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(54) LAMENESS EVALUATION SYSTEM

SYSTEM ZUR LAHMHEITSBEURTEILUNG

SYSTÈME D'ÉVALUATION DE PARALYSIE

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- **KEEGAN K G ET AL: "EVALUATION OF A SENSOR-BASED SYSTEM OF MOTION ANALYSIS FOR DETECTION AND QUANTIFICATION OF FORELIMB AND HIND LIMB LAMENESS IN HORSES", AMERICAN JOURNAL OF VETERINARY RESEARCH, AMERICAN VETERINARY MEDICINE ASSOCIATION, US, vol. 65, no. 5, 1 May 2004 (2004-05-01), pages 665-670, XP008052433, ISSN: 0002-9645, DOI: 10.2460/AJVR.2004.65.665**
- **KEEGAN K G ET AL: "ACCELEROMETER-BASED SYSTEM FOR THE DETECTION OF LAMENESS IN HORSES", BIOMEDICAL SCIENCES INSTRUMENTATION, INSTRUMENT SOCIETY OF AMERICA, PITTSBURGH, US, vol. 38, 1 January 2002 (2002-01-01), pages 107-112, XP008052432, ISSN: 0067-8856**

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Description

Not Applicable.

COMPACT DISK APPENDIX

Not Applicable.

BACKGROUND

[0001] Lameness is the single most common medical condition affecting horses, resulting in an estimated 600 million to one billion dollar annual loss to the horse-owning public. Typically, lameness evaluation in horses is performed primarily by subjective visual evaluation. For example, an equine practitioner will look at how a horse's head or pelvis moves during a trot to detect and/or diagnose lameness. However, lameness of mild severity can be confusing, and the agreement for subjective evaluation even between experts is poor.

[0002] Currently, certain methods and systems have been developed in attempting to achieve more objective evaluation of lameness, but only with limited success. For example, motion analysis systems for detection of lameness in horses, with numerous descriptions, using high-speed video camera, are commercially available. For example, U.S. Patent No. 6,699,207 to Tasch et al. describes a method of using stationary force plates for the detection and evaluation of horse and cattle lameness. Lameness quantification based upon frequency-based head and pelvic motion has also been investigated, e.g. in US 2006/0000420

[0003] Another lameness evaluation system developed in France involves the use of accelerometers on the torso to collect body motion data. A fiber optic-based system with wireless data transmission for the visualization of equine movement has been commercially available from Equine Performance Technologies, Inc., located in Oldwich, New Jersey. However, all of the above mentioned methods and systems are either difficult to implement in the field, expensive, or encumber the natural movement of the horse with excessive or heavy equipment. In addition, although they allow sophisticated data collection, none provide lameness-specific data analysis.

[0004] Horses with forelimb lameness will show a "head nod" (or "head bob"), which can be described as the horse's head moving upward during the weight bearing phase of the lame limb and downward during the weight bearing phase of the sound limb. Indeed, this is what actually happens in horses with severe forelimb lameness and what appears to happen to the naked eye during the trot in horses with mild to moderate forelimb lameness. However, due to the rapid movement of the limbs in a horse and the limited temporal resolution of the human eye, these descriptions of the "head nod" are too simple and not entirely correct. Similarly, "hip hike," "hip drop," and "gluteal rise" are terms frequently used to describe hindlimb lameness in horses, but these descriptions are also imprecise and incomplete. Objective measurements of head and pelvic movement in lame horses have been made in some laboratory-based, experimental studies.

[0005] Therefore, it is desirable to provide a lameness detection and quantification method/system that can measure and evaluate the patterns of vertical head and pelvic motion in correlation with vertical feet movement to detect and quantify lameness in horses. It is also most desirable to provide a method and system to the practicing equine veterinarian in the field that helps in the determination of the specific cause of lameness in a horse.

SUMMARY

[0006] According to the invention there is provided a system for evaluating lameness in animals, as set out in claim 1. The methods and systems described detect lameness in animals, including four-legged animals, and promote health of the animals. One system includes a sensor-based diagnostics data retrieving and analyzing system that enables a user to evaluate the patterns of vertical head and pelvic motion of a four-legged animal in correlation with its vertical feet movement to detect and quantify forelimb and hindlimb lameness.

[0007] According to another aspect, a system evaluates lameness in an animal. The system comprises a plurality of motion sensors configured to generate a corresponding plurality of signals comprising motion data representative of a head motion, a pelvis motion, and at least one limb motion during a stride of the animal. The system further includes a processing system configured to receive the plurality of signals during the stride via wireless communication and to receive input data. The processing system comprises an evaluation application that comprises executable modules. A data-acquisition module is configured to retrieve motion data from the received plurality of signals. A data-decomposition module is configured to generate a simulated vertical head movement pattern and a simulated pelvis movement pattern for the stride. A curve-modification module is configured to modify and smooth the simulated vertical head and pelvis movement patterns based on the input data received from a user via a user-interactive interface. A position-detection module is configured to detect a maximum head position, a minimum head position, a maximum pelvis position, and a minimum pelvis position during the stride based on modified simulated head and pelvis movement patterns. A phase-shift calculation module is configured to identify a limb affected with lameness and to determine a type of the lameness in the identified limb based on a comparison of the detected maximum head position, the detected minimum head position, the detected maximum pelvis position, and the detected minimum pelvis position with at least one lameness reference pattern, the at least one lameness reference pattern indicating a peak time of lameness.

[0008] According to another embodiment, an evaluation system evaluates lameness in an animal and is operable with at least one processor. The evaluation system is configured to receive a plurality of signals comprising motion data representative of a head motion, a pelvis motion, and at least one limb motion during a stride of the animal. The evaluation system comprises executable modules. A data-acquisition module is configured to collect motion data from the received plurality of signals. A data-decomposition module is configured to generate simulated head and pelvis movement patterns for the stride. A curve-modification module is configured to receive input data and to modify and smooth the simulated head and pelvis movement patterns based on the input data. A position-detection module is configured to detect a maximum head position, a minimum head position, a maximum pelvis position, and a minimum pelvis position during the stride based on the modified simulated head and pelvis movement patterns. A phase-shift calculation module is configured to identify a limb affected with lameness based on a comparison of the detected maximum head position, the detected minimum head position, the detected maximum pelvis position, and the detected minimum pelvis position with at least one lameness reference pattern. The lameness reference pattern indicates a peak time of lameness.

[0009] According to another aspect, a computerized method evaluates lameness in a four-legged animal. The method comprises generating a plurality of signals representative of a motion of a head, a pelvis, and at least one limb during a stride of the animal. The method further comprises receiving the plurality of signals via wireless communication at a processing system for processing. Motion data is collected from the received plurality of signals. A stride rate detection method automatically selects segments of the motion that are good for detecting lameness. Simulated head and pelvis movement patterns are generated for the stride. Automatic and user-controlled peak finding and elimination methods optionally may be received. As input data, and calculations are automatically initiated based on automatically selected time indices of the received input data. A maximum head position, the detected minimum head position, the detected maximum pelvis position, and the detected minimum pelvis position are detected in the stride and comparison to lameness reference patterns and a limb affected with lameness is identified in the stride base on an analysis of the detected maximum head position, and the detected minimum pelvis position in the stride and comparison to lameness reference patterns. In one aspect, the reference patterns are previously measured in the laboratory and on animals with natural lameness, the reference lameness patterns indicating peak time of lameness.

[0010] According to another aspect, a computerized method evaluates lameness in a four-legged animal. The method comprises receiving motion data representing a plurality of strides of the animal from a plurality of motion sensors attached to a head, a pelvis, and at least one limb of animal. The received motion data is processed to identify at least two harmonic components and at least one transient component. Simulated vertical head and vertical pelvis movement patterns are generated based on the identified two harmonics and the at least one transient component data. A vertical head movement and a vertical pelvic movement are correlated with a vertical forelimb or hindlimb movement to identify the affected limb or limbs. A phase shift is calculated between the at least two harmonic components to detect a type of lameness suffered by the animal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1A is a block diagram of a lameness evaluation system in accordance with an aspect of the present invention.

FIG. 1B depicts an exemplary operating environment in which the lameness evaluation system of FIG. 1A may be implemented.

FIG. 1C is a block diagram of a lameness evaluation system in accordance with another aspect of the present invention.

FIG. 1D depicts an exemplary operating environment in which the lameness evaluation system of FIG. 1C may be implemented.

FIG. 2 is a block diagram of a lameness evaluation application according to one aspect of a lameness evaluation system.

FIG. 3 illustrates a plot of the vertical movement patterns of a head position and a forelimb position for a horse with peak pain of lameness occurring at the time of hoof impact.

FIGS. 4A-4D illustrate four reference patterns of head movement due to forelimb lameness.

FIGS. 5A-5C illustrate three reference patterns of pelvic movement due to hindlimb lameness.

FIG. 6A is a flow chart illustrating a lameness detection method in accordance with an aspect of a lameness evaluation application.

FIG. 6B is another flow chart illustrating a lameness detection method in accordance with an aspect of a lameness evaluation application

FIG. 7 is a flow chart illustrating a general data acquisition method in accordance with an aspect of a lameness evaluation system.

FIG. 8 is a flow chart illustrating a detailed data acquisition method in accordance with an aspect of a lameness evaluation system.

FIG. 9 is a flow chart illustrating a general data analysis method in accordance with an aspect of a lameness evaluation system.

FIG. 10 is a flow chart illustrating a detailed data analysis method in accordance with an aspect of a lameness evaluation system.

DETAILED DESCRIPTION

[0012] Aspects of the lameness evaluation systems and methods described herein detect and analyze lameness in animals using sensor-based diagnostics. One advantage of the systems is their ability to objectively quantify lameness in the field, especially in diagnosing lameness of mild severity or involving multiple limbs. One technique quantifies lameness using data collected from several contiguous strides or movement by a four-legged animal so lameness variability over short periods of time can be studied and controlled. Furthermore, the systems can be deployed in any environment, are not limited to laboratory treadmills, and are more portable and cost effective than current commercial systems.

[0013] FIG. 1A depicts an exemplary aspect of a lameness evaluation system 100. The evaluation system 100 detects and analyzes the patterns of vertical head and pelvic motion of an animal, such as a four-legged animal, in correlation with its feet movement to identify and quantify lameness.

[0014] A head sensor 102 and a pelvic sensor 104 are outfitted on the head and the pelvis (or along the center of the back), respectively, of the animal. The head sensor 102 and pelvic sensor 104 are motion sensors, such as accelerometers, that obtain motion data relative to the head and pelvis during a period of trotting or walking gait (i.e., during a stride) of the animal. The motion data sensed by the head sensor 102 and the pelvic sensor 104 is referred to herein as acceleration data.

[0015] In one aspect, a forelimb sensor 106 and a hindlimb sensor 108 are outfitted on the bottom part of a forelimb (e.g., forefoot) and the bottom part of a hindlimb (e.g., hindfoot), respectively, of the animal. In another aspect, the sensors 106-108 may be outfitted on other parts of the limbs.

[0016] The forelimb sensor 106 and the hindlimb sensor 108 are motion sensors, such as gyroscopes, that obtain motion data relative to the limb during the period of trotting or walking gait by the animal. The motion data sensed by the forelimb sensor 106 and the hindlimb sensor 108 is referred to herein as limb angular velocity data or gyroscopic data.

[0017] According to one aspect, the forelimb sensor 106 and the hindlimb sensor 108 are attached to the same side of the animal. For example, if the forelimb sensor 106 is attached to the right forefoot, the hindlimb sensor 108 is attached to the right hindfoot.

[0018] Each of the motion sensors 102-108 are configured to generate a signal that comprises motion data representative of motion sensed at the location of the animal to which the sensor is outfitted. For example, the head sensor 102 generates a first signal 110 comprising motion data representative of a head motion. The pelvic sensor 104 generates a second signal 112 comprising motion data representative of a pelvis motion. The forelimb sensor 106 generates a third signal 114 comprising motion data representative of a forelimb motion. The hindlimb sensor 108 generates a fourth signal 116 comprising motion data representative of hindlimb motion. Moreover, each of the sensors 102-108 are configured to transmit the generated signals, including by wireless and/or wired communication.

[0019] A transceiver 118 receives the generated signals 110-116 and transmits the received signals 110-116 to a processing system 120 for processing. In one aspect, the transceiver 118 receives the signals 110-116 emitted from the sensors 102-108, respectively, via a wireless communication link, and transmits the signals 110-116 to the processing system 120 via a wireless communication link. An antenna (not show) may be included within the transceiver 118.

[0020] The processing system 120 includes one or more processors or processing systems and employs a software subsystem, or a software application, to process the motion data included in the received signals 110-116. For example, the processing system 120 executes a lameness evaluation application 122 to process the received motion data and to objectively detect and diagnose lameness in the animal. The processing system 120 includes a transceiver (not shown) that receives the signals 110-116 from the transceiver 118. In one aspect, the transceiver for the processing system 120 is a wireless transceiver configured to receive wireless communication signals.

[0021] In one aspect, the processing system 120 is a remote computer, such as a laptop computer or a personal computer station. In another aspect, the processing system 120 is a server computer. In another aspect, the processing system 120 communicates with the transceiver 118 via a wireless area communication network. In other aspects, other wireless and/or wired communications may be used.

[0022] A user interface (UI) 124 enables a user to input or manipulate motion data and to issue processing commands.

Processing commands comprise, for example, commands to initiate data acquisition and/or commands to initiate data analyses. In one embodiment, the UI 124 includes a display, such as a computer monitor, for viewing motion data and an input device, such as a keyboard or a pointing device (e.g., mouse, trackball, pen, touch pad, or other device), for interacting with the motion data. The UI 112 generates one or more input forms for display via the display. The input forms enable the user, for example to select motion data for viewing and/or editing.

[0023] According to one aspect, the processing system 120 is coupled to a memory 126 for storing motion data for a particular animal, including processed and/or raw motion data. For example, the memory 126 comprises one or more files each comprising processed and/or raw motion data for a particular animal.

[0024] FIG. 1B illustrates an aspect of the evaluation system 100 outfitted on a horse 130. The head sensor 102 and pelvic sensor 104 are depicted as being attached to the head and the pelvis, respectively. The forelimb sensor 106 and the hindlimb sensor 108 are attached to the forelimb and the hindlimb of the horse, respectively, such as on the horse's right feet. FIG. 1B further illustrates the transceiver 118 that receives signals 110-116 from the sensors 102-108 and that transfers the received signals 110-116 to the processing system 120, such as a portable computer. While it is contemplated that the sensors 102-108 may include multiple types of motion sensors, in one embodiment, the head sensor 102 and the pelvic sensor 104 are accelerometers, while the forelimb sensor 106 and the hindlimb sensor 108 are gyroscopes.

[0025] FIG. 1C depicts another exemplary aspect of an evaluation system 100. According to this aspect, the evaluation system 100 includes a head sensor 102, a pelvic sensor 104, and a single limb sensor, such as the forelimb sensor 106.

[0026] Moreover, the processing system 120 depicted in FIG. 1C is configured to receive the generated signals 110-114 directly from the sensors 102-106. In this aspect, a separate intermediate transceiver, such as the transceiver 118, is not used. The processing system 120 then employs the evaluation application 122 to process the motion data included in the generated signals 110-114 to detect and quantify lameness. FIG. ID illustrates an exemplary operating environment based on the evaluation system depicted in FIG. 1C.

[0027] FIG. 2 illustrates an exemplary evaluation application 202 (e.g., evaluation application 122) according to one aspect of the evaluation system 100. The evaluation application 202 comprises instructions or modules that enable a processing system (e.g., processing system 120) to process motion data and objectively detect and/or diagnose lameness.

[0028] A data-acquisition module 204 is configured to collect motion data for pre-determined but unrestricted time intervals. For example, the data-acquisition module 204 collects the motion data transmitted from the transceiver 118 for intervals during the period of trotting or walking gait. According to one aspect, the predefined interval is a default time period retrieved from a memory (e.g., memory 126). In one example, the predefined interval is a fixed period, such as ten minutes. According to another aspect, there is no predefined interval. For example, data-acquisition module 204 collects the motion data transmitted from the transceiver 118 for the entire period during which the animal is trotting or in walking gait.

[0029] In another aspect, the predefined interval is definable by a user. For example, prior to executing the application 202, a user uses the UI 124 to define a desired time interval for collecting motion data. In one example, the time interval is defined as ten minutes.

[0030] The data-acquisition module 204 is further configured to arrange the collected motion data into different data sets according to their generating locations, such as the head, pelvis, forelimb, or hindlimb foot. According to one aspect, the data-acquisition module 204 creates a motion data table that comprises motion data sensed by each of the sensors 102-108, and stores the created tables in the memory 126. For example, the data-acquisition module 204 creates a head motion table for storing motion data sensed by the head sensor 102, a pelvis motion table for storing motion data sensed by the pelvic sensor 104, a forelimb motion table for storing motion data sensed by the forelimb sensor 106, and optionally a hindlimb motion table for storing motion data sensed by the hindlimb sensor 108. For aspects that do not include a hindlimb sensor 108, a hindlimb motion table is not created.

[0031] A data-decomposition module 206 is configured to simulate the vertical head and vertical pelvic movement patterns in accordance with a respective forelimb and hindlimb movement (e.g., head vs. forefoot and pelvis vs. hindfoot) by integrating and decomposing the motion data. For aspects that do not include a hindlimb sensor 108, the data-decomposition module 206 is configured to simulate the vertical head and vertical pelvic movement patterns in accordance with forelimb movement. According to one aspect, the data-decomposition module 206 first performs a double integration of acceleration data from the head and pelvic sensors 102, 104 and calculates the stride rates from the gyroscopic data of the corresponding limb sensor (e.g., forefoot to head and hindfoot to pelvis). For aspects that do not include a hindlimb sensor 108, the data-decomposition module 206 first performs a double integration of acceleration data from the head and pelvic sensors 102, 104 and calculates the stride rates from the gyroscopic data of the forelimb sensor 106 (e.g., forefoot to head and forefoot to pelvis). The calculated stride rate indicates whether the animal is in a trotting phase or a walking gait phase.

[0032] According to another aspect, the data-decomposition module 206 further employs a curve-fitting algorithm (e.g., a Data-Decomposition Algorithm). The Data-Decomposition Algorithm assumes that the vertical head or pelvic movement

($y(t)$) can be described and simulated by three components: 1) a first harmonic component with frequency ω, describing unilateral lameness contribution to vertical head movement (ω = stride rate in strides/second), 2) a harmonic component with a frequency 2ω, describing the normal, biphasic, vertical head movement, and 3) a low-frequency, transient component describing extraneous vertical head or pelvic movement. Based on the above assumption, an animal's vertical head or pelvic movement can be mathematically expressed as

$$y(\bar{t}) = C_1 \cos(\omega\bar{t}) + C_2 \sin(\omega\bar{t}) + C_3 \cos(2\omega\bar{t}) + C_4 \sin(2\omega\bar{t}) + C_5 + C_6\bar{t} + C_7\bar{t}^2 + C_8\bar{t}^3 \quad (1)$$

where $\bar{t} = t - t_m$ is a moving time coordinate and t_m is the observed instant.

[0033] To find the coefficients $C_j(j=1,...8)$ for the data point at $\bar{t} = 0$, the data points around $t=t_m$ are used to minimize the square error (E_{rror}),

$$E_{rror} = \sum_{i=-N}^{N} \kappa_i (y_i - Y_i)^2 \quad (2)$$

where y_i denotes $y(\bar{t}_i)$, Y_i denotes the experimental data at $\bar{t}_i$, κ_i is a weighting factor of the importance of the point at $\bar{t}$, and N is the number of points from each side of the point at $\bar{t}=0$.

[0034] The eight equations to determine the eight coefficients are then obtained by differentiation as

$$\frac{\partial E_{rror}}{\partial C_j} = 0, j = 1,....8 \quad (3)$$

Because the displacement at $\bar{t}=0$ is the sum $C_1 + C_3 + C_5$, it shows that the displacement consists of C_1, the amplitude of the harmonic component $\cos(\omega\bar{t})$, C_3^-, the amplitude of the harmonic component $\cos(2\omega\bar{t})$, and C_5, a moving average. Since the amplitudes of the two harmonics (C_1, C_3) are not constant, we estimate the effective amplitude at each harmonic by computing the root-mean-square $(\sqrt{2}RMS)$. The effective amplitudes of C_1 and C_3 are designated as A_1 and A_2, respectively. Because effective amplitudes can be determined for vertical head movement or vertical pelvic movement, the ratios can be designated as A_{1Head} and A_{2Head} for head movement and $A_{1Pelvis}$ and $A_{2Pelvis}$ for pelvis movement. The ratios A_{1Head}/A_{2Head} and $A_{1Pelvis}/A_{2Pelvis}$ represent the severity of lameness in the forelimb and hindlimb, respectively. For example, a greater ratio indicates more severe lameness and a lesser ratio indicates less severe lameness.

[0035] In aspects, where the hindlimb sensor 108 is not used, the same equation can be used to determine the ratios A_{1Head} / A_{2Head} and $A_{1Pelvis}$ / $A_{2Pelvis}$. During a walking gait, for example, when the forelimb of the animal is down, the hindlimb (i.e., on the same side) is up, and when the forelimb up, the hindlimb (i.e., on the same side) is down. Moreover, if the vertical position of the forelimb is increasing (i.e., going up) the vertical position of the hind limb is decreasing (i.e., going down), and if the vertical position of the forelimb is decreasing the vertical position of the hind limb is increasing. As such, the vertical position of the hindlimb can be mathematically determined based on the position and direction of vertical movement of the forelimb, as determined from the forelimb sensor 106. According to one aspect, the hindlimb sensor 108 is not needed to detect lameness during the walking gait of the animal.

[0036] A curve-modification module 208 is configured to smooth and modify the simulated movement patterns though a user-interactive interface. For example, the user optionally uses the UI 124 to input data to modify the simulated movement patterns of the head or pelvis. For example, the user can use the UI 124 to manually eliminate data points that are deemed erroneous. The curve-modification module 208 receives the user's input and smoothes the simulated movement patterns (i.e., resulting curves) for improved accuracy.

[0037] In another aspect, the curve-modification module 208 is configured to automatically identify and eliminate erroneous data points. For example, the curve-modification module 208 processes the data points produced by the curve fitting algorithm to identify data points that would result in a spike and eliminates such data points from the simulated movement patterns,

[0038] A position-detection module 210 is configured to detect maximum and minimum head and/or pelvic positions during strides along the modified movement patterns. In particular, the maximum and minimum positions of the vertical head and/or pelvis during the animal's movement are determined along the simulated curve first through a Peak-Detection Algorithm. The Peak-Detection Algorithm assigns the first maximum position of the sum of the first and second harmonics as the beginning point for calculating the maximum and minimum differences between the sum of the first and second harmonics as obtained from the aforementioned Data-Decomposition Algorithm. (i.e., equation (1)).

[0039] According to another aspect, a user, such as a veterinarian or a clinician, studying the simulated pattern with maximum and minimum data points can decide if the motion data included in the vertical position signals 110, 112 from the head sensor 102 and pelvic sensor 104 should be smoothed (e.g., eliminate spikes from curves) to reduce or to eliminate errors in the Peak-Detection Algorithm. If smoothing is desired, the user can use the UI 124 to identify which segment of the data should be smoothed. The user can also decide if any computer-assigned maximum or minimum data points should be deleted or if any maximum or minimum data points not automatically assigned by the computer should be manually added.

[0040] FIG. 3 is a plot 300 of the vertical movement pattern of a head (obtained after double integration of the raw vertical head acceleration data) and raw forelimb foot vertical position for a horse with peak pain of lameness occurring at the time of hoof impact. A head pattern curve 302 represents vertical head movement of an affected horse, and a forefoot curve 304 represents vertical right forelimb foot movement. The dips 306 represent less downward movements of the head during the stance phases of the right limb as indicated by reference character 308. The peaks 310 represent less upward movement of the head after the stance phase of the right forelimb.

[0041] Referring again to FIG. 2, a phase-shift calculation module 212 identifies an affected limb and determines severity based on the maximum and minimum data points of the head and pelvic vertical positions. According to one aspect, the evaluation system 100 uses four vertical head movement reference patterns that correspond to forelimb lameness and three pelvic reference patterns that correspond to hindlimb lameness. The reference patterns are based on motion data previously measured in a laboratory for animals with natural lameness. The reference patterns are determined by a theoretical summing of first and second harmonics, as determined from a data decomposition algorithm at gradually increasing phase shifts between the harmonics and are compared to the simulated movements patterns to determine the affected limb. The reference patterns have been confirmed in a laboratory setting using data collected from animals with natural lameness conditions.

[0042] FIGS. 4A-4D illustrate four reference patterns of head movement that correspond to forelimb lameness. In FIGS. 4A-4D, a first curve 400 represents corrected gross vertical head movement, a second curve 402 represents the first harmonic of head movement or the motion of the head due to lameness, a third curve 404 represents the second harmonic of head movement or natural vertical head movement, and a fourth curve 406 represents the stance phase of the right forelimb.

[0043] In one embodiment, the four reference head movement patterns that correspond to forelimb lameness are as follows: 1) Less downward movement of the head during the stance phase of the affected limb and less upward movement of the head after the stance phase of the affected limb occurs when the peak-time-of-lameness is at impact at the beginning of the stance phase of the stride of the affected limb, as illustrated by plot 408 in FIG. 4A; 2) Less downward movement of the head during the stance phase of the affected limb only indicates peak-time-of-lameness at mid-stance when the limb is perpendicular to the ground and the vertical ground reaction forces on the limb are maximal, as illustrated by plot 410 in FIG. 4B; 3) Less downward movement of the head during the stance phase of the affected limb and more upward movement of the head after the stance phase of the affected limb indicates peak-time-of-lameness occurring during the second half of the stance phase of the lame limb (propulsive phase of stance), as illustrated by plot 412 in FIG. 4C; and 4) Only greater upward movement of the head after the stance phase of the affected limb indicates peak-time-of-lameness occurring during breakover (also called pushoff), which is the last part of the stance phase of the limb between heel off and toe off, as illustrated by plot 414 in FIG. 4D.

[0044] FIGS. 5A-5C illustrate four reference patterns of pelvis movement that correspond to forelimb lameness. In one embodiment, the three reference patterns that correspond to hindlimb lameness are as follows: 1) Less downward movement of the pelvis during the stance phase of the affected limb occurs when the peak-time-of-lameness is during the cranial or deceleratory phase of the stance phase of the stride, as illustrated by plot 502 in FIG. 5A; 2) Less upward movement of the pelvis after the stance phase of the affected limb occurs when the peak-time-of-lameness is in the caudal or acceleratory phase of the stance phase of the stride, as illustrated by plot 504 in FIG. 5B; and 3) Less downward movement of the pelvis during the stance phase of the affected limb and less upward movement of the pelvis after the stance phase of the affected limb occurs when lameness occurs throughout the stance phase of the affected limb, as illustrated by plot 506 in FIG. 5C.

[0045] In practice, to identify an affected limb, a user studying the movement pattern with maximum and minimum data points, as illustrated in FIG. 3, identifies the first maximum from the vertical head or vertical pelvic position after a stance phase of a particular limb (e.g., forelimb). The sign (positive or negative) of differences in maximum and minimum positions between right and left stance phases of the stride then determines the affected limb (right versus left).

[0046] Referring back to FIG. 2, after identifying the affected limb, the phase shift calculation module 212 performs a peak-time-of-lameness check to determine the type of lameness by calculating differences in the time indexes between the peaks of the first and second harmonics of vertical head or pelvis positions obtained from equation (1) and the above described Peak-Detection Algorithms.

[0047] A reporting module 214 is configured to generate output data, such as a report, screen, table, or other data that indicates a result of the analyses, such as a summary of the overall severity of lameness, affected limb(s), and type of lameness for display to the user via the UI 124 or an output device. For example, the reporting module 214 generates reports comprising the summary of the severity of lameness, affected limb(s), and type of lameness for viewing by the user.

[0048] In one aspect, the output data is in an electronic format such that it can be viewed via the UI 124. Moreover, such output data can be communicated to one or more remote computers or processing systems via a communication network (not shown), such as the Internet, an intranet, a wireless network, or other networks. In another aspect, the output data is stored on media for transfer to another device. In another aspect, the reports or other output data are in a tangible format such that they can be viewed and physically handled by the user.

[0049] FIG. 6A is a flow diagram illustrating a lameness detection method in accordance with an aspect of the evaluation application 202. At 602A, the evaluation application 202 obtains motion data from sensors located on the head, the pelvis, a forelimb, and a hindlimb of an animal during a period of trotting or walking gait. The motion data from the head and pelvis is considered acceleration data and the motion data from the forelimb and hindlimb is considered gyroscopic data. The evaluation application 202 uses a curve-fitting algorithm to simulate vertical movement patterns of the head in accordance with forelimb movement and to simulate vertical movements of the pelvis in accordance with hindlimb movement during a stride at 604A. The curve-fitting algorithm employs two harmonics and other transient components derived from the motion data. According to one aspect, a first harmonic has a frequency equal to one times (1x) the stride rate and a second harmonic has a frequency equal to two times (2 x) the stride rate.

[0050] At 606A, the evaluation application 202 provides a user an option to modify the simulated movement patterns. For example, the user is provided the ability to eliminate data points from the motion data that is used to by the curve-fitting algorithm to create the simulated movement patterns. The evaluation application 202 identifies a limb affected by lameness by comparing the simulated movement patterns with a reference movement pattern retrieved from a memory (e.g., memory 126) at 608A. At 610A, the evaluation application 202 diagnoses a type of lameness by calculating a phase-shift-value between the first and second harmonics and comparing the calculated phase-shift-value with the reference phase shift value. The evaluation application 202 determines the severity of lameness in the identified limb as a function of a ratio of a calculated effective amplitude of the first harmonic to a calculated effective amplitude of the second harmonic at 612A.

[0051] FIG. 6B is a flow diagram illustrating a lameness detection method in accordance with another aspect of the evaluation application 202. At 602B, the evaluation application 202 obtains motion data from sensors located on the head, the pelvis, and a forelimb of an animal during a period of trotting or walking gait. The motion data from the head and pelvis is considered acceleration data and the motion data from the forelimb and hindlimb is considered gyroscopic data. The evaluation application 202 uses a curve-fitting algorithm to simulate vertical movement patterns of the head in accordance with forelimb movement and to simulate vertical movements of the pelvis in accordance with forelimb movement during a stride at 604B. The curve-fitting algorithm employs two harmonics and other transient components derived from the motion data. According to one aspect, a first harmonic has a frequency equal to one times (1x) the stride rate and a second harmonic has a frequency equal to two times (2 x) the stride rate.

[0052] At 606B, the evaluation application 202 provides a user an option to modify the simulated movement patterns. For example, the user is provided the ability to eliminate data points from the motion data that is used to by the curve-fitting algorithm to create the simulated movement patterns. The evaluation application 202 identifies a limb affected by lameness by comparing the simulated movement patterns with a reference movement pattern retrieved from a memory (e.g., memory 126) at 608B. At 610B, the evaluation application 202 diagnoses a type of lameness by calculating a phase-shift-value between the first and second harmonics and comparing the calculated phase-shift-value with the reference phase shift value. The evaluation application 202 determines the severity of lameness in the identified limb as a function of a ratio of a calculated effective amplitude of the first harmonic to a calculated effective amplitude of the second harmonic at 612B.

[0053] FIG. 7 illustrates a data acquisition method in accordance with an aspect of the evaluation application 202. At 702, the evaluation application 202 is executed to start data acquisition. At 704, the evaluation application 202 performs an equipment check. For example, the evaluation application 202 performs a test communication with motion sensors (e.g., motion sensors 102-108) to ensure that there is a communication link with each of the sensors. The evaluation application 202 allows a user to input trial information at 706. The trial information is collected at 708, and it is saved to a memory at 710.

[0054] FIG. 8 illustrates details of the data acquisition method in accordance with an aspect of the evaluation application 202. At 802, the evaluation application 202 executes the data acquisition module 204, and the motion sensors outfitted to a head, pelvis, and at least one foot of the animal are activated. A communication signal is sent to the motion sensors to establish a communication connection at 804. At 806, the motion sensors receive the communication signal, and the communication connection is established. The motions sensors send power data, such as a battery voltage level, to the evaluation application 202 at 808. At 810, the evaluation application 202 receives the power data and determines whether there is sufficient power available for operating the sensors at 812. If it is determined that sufficient power is not available at 812, the evaluation application 202 displays a message to a user via the UI 124 warning that there is low power (e.g., low battery) at 814, and execution of the evaluation application 202 is stopped at 816. If sufficient power is available at 812, the evaluation application 202 displays an input form to a user via the UI 124 requesting trial information at 818. For example, the user can enter a date of the trial, a trial case number, and whether there are any treatments.

[0055] At 820, the evaluation application 202 sends a start command to the motion sensors to begin collecting and transmitting motion data. At 822, the sensors determine whether the start command signal has been received. If the start command signal has not been received at 822, the sensors continue to monitor for the start command signal. If the start command signal has been received at 822, the sensors convert analog motion data to digital motion data at 824. At 826, the sensors send the digital motion data to the evaluation application 202. The evaluation application 202 begins receiving the digital motion data at 828. At 830, the evaluation application 202 displays motion data values to the user via a user interface (e.g., UI 124) in near real time and stores the motion data values in a memory. According to one aspect, the motion data is stored in the memory as a separate file for each animal from which data is being acquired.

[0056] The user can use the UI 124 to generate a stop command to send to the sensors to stop collecting and transmitting motion data at 832. If the user does not generate a stop command at 832, the evaluation application 202 continues to display motion data values to the user via the UI 124 in near real time. If the user generates a stop command at 832, the evaluation application 202 sends the stop command to the sensors at 834.

[0057] At 836, the sensors determine whether a stop command signal has been received. If the stop command signal has not been received at 836, the sensors continue to monitor for the stop command signal. If the stop command signal has been received at 836, the sensors stop collecting and transmitting motion data and wait for the next a communication signal to be received at 806.

[0058] FIG. 9 illustrates a data analysis method in accordance with an aspect of the evaluation application 202. At 902, the evaluation application 202 starts the data analysis. The evaluation application 202 loads trial data from a memory at 904 and retrieves motion data from the memory for analysis at 906. At 908, the evaluation application 202 executes data analysis algorithms. The results obtained from the data analysis algorithms are provided to a reporting module at 910.

[0059] FIG. 10 illustrates details of the data analysis method in accordance with an aspect of the evaluation application 202. At 1002, the evaluation application 202 receives a data analysis command from a user. The data analysis command may indicate a specific file that contains motion data for a particular animal for which lameness evaluation is desired. The evaluation application 202 loads the file comprising motion data for the particular animal at 1004. At 1006, the evaluation application 202 plots acceleration data corresponding to vertical head movements and vertical pelvis movements in a graph and displays the graph to the user. The user uses the user interface (e.g., UI 124) to select a desired range of motion data to be analyzed at 1008.

[0060] At 1010, the user uses the UI 124 to provide input indicating whether the selected range is accepted. For example, a dialogue box may be displayed to the user via the UI 124 asking whether the user would like to accept the selected range for analysis. If the user does not accept the range at 1010, the user can use the UI 124 to select a different range of motion data to be analyzed at 1008. If the user accepts the range at 1010, the evaluation application 202 performs a double integration, such as described above, of the selected acceleration data at 1012. At 1014, the evaluation application 202 retrieves gyroscopic data corresponding to angular rational movements of the forelimb and optionally the hindlimb of the particular animal.

[0061] At 1016, the evaluation application 202 executes a data-decomposition module that employs a data-decomposition algorithm (see equation 1) to derive simulated motion data that corresponds to the vertical head and pelvic movement patterns in accordance with the respective limb movement (e.g., head vs. forefoot and pelvis vs. hindfoot or optionally head vs. forefoot and pelvis vs. forefoot). The simulated head and/or pelvic motion data is reported to a user via a reporting module at 1018.

[0062] The evaluation application 202 executes a peak detection algorithm to identify maximum and minimum data positions from of the simulated motion data at 1020. As described above, the peak detection algorithm assigns the sum of the first and second harmonics as obtained from the simulated motions data-decomposition algorithm as the maximum and minimum positions. At 1022, the evaluation application 202 generates a plot (FIG. 3) of the sum of harmonics with assigned maximum and minimum positions.

[0063] At 1024, the user uses the UI 124 to provide an input to the evaluation application 202 indicating whether data smoothing is desired. For example, a dialogue box or another input form may be displayed to the user via the UI 124 allowing the user to indicate whether data smoothing is desired. For example, as described above, a user (e.g., veterinarian/clinician) studying the simulated pattern with maximum and minimum positions, such as illustrated in FIG. 3, can determine if the vertical position signals should be smoothed to reduce or eliminate errors in the Peak-Detection Algorithm. If the user provides input indicating that smoothing is desired, the evaluation application 200 allows the user to select a data segment for smoothing at 1026 and smoothes the selected data segment at 1028. The evaluation application 202 then executes the peak detection algorithm to identify the maximum and minimum positions of the smoothed motion data at 1020.

[0064] If the user provides input indicating that smoothing is not desired at 1024, the user can use the UI 124 to provide an input to the evaluation application 202 indicating whether maximum and minimum data points should be added to or deleted from the motion data at 1030. For example, a different dialogue box may be displayed to the user via the UI 124 allowing the user to indicate a desire to add or to delete maximum and/or minimum data points. If the user provides input indicating a desire to add or to delete maximum and/or minimum data points, the evaluation application 202 allows the user to select a data segment at 1032, to select an add option or to select a delete option at 1034, and to select a maximum or minimum data point at 1036. At 1038, the evaluation application 202 adds or deletes the selected maximum and/or selected minimum as indicated by user selections at 1032, 1034, and 1036.

[0065] If the user provides input to the evaluation application 202 indicating the maximum and/or minimum data points should not be added to or deleted from the motion data at 1030, the user can use the UI 124 to provide an input to define a first head position maximum at 1040. The evaluation application 202 calculates a maximum and minimum difference between the first head position defined by the user and the maximum and minimum positions determined by the peak detection algorithm at 1042. The calculated maximum and minimum difference can be used to identify a limb affected with lameness. For example, by comparing the calculated maximum and minimum differences to maximum and minimum differences obtained from reference movement patterns (e.g., FIGS. 4A-4D and FIGS. 5A-5C) that correspond to forelimb lameness and hindlimb lameness, the affected limb can be identified. The evaluation application 202 further calculates the phase shift between harmonics at 1044. The calculated phase shift is used to determine a type of lameness. For example, the calculated phase shift is compared to various reference phase shift values that correspond to a different type of lameness to identify the type of lameness. The calculated maximum and minimum differences and the calculated phase shift are reported to a user via a reporting module at 1018.

[0066] As various changes could be made in the above constructions, systems, and methods without departing from the scope of aspects of the invention, it is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

Claims

1. A system (100) for evaluating lameness in an animal and operable with at least one processor, the evaluation system configured to receive a plurality of signals comprising motion data representative of a head motion, a pelvis motion, and at least one limb motion during a stride of the animal, the evaluation system comprising:

a data-acquisition module (204) configured to collect motion data from the received plurality of signals;
a data-decomposition module (206) configured to generate simulated head and pelvis movement patterns for the stride;
a curve-modification module (208) configured to receive input data and to modify and smooth the simulated head and pelvis movement patterns based on input data;
a position-detection module (210) configured to detect a maximum head position, a minimum head position, a maximum pelvis position, and a minimum pelvis position during the stride based on the modified simulated head and pelvis movement patterns; and
a phase-shift calculation module (212) configured to identify a limb affected with lameness based on a comparison of the detected maximum head position, the detected minimum head position, the detected maximum pelvis position, and the detected minimum pelvis position with at least one lameness reference pattern, the at least one lameness pattern indicating a peak time of lameness.

2. The system (100) of claim 1 wherein the plurality of motion sensors are configured to generate the plurality of signals comprising:

a head sensor (102) configured to generate a first signal (110) comprising first motion data representative of the head motion;
a pelvis sensor (104) configured to generate a second signal (112) comprising second motion data representative of the pelvis motion;
a forelimb sensor (106) configured to generate a third signal (114) comprising third motion data representative of a forelimb motion; and
a hindlimb sensor (108) configured to generate a fourth signal (116) comprising fourth motion data representative of a hindlimb motion

3. The system (100) according to any of claims 1 or 2 wherein head motion data and pelvis motion data correspond to acceleration data, wherein limb motion data corresponds to gyroscopic data, and wherein the data-decomposition module (206) is configured to generate the simulated vertical head and pelvis movement patterns by:

double integrating the acceleration data corresponding to the head motion and the pelvis motion;
calculating a first stride rate component corresponding to the head motion as a function of the gyroscopic data for a forefoot motion;
calculating a second stride rate component corresponding to the pelvis motion as a function of the gyroscopic data for a hind foot motion; and
employing a curve-fitting algorithm to generate the simulated vertical head movement pattern and the simulated pelvis movement pattern as a function of the double integrated acceleration data, the first stride rate component, and the second stride rate component.

4. The system (100) according to any of claims 12 to 14 wherein:

the data-decomposition module (206) is configured to:

determine a first harmonic component comprising a first frequency from the motion data, the first harmonic corresponding to a unilateral lameness contribution to a vertical movement of the head motion;
determine a second harmonic component with a second frequency from the motion data, the second harmonic corresponding to a normal, biphasic, vertical movement of the head motion;
determine a low-frequency transient component corresponding to an extraneous vertical head movement or to an extraneous pelvis movement; and
generate the simulated head and pelvis movement patterns based on the determined first harmonic, the determined second harmonic, and the determined low frequency transient component; and

the phase-shift calculation module (212) is further configured to:

calculate a first effective amplitude of the first harmonic component and to calculate a second effective amplitude of the second harmonic component;
determine a severity of lameness in the identified limb as a function a ratio of the first effective amplitude to the second effective amplitude; and
determine a phase-shift between the first harmonic component and the second harmonic component and to determine a type of lameness based on the determined phase-shift.

5. A system according to claim 1 (100) for evaluating lameness in a four-legged animal there being:

a plurality of motion sensors (102), (104), (106), (108) configured to generate a corresponding plurality of signals comprising motion data representative of a head motion; a pelvis motion, and at least one limb motion during a stride of the animal; and
a processing system (120) configured to receive the plurality of signals during the stride via wireless communication and to receive input data, the processing system (120) comprising an evaluation application (122) comprising the evaluation system as set out in claim 1.

6. The system (100) of claim 5 wherein the plurality of sensors comprise:

a head sensor (102) configured to generate a first signal (110) comprising first motion data representative of the head motion;
a pelvis sensor (104) configured to generate a second signal (112) comprising second motion data representative of the pelvis motion; and
a forelimb sensor (106) configured to generate a third signal (114) comprising third motion data representative of a forelimb motion.

7. The system (100) of claim 6 wherein the plurality of sensors further comprise a hindlimb sensor (108) configured to generate a fourth signal (116) comprising fourth motion data representative of a hindlimb motion.

8. The system (100) according to any of claims 5 to 7 further comprising a reporting module (214) configured to generate a report comprising a summary of the affected limb, a type of lameness, and a severity of lameness.

9. The system (100) according to any of claims 5 to 8 wherein head motion data and pelvis motion data correspond to acceleration data, wherein limb motion data corresponds to gyroscopic data, and wherein the data-decomposition module (206) is configured to generate the simulated vertical head and pelvis movement patterns by:

double integrating the acceleration data corresponding to the head motion and the pelvis motion;
calculating a first stride rate component corresponding to the head motion as a function of the gyroscopic data for a forelimb motion;
calculating a second stride rate component corresponding to the pelvis motion as a function of the gyroscopic data for a hindlimb motion; and
employing a curve-fitting algorithm to generate the simulated vertical head movement pattern and the simulated pelvis movement pattern as a function of the double integrated acceleration data, the first stride rate component, and the second stride rate component.

10. The system (100) according to any of claims 5 to 9 wherein the curve-modification module (208) is further configured to automatically identify at least one erroneous motion data point and to automatically eliminate the at least one erroneous motion data point to smooth the simulated vertical head and pelvis movement patterns.

11. The system (100) according to any of claims 5 to 10 wherein:

the data-decomposition module (206) is further configured to:

determine a first harmonic component comprising a first frequency, the first harmonic corresponding to a unilateral lameness contribution to a vertical movement of the at least one limb motion;
determine a second harmonic component with a second frequency, the second harmonic corresponding to a normal, biphasic, vertical movement of the at least one limb motion; and
determine a low-frequency transient component corresponding to an extraneous vertical head movement or to an extraneous pelvis movement;
wherein the data-decomposition module (206) is configured to generate the simulated head and pelvis movement patterns based on the determined first harmonic, the determined second harmonic component, and the determined low-frequency transient component; and

the phase-shift calculation module (212) is further configured to:

calculate a first effective amplitude of the first harmonic component and to calculate a second effective amplitude of the second harmonic component; and
determine a severity of lameness in the identified limb as a function of a ratio of the first effective amplitude to the second effective amplitude.

12. The system (100) of claim 11 wherein the phase-shift calculation module (212) is further configured to determine a phase-shift between the first harmonic component and the second harmonic component and to determine a type of lameness based on the determined phase-shift.

13. The system (100) according to any of claims 5 to 12 wherein the at least one lameness reference pattern (300) comprises four vertical head movement reference patterns with forelimb lameness and three vertical pelvis movement reference patterns with hindlimb lameness.

14. The system (100) of claim 13 wherein the four vertical head movement reference patterns comprise:

a first vertical head pattern (408) depicting less downward movement of a head of the animal during a stance phase of an affected forelimb and less upward movement of the head after the stance phase of the affected forelimb, the first vertical head pattern corresponding to a peak-time-of-lameness occurring at impact at a beginning of the stance phase of the stride of the affected forelimb;
a second vertical head pattern (410) depicting less downward movement of the head during the stance phase of the affected forelimb, the second vertical head pattern corresponding to the peak-time-of-lameness occurring at mid-stance when the affected forelimb is perpendicular to a ground level and vertical ground reaction forces on the affected forelimb are maximal;
a third vertical head position pattern (412) depicting less downward movement of the head during the stance phase of the affected forelimb and more upward movement of the head after the stance phase of the affected forelimb, the third vertical head position pattern corresponding to the peak-time-of-lameness occurring during a second half of the stance phase of the forelimb; and
a fourth vertical head position pattern (414) only depicting a greater upward movement of the head after the stance phase of the affected forelimb, the fourth vertical head position pattern corresponding to the peak-time-

of-lameness occurring during a push off.

15. The system (100) according to any of claims 13 or 14 wherein the three vertical pelvis movement reference patterns for hindlimb lameness comprise:

a first vertical pelvis pattern (502) depicting less downward movement of a pelvis of the four-legged animal during a stance phase of an affected hindlimb, the first vertical pelvis pattern corresponding to a peak-time-of-lameness occurring during a deceleratory phase of the stance phase of the affected hindlimb;
a second vertical pelvis pattern (504) depicting less upward movement of the pelvis after the stance phase of the affected hindlimb, the second vertical pelvis pattern corresponding to the peak-time-of-lameness occurring during an acceleratory phase of the stance phase of the of the affected hindlimb; and
a third vertical pelvis pattern (506) depicting less downward movement of the pelvis during the stance phase of the affected hindlimb and less upward movement of the pelvis after the stance phase of the affected hindlimb, the third vertical pelvis pattern corresponding to the peak-time-of lameness occurring when lameness occurs throughout the stance phase of the affected hindlimb.

Patentansprüche

1. System (100) zur Lahmheitsbeurteilung eines Tieres, wobei das Beurteilungssystem mit wenigstens einem Prozessor betreibbar ist und zum Empfang einer Vielzahl von Signalen ausgebildet ist, wobei die Signale Bewegungsdaten umfassen, die eine Kopfbewegung, eine Beckenbewegung und wenigstens eine Gliedmaßenbewegung während eines Gangs des Tieres repräsentieren, wobei das Beurteilungssystem folgendes umfasst:

eine Datenerfassungseinheit (204), die zum Erfassen von Bewegungsdaten aus der Vielzahl von empfangenen Signalen ausgebildet ist,
eine Datenaufschlüsselungseinheit (206), die zum Generieren von simulierten Kopf-und Beckenbewegungsmustern des Ganges ausgebildet ist,
eine Kurvenmodifiziereinheit (208), die zum Empfang von Eingabedaten und zur Modifikation und Glättung der simulierten Kopf- und Beckenbewegungsmuster anhand der Eingabedaten ausgebildet ist,
eine Positionsdetektiereinheit (210), die zur Detektion einer maximalen Kopfposition, einer minimalen Kopfposition, einer maximalen Beckenposition und einer minimalen Beckenposition während des Ganges, basierend auf den modifizierten Kopf- und Beckenbewegungsmustern ausgebildet ist, und
eine Phasenverschiebungsberechnungseinheit (212), die zur Identifikation einer von Lahmheit betroffenen Gliedmaße, basierend auf einem Vergleich der detektierten maximalen Kopfposition, der detektierten minimalen Kopfposition, der detektierten maximalen Beckenposition und der detektierten minimalen Beckenposition mit wenigstens einem Lahmheitsreferenzmuster, ausgebildet ist, wobei das wenigstens eine Lahmheitsmuster eine Spitzenzeit von Lahmheit angibt.

2. System (100) nach Anspruch 1, wobei die Vielzahl an Bewegungssensoren dazu ausgebildet sind, die Vielzahl von Signalen zu erzeugen, umfassend:

einen Kopfsensor (102), der zur Erzeugung eines ersten Signals (110) ausgebildet ist, welches erste, die Kopfbewegung repräsentierende Bewegungsdaten umfasst,
einen Beckensensor (104), der zur Erzeugung eines zweiten Signals (112) ausgebildet ist, welches zweite, die Beckenbewegung repräsentierende Bewegungsdaten umfasst,
einen Vordergliedmaßensensor (106), der zur Erzeugung eines dritten Signals (114) ausgebildet ist, welches dritte, die Vordergliedmaßenbewegung repräsentierende Bewegungsdaten umfasst, und
einen Hintergliedmaßensensor (108), der zur Erzeugung eines vierten Signals (116) ausgebildet ist, welches vierte, die Hintergliedmaßenbewegung repräsentierende Bewegungsdaten umfasst.

3. System (100) nach einem der Ansprüche 1 oder 2, wobei Kopfbewegungsdaten und Beckenbewegungsdaten Beschleunigungsdaten entsprechen, wobei Gliedmaßenbewegungsdaten gyroskopischen Daten entsprechen, und wobei die Datenaufschlüsselungseinheit (206) dazu ausgebildet ist, die simulierten vertikalen Kopf- und Beckenbewegungsmuster zu erzeugen durch:

doppeltes Integrieren der Beschleunigungsdaten, die der Kopfbewegung und der Beckenbewegung entsprechen,

Berechnen eines ersten Gangverhältnisanteils, der der Kopfbewegung als eine Funktion der gyroskopischen Daten für die Vordergliedmaßenbewegung entspricht,
Berechnen eines zweiten Gangverhältnisanteils, der der Beckenbewegung als eine Funktion der gyroskopischen Daten für die Hintergliedmaßenbewegung entspricht, und
Einsetzen eines kurvenanpassenden Algorithmus zur Erzeugung der simulierten vertikalen Kopfbewegungsmuster und der simulierten Beckenbewegungsmuster als eine Funktion der doppelt integrierten Beschleunigungsdaten, des ersten Gangverhältnisanteils und des zweiten Gangverhältnisanteils.

4. System (100) nach einem der Ansprüche 12 bis 14, wobei die Datenaufschlüsselungseinheit (206) dazu ausgebildet ist:

eine erste harmonische Komponente der Bewegungsdaten, umfassend eine erste Frequenz, zu ermitteln, wobei die erste harmonische Komponente dem Beitrag einer einseitigen Lahmheit zu einer vertikalen Bewegung der Kopfbewegung entspricht,
eine zweite harmonische Komponente der Bewegungsdaten mit einer zweiten Frequenz zu ermitteln, wobei die zweite harmonische Komponente einer normalen, zweiphasigen Vertikalbewegung der Kopfbewegung entspricht,
eine transiente Komponente mit niedriger Frequenz zu ermitteln, die einer belanglosen vertikalen Kopfbewegung oder einer belanglosen Beckenbewegung entspricht, und
die simulierten Kopf- und Beckenbewegungsmuster basierend auf der ermittelten ersten harmonischen Komponente, der ermittelten zweiten harmonischen Komponente und der ermittelten transienten Komponente mit niedriger Frequenz zu erzeugen, und
wobei die Phasenverschiebungsberechnungseinheit (212) darüber hinaus dazu ausgebildet ist:

eine erste wirksame Amplitude der ersten harmonischen Komponente zu berechnen und eine zweite wirksame Amplitude der zweiten harmonischen Komponente zu berechnen,
einen Schweregrad der Lahmheit an der identifizierten Gliedmaße als eine Funktion der ersten wirksamen Amplitude zur zweiten wirksamen Amplitude zu bestimmen, und
eine Phasenverschiebung zwischen der ersten harmonischen Komponente und der zweiten harmonischen Komponente zu bestimmen und einen Lahmheitstyp anhand der bestimmten Phasenverschiebung zu bestimmen.

5. System (100) nach Anspruch 1 zur Lahmheitsbeurteilung eines vierbeinigen Tieres mit:

einer Vielzahl von Bewegungssensoren (102, 104, 106, 108), die zur Erzeugung einer entsprechenden Vielzahl von Signalen ausgebildet sind, wobei die Signale Bewegungsdaten umfassen, die eine Kopfbewegung, eine Beckenbewegung und wenigstens eine Gliedmaßenbewegung während eines Gangs des Tieres repräsentieren, und
einem Verarbeitungssystem (120), das zum kabellosen Empfang der Vielzahl von Signalen während des Ganges und zum Empfang von Eingabedaten ausgebildet ist, wobei das Verarbeitungssystem (120) eine Beurteilungsanwendung (122) umfasst, die das in Anspruch 1 beschriebene Beurteilungssystem umfasst.

6. System (100) nach Anspruch 5, wobei die Vielzahl von Sensoren umfasst:

einen Kopfsensor (102), der zur Erzeugung eines ersten Signals (110) ausgebildet ist, welches erste, die Kopfbewegung repräsentierende Bewegungsdaten umfasst,
einen Beckensensor (104), der zur Erzeugung eines zweiten Signals (112) ausgebildet ist, welches zweite, die Beckenbewegung repräsentierende Bewegungsdaten umfasst, und
einen Vordergliedmaßensensor (106), der zur Erzeugung eines dritten Signals (114) ausgebildet ist, welches dritte, die Vordergliedmaßenbewegung repräsentierende Bewegungsdaten umfasst.

7. System (100) nach Anspruch 6, wobei die Vielzahl von Sensoren weiter einen Hintergliedmaßensensor (108) umfasst, der zur Erzeugung eines vierten Signals (116) ausgebildet ist, welches vierte, die Hintergliedmaßenbewegung repräsentierende Bewegungsdaten umfasst.

8. System (100) nach einem der Ansprüche 5 bis 7, weiter umfassend eine Berichteinheit (214), die zur Erstellung eines Berichtes umfassend eine Zusammenfassung der betroffenen Gliedmaße, einen Lahmheitstyp und den Schweregrad der Lahmheit, ausgebildet ist.

9. System (100) nach einem der Ansprüche 5 bis 8, wobei Kopfbewegungsdaten und Beckenbewegungsdaten Beschleunigungsdaten entsprechen, wobei Gliedmaßenbewegungsdaten gyroskopischen Daten entsprechen, und wobei die Datenaufschlüsselungseinheit (206) dazu ausgebildet ist, die simulierten vertikalen Kopf- und Beckenbewegungsmuster zu Erzeugen durch:

doppeltes Integrieren der Beschleunigungsdaten, die der Kopfbewegung und der Beckenbewegung entsprechen,
Berechnen eines ersten Gangverhältnisanteils, der der Kopfbewegung als eine Funktion der gyroskopischen Daten für die Vordergliedmaßenbewegung entspricht,
Berechnen eines zweiten Gangverhältnisanteils, der der Beckenbewegung als eine Funktion der gyroskopischen Daten für die Hintergliedmaßenbewegung entspricht, und
Einsetzen eines kurvenanpassenden Algorithmus zur Erzeugung der simulierten vertikalen Kopfbewegungsmuster und der simulierten Beckenbewegungsmuster als eine Funktion der doppelt integrierten Beschleunigungsdaten, des ersten Gangverhältnisanteils und des zweiten Gangverhältnisanteils.

10. System (100) nach einem der Ansprüche 5 bis 9, wobei die Kurvenmodifiziereinheit (208) weiter dazu ausgebildet ist, automatisch wenigstens einen fehlerhaften Bewegungsdatenpunkt zu identifizieren und den wenigstens einen fehlerhaften Bewegungsdatenpunkt automatisch zu eliminieren, um die simulierten vertikalen Kopf- und Beckenbewegungsmuster zu glätten.

11. System (100) nach einem der Ansprüche 5 bis 10, wobei die

Datenaufschlüsselungseinheit (206) weiter dazu ausgebildet ist:

eine erste harmonische Komponente, umfassend eine erste Frequenz, zu ermitteln, wobei die erste harmonische Komponente dem Beitrag einer einseitigen Lahmheit zu einer vertikalen Bewegung der wenigstens einen Gliedmaßenbewegung entspricht,
eine zweite harmonische Komponente mit einer zweiten Frequenz zu ermitteln, wobei die zweite harmonische Komponente einer normalen, zweiphasigen Vertikalbewegung der wenigstens einen Gliedmaßenbewegung entspricht, und eine transiente Komponente mit niedriger Frequenz zu ermitteln, die einer belanglosen vertikalen Kopfbewegung oder einer belanglosen Beckenbewegung entspricht,
wobei die Datenaufschlüsselungseinheit (206) dazu ausgebildet ist, die simulierten Kopf- und Beckenbewegungsmuster, basierend auf der ermittelten ersten harmonischen Komponente, der ermittelten zweiten harmonischen Komponente und der ermittelten transienten Komponente mit niedriger Frequenz, zu erzeugen, und

wobei die Phasenverschiebungsberechnungseinheit (212) darüber hinaus dazu ausgebildet ist:

eine erste wirksame Amplitude der ersten harmonischen Komponente zu berechnen und eine zweite wirksame Amplitude der zweiten harmonischen Komponente zu berechnen, und
einen Schweregrad der Lahmheit an der identifizierten Gliedmaße als eine Funktion eines Verhältnisses der ersten wirksamen Amplitude zur zweiten wirksamen Amplitude zu bestimmen.

12. System (100) nach Anspruch 11, wobei die Phasenverschiebungsberechnungseinheit (212) darüber hinaus dazu ausgebildet ist, eine Phasenverschiebung zwischen der ersten harmonischen Komponente und der zweiten harmonischen Komponente zu bestimmen und einen Lahmheitstyp anhand der bestimmten Phasenverschiebung zu bestimmen.

13. System (100) nach einem der Ansprüche 5 bis 12, wobei das wenigstens eine Lahmheitsreferenzmuster (300) vier vertikale Kopfbewegungs-Referenzmuster mit Vordergliedmaßenlahmheit und drei vertikale Beckenbewegungs-Referenzmuster mit Hintergliedmaßenlahmheit umfasst.

14. System (100) nach Anspruch 13, wobei die vier vertikalen Kopfbewegungs-Referenzmuster umfassen:

ein erstes vertikales Kopfmuster (408), das weniger Abwärtsbewegung eines Kopfes des Tieres während einer Standphase einer betroffenen Vordergliedmaße und weniger Aufwärtsbewegung des Kopfes nach der Standphase der betroffenen Vordergliedmaße wiedergibt, wobei das erste vertikale Kopfmuster einem Spitzenzeitpunkt der Lahmheit entspricht, die beim Auftreffen zu Beginn einer Standphase des Ganges der betroffenen

Vordergliedmaße auftritt,
ein zweites vertikales Kopfmuster (410), das weniger Abwärtsbewegung des Kopfes des Tieres während der Standphase der betroffenen Vordergliedmaße wiedergibt, wobei das zweite vertikale Kopfmuster dem Spitzenzeitpunkt der Lahmheit entspricht, die in der Mitte der Standphase auftritt, wenn die betroffene Vordergliedmaße orthogonal zur Ebene des Bodens steht und die vertikale Bodenreaktionskraft auf die betroffene Vordergliedmaße maximal ist,
ein drittes vertikales Kopfpositionsmuster (412), das weniger Abwärtsbewegung des Kopfes während der Standphase der betroffenen Vordergliedmaße und mehr Aufwärtsbewegung des Kopfes nach der Standphase der betroffenen Vordergliedmaße wiedergibt, wobei das dritte vertikale Kopfpositionsmuster dem Spitzenzeitpunkt der Lahmheit entspricht, die in einer zweiten Hälfte der Standphase der betroffenen Vordergliedmaße auftritt, und
ein viertes vertikales Kopfpositionsmuster (414), das nur eine größere Aufwärtsbewegung des Kopfes nach der Standphase der betroffenen Vordergliedmaße wiedergibt, wobei das vierte vertikale Kopfpositionsmuster dem Spitzenzeitpunkt der Lahmheit entspricht, die während eines Abstoßens auftritt.

15. System (100) nach einem der Ansprüche 13 oder 14, wobei die drei vertikalen Beckenbewegungs-Referenzmuster für Hintergliedmaßenlahmheit umfassen:

ein erstes vertikales Beckenmuster (502), das weniger Abwärtsbewegung eines Beckens des vierbeinigen Tieres während einer Standphase einer betroffenen Hintergliedmaße wiedergibt, wobei das erste vertikale Beckenmuster einem Spitzenzeitpunkt der Lahmheit entspricht, die während einer Verzögerungsphase der Standphase der betroffenen Hintergliedmaße auftritt,
ein zweites vertikales Beckenmuster (504), das weniger Aufwärtsbewegung des Beckens nach der Standphase der betroffenen Hintergliedmaße wiedergibt, wobei das zweite vertikale Beckenmuster dem Spitzenzeitpunkt der Lahmheit entspricht, die während einer Beschleunigungsphase der Standphase der betroffenen Hintergliedmaße auftritt, und
ein drittes vertikales Beckenmuster (506), das weniger Abwärtsbewegung des Beckens während der Standphase der betroffenen Hintergliedmaße und weniger Aufwärtsbewegung des Beckens nach der Standphase der betroffenen Hintergliedmaße wiedergibt, wobei das dritte vertikale Beckenmuster dem Spitzenzeitpunkt der Lahmheit entspricht, die auftritt, wenn Lahmheit durchgehend während der Standphase der betroffenen Hintergliedmaße auftritt.

Revendications

1. Système (100) pour évaluer la claudication chez un animal et utilisable avec au moins un processeur, le système d'évaluation étant configuré pour recevoir une pluralité de signaux comprenant des données de mouvement représentatives d'un mouvement de la tête, d'un mouvement du bassin et d'au moins un mouvement de membre pendant la foulée d'un animal, le système d'évaluation comprenant :

un module d'acquisition de données (204) configuré pour collecter des données de mouvement à partir de la pluralité de signaux reçus ;
un module de décomposition de données (206) configuré pour générer des modèles de mouvement simulés de la tête et du bassin pour la foulée ;
un module de modification de courbe (208) configuré pour recevoir des données d'entrée et modifier et égaliser les modèles de mouvements simulés de la tête et du bassin sur la base des données d'entrée ;
un module de détection de position (210) configuré pour détecter une position de tête maximale, une position de tête minimale, une position de bassin maximale et une position de bassin minimale pendant la foulée sur la base des modèles de mouvement de tête et de bassin simulés modifiés ; et
un module de calcul de changement de phase (212) configuré pour identifier un membre affecté par une claudication sur la base d'une comparaison de la position de tête maximale détectée, de la position de tête minimale détectée, de la position de bassin maximale détectée et de la position de bassin minimale détectée avec au moins un modèle de référence de claudication, ledit au moins un modèle de référence de claudication indiquant un temps de pic de claudication.

2. Système (100) selon la revendication 1, dans lequel la pluralité de capteurs de mouvement est configurée de façon à générer la pluralité de signaux comprenant :

un capteur de tête (102) configuré pour générer un premier signal (110) comprenant de premières données de

mouvement, représentatives du mouvement de la tête ;
un capteur de bassin (104) configuré pour générer un second signal (112) comprenant de secondes données de mouvement représentant le mouvement du bassin ;
un capteur de membre antérieur (106) configuré pour générer un troisième signal (114) comprenant de troisièmes données de mouvement représentatives d'un mouvement d'un membre antérieur ; et
un capteur de membre postérieur (108) configuré pour générer un quatrième signal (116) comprenant de quatrièmes données de mouvement représentatives d'un mouvement d'un membre postérieur.

3. Système (100) selon l'une quelconque des revendications 1 ou 2, dans lequel les données relatives au mouvement de la tête et les données relatives au mouvement du bassin correspondent à des données d'accélération, dans lequel les données relatives au mouvement de membre correspondent à des données gyroscopiques, et dans lequel le module de décomposition de données (206) est configuré pour générer les modèles de mouvements verticaux simulés de la tête et du bassin en :

intégrant doublement les données d'accélération correspondant au mouvement de tête et au mouvement du bassin ;
calculant un premier composant de vitesse de foulée correspondant au mouvement de la tête en fonction des données gyroscopiques pour un mouvement de l'avant-pied ;
calculant un second composant de vitesse de foulée correspondant au mouvement du bassin en fonction des données gyroscopiques pour un mouvement de l'arrière-pied ; et
employant un algorithme d'ajustement de courbe pour générer le modèle de mouvement de tête et le modèle de mouvement de bassin verticaux simulés, en fonction de la double intégration des données d'accélération, du premier composant de la vitesse de foulée et du second composant de la vitesse de foulée.

4. Système (100) selon l'une quelconque des revendications 12 à 14, dans lequel :

le module de décomposition de données (206) est configuré pour :

déterminer un premier composant harmonique comprenant une première fréquence à partir des données de mouvement, la première harmonique correspondant à une contribution de claudication unilatérale à un mouvement vertical du mouvement de tête ;
déterminer un second composant harmonique avec une seconde fréquence à partir des données de mouvement, la seconde harmonique correspondant à un mouvement normal, biphasique, vertical du mouvement de tête ;
déterminer un composant transitoire basse fréquence correspondant à un mouvement de tête vertical parasite ou à un mouvement de bassin parasite ; et
générer les modèles de mouvement de tête et de bassin simulés sur la base de la première harmonique déterminée, de la seconde harmonique déterminée, et du composant transitoire basse fréquence déterminé et
le module de calcul de changement de phase (212) étant en outre configuré pour :

calculer une première amplitude effective du premier composant harmonique et calculer une seconde amplitude effective du second composant harmonique ;
déterminer une gravité de la claudication dans le membre identifié en fonction d'un rapport entre la première amplitude et la seconde amplitude effective et
déterminer un changement de phase entre le premier composant harmonique et le second composant harmonique et déterminer un type de claudication basé sur le changement de phase déterminé.

5. Système selon la revendication 1 (100) pour évaluer la claudication d'un animal à quatre pattes, comprenant :

une pluralité de capteurs de mouvement (102), (104), (106), (108) configurés pour générer une pluralité correspondante de signaux comprenant des données de mouvement représentatives d'un mouvement de la tête, d'un mouvement du bassin et d'au moins un mouvement de membre pendant une foulée de l'animal ; et
un système de traitement (120) configuré pour recevoir la pluralité de signaux pendant la foulée par une communication sans fil et pour recevoir des données d'entrée, le système de traitement (120) comprenant une application d'évaluation (122) comprenant le système d'évaluation comme indiqué dans la revendication 1.

6. Système (100) selon la revendication 5 dans lequel la pluralité de capteurs comprend :

un capteur de tête (102), configuré pour générer un premier signal (110) comprenant de premières données de mouvement représentatives du mouvement de la tête ;
un capteur de bassin (104) configuré pour générer un second signal (112) comprenant de secondes données de mouvement représentatives du mouvement du bassin ; et
un capteur de membre antérieur (106) configuré pour générer un troisième signal (114) comprenant de troisièmes données de mouvement représentatives d'un mouvement d'un membre antérieur.

7. Système (100) selon la revendication 6, dans lequel la pluralité de capteurs comprend en outre un capteur de membre postérieur (108) configuré pour générer un quatrième signal (116) comprenant de quatrièmes données de mouvement, représentatives d'un mouvement d'un membre postérieur.

8. Système (100) selon l'une quelconque des revendications 5 à 7, comprenant en outre un module de compte-rendu (214) configuré pour générer un rapport comprenant un résumé du membre affecté, un type de claudication et une gravité de la claudication.

9. Système (100) selon l'une quelconque des revendications 5 à 8, dans lequel les données relatives au mouvement de la tête et les données relatives au mouvement du bassin correspondent aux données d'accélération, dans lequel les données relatives au mouvement de membre correspondent aux données gyroscopiques, et dans lequel le module de décomposition des données (206) est configuré pour générer les modèles de mouvement de la tête et du bassin simulés verticaux en :

intégrant doublement les données d'accélération correspondant au mouvement de la tête et au mouvement du bassin ;
calculant un premier composant de vitesse de foulée correspondant au mouvement de la tête en fonction des données gyroscopiques pour un mouvement de membre antérieur ;
calculant un second composant de vitesse de foulée correspondant au mouvement du bassin en fonction des données gyroscopiques pour un mouvement de membre postérieur, et
employant un algorithme d'ajustement de courbe pour générer le modèle de mouvement simulé vertical de la tête et le modèle de mouvement simulé du bassin, en fonction de la double intégration des données d'accélération, du premier composant de vitesse de foulée et du second composant de vitesse de foulée.

10. Système (100) selon l'une quelconque des revendications 5 à 9, dans lequel le module de modification de courbe (208) est en outre configuré pour identifier automatiquement au moins un point de donnée de mouvement erroné et pour éliminer automatiquement ledit au moins un point de donnée de mouvement erroné, afin d'égaliser les modèles de mouvements simulés verticaux de la tête et du bassin.

11. Système (100) selon l'une quelconque des revendications 5 à 10, dans lequel :

le module de décomposition de données (206) est en outre configuré pour :

déterminer un premier composant harmonique comprenant une première fréquence, la première harmonique correspondant à une contribution unilatérale de claudication à un mouvement vertical dudit au moins un mouvement de membre ;
déterminer un second composant harmonique avec une seconde fréquence, la seconde harmonique correspondant à un mouvement normal, biphasique, vertical dudit au moins un mouvement de membre ; et
déterminer un composant transitoire basse fréquence correspondant à un mouvement de la tête vertical parasite ou à un mouvement du bassin parasite ;
dans lequel le module de décomposition de données (206) est configuré pour générer les modèles de mouvement simulés de la tête et du bassin sur la base du premier composant harmonique déterminé, du second composant harmonique déterminé, et du composant transitoire basse fréquence déterminé ; et
le module de calcul de changement de phase (212) étant en outre configuré pour :

calculer une première amplitude effective du premier composant harmonique et pour calculer une seconde amplitude effective du second composant harmonique ; et
déterminer une gravité de la claudication dans le membre identifié en fonction d'un rapport entre la première amplitude effective et la seconde amplitude effective.

12. Système (100) selon la revendication 11, dans lequel le module de calcul de changement de phase (212) est en outre configuré pour déterminer un changement de phase entre le premier composant harmonique et le second composant harmonique et pour déterminer un type de claudication sur la base du changement de phase déterminé.

13. Système (100) selon l'une quelconque des revendications 5 à 12, dans lequel ledit au moins un modèle de référence de claudication (300) comprend quatre modèles de référence de mouvement de la tête vertical avec la claudication du membre antérieur et trois modèles de référence de mouvement du bassin vertical avec la claudication du membre postérieur.

14. Système (100) selon la revendication 13, dans lequel les quatre modèles de référence de mouvement de la tête vertical comprennent :

un premier modèle de tête vertical (408) représentant un mouvement moins vers le bas de la tête d'un animal pendant une phase d'aplomb d'un membre antérieur affecté et un mouvement moins vers le haut de la tête après la phase d'aplomb du membre antérieur affecté, le premier modèle de tête vertical correspondant à un temps de pic de claudication survenant à l'impact au début d'une phase d'aplomb de la foulée du membre antérieur affecté ;
un second modèle de tête vertical (410) représentant un mouvement moins vers le bas de la tête pendant la phase d'aplomb du membre antérieur affecté, le second modèle de tête vertical correspondant au temps de pic de claudication survenant à mi-aplomb lorsque le membre antérieur affecté est perpendiculaire au niveau du sol et que les forces de réaction verticales du sol sur le membre antérieur affecté sont maximales ;
un troisième modèle de position de tête verticale (412) représentant un mouvement moins vers le bas de la tête pendant la phase d'aplomb du membre antérieur affecté et un mouvement plus vers le haut de la tête après la phase d'aplomb du membre antérieur affecté, le troisième modèle de position de tête vertical correspondant au temps de pic de claudication survenant pendant une seconde moitié de la phase d'aplomb du membre antérieur ; et
un quatrième modèle de position de tête verticale (414) représentant uniquement un mouvement vers le haut supérieur de la tête après la phase d'aplomb du membre antérieur affecté, le quatrième modèle de position de tête verticale correspondant au temps de pic de claudication survenant pendant un lancement.

15. Système (100) selon l'une quelconque des revendications 13 ou 14, dans lequel les trois modèles de référence de mouvement du bassin vertical pour la claudication du membre postérieur comprennent :

un premier modèle de bassin vertical (502) représentant moins de mouvement vers le bas d'un bassin d'un animal à quatre pattes pendant une phase d'aplomb d'un membre postérieur affecté, le premier modèle de bassin vertical correspondant à un temps de pic de claudication survenant pendant une phase de décélération de la phase d'aplomb du membre postérieur affecté ;
un second modèle de bassin vertical (504) représentant moins de mouvement vers le haut du bassin après la phase d'aplomb du membre postérieur affecté, le second modèle de bassin vertical correspondant au temps de pic de claudication survenant pendant une phase d'accélération de la phase d'aplomb dudit membre postérieur affecté ; et
un troisième modèle de bassin vertical (506) représentant moins de mouvement vers le bas du bassin pendant la phase d'aplomb du membre postérieur affecté et moins de mouvement vers le haut du bassin après la phase d'aplomb du membre postérieur affecté, le troisième modèle de bassin vertical correspondant au temps de pic de claudication survenant lorsque la claudication se produit pendant la phase d'aplomb du membre postérieur affecté.

FIG. 1A

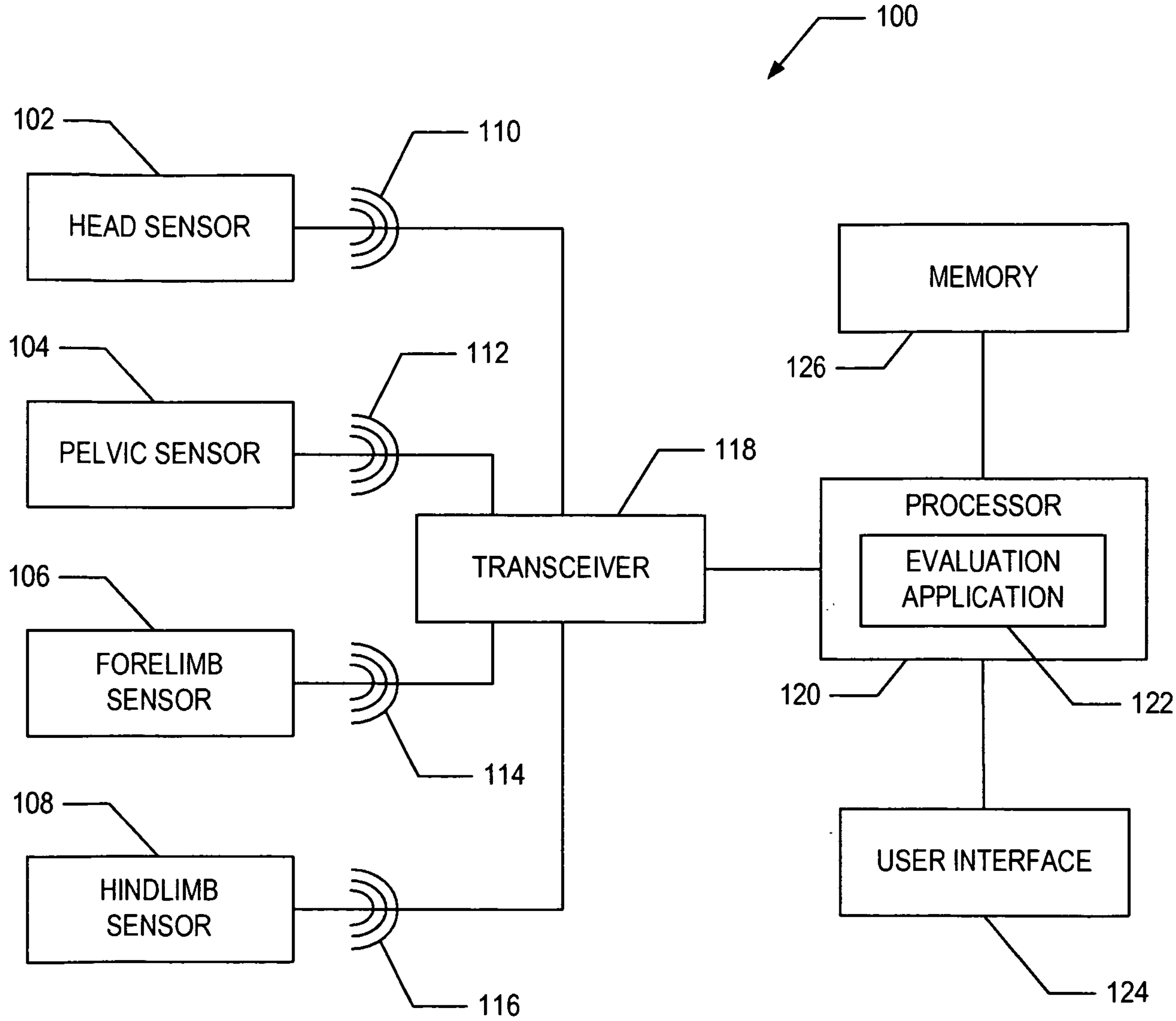

100
102
HEAD SENSOR
110
104
PELVIC SENSOR
112
106
FORELIMB SENSOR
114
108
HINDLIMB SENSOR
116
TRANSCEIVER
118
MEMORY
126
PROCESSOR
EVALUATION APPLICATION
120
122
USER INTERFACE
124

FIG. 1B

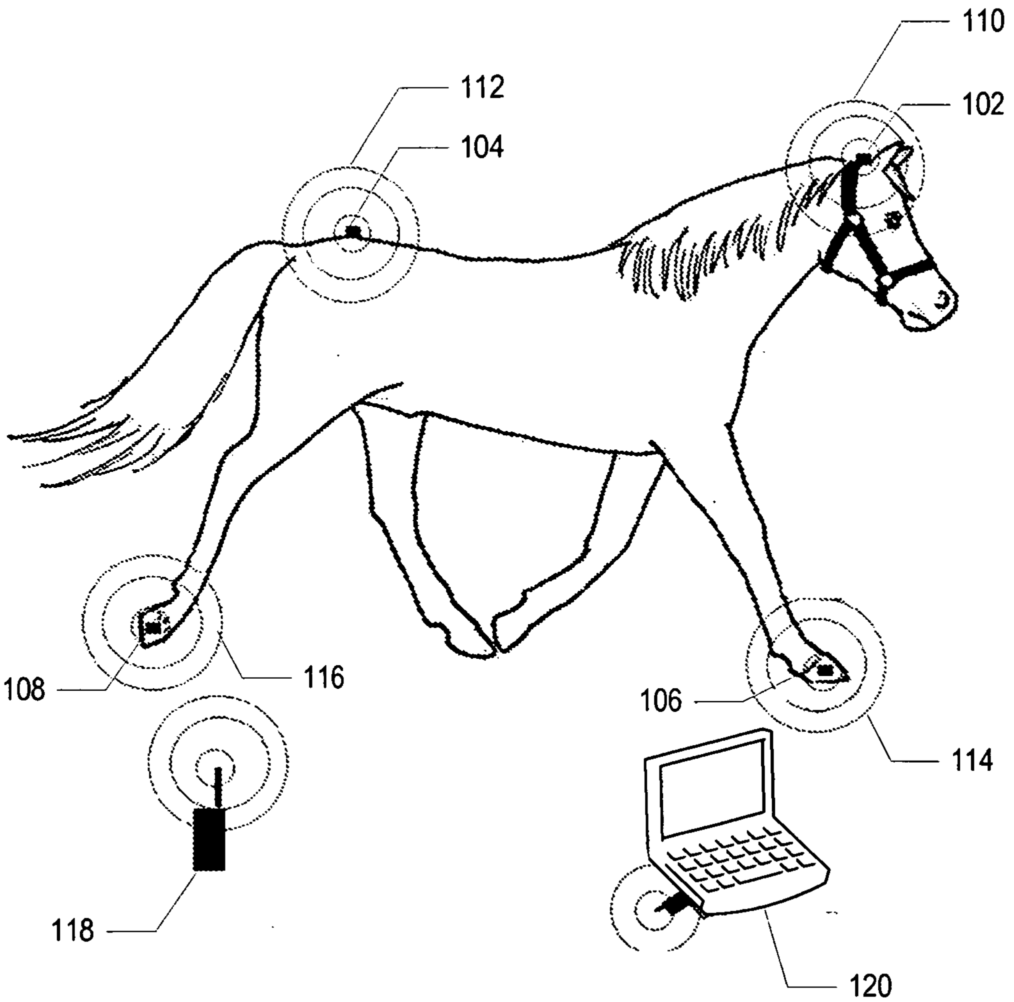


FIG. 1C

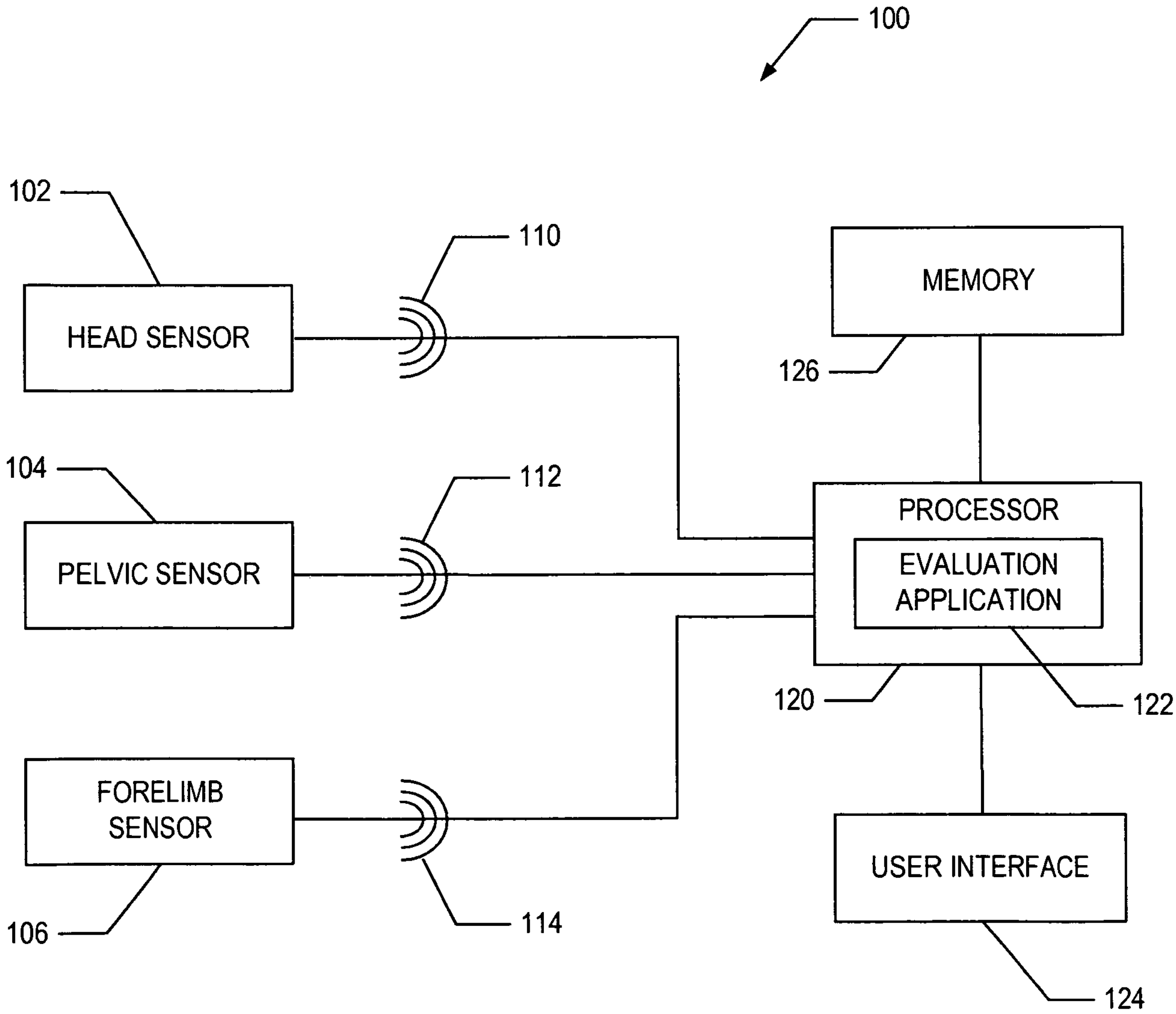

100
102
HEAD SENSOR
110
MEMORY
126
104
112
PELVIC SENSOR
PROCESSOR
EVALUATION APPLICATION
120
122
FORELIMB SENSOR
106
114
USER INTERFACE
124

FIG. 1D

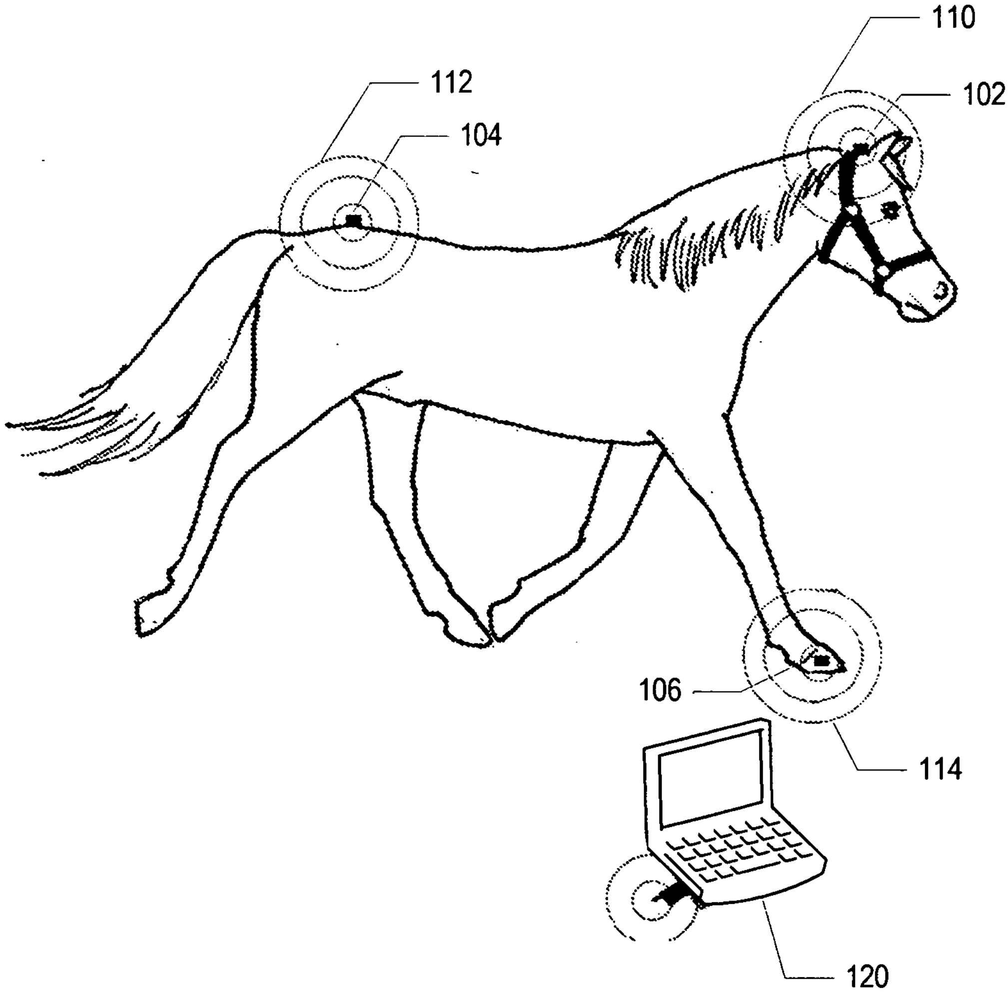


FIG. 2

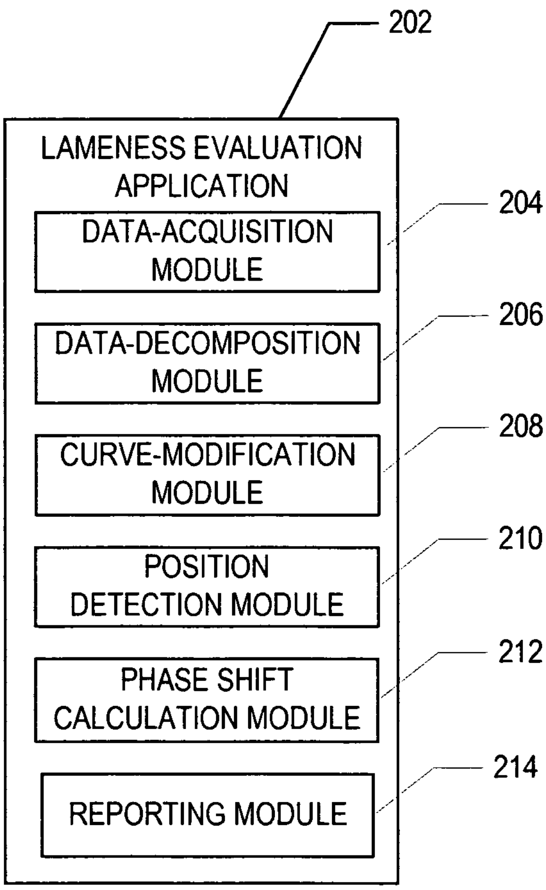

202
LAMENESS EVALUATION APPLICATION
204
DATA-ACQUISITION MODULE
206
DATA-DECOMPOSITION MODULE
208
CURVE-MODIFICATION MODULE
210
POSITION DETECTION MODULE
212
PHASE SHIFT CALCULATION MODULE
214
REPORTING MODULE

FIG. 3

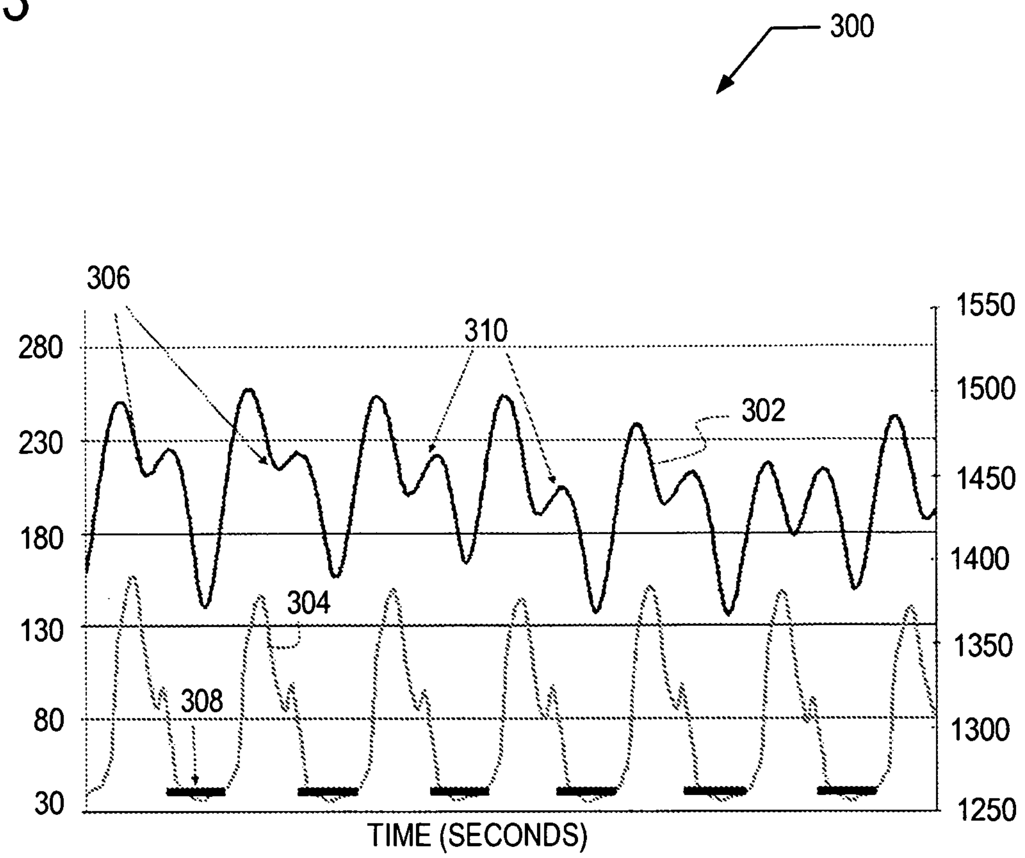

300
306
310
302
304
308
280
230
180
130
80
30
1550
1500
1450
1400
1350
1300
1250
TIME (SECONDS)

FIG. 4A

FIG. 4B

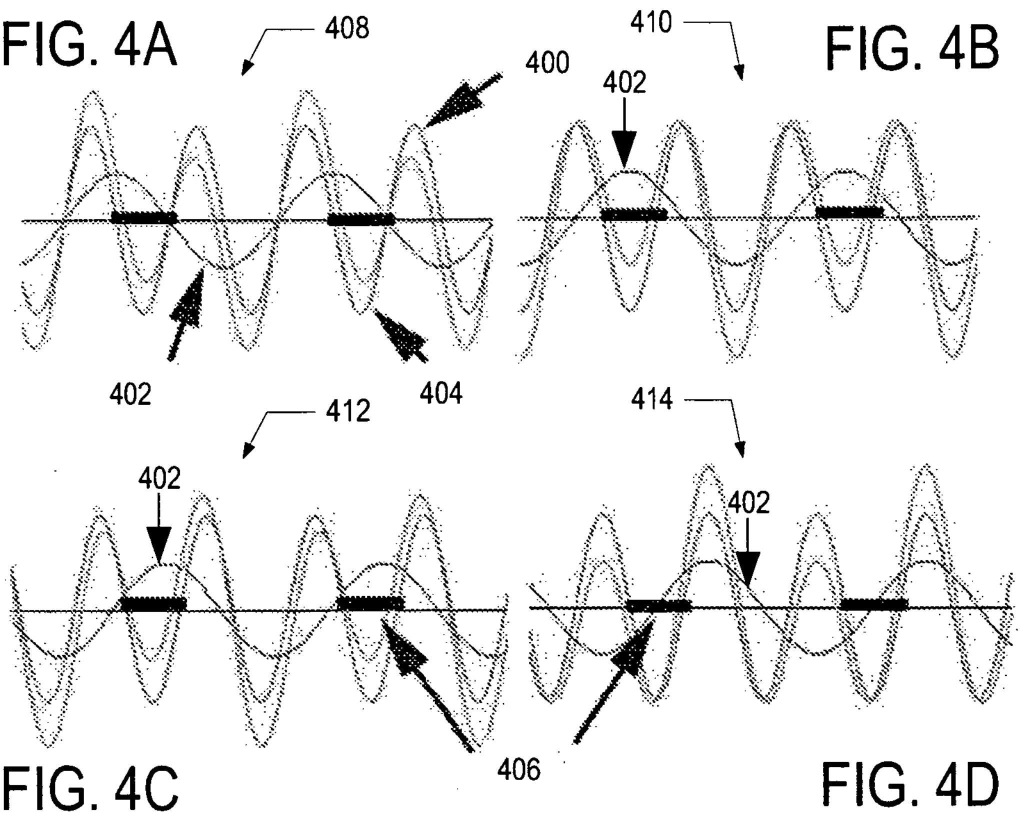


FIG. 4C

FIG. 4D

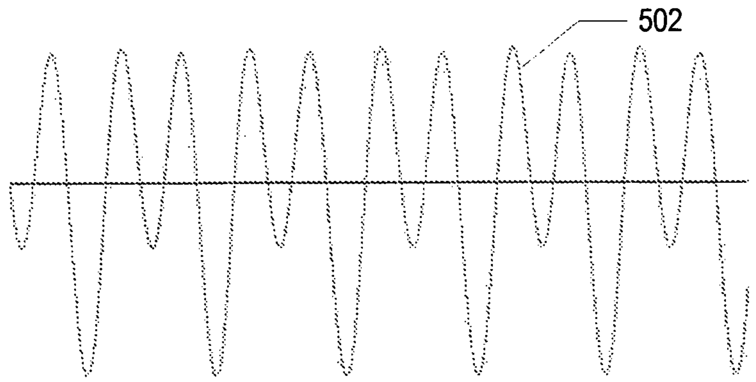


FIG. 5A

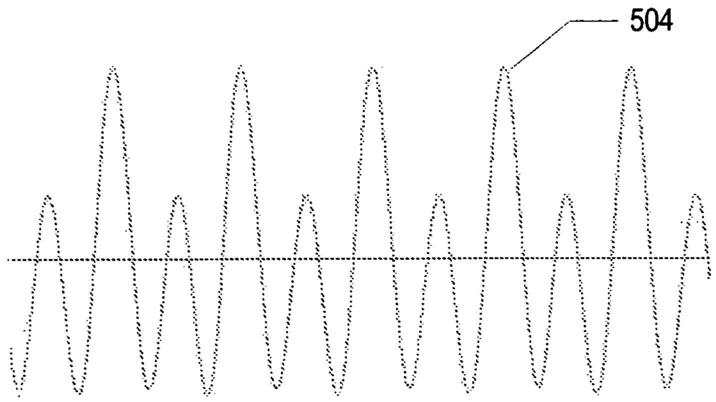


FIG. 5B

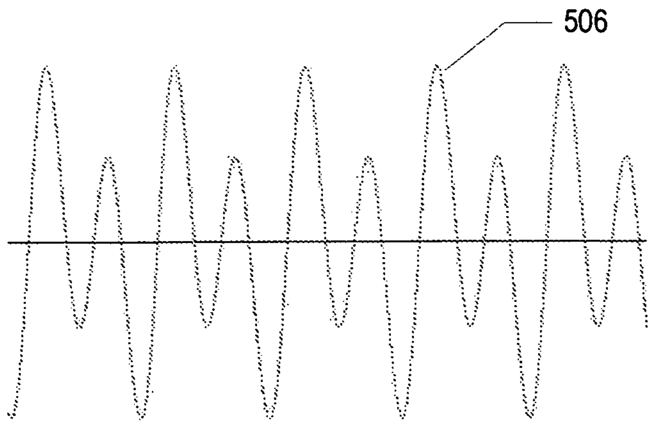


FIG. 5C

FIG. 6A

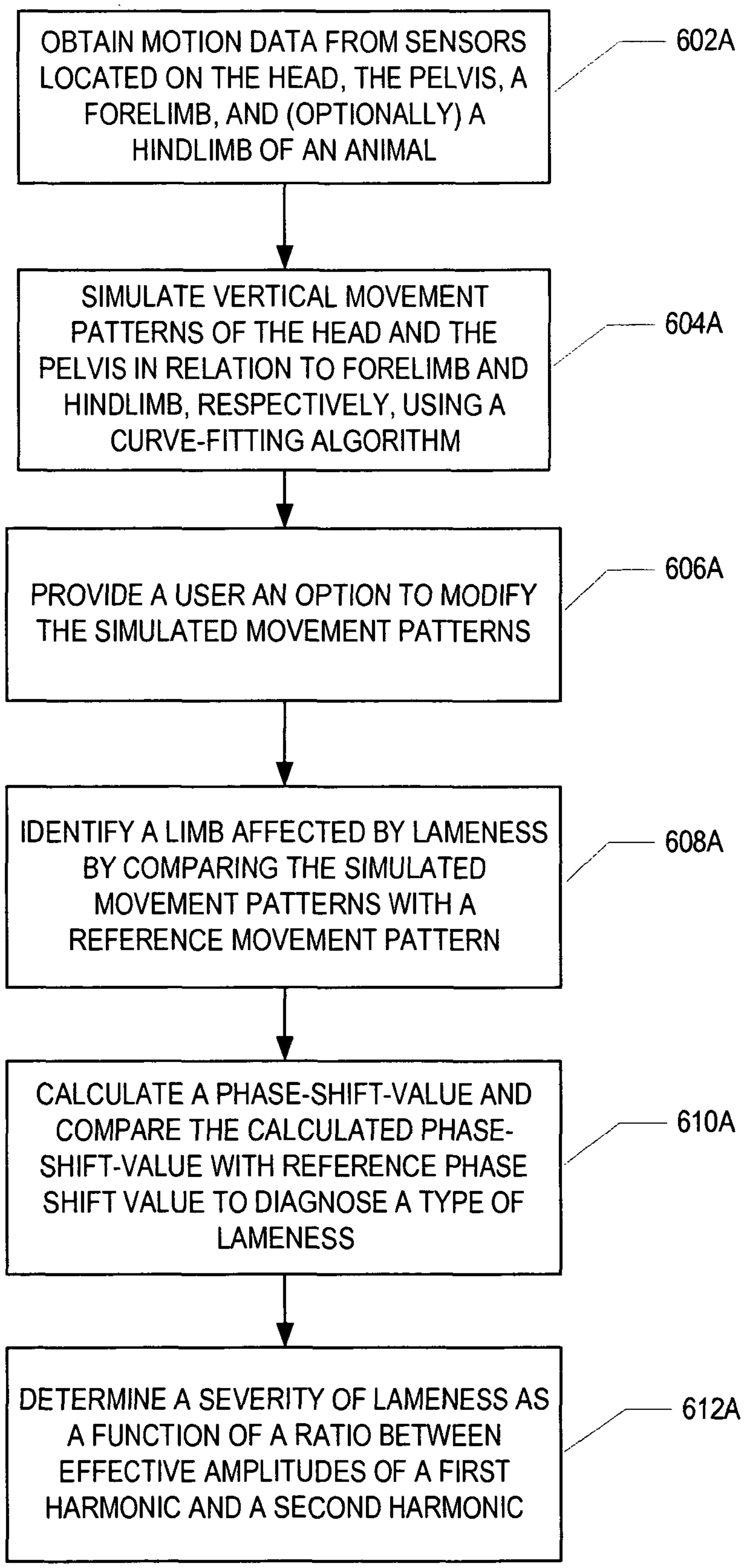

OBTAIN MOTION DATA FROM SENSORS LOCATED ON THE HEAD, THE PELVIS, A FORELIMB, AND (OPTIONALLY) A HINDLIMB OF AN ANIMAL
602A
SIMULATE VERTICAL MOVEMENT PATTERNS OF THE HEAD AND THE PELVIS IN RELATION TO FORELIMB AND HINDLIMB, RESPECTIVELY, USING A CURVE-FITTING ALGORITHM
604A
PROVIDE A USER AN OPTION TO MODIFY THE SIMULATED MOVEMENT PATTERNS
606A
IDENTIFY A LIMB AFFECTED BY LAMENESS BY COMPARING THE SIMULATED MOVEMENT PATTERNS WITH A REFERENCE MOVEMENT PATTERN
608A
CALCULATE A PHASE-SHIFT-VALUE AND COMPARE THE CALCULATED PHASE-SHIFT-VALUE WITH REFERENCE PHASE SHIFT VALUE TO DIAGNOSE A TYPE OF LAMENESS
610A
DETERMINE A SEVERITY OF LAMENESS AS A FUNCTION OF A RATIO BETWEEN EFFECTIVE AMPLITUDES OF A FIRST HARMONIC AND A SECOND HARMONIC
612A

FIG. 6B

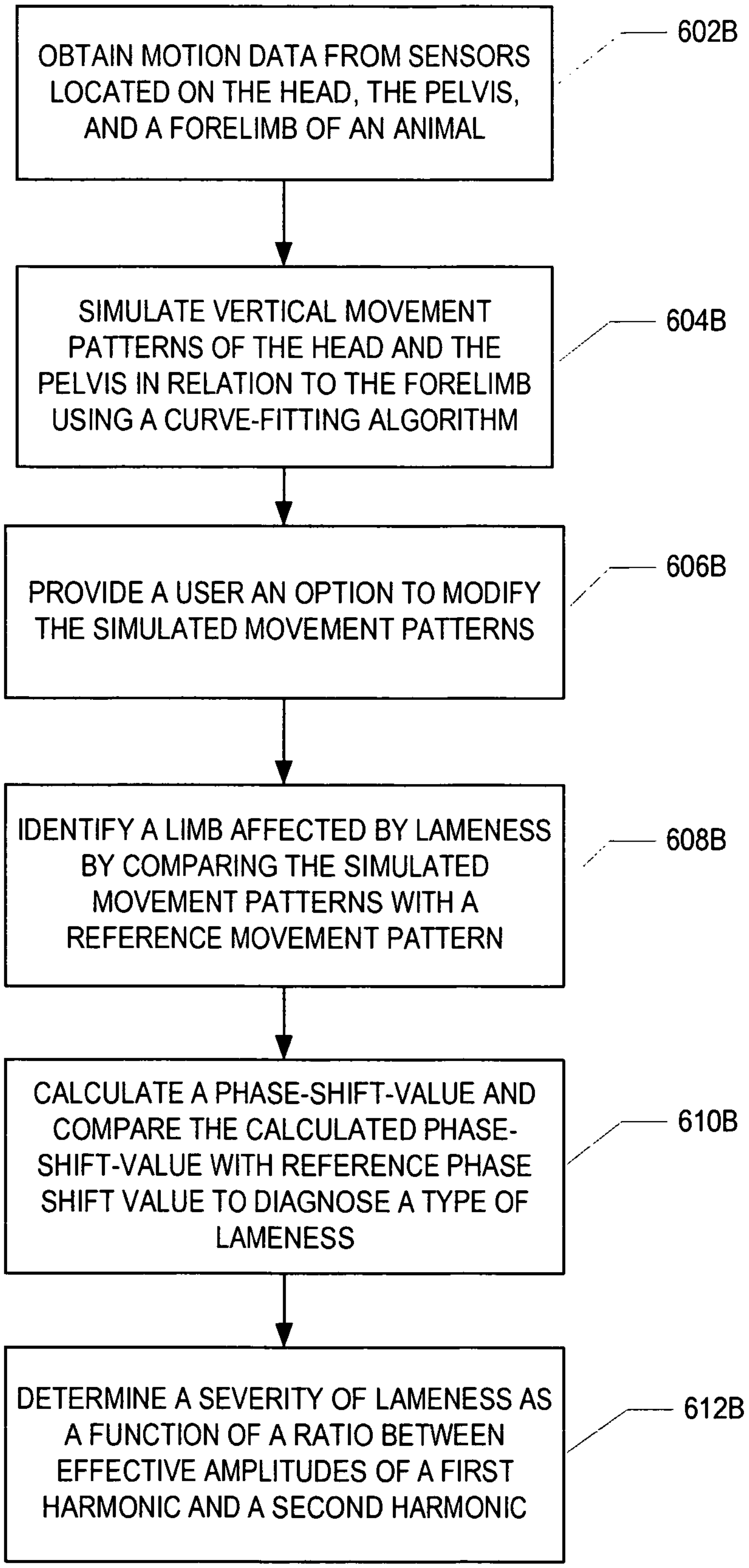

OBTAIN MOTION DATA FROM SENSORS LOCATED ON THE HEAD, THE PELVIS, AND A FORELIMB OF AN ANIMAL
602B
SIMULATE VERTICAL MOVEMENT PATTERNS OF THE HEAD AND THE PELVIS IN RELATION TO THE FORELIMB USING A CURVE-FITTING ALGORITHM
604B
PROVIDE A USER AN OPTION TO MODIFY THE SIMULATED MOVEMENT PATTERNS
606B
IDENTIFY A LIMB AFFECTED BY LAMENESS BY COMPARING THE SIMULATED MOVEMENT PATTERNS WITH A REFERENCE MOVEMENT PATTERN
608B
CALCULATE A PHASE-SHIFT-VALUE AND COMPARE THE CALCULATED PHASE-SHIFT-VALUE WITH REFERENCE PHASE SHIFT VALUE TO DIAGNOSE A TYPE OF LAMENESS
610B
DETERMINE A SEVERITY OF LAMENESS AS A FUNCTION OF A RATIO BETWEEN EFFECTIVE AMPLITUDES OF A FIRST HARMONIC AND A SECOND HARMONIC
612B

FIG. 7

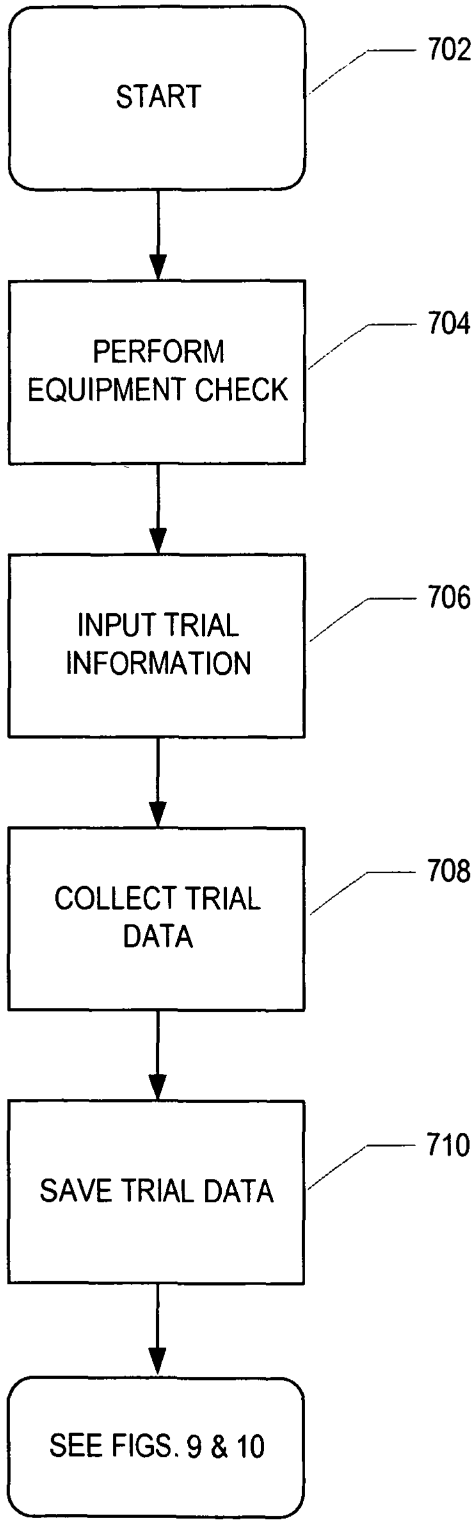

START
702
PERFORM EQUIPMENT CHECK
704
INPUT TRIAL INFORMATION
706
COLLECT TRIAL DATA
708
SAVE TRIAL DATA
710
SEE FIGS. 9 & 10

FIG. 8

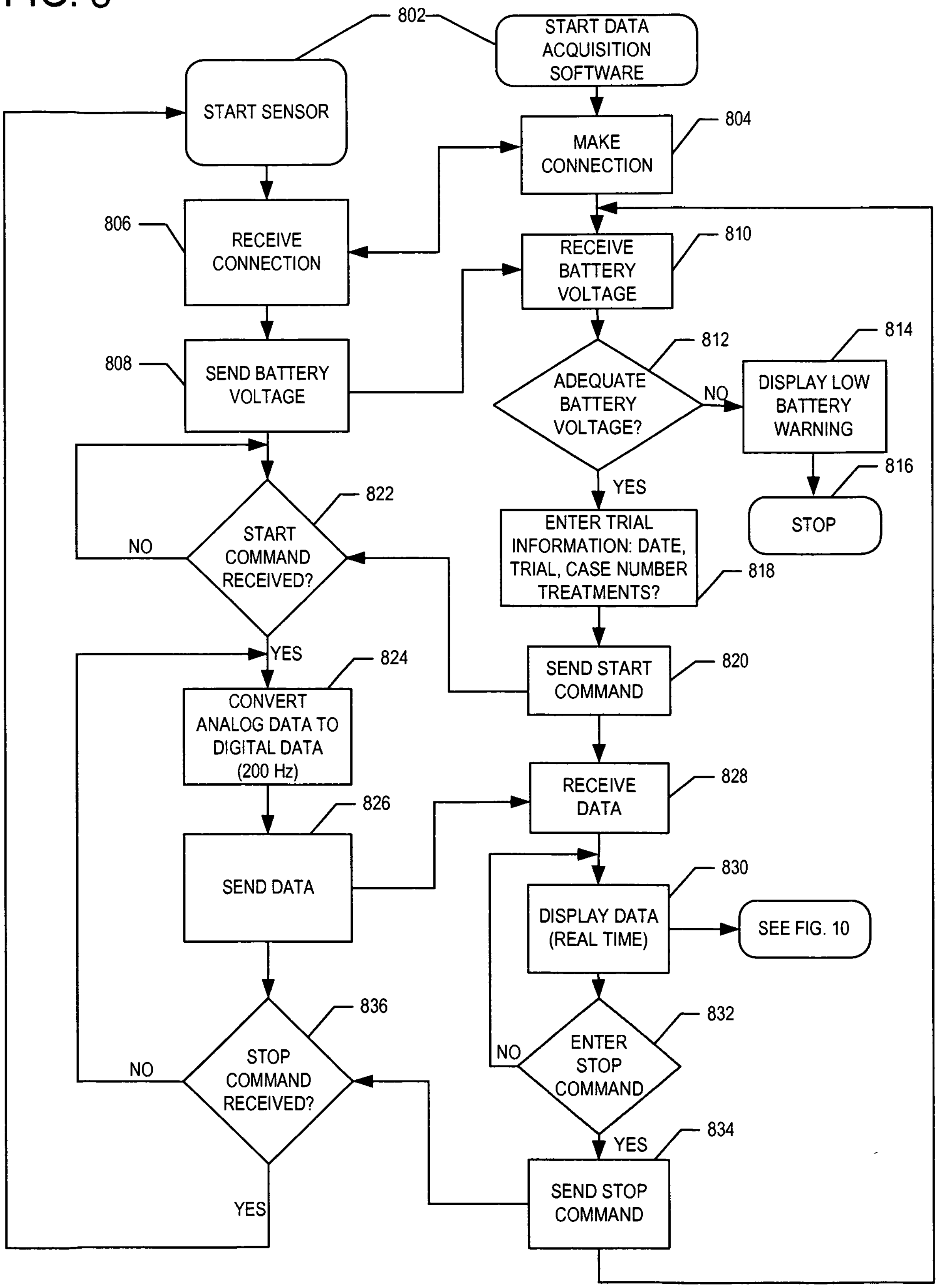

802
START DATA ACQUISITION SOFTWARE
START SENSOR
MAKE CONNECTION
804
806
RECEIVE CONNECTION
RECEIVE BATTERY VOLTAGE
810
808
SEND BATTERY VOLTAGE
ADEQUATE BATTERY VOLTAGE?
812
NO
DISPLAY LOW BATTERY WARNING
814
816
STOP
YES
ENTER TRIAL INFORMATION: DATE, TRIAL, CASE NUMBER TREATMENTS?
818
START COMMAND RECEIVED?
822
NO
YES
CONVERT ANALOG DATA TO DIGITAL DATA (200 Hz)
824
SEND START COMMAND
820
RECEIVE DATA
828
SEND DATA
826
DISPLAY DATA (REAL TIME)
830
SEE FIG. 10
STOP COMMAND RECEIVED?
836
NO
YES
ENTER STOP COMMAND
832
NO
YES
834
SEND STOP COMMAND

FIG. 9

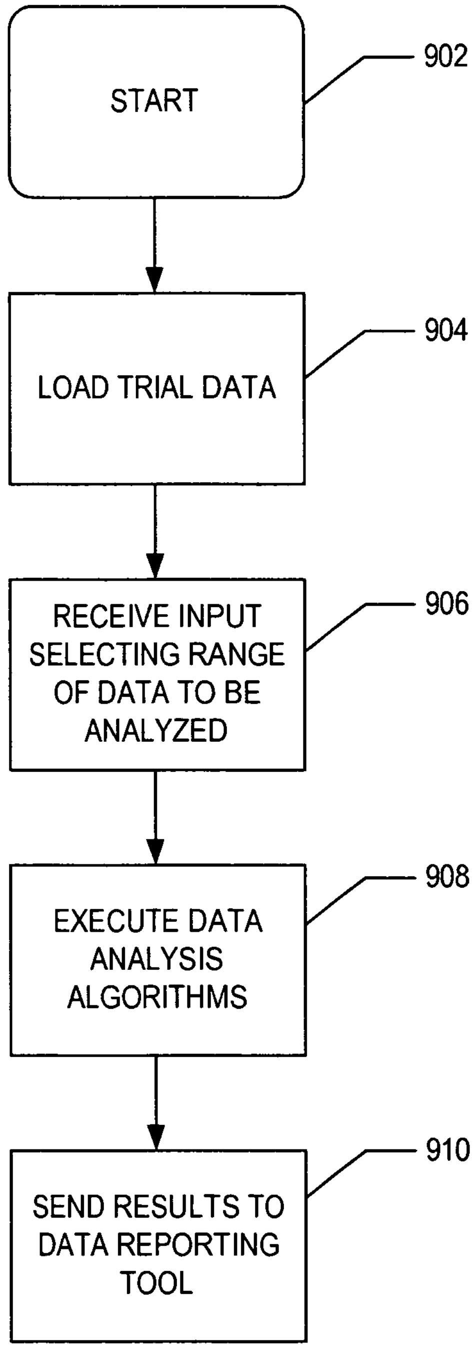
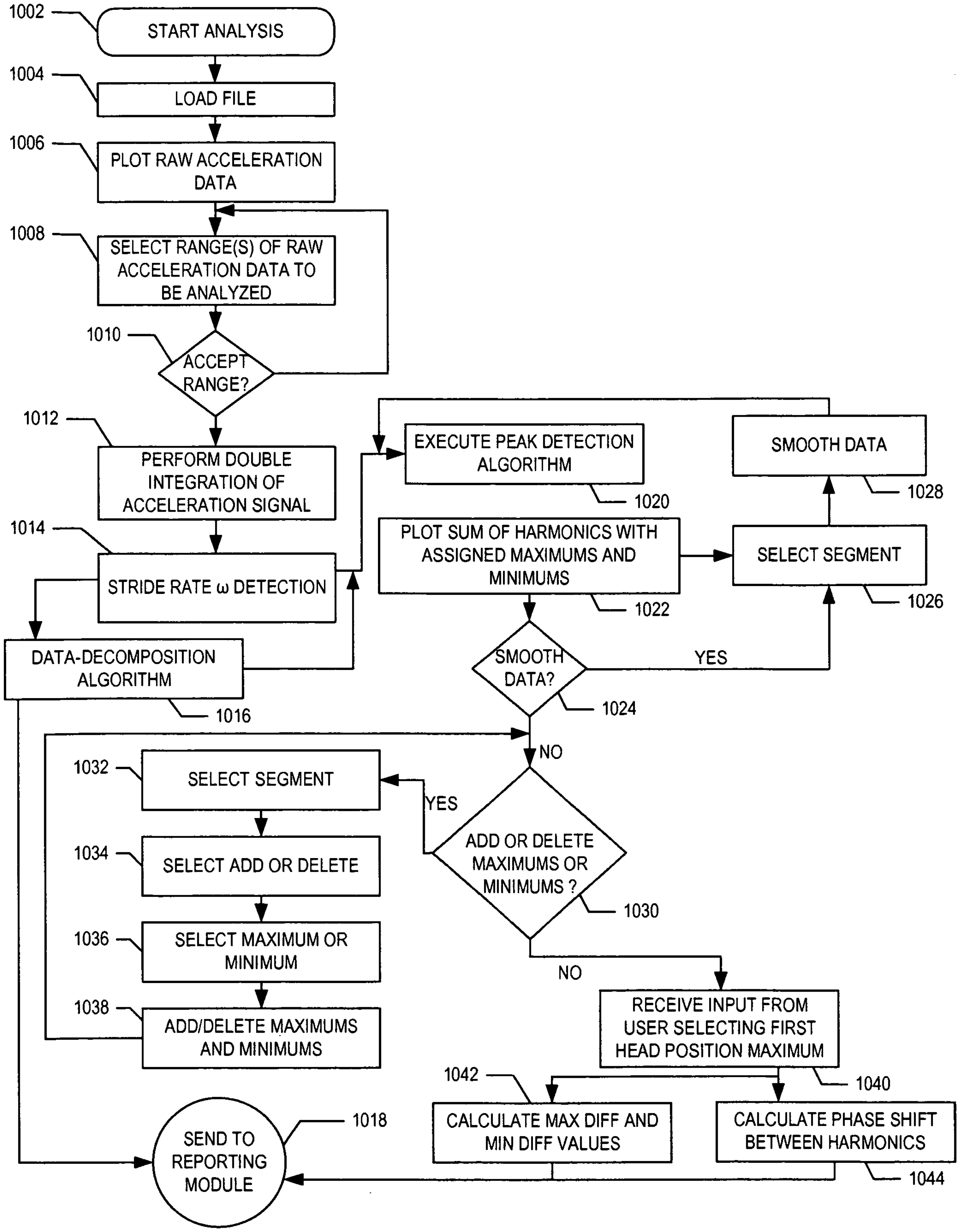

START
902
LOAD TRIAL DATA
904
RECEIVE INPUT SELECTING RANGE OF DATA TO BE ANALYZED
906
EXECUTE DATA ANALYSIS ALGORITHMS
908
SEND RESULTS TO DATA REPORTING TOOL
910

FIG. 10


1002
START ANALYSIS
1004
LOAD FILE
1006
PLOT RAW ACCELERATION DATA
1008
SELECT RANGE(S) OF RAW ACCELERATION DATA TO BE ANALYZED
1010
ACCEPT RANGE?
1012
PERFORM DOUBLE INTEGRATION OF ACCELERATION SIGNAL
1014
STRIDE RATE ω DETECTION
DATA-DECOMPOSITION ALGORITHM
1016
EXECUTE PEAK DETECTION ALGORITHM
1020
SMOOTH DATA
1028
PLOT SUM OF HARMONICS WITH ASSIGNED MAXIMUMS AND MINIMUMS
1022
SELECT SEGMENT
1026
SMOOTH DATA?
YES
1024
NO
1032
SELECT SEGMENT
YES
1034
SELECT ADD OR DELETE
ADD OR DELETE MAXIMUMS OR MINIMUMS ?
1030
1036
SELECT MAXIMUM OR MINIMUM
NO
1038
ADD/DELETE MAXIMUMS AND MINIMUMS
RECEIVE INPUT FROM USER SELECTING FIRST HEAD POSITION MAXIMUM
1042
1040
SEND TO REPORTING MODULE
1018
CALCULATE MAX DIFF AND MIN DIFF VALUES
CALCULATE PHASE SHIFT BETWEEN HARMONICS
1044

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 6699207 B, Tasch **[0002]**
- US 20060000420 A **[0002]**

patsnap

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其他公开文献	EP2043519A4 EP2043519A2		
外部链接	Espacenet		

摘要(译)

基于无线传感器的跛行评估系统检测和分析与至少一个肢体运动相关的四足动物的垂直头部和骨盆运动的模式。该系统包括多个运动传感器，其连接到头部，骨盆（或沿着背部的中心），以及动物的至少一个肢体。处理系统接收运动数据并处理运动数据以检测和量化动物中的前肢和/或后肢跛足。

$$y(t) = C_1\cos(\omega t) + C_2\sin(\omega t) + C_3\cos(2\omega t) + C_4\sin(2\omega t) + C_5 + C_6 t + C_7 t^2 + C_8 t^3 \quad (1)$$