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Adjustable mount for implement camera

Abstract

An adjustable camera system comprises a camera, a mounting assembly and a controller. The mounting assembly is coupled to the camera and adapted to raise and lower the camera. The controller is configured to use an image of an object from the camera to determine whether the camera is at an optimal position from the object. If the controller determines that the camera is not at the optimal position, the controller sends a signal to the mounting assembly to raise or lower the camera.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION (1) This application is a continuation-in-part of U.S. patent application Ser. No. 17/499,237 entitled TRAILED IMPLEMENT WITH VISION GUIDANCE, which was filed on Oct. 12, 2021, and which is incorporated in its entirety by reference. This application is also a continuation-in-part of U.S. patent application Ser. No. 17/499,333 entitled PRECISION CULTIVATOR WITH VISION GUIDANCE, which was filed on Oct. 12, 2021, and which is incorporated in its entirety by reference.

BACKGROUND OF THE INVENTION
1. Field of the Invention
(1) The present invention relates to a system and method for autonomously adjusting a position of a camera mounted on an agricultural machine.
2. Description of the Related Art
(2) Cameras are known to be mounted on farming equipment to visually capture the surrounding area. The data from the cameras is known to be used for monitoring the spatial relationship between the agricultural machine to which it is attached and the crops growing in the field. The data captured by the cameras is used for multiple purposes, including but not limited to, assisting with autonomous control of the agricultural machine. Therefore, the placement and resulting perspective of the camera with respect to the crop is critically important. Currently, cameras are manually positioned on and attached to an agricultural machine prior to beginning work on a field

of crop and are manually adjusted throughout the process of working on the field, as necessary. The manual adjustment of the camera can be a time-consuming and burdensome task, particularly when necessary while working in the middle of a field.

(3) Maintaining the proper perspective is important for accurate data gathering and it is known to manually adjust the camera at multiple points in time, including but not limited to, during the initial pre-operation setup, during operation in the field, and when the agricultural machine travels between fields of different crops. During the initial set-up, prior to operation of the agricultural machine, an operator will adjust the camera's mounted position on the agricultural machine by manually, physically attaching the camera to the agricultural machine at the desired position. During operation, as the agricultural machine travels across the field or fields, the rows of crop may be growing at different rates. As a result, the camera's fixed perspective is no longer ideal for the height of the crop being traversed by the agricultural machine. Therefore, the data being captured by the camera may not be accurate because the camera is blocked due to the height of the crop. Another scenario during operation is when the agricultural machine moves from a field growing one type of crop to a different field growing a different type of crop, the spacing of the crop rows may change. For example, if the prior field has 15 inch spacing between the rows and the next field has 38 inch spacing between the rows, this change would also impact the perspective of the camera's position with respect to the rows of crop.

SUMMARY OF THE INVENTION

(4) Therefore, there is a need for a camera that is mounted to an agricultural machine that automatically and autonomously adjusts its position to gain the correct perspective with respect to the crop prior to starting work on a field of crop and as the agricultural machine is working on the field to yield accurate information.

(5) The current invention satisfies these needs by configuring a system that autonomously adjusts a position of a camera mounted to an agricultural machine. According to one embodiment, an adjustable camera system comprises a camera, a mounting assembly and a controller. The mounting assembly is coupled to the camera and adapted to raise and lower the camera. The controller is configured to use an image of an object from the camera to determine whether the camera is at an optimal position from the object. If the controller determines that the camera is not at the optimal position, the controller sends a signal to the mounting assembly to raise or lower the camera.

(6) According to another embodiment, there is provided a method for autonomously adjusting a position of a camera mounted to an agricultural machine. The method comprises obtaining an image of an object from the camera, using the image to determine whether the camera is at an optimal position from the object, and if it is determined that the camera is not at the optimal position, raising or lowering the camera.

(7) Other objects and purposes of the invention, and variations thereof, will be apparent upon reading the following specification and inspecting the accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) Advantages of the present disclosure will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

(2) FIG. **1** illustrates a perspective view of an adjustable camera system mounted on an agricultural machine according to one embodiment of the present invention;

(3) FIG. **2** illustrates a side view of the adjustable camera system and agricultural machine of FIG. **1**;

(4) FIG. **3**A illustrates a perspective view of the adjustable camera system of FIG. **1** in a retracted position;
(5) FIG. **3**B illustrates a perspective view of an alternative embodiment of an adjustable camera system;
(6) FIG. **3**C illustrates a perspective view of another alternative embodiment of an adjustable camera system;
(7) FIG. **4** illustrates a side view of the adjustable camera system of FIG. **3**A;
(8) FIG. **5** illustrates a rear view of the adjustable camera system of FIG. **3**A;
(9) FIG. **6** illustrates a rear view of the adjustable camera system of FIG. **5** in an extended position;
(10) FIG. **7** illustrates a front view of the adjustable camera system of FIG. **1** attached to an unfolded tool bar in a retracted position;
(11) FIG. **8** illustrates a front view of the adjustable camera system and tool bar of FIG. **7** where the adjustable camera system is in an extended position;
(12) FIG. **9** illustrates a front view of the adjustable camera system and tool bar of FIG. **7** where the tool bar is in a folded position;
(13) FIG. **10** illustrates a perspective view of the adjustable camera system and tool bar of FIG. **9**;
(14) FIG. **11** illustrates a block diagram of the adjustable camera system according to one embodiment of the present invention;
(15) FIG. **12** illustrates a flow diagram of an exemplary method performed by the adjustable camera system according to one embodiment of the present invention;
(16) FIG. **13** illustrates a flow diagram illustrating the processing performed on an image by the adjustable camera system;
(17) FIG. **14** illustrates a flow diagram of an exemplary method performed by the adjustable camera system according to another embodiment of the present invention;
(18) FIG. **15** illustrates a processed image from the adjustable camera system when the camera is at an optimal distance from the top of the crop rows;
(19) FIG. **16** illustrates a processed image from the adjustable camera system when the camera is lower than an optimal distance from the top of the crop rows; and
(20) FIG. **17** illustrates a processed image from the adjustable camera system when the camera is higher than an optimal distance from the top of the crop rows.
(21) Certain terminology will be used in the following description for convenience and reference only and will not be limiting. For example, the words “upwardly”, “downwardly”, “rightwardly” and “leftwardly” will refer to directions in the drawings to which reference is made. The words “inwardly” and “outwardly” will refer to directions toward and away from, respectively, the geometric center of the arrangement and designated parts thereof. The terminology will include the words specifically mentioned, derivatives thereof, and words of similar import.

DETAILED DESCRIPTION OF THE EMBODIMENTS

(22) Referring to the Figures, wherein like numerals indicate like or corresponding parts throughout the several views, an adjustable camera system **20** according to embodiments of the present invention is shown. The system **20** includes a camera **28** coupled to a mounting assembly **38**. The mounting assembly **38** is adapted to raise and lower the camera **28**. Referring to FIGS. **1-3**A and **4-10**, in one embodiment, the mounting assembly **38** includes a mounting arm **36** having a length configured to adjust between a retracted position, as reflected in FIG. **5**, and an extended position, as reflected in FIG. **6**. An exemplary mounting arm **36** comprises a telescoping arm. The mounting arm **36** comprises a mounting bracket **22**, a rail **26** and an actuator **34**. The mounting bracket **22** is adapted for mounting to an agricultural machine **24**. The mounting bracket **22** may attach directly to the agricultural machine **24**, or it may attach to any type of attachment or implement on the agricultural machine **24**. The rail **26** is slidingly coupled to the mounting bracket **22**, and the camera **28** is mounted to a distal end of the rail **26**. The actuator **34** is coupled between the mounting bracket **22** and the rail **26**, and is configured to slide the rail **26** along the mounting

bracket **22**. FIG. **5** shows the rail in a retracted position with respect to the mounting bracket **22**, and FIG. **6** shows the rail **26** in an extended position with respect to the mounting bracket **22**. The actuator **34** can be, but is not limited to, a hydraulic cylinder actuator, a linear actuator, or a rack and pinion. Hydraulic or electric power actuation may be provided by the agricultural machine **24** or implement as is commonly known.
(23) A second embodiment of the mounting assembly **38′** is shown in FIG. **3**B, where like primed reference numerals represent similar elements as those described above. Only significant differences between the two embodiments are reflected in the Figures and the description below.
(24) The mounting assembly **38′** in the second embodiment includes a mounting bracket **22′**, a rail **26′**, a camera mount **46** and an actuator **34′**. The rail **26′** is fixedly coupled to the mounting bracket **22′**, the camera mount **46** is slidingly coupled to the rail **26′**, and the camera **28** is mounted to the camera mount **46**. The actuator **34′** is coupled between camera mount **46** and the rail **26′**, and is configured to slide the camera mount **46** along the rail **26′**.
(25) A third embodiment of the mounting assembly **38″** is shown in FIG. **3**C, where like double-primed reference numerals represent similar elements as those described above. Only significant differences between the embodiments are reflected in the Figures and the description below.
(26) The mounting assembly **38″** in the third embodiment includes a mounting bracket **22″**, a camera mount **46″** and an actuator **34″**. The camera mount **46″** is slidingly coupled to the mounting bracket **22″**, and the camera **28** is mounted to the camera mount **46″**. The actuator **34″** is coupled between camera mount **46″** and the mounting bracket **22″**, and is configured to slide the camera mount **46″** along the mounting bracket **22″**. In this embodiment, the mounting bracket **22″** has a taller height dimension than the height dimension of the mounting brackets **22**, **22′** in the previously described embodiments.
(27) As shown in FIG. **8**, the camera **28** may rotate, or pivot, about a vertical axis **42** that runs parallel with the length of the rail **26**, **26′** and the mounting bracket **22″**. The camera **28** may also be equipped to pan up and down by rotating, or pivoting, about an axis **44** that runs perpendicular to the vertical axis **42**.
(28) Referring to FIGS. **7-10**, the mounting bracket **22**, **22′**, **22″** may be attached to a foldable toolbar **48**. The foldable toolbar **48** preferably is configured with opposite end sections **49** (only one end section shown) pivotally mounted via a pivotal connection **53** on a central toolbar section **51**. The toolbar end sections **49** are foldable for storage and transport. The mounting bracket **22**, **22′**, **22″** and attached camera **28** are preferably attached to the toolbar **48** on one of the end sections **49**. During operation, the toolbar **48** is in an unfolded position, as reflected in FIGS. **7-8**, allowing actuator **34**, **34′**, **34″** to raise and lower the camera **28**. During storage and transport, the actuator **34**, **34′**, **34″** is fully retracted and the toolbar **48** is folded, as reflected in FIGS. **9-10**, which enables reduction in size of the transport envelope.
(29) The adjustable camera system **20** is configured to automatically reposition the camera **28** so that it is at an optimal distance from the top of the crop rows. If the system **20** determines that the camera **28** is at the optimal distance, it does not adjust the height of the camera **28**. If the system **20** determines that the camera **28** is too high, it lowers the camera **28**. If the system **20** determines that the camera **28** is too low, the system **20** raises the camera **28**.
(30) Referring to FIG. **11**, in one embodiment, the adjustable camera system **20** also includes a controller **40** to automatically adjust the height of the camera **28**. FIG. **12** illustrates an exemplary method **100** for automatically adjusting the height of the camera **28** using the system reflected in FIG. **11**. The camera **28** obtains images **30** of the field (step **102**), and the controller **40** determines whether the image **30** is in focus (step **104**). If the controller **40** determines that the image **30** is in focus, then the camera **28** is at an optimal distance from the top of the crop rows, and the system **20** returns to step **102** to continue monitoring the camera images **30**. If at step **104** the controller **40** determines that the image **30** is not in focus, then the controller **40** determines whether the position of the camera **28** is too high above the top of the crop rows (step **106**). If the controller **40**

determines that the position of the camera **28** is too high, the controller **40** sends a signal to retract the actuator **34**, **34′**, **34″**, thereby lowering the position of the camera **28**. If at step **106** the controller **40** determines that the position of the camera **28** is not too high, then the controller **40** sends a signal to extend the actuator **34**, **34′**, **34″**, thereby raising the position of the camera **28**. The system **20** then returns to step **102** to process the next image **30**.

(31) Referring to FIG. **13**, in one embodiment, the controller **40** includes a convolutional neural network based semantic segmentation model **50**. The model **50** is trained to identify crop rows using annotated images **52** of crop at various growth stages. The annotated images **52** include weak annotations **54** defining row positions on the images **52**. Each weak annotation **54** comprises a line drawn above the crop row, and the model **50** is trained to infer larger scale row features in the image **52**.

(32) FIG. **14** illustrates an exemplary process **112** performed by the adjustable camera system **20** to raise and lower the position of the camera **28**. Referring to FIGS. **13** and **14**, the camera **28** obtains an image **30** of the field, which includes images **30** of the rows of crop **32** (step **114**). The controller **40** processes the image **30** to identify the top of the crop rows (step **116**). In one embodiment, to identify the top of the crop rows, the semantic segmentation model **50** segments the image **30** (step **118**) to create a pixel-wise classification **58** of the image **30**. The pixel-wise classification **58** distinguishes the crop rows **60** from the other parts of the plant and any other background information, including the soil and other plants that may be in the image **30**. The controller **40** applies a linear regression model to a kernel-based calculation of intensity peaks from the generated image mask. For example, the controller **40** may divide the pixel-wise classification **58** into **6** rows and **2** columns (step **120**), i.e., into **12** sections. Alternatively, rather than dividing the entire pixel-wise classification **58** into sections, the controller **40** may focus on sections closer to the classified rows **60**. The number of columns selected depends on the number of crop rows being analyzed. The controller **40** identifies the intensity peaks **64** within each section (step **122**) by identifying the points with the highest number of crop row pixels across the width of each section. The intensity peaks **64** correspond to the center of the crop row within each section. The controller **40** applies a linear regression model to the intensity peaks **64** to create regression lines **66** representing the crop rows in the image **62** (step **124**).

(33) Because the actual distance between crop rows is known and fixed, when the camera **28** is at an optimal distance from the top of the crop rows, the average distance between the crop rows in the images **30** will also be fixed. The fixed distance is reflected in FIGS. **15-17** as expected stationary lines **68***a*, **68***b*. FIG. **15** illustrates a processed image **84** when the camera is at the optimal distance from the top of the crop rows. Here, the regression lines **66***a*, **66***b* align with expected stationary lines **68***a*, **68***b*, and the distance between the regression lines **66***a*, **66***b* D.sub.measured is equal to the distance between the expected stationary lines **68***a*, **68***b* D.sub.optimal. The present invention uses this optimal distance D.sub.optimal to determine whether to raise or lower the camera **28**. If the camera **28** is too close to the top of the crop rows, as reflected in FIG. **16**, the average distance between the crop rows measured from the image **30** D.sub.measured will be greater than the optimal distance D.sub.optimal because the image **30** will appear to expand the distance between the crop rows. Likewise, if the camera **28** is too far from the top of the crop rows, as reflected in FIG. **17**, the average distance between the regression lines **66***a*, **66***b* D.sub.measured will be less than the optimal distance D.sub.optimal because the image **30** will appear to compress the distance between the crop rows.

(34) Referring back to FIG. **14**, the system determines the average distance D.sub.measured between the regression lines **66** (step **126**) and determines whether the average distance D.sub.measured between the regression lines **66** is equal to the optimal distance D.sub.optimal (step **128**). If the distances are equal, then the camera **28** is at an optimal distance from the top of the crop rows, and the system **20** returns to step **114** to continue monitoring the camera images **30**. If at step **128** the system **20** determines that the distances are not equal, then the system **20**

determines whether the average distance D.sub.measured between the regression lines **66** is greater than the optimal distance D.sub.optimal (step **130**). If the system **20** determines that the average distance D.sub.measured between the regression lines **66** is greater than the optimal distance D.sub.optimal, the controller **40** sends a signal to extend the actuator **34**, **34′**, **34″**, thereby raising the position of the camera **28** (step **132**). Otherwise, the average distance D.sub.measured between the regression lines **66** is less than the optimal distance D.sub.optimal, and the controller **40** sends a signal to retract the actuator **34**, **34′**, **34″**, thereby lowering the position of the camera **28** (step **134**). The system **20** then returns to step **114** to process the next image **30**.

(35) The system **20** may be configured with a list of predetermined optimal distances D.sub.optimal, selectable by the operator of the harvester. The predetermined optimal distances D.sub.optimal may depend on a number of factors, such as the type of crop or the actual distance between crop rows.

(36) The invention has been described in an illustrative manner, and it is to be understood that the terminology which has been used is intended to be in the nature of words of description rather than of limitation. Directional references employed or shown in the description, figures or claims, such as top, bottom, upper, lower, upward, downward, lengthwise, widthwise, longitudinal, lateral, vertical, horizontal, and the like, are relative terms employed for ease of description and are not intended to limit the scope of the invention in any respect. Many modifications and variations of the present invention are possible in light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced other than as specifically described.

Claims

1. An adjustable camera system comprising: a camera; a mounting assembly including a mounting bracket coupled to the camera, wherein the mounting assembly is adapted to raise and lower the camera; a toolbar having a central section and an end section connected to the central section by a pivotal connection, wherein the mounting bracket is attached to the end section of the toolbar; and a controller configured to use an image of an object from the camera to determine whether the camera is at an optimal position from the object, and if the controller determines that the camera is not at the optimal position, the controller sends a signal to the mounting assembly to raise or lower the camera.
2. The adjustable camera system according to claim 1, wherein the mounting assembly comprises: a camera mount slidingly coupled to the mounting bracket; and an actuator coupled between the camera mount and the mounting bracket, wherein the actuator is configured to slide the camera mount along the mounting bracket; wherein the camera is coupled to the camera mount and if the controller determines that the camera is not at the optimal position, the controller sends a signal to the actuator to slide the camera mount along the mounting bracket.
3. The adjustable camera system according to claim 2, wherein the controller determines whether the camera is at the optimal position by determining whether the image is in focus.
4. The adjustable camera system according to claim 3, wherein: the mounting bracket is adapted for attachment to an agricultural machine; the object comprises rows of crop; and the controller determines whether the camera is at the optimal position by determining whether a distance between the rows of crop in the image equals an optimal distance.
5. The adjustable camera system according to claim 4, wherein if the controller determines that the distance between the rows of crop in the image is greater than the optimal distance, the controller sends a signal to the actuator to raise the camera.
6. The adjustable camera system according to claim 4, wherein if the controller determines that the distance between the rows of crop in the image is less than the optimal distance, the controller sends a signal to the actuator to lower the camera.

7. The adjustable camera system according to claim 4, wherein the end section of the toolbar and the attached camera pivot about the pivotal connection between an unfolded position and a folded position.
8. The adjustable camera system according to claim 4, wherein the camera mount is pivotally coupled to the mounting bracket.
9. The adjustable camera system according to claim 1, wherein the mounting assembly comprises a mounting arm having a length configured to adjust between a retracted position and an extended position; and wherein: the camera is mounted to one end of the mounting arm; and if the controller determines that the camera is not at the optimal position, the controller sends a signal to the mounting arm to adjust the length of the mounting arm.
10. The adjustable camera system according to claim 9, wherein the mounting arm comprises a telescoping arm.
11. The adjustable camera system according to claim 9, wherein the controller determines whether the camera is at the optimal position by determining whether the image is in focus.
12. The adjustable camera system according to claim 9, wherein the mounting arm comprises: a rail slidingly coupled to the mounting bracket; and an actuator coupled between the mounting bracket and the rail, wherein the actuator is configured to slide the rail along the mounting bracket, and wherein if the controller determines that the camera is not at the optimal position, the controller sends a signal to the actuator to slide the rail along the mounting bracket.
13. The adjustable camera system according to claim 12, wherein: the mounting bracket is adapted for attachment to an agricultural machine; the object comprises rows of crop; and the controller determines whether the camera is at the optimal position by determining whether a distance between the rows of crop in the image equals an optimal distance.
14. The adjustable camera system according to claim 13, wherein if the controller determines that the distance between the rows of crop in the image is greater than the optimal distance, the controller sends a signal to the actuator to raise the camera.
15. The adjustable camera system according to claim 13, wherein if the controller determines that the distance between the rows of crop in the image is less than the optimal distance, the controller sends a signal to the actuator to lower the camera.
16. The adjustable camera system according to claim 13, wherein the end section of the toolbar and the attached camera pivot about the pivotal connection between an unfolded position and a folded position.
17. The adjustable camera system according to claim 13, wherein the camera is pivotally coupled to the rail.
18. A method for autonomously adjusting a position of a camera mounted to an agricultural machine with a controller, the method comprising: obtaining an image of rows of crop from the camera; processing the image with the controller using a convolutional neural network based semantic segmentation model to identify tops of the rows of crop; using the identified tops of the rows of crop to determine whether the camera is at an optimal position from the object; and if it is determined that the camera is not at the optimal position, raising or lowering the camera.
19. The method according to claim 18, wherein the step of determining whether the camera is at the optimal position comprises determining whether the image is in focus.
20. The method according to claim 19, wherein the step of determining whether the camera is at the optimal position comprises determining whether a distance between the rows of crop in the image equals an optimal distance.
21. The method according to claim 20, further comprising the step of determining whether the distance between the rows of crop is greater than the optimal distance, and if it determined that the distance between the rows of crop is greater than the optimal distance, raising the camera.
22. The method according to claim 20, further comprising the step of determining whether the

distance between the rows of crop is less than the optimal distance, and if it is determined that the distance between the rows of crop is less than the optimal distance, lowering the camera.