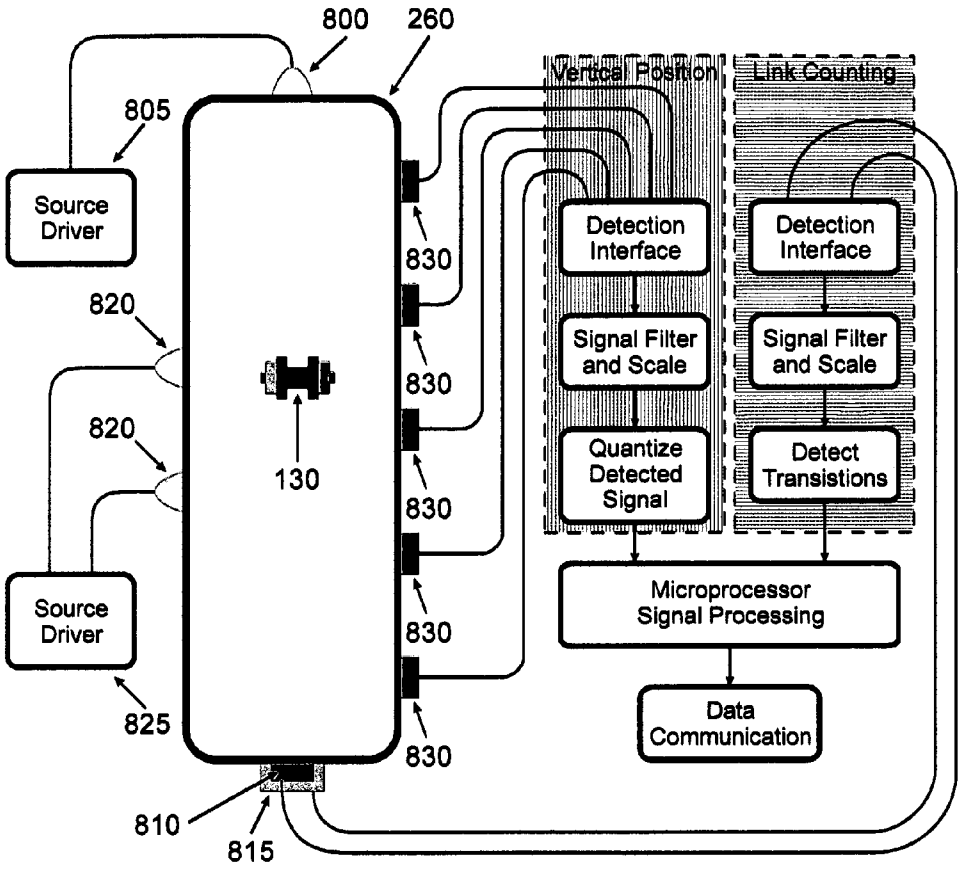
800
260
805
Source Driver
820
820
Source Driver
825
130
830
830
830
830
830
810
815
Vertical Position
Link Counting
Detection Interface
Signal Filter and Scale
Quantize Detected Signal
Detection Interface
Signal Filter and Scale
Detect Transistions
Microprocessor Signal Processing
Data Communication

FIGURE 28

APPARATUS FOR THE IMPROVEMENT OF ROWING TECHNIQUE

CROSS-REFERENCES

[0001] This application claims priority of U.S. provisional application Ser. No. 60/511,876 filed Oct. 15, 2003 and titled "The Rower's Shadow".

BACKGROUND

[0002] Rowing is a sport where one or more people ("rowers") propel a narrow boat through water using oars. The narrow boat, also referred to as a "shell" may be a "single" carrying a single rower or may be a boat that typically carries two, four, eight, or another number of rowers. Each rower typically sits on a sliding seat mounted inside the shell.

[0003] Two basic oar configurations are employed in rowing. In one asymmetric configuration referred to as "sweeping", each rower uses a single oar dedicated to one side, port or starboard side of the boat. In another configuration, referred to as "sculling", each rower mans two oars which are symmetrically paired and extend from each side of the boat. The rower moves the boat by stroking the oars while sliding forward and back in the seat.

[0004] There are four main parts to the stroke: the catch, the drive, the release and the recovery. The catch is point of the rowing cycle at which the blade enters the water after the rower has prepared for the stroke by sliding forward on the seat (described later in the definition of recovery). The catch is accomplished by an upward motion of the arms and hands. The drive is that part of the rowing cycle when the rower applies power to the oar. This is typically a blended sequence of the rower applying power primarily with a leg extension, then with the rower's back and finally the rower's arms. The release is a sharp downward and away motion of the hands from the body which serves to remove the oar blade from the water at the end of the drive. At this point, the rower has slid the seat back to his or her biometrically physical limit and finished applying power. The recovery is the series of activities preparing for the catch and drive including sliding the seat forward combined with gradual rolling of the oar blade from a position parallel to the water to a position substantially perpendicular to the surface of the water (called "squaring the oar"). Squaring the oar blade is done in preparation for the catch.

[0005] "Rowing" may also be done on land on a rowing machine. A rowing machine is typically used to improve rowing and general fitness off the water or when it is not possible to row on water. In general, a rowing machine includes a sliding seat attached to a standing frame and an oar-simulation portion such as short oars or a pulley attached to a resistance device. The pulley-type rowing machine is also referred to as an "erg" because it often includes an ergometer to measure the power of the rower's stroke. One example of a rowing machine is the Indoor Rower from Concept 2, Inc. of Vermont. Generally, the rower does not receive feedback on their rowing technique from the machine. Feedback for rowing technique may be provided, for example, by external cues from either a coach or trained individual prompting the rower with proper rowing etiquette.

[0006] In order to row efficiently on water (and in some cases, to avoid injury), precise and subtle technique is required of the rower. The positions of the rower's body including the torso and the hands at each point during the stroke are important to effectively move the boat. Even minor deviations from proper body or hand position can negatively impact the rower's ability to move the boat. For example, it is important for the rower's arms and upper body to be properly positioned for the drive early in the recovery portion of the stroke in order to make a smoother transition into the drive and to avoid the arms hitting the legs or any excess motion of the arms and body before the drive begins. A rower should avoid over reaching which is a further compression of the upper body at the end of the recovery in order to add length to the oar stroke. Over reaching places the rower's back in a weak position which may lead to injury. Over reaching also tends to weaken the drive because the drive sequence from the overly compressed position is generally initiated by the rower's back rather then the rower's leg. Another example of poor rowing technique is called "skying" where the rower's hands are too low just before the start of the drive. As a result, the rower must excessively lift the oar handles in order to make a proper catch. In the case of "skying," the rower will typically start the leg extension without the oar firmly anchored in the water while raising the hands to make the catch causing the rower to miss water at the catch. Similarly, the rower's hands may be too high at the finish of the drive which causes the oar blade(s) to go deep in the water making it difficult to pull the oar out of the water at the release. Hands may also be too low at the finish of the drive, shortening the power phase of the stroke, placing the oar partially in the water allowing the rower to tear away at the surface of the water ("washing out"), and causing imbalance on the side of the boat opposite the oar washed out. Using the back before the legs on the drive also decreases the power of the stroke. "Grabbing" is another example of poor rowing technique. In grabbing, the rower initiates the drive sequence with his or her arms rather than legs (or legs and back). A rower may also "shoot the slide" in which the rower initiates the drive with the legs but leans forward failing to bring the oars back in concert with the legs. There are many other examples of poor rowing technique.

[0007] Because rowing technique is so precise and subtle, it is difficult for the rower himself or herself to know what deviations from proper rowing technique are causing problems in the boat. The reaction of the oars and the boat in the water provides some feedback to the rower, but that feedback is not complete. When rowing on a typical rowing machine, the ergometer provides feedback in the form of power exerted, however, all of the feedback provided by the action of the oars, the boat on water, and traditional coaching and/or coxswain observation are absent. Typical ways of receiving more feedback in order to improve rowing technique include the use of coaching, videotaping and mirrors. Coaching a rower on each stroke is not practical or generally desirable for a rower. Video tapes are typically shown after a practice session and are generally not as helpful as if the feedback were more immediate, such as if the feedback were provided immediately during the act of taking an oar stroke in a boat on the water. Additionally, though the rower can view his or her own stroke on the videotape, the rower may not have a clear idea of what the oar stroke should be in action on the water. Mirrors provide more immediacy than

video tape but the rower cannot get a profile view without turning his or her head thus altering body position and, therefore, also the stroke. Finally, with any of the solutions described above, it is difficult to determine the spatial relationship of the rower's hips (or the seat) to the rower's hands which are important indicators of whether the rowing is using proper technique.

[0008] Information relevant to attempts to address the problem of training rowers in proper rowing technique can be found in U.S. Pat. No. 4,984,986. This reference, however, suffers from the disadvantage that the outputs of the device indicate the results of poor rowing technique rather than the actual deviations from proper rowing technique.

[0009] For the foregoing reasons, it remains desirable to have a device that provides immediate feedback to rowers in order to learn and to improve body mechanics for rowing.

SUMMARY

[0010] The present invention is directed to a position reference device that provides immediate and constant feedback to a rower. The position reference device indicates the body positions of the rower over the course of each rowing stroke. The position reference device thus provides a reference for kinesthetic learning through constant feedback about hip, torso and hand position. Embodiments of the feedback device can be used on either a boat or on a rowing machine. The embodiments for boats in particular provide the immediate on-the-water feedback that enables a rower to improve technique in a way that conventional feedback devices generally do not. The rowing machine embodiments enable rowers a means to improve skill while off the water thus enabling the rower to learn better technique even when it is not possible to row on water.

[0011] A first embodiment of the position reference device include a seat locator attached to the rowing apparatus where the seat locator indicates the hip location of a rower positioned on a seat of the rowing apparatus and a hand locator attached to the rowing apparatus where the hand locator indicates hand position of the rower. The seat locator and hand locator are positioned relative to each other according to biometric data of the rower such that the position reference device indicates the rower's body position during at least one selected stroke point. The rowing apparatus may be either in a boat on the water or on a rowing machine.

[0012] In an alternative embodiment of the position reference device, the seat locator is an adjustable guide bar having a first end and a second end, the adjustable guide bar attached to the seat at the first end and the hand locator is a cross bar attached substantially perpendicular to the second end of the guide bar. In a further alternative embodiment of the invention, the guide bar is shaped and configured to prevent axial rotation of the guide bar. A first example of such a shape and configuration is a guide bar that is oval in cross-section. A second example of such a shape and configuration is a guide bar that is rectangular in cross-section. The seat locator further includes an adjustment assembly attached to the seat. The adjustment assembly holds the guide bar and enables a tilt adjustment and an extension adjustment so that the position reference device may be fitted to the rower according to the rower's biometric data. The guide bar includes additional embodiments such as a further adjustment device to enable a height adjustment so that the cross bar may be raised or lowered according to the rower's biometric data.

[0013] A first embodiment of the adjustment assembly includes an adjustment frame that saddles a rowing machine rail. The adjustment frame attaches to the side of the seat carriage for example via the axle bolts. In alternative embodiments of the invention, the adjustment frame attaches under the seat top, above the seat carriage. In one embodiment, the guide bar is attached at one side of the adjustment frame. The guide bar in one embodiment is attached to the adjustment frame with clamps. The adjustment frame further includes a slot and a hole configured to receive the clamps to allow for a tilt adjustment of the guide bar. In an alternative embodiment, the position reference device has two guide bars, one attached symmetrically on either side of the adjustment frame and the cross bar is attached between the two guide bars. The adjustment frame that symmetrically saddles the rowing machine rail provides balance to the position reference device. The second guide bar provides further balance and stability to the position reference device.

[0014] In a further alternative embodiment of the adjustment frame, the adjustment assembly is a half saddle attached to the seat where the guide bar is attached to the half saddle in similar fashion as in the full saddle. This embodiment is less bulky and lighter than the full saddle embodiment.

[0015] In a rowing machine embodiment of the position reference device, the cross bar is extended in length so that this extension spans across a second rowing machine located next to the rowing machine with the attached position reference device. The extended cross bar enables a second rower on the second rowing machine to operate the second rowing machine in synchronization with the rower on the rowing machine with the attached position reference device. Alternatively, a first and a second rowing machine are fitted with position reference devices where each position reference device includes an extension. The extensions are configured so that they are in proximity when the rowers row synchronously.

[0016] In another rowing machine embodiment of the position reference device, the rowing machine includes a cable attached at a first end to a resistance wheel and a handle attached at a second end of the cable, the handle to be held by the rower. The seat includes rollers and the rowing machine further includes a rail along which the seat rolls. The seat locator has a first sensor to detect location of the seat relative to the rowing machine the hand locator has a second sensor to sense the handle position relative to the rowing machine. The sensors are coupled to a transmitter to transmit the data to a receiver. The transmitters may, for example, be for wired transmission or broadcast transceivers for wireless transmission. This embodiment also typically includes a display device coupled to the receiver to collect the data generated by all of the sensors. Batteries are included to power the sensors in a first embodiment. In an alternative embodiment, a power scavenging device, such as a solar collector, is included in the configuration to provide further energy. The power scavenging device can either augment battery power or replace it all together. The sensor embodiment allows the rower's position to be determined

electronically and generates data that can be studied later as well as immediate feedback to the rower. Sensors and transmitters are similarly applied to a boat where the hand sensors are mounted such to sense the movement of the oar handle(s).

[0017] In the embodiments of the position reference device in which sensors are used, the position reference device includes a computation device storing the biometric data of the rower, hand and seat locations for selected stroke points for specific rowers. This biometric data, such as height, inseam, and arm length for example, coupled with typical data covering the physical variation range of rowers adequately describes the body position of the rower. The computation device correlates sensor data with biometric data to determine the body position relative to the rowing device and the oar handle relative to the rowing device, processes this correlated data to classify the deviation and degree from proper rowing technique, such as over-reaching at the catch, grabbing, skying, shooting the slide as described above, and sending this classified and degreed data to the display device to display output of this correlated data in order to provide specific position feedback data to the rower.

[0018] Various types of sensors may be used to determine provide hand and seat location. A first embodiment includes a gyroscope and an accelerometer combination. Typically a first gyroscope and first accelerometer is located in the seat and a second gyroscope and a second accelerometer is located in the rowing machine handle or in the oar attached to a boat. The gyroscope and accelerometer combination could instead be replaced by a global positioning sensor (GPS) in communication with global positioning satellites. On a rowing machine, the handle location may be detected by a chain length sensor, such as chain tooth counter or sprocket rotation counter, combined with chain angle sensor on the rowing machine chain. The position of the seat on either a rowing machine or a boat may be detected by a linear position encoder or by a rotation encoder using the rotation of the seat wheels.

[0019] Another alternative embodiment of the position reference device includes a seat locator where the seat locator is a guide bar attached at a first end to the seat at the center front of the seat and where the hand locator is a transparent plate (alternatively, a screen) attached at the second end of the guide bar where the transparent plate has markings to indicate hand position. The transparent plate is centered with respect to the seat. The transparent plate includes indicator marking so that the rower can determine his or her proper hand position. One embodiment the transparent plate has markings for sculling while other embodiments have markings for sweep rowing. The guide bar is extendible forward and backward from the seat and the transparent plate may be raised or lowered on the guide bar thus providing adjustability according to the biometric characteristics of the rower.

[0020] A further alternative boat embodiment of the position reference device includes a camera attached to the oarlock and facing the rower, the camera adjusted to encompass the rower in its field of view. The camera communicates with a display mounted within the confines of the boat. The display in one example embodiment is mounted at the rower's feet. Alternatively, the display is suitably mounted, permitting the rower clear view, to another rower in front of the rower being viewed by the camera. The camera further transmits data to a processing device that together with the rower's biometric data produces information about the rower's deviation from proper rowing technique. This information is in some embodiments displayed to the rower while rowing. Alternatively, the data is stored for later examination. A second camera also mounted on the oar lock and facing out provides a view of the oar position.

[0021] The present invention together with the above and other advantages may best be understood from the following detailed description of the embodiments of the invention illustrated in the drawings, wherein:

DRAWINGS

[0022] **FIG. 1** is a side view sketch of a conventional rowing machine;

[0023] **FIG. 2** is a side view sketch of a rowing machine including a position reference device according principles of the invention;

[0024] **FIG. 3** is a perspective view of the rowing machine of **FIG. 2**;

[0025] **FIG. 4** is a perspective view of an alternative embodiment of the position reference device of the present invention;

[0026] **FIG. 5** is a side view of the embodiment of the position reference device of **FIG. 2** including a rower operating the rowing machine where the rower is positioned at the beginning of the drive portion of the rowing stroke, the "catch";

[0027] **FIG. 6** is a side view of the position reference device of **FIG. 2** where the rower is positioned properly at the start of the back swing of the drive portion of the rowing stroke, "body-over";

[0028] **FIG. 7** is a side view of the position reference device of **FIG. 2** where the rower is properly positioned at the back swing end of the drive portion of the rowing stroke, "hands- away";

[0029] **FIG. 8** is a side view of the position reference device of **FIG. 2** where the rower is positioned properly at the end of the drive portion of the rowing stroke, the "finish";

[0030] **FIG. 9** is a side view of the position reference device of **FIG. 2** where the rower is improperly positioned by "over-reaching" at the catch portion of the rowing stroke;

[0031] **FIG. 10** is a side view of the position reference device of **FIG. 2** where the rower is improperly positioned by using the back before the legs during the drive portion of the rowing stroke;

[0032] **FIG. 11** is a side view of the position reference device of **FIG. 2** where the rower is improperly positioned by driving the legs without moving the rowing machine handle during the drive portion of the rowing stroke, "shooting the slide";

[0033] **FIG. 12** is a side view of the position reference device of **FIG. 2** where the rower is improperly positioned by pulling in with the arms during the drive portion of the rowing stroke while the legs are bent, "grabbing";

[0034] **FIG. 13** is a side view of the position reference device of **FIG. 2** where the rower is improperly positioned by hands too low at the finish of the drive portion of the rowing stroke, "washing out";

[0035] **FIG. 14** is a side view of the position reference device of **FIG. 2** where the rower is improperly positioned by hands too high at the finish of the drive portion of the rowing stroke, "digging at the finish";

[0036] **FIG. 15** is a side view of the position reference device of **FIG. 2** where the rower is improperly positioned by hands too low at the catch, "skying";

[0037] **FIG. 16** is a perspective sketch of an alternative embodiment of the position reference device according to principles of the invention where the position reference device is attached to a rowing machine;

[0038] **FIG. 17** is a perspective sketch of another alternative embodiment of the position reference device of **FIG. 16** where the position reference device is attached to a rowing machine;

[0039] **FIG. 18** is a perspective sketch of a further alternative embodiment of the position reference device of **FIG. 17** where the position reference device is attached to a seat in a boat;

[0040] **FIG. 19A** is a top view of a first alternative embodiment of the cross bar of **FIG. 18** for sculling;

[0041] **FIG. 19B** is a top view of a second alternative embodiment of the cross bar of **FIG. 18** for a starboard sweep oar;

[0042] **FIG. 19C** is a top view of a third alternative embodiment of the cross bar of **FIG. 18** for a port sweep oar;

[0043] **FIG. 20** is a perspective sketch of an alternative embodiment of the position reference device according to principles of the invention where the rower's position is indicated through electronics;

[0044] **FIG. 21** is a diagram of the hand position sensors of the position reference device of **FIG. 20** where the sensors are located inside the oar handle;

[0045] **FIG. 22** is a diagram of the hand position sensors of the position reference device of **FIG. 20** where the sensors are arranged in a configuration that is attached to the outside of the oar handle;

[0046] **FIG. 23** is a block diagram of the sensor configuration of the electronic position locator of **FIG. 21**;

[0047] **FIG. 24** is a block diagram of the sensor configuration in a multiple rower boat;

[0048] **FIG. 25** is a sketch of an embodiment of the position reference device of the invention where a camera is used to determine the rower's body position;

[0049] **FIG. 26** is a sketch of an embodiment of the position reference device of the invention to be mounted in a boat where two cameras are used to follow the rower's movements;

[0050] **FIG. 27** is a block diagram of a computer used to process data received from the cameras of **FIGS. 25 and 26**; and

[0051] **FIG. 28** is a rowing machine chain position detection device according to principles of the present invention.

DESCRIPTION

[0052] The position reference device of the present invention includes a hand locator and a seat locator positioned relative to each other according to the rower's biometric data to indicate torso and hand positions of the rower over the course of the rowing stroke. The immediate feedback to the rower enables the rower to improve rowing technique while rowing. Embodiments for the rowing machine enable the rower to learn proper rowing technique when "rowing" off the water.

[0053] **FIG. 1** is a side view sketch of a conventional rowing machine **100**. The rowing machine **100** is the Indoor Rower from Concept 2, Inc. of Vermont. This rowing machine is merely one example of a rowing machine that may be used in conjunction with the present invention. Other rowing machines are contemplated within the scope of the present invention. The rowing machine **100** has a sliding seat **105** mounted on a rail **110**. The sliding seat **105** uses rollers **115** to slide along the rail **110**. The rowing machine **100** includes a resistance device **120**. A handle **125** attached to a cable **130** (or chain) is connected to the resistance device **120**.

[0054] In operation, a rower on the rowing machine **100** sits on the sliding seat **105** with his or her feet in the foot stretchers **140** and holds the handle **125**. The rower "rows" on the rowing machine **100** while sliding on the sliding seat **105** and pulling on the handle **125**.

[0055] **FIG. 2** is a side view sketch of the rowing machine **100** including a position reference device according principles of the invention. The position reference device includes a seat locator attached to the rowing machine **100** where the seat locator indicates the leg extension of a rower operating the rowing machine. The position reference device also includes a hand locator attached to the rowing machine **100** where the hand locator indicates hand position of the rower operating the rowing machine **100**. In the embodiment of the position reference device shown in **FIG. 2**, the seat locator is a guide bar **205** attached at the seat **105** and extending forward toward the front of the rowing machine **100**. The hand locator is a cross bar **210** attached substantially perpendicularly to the guide bar **205** at the forward end of the guide bar **205**. The guide bar **205** and the cross bar **210** are illustrated in perspective view in **FIG. 3**.

[0056] The guide bar **205** in **FIG. 2** is attached at the seat **225** through a mounting frame **215** saddling the rail **110**. The seat **225** rolls along the rail **110** on a carriage **220** having rollers (not shown) similar to the rollers **115** shown in **FIG. 1**. The mounting frame **215** is mounted on the carriage **220**. The mounting frame **215** also holds a seat top **105**. Accordingly the mounting frame **215** and seat top **105** together form the rower's seat **225**. The mounting frame **215** is mounted under the seat top **105** above the seat carriage using existing seat carriage mounting features. Alternatively, as shown in **FIG. 16**, the combination mounting frame **215** and adjustment bracket **520** is mounted to the side of the seat carriage, below seat top **105**, via the fixed axle bolts attaching the rollers **115** to the seat carriage. Any attachment that provides a fixed reference with regard to the seat top **105** is contemplated within the scope of the invention. The guide bar **205**

is adjustable so that the guide bar **205** and the cross bar **210** are positioned relative to the seat **225** according to the rower's biometric data such that the position reference device indicates the rower's body position during at least one selected stroke point. Biometric data includes such measurements as the arm length, inseam and height of the rower. Examples of positioning for at least one selected stroke point are provided below in **FIGS. 5-15**.

[**0057**] The guide bar **205** is adjustable in length in the present embodiment at a clamp **230** on the adjustment bracket **245**, which attached to the mounting frame **215** by adjustment screws **235**, that enables the guide bar **205** to be adjusted forward or backward according to the rower's biometric data. Other ways of adjusting the guide bar **205** are possible. One example of an alternative length adjustment scheme is a telescoping joint. The invention is not limited to the clamp **230** shown here. The present embodiment provides height adjustment of the cross bar **210** with respect to the seat **225** by a tilt adjustment of the guide bar **205**, which connects to the cross bar **210** at one end, according to the rower's biometric data. This tilt adjustment is accommodated by the tilt slot **240** in the adjustment bracket **245**. The guide bar **205**, which is attached to the adjustment bracket **245** with clamp **230**, is tilted by rotation of the adjustment bracket **245** about hole **250** with screw **235** through hole **250** acting as rotational pin guided by the arced slot **240** and the corresponding screw **235** acting as a slot guide pin. An alteration in the tilt of the guide bar **205** raises or lowers the cross bar **210** as needed to indicate hand position of the rower according to the rower's biometric data. Once the desired height is achieved in this described tilting motion, the screws **235** are tightened to maintain the height adjustment. The height adjustment scheme shown in the present embodiment is merely exemplary. Other height adjustment schemes are possible within the scope of the invention. For example, an additional adjustment joint could be added to the guide bar itself to provide variation in height of the cross bar **210**. The guide bar **205** may also include a breakaway joint for safety purposes. Alternatively, the guide bar **205** may be made of a flexible material maintain appropriate stiffness to shape and affix clamps.

[**0058**] In alternative embodiments of the invention, the guide bar **205** is shaped and configured to prevent rotation of the guide bar **205** with respect to the adjustment bracket **245**. For example, the guide bar **205** could be oval-shaped in cross-section. Alternatively, the guide bar **205** could be rectangular in cross-section. These alternative embodiments are merely exemplary. Alternative guide bar cross-sectional shapes are contemplated within the scope of the invention. A further alternative embodiment to prevent the rotation of the guide bar with respect to the adjustment bracket **245** is a pin inserted through the guide bar **205** and adjustment bracket **245**.

[**0059**] While the mounting frame **215** shown in **FIG. 2** (also **FIG. 3** in perspective view) extends over the rail **100** at both sides, the mounting frame **215** could, in an alternative embodiment be a half-frame holding the seat top **105** and extending over only one side of the rail **100**. This embodiment, however, is not as balanced as the mounting frame **215** shown in **FIGS. 2 and 3** and this configuration may unevenly wear the seat rollers **115** and the rail **100**.

[**0060**] In a further alternative embodiment of the invention, the length of the cross bar **210** is extended so that the cross bar **210** extends over a second rowing machine positioned next to and aligned parallel to the first rowing machine **100**. This embodiment enables a second rower operating the second rowing machine to row in synchronization with the first rower operating the first rowing machine. This embodiment further includes a breakaway joint in the cross bar **210** for safety purposes. In a still further embodiment of the invention, the extension extends to within close proximity of a similar extension from the second rowing machine having its own position reference device so that each rower can see whether or not rowing is being performed in synchronicity.

[**0061**] **FIG. 4** is a perspective view of an alternative embodiment of the position reference device of the present invention. That is, **FIG. 4** shows a perspective view of the rowing machine **100** including an alternative embodiment of the position reference device of the present invention. The embodiment shown in **FIG. 4** includes the guide bar **205** and cross bar **210** of the embodiment shown in **FIG. 2**. The guide bar **105** is attached to the adjustment bracket **245**, which is attached to mounting frame **215**, as described with regard to **FIG. 2**. The present embodiment of the invention further includes a second guide bar **300** attached at a first end to the second adjustment bracket **405**, which is attached to the mounting frame **215** in similar fashion to the first adjustment bracket **245**. The second guide bar **300** is attached at its second end to the cross bar **210**. The second guide bar **300** provides a further balancing factor to the position reference device.

[**0062**] **FIG. 5** is a side view of the embodiment of the position reference device of **FIG. 2** including a rower **400** operating the rowing machine **100** where the rower **400** is positioned at the beginning of the drive portion of the rowing stroke at the "catch." The rower **400** sitting on the seat **225** is compressed forward with the arms extended straight away. The guide bar **205** and cross bar **210** have been positioned so that the rower's hands are located under the cross bar **210** at this point of the stroke.

[**0063**] **FIG. 6** is a side view of the position reference device of **FIG. 2** where the rower **400** is positioned properly at the start of the back swing of the drive portion of the rowing stroke in the "body over" position. The guide bar **205** and cross bar **210** are positioned as in **FIG. 4**. The rower **400** has begun the drive portion of the stroke by extending his legs but has not yet pulled back from the forward-leaning position. The rower **400** has maintained proper position by keeping his hands under the cross bar **210**.

[**0064**] **FIG. 7** is a side view of the position reference device of **FIG. 2** where the rower **400** is properly positioned at the back swing end of the drive portion of the rowing stroke at the "hands-away" position. The guide bar **205** and cross bar **210** are positioned as in **FIG. 4**. The rower **400** has reached full leg extension in the drive and has completed his back pull. This caused the rower's hands (pulling on the handle **125** of the rowing machine **100**) to come back from the cross bar **210**. The cross bar **210** continues to indicate whether the rower's hands are in proper position because the chain **130** (alternatively, a cable) of the rowing machine **100** remains at even height under the cross bar **210**.

[**0065**] **FIG. 8** is a side view of the position reference device of **FIG. 2** where the rower is positioned properly at the end of the drive portion of the rowing stroke at the

"finish." The guide bar **205** and cross bar **210** are positioned as in **FIG. 5**. The rower **400** has completed the leg extension and back swing of the drive and has additionally pulled his arms and hands (grasping the rowing machine handle **125**) in towards his body. The cross bar **210** continues to indicate whether the rower's hands are in proper position because the chain **130** of the rowing machine **100** remains at even height under the cross bar **210**.

[**0066**] **FIG. 9** is a side view of the position reference device of **FIG. 2** where the rower **400** is improperly positioned by over-reaching at the catch portion of the rowing stroke. The guide bar **205** and cross bar **210** are positioned as in **FIG. 5**. The rower **400** is overly compressed with the shoulders dropped at the beginning of the drive portion of the stroke and this is indicated by the rower's hands (holding the rowing machine handle **125**) are beyond the cross bar **210**.

[**0067**] **FIG. 10** is a side view of the position reference device of **FIG. 2** where the rower **400** is improperly positioned by using the back before the legs during the drive portion of the rowing stroke. The guide bar **205** and cross bar **210** are positioned as in **FIG. 5**. The rower **400** has started the back swing before the leg extension which is indicated by the rower's hands (holding the rowing machine handle **125**) coming back from the cross bar **210** before the legs are extended.

[**0068**] **FIG. 11** is a side view of the position reference device of **FIG. 2** where the rower **400** is improperly positioned by driving the legs without moving the rowing machine handle **125** during the drive portion of the rowing stroke "shooting the slide." The guide bar **205** and cross bar **210** are positioned as in **FIG. 5**. The improper position of the rower **400** is indicated by the cross bar **205** coming forward over the rower's arms during the leg extension portion of the stroke.

[**0069**] **FIG. 12** is a side view of the position reference device of **FIG. 2** where the rower is improperly positioned by grabbing with the arms during the drive portion of the rowing stroke, "grabbing" at the catch. The guide bar **205** and cross bar **210** are positioned as in **FIG. 5**. The rower **400** has initiated the drive portion of the stroke with the arms. The improper position of the rower **400** is indicated by the rower's hands (holding the rowing machine handle **125**) pulled away from the cross bar **210**.

[**0070**] **FIG. 13** is a side view of the position reference device of **FIG. 2** where the rower is improperly positioned by hands too low at the finish of the drive portion of the rowing stroke, "washing out." The guide bar **205** and cross bar **210** are positioned as in **FIG. 5**. The rower **400** has completed the leg extension and back swing of the drive but the rower's hands are pulled too low toward the rower's body. This is indicated by the relative position of the chain **130** of the rowing machine **100** with respect to the cross bar **210**. The chain **130** when the rower **400** maintains proper hand height during the drive should remain at a constant height with respect to the cross bar **210**.

[**0071**] **FIG. 14** is a side view of the position reference device of **FIG. 2** where the rower is improperly positioned by hands too high at the finish of the drive portion of the rowing stroke "digging" at the finish. The guide bar **205** and cross bar **210** are positioned as in **FIG. 5**. The rower **400** has completed the leg extension and back swing of the drive but the rower's hands are pulled too high on the rower's body. This is indicated by the relative position of the chain **130** of the rowing machine **100** with respect to the cross bar **210**. The chain **130** when the rower **400** maintains proper hand height during the drive should remain at a constant height with respect to the cross bar **210**.

[**0072**] **FIG. 15** is a side view of the position reference device of **FIG. 2** where the rower is improperly positioned by hands too low at the catch, "skying." The guide bar **205** and cross bar **210** are positioned as in **FIG. 5**. The rower **400** is compressed forward with arms straight forward. The rower's hand (holding the handle **125** of the rowing machine **100**) are positioned under the cross bar **210** but are positioned too low under the cross bar.

[**0073**] The indicators provided by the position reference device are merely examples. The position reference device can be used to indicate other proper or improper rowing technique. Additionally, the cross bar **210** could be positioned below the rower's hands and effectively indicate proper or improper rowing technique. In a further alternative embodiment of the invention, there are two cross bars, one above the rower's hands and one below the rower's hands. In a still further embodiment of the invention, additional indicators extending from the guide bar **205** indicate other joint and body centers such as head and shoulders.

[**0074**] **FIG. 16** is a perspective sketch of an alternative embodiment of the position reference device according to principles of the invention where the position reference device is attached to the rowing machine **100**. In this embodiment, the guide bar **205** is extended and turned back on itself at the seat end of the guide bar **205**. The seat end of the guide bar **205** is then attached to the combination mounting frame and adjustment bracket **520**. In this embodiment, the combination mounting frame and adjustment bracket **520** is mounted to the side of the seat carriage, below seat top **105**, via the fixed axle bolts attaching the rollers **115** to the seat carriage **220**. The guide bar **205** is attached to the combination mounting bracket and adjustment bracket by clamps **505**. The cross bar **210** is attached substantially perpendicular to the guide bar **205** as in **FIG. 2**. The guide bar **205** and the cross bar **210** in this embodiment may be extended forward and back by sliding the guide bar **205** forward and back in the clamps **505**. Height adjustment is accomplished similarly to **FIG. 2**, discussed above, by a third clamping screw **505** guiding an arced slot in the combination mounting frame and adjustment bracket **520**.

[**0075**] **FIG. 17** is a perspective sketch of another alternative embodiment of the position reference device of **FIG. 16** where the position reference device is attached to the rowing machine **100**. In this embodiment, the position reference device includes the guide bar **205** and the cross bar **210**. A first end of the guide bar **205** is attached to the seat **225** at the middle front with a first clamp **510**. The guide bar **205** is typically made of a lightweight material but material having sufficient stiffness to hold clamps. The cross bar **210** is attached substantially perpendicular to the guide bar **205** at a second end of the guide bar **205**. The cross bar **210** in this embodiment is attached to the guide bar **205** with a second clamp **515**. The first clamp **510** enables the guide bar **205** to be extended forward or backward. The second clamp **515** enables the cross bar **210** to be raised or lowered on the

guide bar **205**. Using the clamps **510**, **515** the guide bar **205** and cross bar **210** can be adjusted in both length and height according to the rower's biometric data. In this embodiment, the guide bar **205** and cross bar **210** are adjusted such that the rower's hands move over the cross bar **210** and the guide bar **205** rather than under the guide bar. In an alternative embodiment of the invention, as it pertains to usage on a rowing machine, the cross bar **210** clamp **515** mounting feature is extended well below the cross bar **210** to allow for telescoping adjustment of the cross bar **210** height along a shortened guide bar **205** when the cross bar **210** is positioned below the hands to prevent interference with the rowing machine handle **125**. In an alternative embodiment of the invention, as it pertains to usage on a rowing machine, the cross bar is shaped, for example, in a "question mark"-shape to prevent interference with the rower's hands on the rowing machine handle **125** while maintaining the over-the-hands cross bar reference and the cross bar is adjustably attached to a shortened guide bar **205** by clamp **515** below the lowest possible rowing machine chain **120** height.

[**0076**] **FIG. 18** is a perspective sketch of a further alternative embodiment of the position reference device of **FIG. 17** where the position reference device is attached to a seat **605** in a boat **600**. Only the section of the boat **600** where the seat **605** is attached is shown in this illustration. In this embodiment, the position reference device includes the guide bar **205** and alternative embodiment of a cross bar **615**. The guide bar **205** is attached at a first end to the seat in similar fashion to the embodiment shown in **FIG. 17**. The alternative cross bar **615** is attached substantially perpendicular to the guide bar **205**. The guide bar **205** and alternative cross bar **615** are adjustable according to the rower's biometric data. The guide bar **205** can be moved forward and backward at the seat and the alternative cross bar **615** can be adjusted up or down on the guide bar **205**. The alternative cross bar **615** is a transparent plate **620** with markings as shown in **FIGS. 19A, 19B** and **19**C. The rower is able to view his or her hands through the transparent plate **620** and the markings enable the rower to determine whether he or she is rowing with proper technique. In alternative embodiments of the invention, the transparent plate **620** is a translucent plate with markings or a screen with markings. The screen, in particular, has the advantages that it is non-glare and can be light in weight.

[**0077**] **FIG. 19A** is a top view of a first embodiment of the transparent plate **620** of **FIG. 18**. The transparent plate **620** has markings **650** and **655** configured and arranged to provide indications for sculling (that is, where the rower is using two oars). The markings **655**, positioned towards the stern of the boat, indicate proper position for each hand on its oar at a selected point of the oar stroke, such as the catch. The marking **650** is positioned toward the bow of the boat indicates the second selected point of the oar sequence, such as the hands-away body forward position.

[**0078**] **FIG. 19B** is a top view of the cross bar of the transparent plate **620** of **FIG. 18** for a starboard sweep oar. The transparent plate **620** has markings **650** and **660**. The markings **660**, positioned towards the stern of the boat, indicate proper position for the starboard sweep oar at a selected point of the oar stroke, such as the catch. The marking **650** is positioned toward the bow of the boat indicates the second selected point of the sweep oar sequence, such as the hands- away body forward.

[**0079**] **FIG. 19C** is a top view of the cross bar of the transparent plate **620** of **FIG. 18** for a port sweep oar. The transparent plate **620** has markings **650** and **665**. The markings **665**, positioned towards the stem of the boat, indicate proper position for the port sweep oar at a selected point of the oar stroke, such as the catch. The marking **650** is positioned toward the bow of the boat indicates the second selected point of the sweep oar sequence, such as the hands-away body forward position.

[**0080**] **FIG. 20** is a perspective sketch of an alternative embodiment of the position reference device according to principles of the invention where the rower's position is indicated through electronics. A portion of the boat **600** is shown. In one embodiment, the seat position is determined by monitoring the rotation of the wheel **702** with sensor **700** attached to the seat **725**. In another embodiment, the seat position is determined with optical sensor **705** attached to the seat **725** viewing position indicator strip **707**. The described electronic measurement means of the seat position are exemplary and other means for measurement are possible. A rigger **720** attached to the boat **600** holds an oar **730**. A third sensor and a fourth sensor (shown in **FIG. 20**) are mounted inside the oar handle **710**. Alternatively, a fifth sensor **735** and a sixth sensor **740** located on rigger **720** near oar lock **745**. Foot stretchers **715** are attached to the boat **600** forward of the rigger **720**. In one embodiment the third sensor, a gyroscope, and the fourth sensor, an accelerometer, determine the position of the hands by determining the position of the oar handle in space. In second embodiment the fifth sensor, an electronic oar lock angle measurement, and the sixth sensor, an electronic oar pitch measurement with respect to the rigger **720**, determine the position of the hands by determining the position of the oar with respect to the rigger **720**. The sensors in the seat **725** and in the either the oar handle **710** or by the oar lock **735** locate the seat and the rower's hands with respect to the foot stretchers **715**. The sensors provide continuous location data of the rower's position over the course of each oar stroke. The sensors are typically associated with wireless transmitters that transmit the position data to a receiver. The received data is used to determine the position of the rower's body, which compared against correct positions for the rower. Generally, deviations from proper rowing technique are displayed on a display device to provide feedback to the rower. Full rower data is stored for later detailed analysis of the rower's body position through many complete rowing strokes.

[**0081**] In an alternative embodiment of the gyroscope and accelerometer combination is replaced by a global position reference device sensor sensing the location of the oar handle.

[**0082**] **FIG. 21** is a diagram of the hand position sensors of the position reference device of **FIG. 20** where the sensors are located inside the oar handle. A gyroscope **750**, an accelerometer **755**, a battery **760**, a wireless transmitter **765** and a microprocessor **770** are embedded in the oar handle **710**. The gyroscope **750** and accelerometer **755** sense the location of the oar handle **710** and therefore the rower's hand(s) with respect to the foot stretchers **715** (shown in **FIG. 20**). The data from the sensors **750** and **755** is processed by the microprocessor **770** to determine the oar position in space. This processed data is transmitted by the wireless transmitter **765** to a receiving device within the display unit (not shown) or to another receiver. The gyro-

scope **750**, accelerometer **755**, wireless transmitter **765** and microprocessor **770** are powered by the battery **760**. The battery **760** could be a typical chemical battery, solar cell, a novel power scavenging device or any combination of power sources. The gyroscope **750**, accelerometer **755**, battery **760** and wireless transmitter **765** may also be used in the handle of the rowing machine. Alternatively, the wireless transmitter **765** can be a wired transmitter.

[**0083**] **FIG. 22** is a diagram of the hand position sensors of the position reference device of **FIG. 21** where the sensors are located in a configuration that is attached to the outside of the oar handle. The gyroscope **750**, the accelerometer **755**, the battery **760**, the wireless transmitter **765** and the microprocessor **770** of **FIG. 20** are embedded in a torus-shaped form **775** that can be slipped onto the oar handle **710** and fastened there.

[**0084**] **FIG. 23** is a block diagram of the hand locator and seat locator sensor configuration. The electronic seat locator **900** includes a seat position sensor **905** and a first data communication device **910**. An electronic hand locator **915** includes an oar position sensor **920** and a second communication device **925**. The first communication device **910** and the second communication device **925** communicate with a central data device **930**. The central data device **930** includes a third data communications device **935**, a biometric storage device **940**, a position calculation device **945**, a data storage device **950**, a display data device formatting device **955** and an information display device **960**. In operation, the third data communications device **935** receives data from the first and second communications devices **910**, **925**. The position calculation device **945** calculates position data using the received data and rower biometric data stored in the biometric data device **940**. The central data device **930** stores the position data in the data storage device **950**. The display data formatting device **955** formats the position data for display on the information display device **960**. The data is stored in data storage device **950** so that the data may be later downloaded and reviewed.

[**0085**] **FIG. 24** is a block diagram of the sensor configuration of **FIG. 23** including a plurality of seat and hand locator devices.

[**0086**] **FIG. 25** is a sketch of an embodiment of the positioning device of the invention where a camera is used to determine the rower's body position. In this embodiment, hand and seat location are determined by taking an image of the rower in motion and measuring the positions of the hands and seat relative to a fixed reference on the rowing machine **100** or boat **600**, such as the foot stretchers **140** and **715** respectively. To acquire this image, a camera **580** as shown in **FIG. 25** is placed a distance away from the rowing machine or on a fixed reference from a rower seated in a boat such that the camera field of view **585** encompasses the entire length of the seated rower's stroke. The camera takes a number of sequential images of the rower as the rowing stroke is executed. After each image is acquired, the camera transfers the image to a sufficiently high-speed computer **590**, such as a desktop, laptop, or handheld computer to process the image. Appropriate signal processing will detect the rower's body position, such as the hands, arms, legs, and torso, in relation to features of the rowing device, such as the seat and foot stretcher. The signal processing will determine the hands and seat locations relative to the fixed reference on the rowing device for each image. Biometric data stored for the seated rower determines the proper hand and body positions as discussed above with regard to **FIGS. 5-17**. For coaching considerations, the desired rowing positions may be calibrated at positions throughout the rowing stroke for the seated rower. The measured position of the hands and seat relative to the fixed reference on the rowing device, such the foot stretcher, compared to the rower's biometric data determines whether there is deviation from proper rowing technique, These parameters also determine the degree of deviation. Various configurations of displayed results are possible. The displayed results may include actual rowing strokes with a stick figure indicating the proper rower position, pictorial highlights indicating the deviation from ideal position and accentuated highlights to indicate the degree of deviation, or signals to indicate the deviations and degree thereof. The display may instead be of the acquired image data directly without technical critique. The display is any form of information display device formatted appropriately to display continuously updated results, for example, a desk top, laptop or handheld computer display. The display is oriented so that the rower could receive feedback while rowing and data saved for review after the workout is complete.

[**0087**] **FIG. 26** is a further embodiment of the camera system of **FIG. 25** for on the water usage. As shown in **FIG. 26**, the hand and body positions of a rower seated on seat **725** in boat **600** are obtained by acquiring a number of sequential images of the rower with a camera **560** mounted on oar lock **745** throughout the rowing stroke. The camera **560** is mounted on a moving reference, the oar lock **745**, synchronized to the sweep angle of the rowing oar **730**. The camera **560** is positioned in such a way to capture the rower's body position centered within the field of view of the camera **560** while the rower is holding the oar handle **710**. The camera **560** mounting fixture on the moving reference **745** is attached without interference to any of the rowing mechanisms, such as rigger **720**, oar **730**, and oar lock **745**, throughout the rowing stroke. As the oar moves, the camera **560** will capture images of the hands, body and boat positions as referenced to the oar **730**. A second camera **570** may additionally be attached to the moving reference, oar lock **745**, without creating interference with the rowing mechanisms. The second camera **570** is mounted in such a way to capture the end of the oar, blade, and water centered within the field of view of the camera **570**. This second camera **570** views the action of the oar **730** throughout the rowing stroke. The data from cameras **560** and **570** are processed in a similar fashion as in the embodiment shown in **FIG. 25**. The data from camera **560** and **570** may be sent directly to the display device without critique for direct observation by the rower. The display device is mounted in the boat **600** above the foot stretchers **715** for view by the seated rower. **FIG. 26** is exemplary of port sweep oar and rowing in the starboard configuration follows as above with the rowing mechanisms and camera(s) on the opposite side and rowing in the sculling configuration follows as above with the rowing mechanisms and camera(s) on both sides.

[**0088**] **FIG. 27** is a block diagram of the computer **590** used to process data received from the cameras of **FIGS. 25 and 26**. The computer **590** includes a processor **1100**, a storage device **1115** storing rower biometric data **1135**, and a memory **1120**. The processor **1100** includes a hand position subprocessor **1105** and a seat position subprocessor

1110. The computer **590** further includes an input/output interface **1125** through which the computer **590** communicates to the cameras **560**, **570** and a display **1130**. In operation, the processor **1100** receives data from at least the camera **560** capturing images of the rower. The hand position subprocessor **1105** calculates the hand position relative to the rowing device from the captured image. The seat position subprocessor **1110** calculates the seat position relative to the rowing device from the captured image. The hand and seat positions reported by subprocessors **1105** and **1110** respectively are correlated to the biometric data by the processor **1100** to produce data about the rower's deviation from proper rower technique. This deviation data can be stored in the storage device **1115** for later examination. The images from the camera and any data stored on or produced by the computer **590** may be displayed on the display **1130**. Other locations of the rower's body in space are also possible within the scope of the invention. The present invention is not limited to hand and seat locations but could determine any point such as the rower's head or shoulders.

[**0089**] **FIG. 28** is a rowing machine chain position detection device according to principles of the present invention. In an alternative embodiment, pertaining to the rowing machine, the position of the hands holding the rowing machine handle **125** as in **FIG. 2** are sensed electronically by measuring the length of the rowing machine chain **130** and the angle the rowing machine chain **130** makes with respected to axle of the rowing machine **100** resistance wheel throughout the entire rowing sequence. To determine the angle and length of the rowing machine chain, a fixed measurement plane, for example the chain aperture **260** as shown in **FIGS. 3, 4** and **28**, between the rowing machine handle **125** and the axle of the rowing machine **100** resistance wheel is selected. The length of the rowing machine chain **130** is measured by counting the number of links passing through the fixed measurement plane **260** and multiplying by the link length, which is a known characteristic length. The angle of the rowing machine chain **130** is determined geometrically by measuring the vertical displacement of the rowing machine chain **130** within the fixed measurement plane **260** correlated to the distance from the fixed measurement plane **260** to the center of rotation of the rowing machine **100** resistance wheel.

[**0090**] To measure the length of the rowing machine chain **130**, an illumination device **800** shown in **FIG. 28**, which is driven by a source driver **805**, illuminates the fixed measurement plane **260** shining light through the link openings in rowing chain **130**. The single illumination device **800** is exemplary and multiple illumination devices are possible. The light passing through the rowing chain **130** illuminates the first light sensor **810** and the second light sensor **815**, which is directly behind the first light sensor **810**. The first light sensor **810** senses intensity changes as the links in rowing machine chain **130** pass through the fixed measurement plane **260**. The second light sensor **815** also senses intensity changes as the rowing machine chain **130** but by being displaced behind the first sensor **810**, the second sensor **815** detects the direction the rowing machine chain **130** is traveling. The electronic signals from light sensors **810** and **815** are passed are appropriately detected and filtered so that the transitions between the open and closed sections of the rowing machine chain are counted. The two count signals derived from the first and second light sensors, **810** and **815**, are passed to the microprocessor for signal processing. The relative phase between the count signals determines the direction of the change movement. The microprocessor calculates the direction and length of rowing machine chain **130** displaced during the rowing cycle.

[**0091**] To measure the angle of the rowing machine chain **130**, illumination devices **820** shown in **FIG. 28**, which are driven by source driver **825**, illuminates the fixed measurement plan **260** horizontally. The number of illumination devices **820** as illustrated in **FIG. 27** are exemplary and any number of illumination devices are possible. The light from illumination devices **820** impinges the rowing machine chain **130**, which blocks a portion of the intensity profile from the illumination devices **820**. The light sensors **830** shown in **FIG. 27** receive the intensity profile from the illumination devices **820** partially blocked by the rowing machine chain **130**. Over multiple light sensors **830**, the detected intensity profile is sampled indicating the position of the intensity dip due to the occlusion of the illumination profile by the rowing machine chain **130**. The relative intensities received by each sensor determine the position of the rowing machine chain **130** within the fixed measurement plane. The electronic signals from light sensors **830** are passed, appropriately detected and filtered so that the analog signals can be quantized and processed by the microprocessor. The microprocessor determines the vertical displacement of the intensity dip in the illumination profile and then calculates the angle of the rowing machine chain **130** by geometric relationship to the center of rotation of the rowing machine **100** resistance wheel.

[**0092**] The hand locator sensors and seat locator sensors described above may be similarly applied to the rowing machine **100**.

[**0093**] It is to be understood that the above-identified embodiments are simply illustrative of the principles of the invention. Various and other modifications and changes may be made by those skilled in the art which will embody the principles of the invention and fall within the spirit and scope thereof. For example, one alternative embodiment for a rowing machine includes a display device mounted to the cross bar so that the rower may view the data while rowing on the rowing machine without turning his or her head to the side.

We claim:

1. A position reference device for a rowing apparatus, comprising:

a seat locator attached to the rowing apparatus, the seat locator to indicate hip location of a rower positioned on a seat on the rowing apparatus; and

a hand locator attached to the rowing apparatus to indicate hand position of the rower, the seat locator and hand locator positioned relative to each other according to biometric data of the rower such that the position reference device indicates the rower's body position during at least one selected stroke point.

2. The position reference device of claim 1 wherein the seat locator further comprises an adjustable guide bar having a first end and a second end, the adjustable guide bar attached to the seat at the first end; and

wherein the hand locator further comprises a cross bar attached substantially perpendicular to the second end of the guide bar.

3. The position reference device of claim 2 wherein the adjustable guide bar is shaped and configured to prevent axial rotation of the guide bar.

4. The position reference device of claim 2 wherein the rowing apparatus is a rowing machine.

5. The position reference device of claim 4 wherein the seat locator further comprises an adjustment assembly attached to the rowing apparatus at the seat, the adjustment assembly to hold the guide bar at the first end, the adjustment assembly configured to enable an extension adjustment of the guide bar.

6. The position reference device of claim 5 wherein the adjustment assembly is further configured to enable a tilt adjustment of the guide bar.

7. The position reference device of claim 6 wherein the guide bar is extendible to enable height adjustment of the hand locator.

8. The position reference device of claim 7 wherein the guide bar has a telescoping portion that enables the height adjustment of the hand locator.

9. The position reference device of claim 5 wherein the adjustment assembly further comprises an adjustment frame holding a seat top while saddling a rail positioned underneath the seat on which the seat slides, the adjustment frame having two sides positioned on either side of the rail, one of the sides of the adjustment frame configured to adjustably hold the guide bar.

10. The position reference device of claim 5 wherein the guide bar is a first guide bar attached to one side of the seat;

wherein the position reference device further comprises a second guide bar substantially similar to the first guide bar similarly attached to an opposing side of the seat from the first guide bar; and

wherein the cross bar is attached between the first guide bar and the second guide bar.

11. The position reference device of claim 5 wherein the seat rolls on the rail on wheels having bearings and wherein the adjustment assembly further comprises a single-side adjustment frame that is a half saddle attached to the seat at the seat bearings, the half saddle hanging over one side of the rail and wherein the guide bar is attached to the half saddle.

12. The position reference device of claim 9 wherein the side holding the adjustment assembly includes two clamps configured to receive and retain the guide bar and a slot and a hole to receive the clamps, the clamps configured to be tightened in position in the slot and the hole, the slot, the hole, and clamps providing tilt and extension adjustment of the guide bar.

13. The position reference device of claim 9 wherein the cross bar is extended such that a second rower on the second rowing machine can operate the second rowing machine in synchronicity with the rowing machine holding the position reference device.

14. The position reference device of claim 4 wherein the rowing machine includes a cable attached at a first end to a resistance wheel and including a handle attached at a second end of the cable, the handles to be held by the rower, and the seat further includes rollers and the rowing machine further comprises a rail along which the seat rolls,

wherein the seat locator comprises a first sensor to detect location of the seat relative to the rowing machine; and

wherein the hand locator comprises a second sensor to sense the handle position relative to the rowing machine.

15. The position reference device of claim 14 further comprising a display device coupled to a receiver and wherein the first sensor is coupled to a first transmitter that transmits first sensor data to the receiver and wherein the second sensor is coupled to a second transmitter that transmits second sensor data to the receiver, the display device to display the first sensor data and the second sensor data.

16. The position reference device of claim 15 wherein the first transmitter and the second transmitter and the receiver are wireless.

17. The position reference device of claim 15 wherein the display device is coupled to a computation device storing the biometric data of the rower and hand and seat locations for selected stroke points for specific rowers, the computation device to correlate sensor data with biometric data and the display device to display output of the correlated sensor and biometric data.

18. The position reference device of claim 14 wherein the second sensor is a chain position sensor

wherein at least one light source illuminates the link openings of a chain and at least one detector senses the light passing through the chain and the transitions in the detector signal are counted; and

wherein at least one light source illuminates the solid side of a chain and a plurality of detectors sense the light pattern detected by the plurality of detectors and the minimum in the detected light pattern indicates the position of the chain relative to the plurality of detectors.

19. The position reference device of claim 14 wherein the first sensor is a linear position encoder.

20. The position reference device of claim 14 wherein the first sensor is a rotation encoder.

21. The position reference device of claim 14 wherein the first sensor is a gyroscope and an accelerometer.

22. The position reference device of claim 14 wherein the second sensor is a gyroscope and an accelerometer.

23. The position reference device of claim 14 wherein the first sensor is a first GPS device.

24. The position reference device of claim 2 where the rowing apparatus is a boat.

25. The position reference device of claim 24 wherein the seat locator further comprises

a guide bar having a first end and a second end, the guide bar attached at the first end to the seat at the center front of the seat; and

the hand locator further comprises a transparent plate attached at the second end of the guide bar, the transparent plate having markings to indicate hand position.

26. The position reference device of claim 25 wherein the transparent plate is centered with respect to the seat.

27. The position reference device of claim 25 wherein the transparent plate is positioned off- center with respect to the seat.

28. The position reference device of claim 25 wherein the transparent plate is a screen.

29. The position reference device of claim 25 wherein the guide bar is flexible.

30. The position reference device of claim 29 wherein the guide bar further comprises at least one flexible joint.

31. The position reference device of claim 25 wherein the boat further includes at least one seat that slides along rails attached to the boat and wherein the rower rows with at least one oar having a handle,

wherein the seat locator comprises a first sensor to indicate the position of the seat relative to the boat; and

wherein the hand locator comprises a second sensor to indicate the position of the oar relative to the boat.

32. The position reference device of claim 31 wherein the hand locator further comprises a battery and a wireless transmitter to transmit data to a rower feed back device.

33. The position reference device of claim 32 wherein the hand locator further comprises a solar collector to power the hand locator.

34. The position reference device of claim 32 wherein the hand locator is configured inside the oar handle.

35. The position reference device of claim 32 wherein the hand locator is configured inside a torus-shaped form that is configured to fit over the oar handle.

36. The position reference device of claim 31 wherein the rower rows with two oars wherein each of the oars includes a hand locator.

37. The position reference device of claim 31 wherein the first sensor is a linear position encoder.

38. The position reference device of claim 31 wherein the first sensor is a rotation encoder.

39. The position reference device of claim 31 wherein the first sensor is a gyroscope and an accelerometer.

40. The position reference device of claim 31 wherein the second sensor is a gyroscope and an accelerometer.

41. The position reference device of claim 31 wherein the second sensor is a GPS device.

42. The position reference device of claim 31 wherein the second sensor comprises an angle sensor to measure the sweep angle of the oar and angle sensor to measure the tilt of the oar.

43. A position reference device for a rowing boat, comprising:

a fixed reference on the rowing apparatus;

a camera located at the fixed reference, the camera to take a plurality of sequential images of a rower operating the rowing boat; and

a display device located in the rowing boat to receive the images from the camera, the display device viewable by the rower.

44. The position reference device of claim 43 further comprising:

a computer to receive and process the sequential images from the camera and to detect hand position and seat position of the rower with regard to the fixed reference point.

45. The fixed reference of claim 43 is the oar lock.

46. The fixed reference of claim 43 is the rigger.

47. The position reference device of claim 43 further comprising:

a second camera located at the fixed reference, the second camera to take a plurality of sequential images of an oar used by the rower.

48. The position reference device of claim 31 further comprising a display device coupled to a receiver and wherein the first sensor is coupled to a first transmitter that transmits first sensor data to the receiver and wherein the second sensor is coupled to a second transmitter that transmits second sensor data to the receiver, the display device to display the first sensor data and the second sensor data.

49. The position reference device of claim 48 wherein the first transmitter and the second transmitter and the receiver are wireless.

50. The position reference device of claim 48 wherein the display device is coupled to a computation device storing the biometric data of the rower and hand and seat locations for selected stroke points for specific rowers, the computation device to correlate sensor data with biometric data and the display device to display output of the correlated sensor and biometric data.

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