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Method and system for detecting livestock respiratory compromise

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Abstract

Video cameras capture video images of livestock and transmit the images to a computer. The computer identifies individual livestock based on biometric markings. The computer performs pixel enhancement to amplify breathing motion and calculates a respiration rate. A sudden increase in respiration rate indicates respiratory compromise, such as pneumonia or BRD.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS (1) The present application claims benefit of U.S. Provisional Patent Application No. 63/387,491, entitled "METHOD AND SYSTEM FOR DETECTING LIVESTOCK RESPIRATORY COMPROMISE", filed Dec. 14, 2022; U.S. Provisional Patent Application No. 63/387,488, entitled "LIVESTOCK HEART RATE MONITORING", filed Dec. 14, 2022 and U.S. Provisional Patent Application 63/387,490, entitled "COMPUTER METHOD AND APPARATUS FOR TAGLESS TRACKING OF LIVESTOCK", filed Dec. 14, 2022.

(1) The foregoing applications, to the extent not inconsistent with the disclosure herein, are incorporated by reference.
SUMMARY
(2) According to an embodiment, a computer method for measuring respiration rate in livestock includes receiving a video stream including images of one or more livestock; determining, from the video stream images, a digital identity of a livestock individual; finding, in frames of the video stream, a feature of the livestock individual that exhibits respiration rate-correlated periodic

movement; performing pixel amplification at the feature to amplify the periodic movement; and calculating a respiration rate of the livestock individual from a sequence of the amplified periodic movement. The computer method may further include outputting information about the respiration rate of the livestock individual on an electronic display.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a diagram of a system for monitoring livestock health, according to an embodiment.
(2) FIG. **2** is a block diagram of a computer system for tagless tracking and biometric identification of livestock, according to an embodiment.
(3) FIG. **3** is a flowchart showing a computer method for livestock biometric identification and tracking, according to an embodiment.
(4) FIG. **4** is a diagram of information including livestock milling about with respective electronic identities output to an electronic display, according to an embodiment.
(5) FIG. **5** is a diagram of an individual livestock with biometric markers for determining a biometric identity, according to an embodiment.
(6) FIG. **6** is a diagram showing an electronic display where an electronic identity is adjusted to correspond to a biometric identity, according to an embodiment.
(7) FIG. **7** is a flow chart showing a computer method for detecting respiration compromise in livestock, according to an embodiment.
(8) FIG. **8** is a diagram showing a livestock individual with a feature that exhibits periodic movement with respiration, according to an embodiment.
(9) FIG. **9** is a diagram showing a sequence of video frames exhibiting pixel-amplified periodic movement at the feature of the livestock, according to an embodiment.
DETAILED DESCRIPTION
(10) In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. Other embodiments may be used and/or other changes may be made without departing from the spirit or scope of the disclosure.
(11) FIG. **1** is a diagram of a system **100** for monitoring livestock health, according to an embodiment. A plurality of livestock **102** may be constrained by a peripheral fence, for example in a feedlot. The computer methods described herein may be performed on such a peripherally constrained plurality of livestock, or may be performed on livestock with no nearby constraint.
(12) A plurality of sensors **104**, here shown as cameras **104***a*, **104***b*, **104***c*, **104***d*, **104***e*, are disposed to obtain digital video or sequences of still frames including the livestock **102**. The digital video or sequences of still frames are transmitted to a computer **106**. The computer **106** may process the digital video or sequences of still frames as described below. The computer **106** may display the videos or sequences of still frames on an electronic display **108** for viewing by a user. Additionally or alternatively the computer **106** may display other indicia, optionally overlaying the fields of view, derived from processing described below.
(13) FIG. **2** is a block diagram of a computer system for tag-less tracking and biometric identification of livestock, according to an embodiment. The cameras **104***a*, **104***b*, **104***c*, **104***d*, **104***e* are indicated as sensors **104**. The sensors **104** may optionally include other sensing modalities in addition to focal plane imaging. Optionally, the sensors **104** are configure to provide hyper-spectral imaging. The sensors are operatively coupled to a computer **202**. As shown in FIG. **2**, the computer **106** shown in FIG. **1** may be configured as a client or peer device. Optionally all processing described herein may be performed in a single computer **106**. The computer **106** may include a thin client, a portable or non-portable computer, a personal electronic device such as a smart phone, or

other platform capable of receiving data and driving an electronic display **108**.

(14) The computer **202** may be a server computer, and/or may include a server farm, a set of pipelined servers, relay servers, etc. as is known in the art of computer networking. The server **202** may receive data from the sensors **104** and process the data as describe herein. The server may include an application program interface (API) portion **206** operatively coupled to an application platform **204**. The application platform **204** may be included in the server **202**, may be included in the local computer **106**, or may be otherwise operatively coupled therebetween. The server **202** (and/or computer **106**) include a non-transitory computer readable memory **208** such as a rotating disk or solid state memory. The non-transitory computer readable memory may support a database, look-up table, or other software structure to enable storage and retrieval of information described below. Typically, the computer **202** includes a microprocessor, memory, and other components appropriate for performing image processing on the data received from the sensors **104**.

(15) FIG. **3** is a flow chart showing a computer method **300** for livestock tracking and biometric identification, according to an embodiment which includes, at step **302**, receiving, into a computer **106**, **202**, a first digital video or sequence of digital photographic frames from one or more digital image capture devices **104a**, **104b**, **104c**, **104d**, **104e**. The digital image capture devices **104a**, **104b**, **104c**, **104d**, **104e** may be referred to, collectively or individually, as **104** herein. The first digital video or sequence of digital photographic frames may include a plurality of livestock locations **102**. Proceeding to step **304**, a digital identity is assigned to each livestock individual in the pen. In step **308**, locations of the livestock individuals are tracked as the livestock mill about. Referring to FIGS. **3** and **5**, the method **300** may further include, at step **310**, receiving a second digital video or digital photographic frame **500** including at least a portion of a biometric identification area **504**, **506**, **508** of an individual livestock body **502**. A biometric deep sort is performed in step **312** to produce at least a portion of an individual livestock biometric identity. Proceeding to step **314**, the individual livestock biometric identity is associated with a corresponding livestock digital identity. Step **314** may, for example, include associating the biometric and digital identities in a look up table, database, or other logical construct saved onto a non-transitory computer readable medium.

(16) Referring to FIGS. **3** and **4**, the method **300** may further include, in step **306**, displaying a labeled image **400** on an electronic display **108**, the labeled image including the current digital identities **402** corresponding each livestock individual.

(17) According to an embodiment, tracking locations of the livestock individuals as the livestock mill about, in step **308**, is performed using a Kalman filter. According to embodiments, tracking the locations of the livestock individuals may employ at least some parts of simultaneous localization and mapping (SLAM) which uses the Kalman filter. SLAM is usually used in robotics so the robot knows where in the environment it is located based on a few measurements.

(18) In standard SLAM, the robot sends some lasers or pings in the environment to figure out where it is, based on a few reference points. In the present embodiment, if one uses multiple poles, each supporting a digital camera or video device, the pole locations serve as reference points from which the computer method, and specifically step **308**, obtains measurements of the location and velocity of each detected class. In this case, the detected class is "livestock". With measurements from one or many poles, step **308** includes calculating a probability that a particular detected livestock individual is the same detected livestock individual from a previous few frames. The more poles there are, the more accurate the measurements will be for both tracking and identification.

(19) Referring to FIG. **5**, receiving, in step **310**, the second digital video or digital photographic frame including at least a portion of a biometric identification area of an individual livestock body may include receiving a plurality of frames. According to an embodiment, performing the biometric deep sort further includes operating a Harris filter to locate livestock biometric markers. The Harris filter identifies corners in the frame, the corners being associated with the biometric

markers. Performing the biometric deep sort in step **312** may include identifying, on a grid, relative locations of individual livestock biometric markers and storing the grid locations in an individual livestock biometric identity record in a livestock population model.

(20) The individual livestock biometric markers include at least two of a corner of an eye, a corner formed by a horn, a corner formed by an ear, a snout corner, a hide color corner, a hoof corner, and/or a tail corner. Identifying individual biometric markers may include assigning classes of livestock body surface features and performing a semantic segmentation to classify each pixel as belonging to a livestock body surface feature. Assigning classes of livestock body surface features may include assigning livestock eye, livestock horn, livestock ear, livestock snout, livestock hide color patterns, livestock hoof, and/or livestock ear classes. Assigning classes of livestock body surface features may include assigning livestock eye corners and assigning livestock snout corners. Assigning classes of livestock body surface features may include assigning contrasting locations of skin and/or fur coloration. To perform identification, the computer method includes receiving a high resolution snapshot at a given time at which all heads, eyes, and snouts, are detected. Step **312** may include computing all face geometries. In step **314**, the computer method **300** may include performing a probability computation against the database to get the most likely candidate electronic IDs corresponding to the biometric IDs. If a good candidate is obtained, the ID of that candidate may be assigned to the data recorded for the aforementioned detection. If multiple candidates are obtained, the multiple candidates, as well as secondary candidates, may be set to be reviewed during subsequent algorithm improvement iterations.

(21) The first digital video or sequence of digital photographic frames received in step **302** may include a wider angle view including a plurality of livestock in the frame, compared to the second digital video or sequence of digital photographic frames includes a narrower angle view that includes less than all of the plurality of livestock in the frame. The narrower angle view may primarily include at least a portion of an individual livestock. In an embodiment, the narrower angle view consists essentially of the biometric identification area (e.g., see FIG. **5**, **504**, **506**, **508**) of the individual livestock's body **502**.

(22) The computer method **300** may further include receiving a third digital video or sequence of digital photographic frames including plurality of livestock locations in the pen as the livestock mill about, the plurality of livestock having corresponding digital identities and at least a portion of the plurality of livestock having been assigned a biometric identity. The individual livestock may be tracked (see step **308**) as the livestock mill about, the individual livestock nominally being assigned livestock digital identities. The computer method **300** may further include receiving the second digital video or digital photographic frame corresponding to one of the individual livestock and including at least a portion of the biometric identification area of the individual livestock body, performing, in step **316**, a second biometric identification of the individual livestock; and, in step **318**, verifying that the tracked individual livestock is the individual livestock associated with the current livestock digital identity.

(23) According to an embodiment, the computer method **300** may include tracking the individual livestock as the livestock mill about in step **308**, the individual livestock nominally being assigned livestock digital identities, receiving the second digital video or digital photographic frame corresponding to one of the individual livestock and including at least a portion of the biometric identification area of the individual livestock body (see step **310**), and performing biometric identification of the individual livestock.

(24) The computer method **300** may include determining the individual livestock does not match a biometric identity of an individual livestock. If an individual livestock has not been biometrically identified, the computer method **300** may include performing the biometric deep sort (see step **312**) to produce at least a portion of an individual livestock biometric identity, and (referring to step **314**), associating the individual livestock biometric identity with the corresponding livestock digital identity. This may be used to gradually match individual livestock digital identities to

individual livestock biometric identities after beginning tracking the livestock as the livestock mill about.

(25) Improvement of the biometric identity may be obtained by determining that the biometric identity includes biometric markers not previously included in the biometric identity of the individual livestock (not shown) and augmenting the biometric identity with the additional biometric markers.

(26) As may be appreciated with reference to FIG. **6**, the individual livestock may occasionally be partially or completely obscured as the livestock mill about. This may cause the image processing software to, on occasion, lose certainty as to correct digital identities, thereby causing a reduction of correspondence between current digital identities and biometric identities of the livestock. To overcome this, the computer method may include periodically repeating biometric identification and, as appropriate, updating the digital identity. The computer method **300** may include determining that the tracked individual livestock **404***a* is an individual livestock associated with a different individual livestock digital identity **402***b* than an incorrect livestock digital identity **402***a* currently assigned to the first individual livestock **404***a*. The method **300** may then include, in step **318**, assigning the correct individual livestock digital identity to the individual livestock. For example, comparing FIG. **4** to FIG. **6**, see that individual livestock **404***a*, was incorrectly associated with digital identity **402***a* "342ffff". Upon the biometric deep sort, the individual livestock **404***a*, was found to have been assigned the digital identity associated with a different livestock **404***b*. Step **318** may include assigning the correct livestock digital identity **402***b* "1234567" previously associated with a different individual livestock **404***b* than the individual livestock **404***a*. Step **318** may include assigning the incorrect livestock digital identity **402***a* "342ffff" previously associated with the first individual livestock **404***a* to a second individual livestock **404***b*.

(27) The livestock may be cows and/or steers. In other embodiments, the livestock may include sheep or goats.

(28) FIG. **7** is a flowchart showing a computer method **700** for detecting respiratory compromise in livestock, according to an embodiment. Step **702** includes receiving a video stream including images of one or more livestock. In step **704**, a digital identity of a livestock individual is determined from the video stream images. Step **706** includes finding, in frames of the video stream, an edge of the livestock individual that exhibits respiratory motion. Step **708** includes performing pixel amplification at the edge to amplify the respiratory motion. In step **710** a respiration rate of the livestock individual is determined from a sequence of the amplified edge pixels. In step **714**, information about the respiration rate of the livestock individual is displayed on an electronic display.

(29) Displaying information about the respiration rate of the livestock individual on an electronic display in step **714** may include displaying a notice that an individual livestock has a respiration rate that meets a threshold respiration rate indicative of respiratory distress. Displaying information about the respiration rate of the livestock individual on an electronic display in step **714** may include displaying an image of the individual livestock exhibiting a respiration rate that meets a threshold respiration rate indicative of respiratory distress. Displaying information about the respiration rate of the livestock individual on an electronic display in step **714** may include displaying an image of the one or more livestock as they mill about with the imaged of the individual livestock exhibiting a respiration rate highlighted. In this way, an individual livestock exhibiting respiratory distress, the cause of which may include communicable disease, may be quickly identified and removed from the population.

(30) The computer method **700** may further include step **716**, storing the determined respiration rate in a database including previously determined respiration rates of the livestock individual. In step **712**, the determined respiration rate of the livestock individual may be compared to previously determined respiration rates of the first livestock individual. Step **712** may include determining if the determined respiration rate is different than the previously determined respiration rates. In step

714, the information corresponding to the respiration rate of the first livestock individual may be physically output.

(31) FIG. **8** is a diagram showing a feature of a livestock individual **502** that exhibits periodic movement with respiration. Referring to FIG. **7** in view of FIG. **8**, finding the feature **804** that periodically moves with respiration, in step **706**, may include producing a zoomed image **802***a* or **802***b* comprising a portion of the livestock individual **502**. Finding the feature that periodically moves with respiration in step **706** may include, for example, finding a portion **802***a* on the back of the livestock individual **502**, the belly **802***b* of the livestock individual, or other feature, depending on the posture (standing or laying) and orientation of the livestock to the camera **104** that captures the stream of images.

(32) Performing pixel amplification at the edge to amplify the respiratory motion in step **708** may be performed using a Laplacian Pyramid. Using the Laplacian Pyramid may include creating negatives of each image at various resolutions and performing image addition with the original image on a frame-to-frame basis.

(33) Performing pixel amplification at the edge to amplify the respiratory motion in step **708** may further include removing high frequency noise from an image addition frame sequence using a maximally flat magnitude filter within a passband corresponding to livestock respiration rate range. In an embodiment, the maximally flat magnitude filter within the passband comprises a Butterworth filter. In other embodiments, the maximally flat magnitude filter within the passband may include a Chebyshev filter or an elliptical filter.

(34) In step **708**, performing pixel amplification may include performing a Laplacian Pyramid and applying a Butterworth filter to form a video stream image traversing more pixels than not performing pixel amplification. In step **710**, determining the respiration rate may include performing image analysis on one or more pixel-amplified video frame sequences. Additionally or alternatively, determining respiration rate in step **710** may include obtaining at least three video clips of pixel-amplified intervals and applying a filter to ensure the determined respiration rate is representative of an actual respiration rate of the livestock individual.

(35) FIG. **9** is a diagram **900** showing a sequence of video frames **904**, **906**, **908**, **910**, including the feature **804** exhibiting pixel-amplified periodic movement, according to an embodiment. Referring to FIG. **7** in view of FIG. **9**, performing pixel amplification at the feature **804** to amplify the periodic movement in step **708** may be performed using a Laplacian Pyramid. Using the Laplacian Pyramid may include creating negatives of each image at various resolutions and performing image addition with the original image on a frame-to-frame basis.

(36) Performing pixel amplification at the feature **804** to magnify periodic movement in step **708** may include removing high frequency noise from an image addition frame sequence using a maximally flat magnitude filter within a passband corresponding to livestock respiration rate range. In an embodiment, the maximally flat magnitude filter within the passband comprises a Butterworth filter. In other embodiments, the maximally flat magnitude filter within the passband may include a Chebyshev filter or an elliptical filter. Performing pixel amplification in step **708** may include performing a Laplacian Pyramid and applying a Butterworth filter to form a video stream with greater dynamic range than a video stream where pixel amplification was not performed.

(37) In step **710**, calculating the respiration rate may include performing image analysis on one or more pixel-amplified video frame sequences. Determining respiration rate in step **710** may include obtaining at least three video clips of pixel-amplified intervals and applying a filter to ensure the calculated respiration rate is representative of an actual real time respiration rate of the livestock individual. Applying the filter to ensure the calculated respiration rate is representative of an actual respiration rate of the livestock individual may include applying a voting algorithm or performing respiration rate averaging.

(38) While various aspects and embodiments have been disclosed herein, other aspects and

embodiments are contemplated. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

Claims

1. A computer method for detecting respiratory compromise in livestock, comprising: receiving a video stream including images of one or more livestock; determining, from the video stream images, a digital identity of a livestock individual; finding, in frames of the video stream, an edge of the livestock individual that exhibits respiratory motion; performing pixel amplification at the edge to amplify the respiratory motion; determining a respiration rate of the livestock individual from a sequence of the amplified edge pixels; and displaying information about the respiration rate of the livestock individual on an electronic display.

2. The computer method for detecting respiratory compromise in livestock of claim 1, wherein displaying information about the respiration rate of the livestock individual on an electronic display includes displaying a notice that an individual livestock has a respiration rate that meets a threshold respiration rate indicative of respiratory distress.

3. The computer method for detecting respiratory compromise in livestock of claim 1, wherein displaying information about the respiration rate of the livestock individual on an electronic display includes displaying an image of the individual livestock exhibiting a respiration rate that meets a threshold respiration rate indicative of respiratory distress.

4. The computer method for detecting respiratory compromise in livestock of claim 1, wherein displaying information about the respiration rate of the livestock individual on an electronic display includes displaying an image of the one or more livestock as they mill about with the image of the individual livestock exhibiting a respiration rate highlighted.

5. The computer method for detecting respiratory compromise in livestock of claim 1, further comprising: storing the determined respiration rate in a database including previously determined respiration rates of the livestock individual.

6. The computer method for detecting respiratory compromise in livestock of claim 1, further comprising: comparing the determined respiration rate of the livestock individual to previously determined respiration rates of the first livestock individual; and determining if the determined respiration rate is different than the previously determined respiration rates.

7. The computer method for detecting respiratory compromise in livestock of claim 1, wherein performing pixel amplification at the edge to amplify the respiratory motion is performed using a Laplacian Pyramid.

8. The computer method for detecting respiratory compromise in livestock of claim 7, wherein using the Laplacian Pyramid includes: creating negatives of each image at various resolutions; and performing image addition with the original image on a frame-to-frame basis.

9. The computer method for detecting respiratory compromise in livestock of claim 1, wherein performing pixel amplification at the edge to amplify the respiratory motion further comprises: removing high frequency noise from an image addition frame sequence using a maximally flat magnitude filter within a passband corresponding to livestock respiration rate range.

10. The computer method for detecting respiratory compromise in livestock of claim 1, wherein performing pixel amplification includes performing a Laplacian Pyramid and applying a Butterworth filter to form a processed video stream traversing more pixels than not performing pixel amplification.

11. The computer method for detecting respiratory compromise in livestock of claim 1, wherein determining the respiration rate includes performing image analysis on one or more pixel-amplified video frame sequences.

12. The computer method for detecting respiratory compromise in livestock of claim 1, wherein

determining respiration rate includes: obtaining at least three video clips of pixel-amplified intervals; and applying a filter to ensure the determined respiration rate is representative of an actual respiration rate of the livestock individual.

13. The computer method for detecting respiratory compromise in livestock of claim 12, wherein applying the filter to ensure the determined respiration rate is representative of an actual respiration rate of the livestock individual includes applying a voting algorithm or performing respiration rate averaging.