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(54) **SYSTEM AND METHOD FOR SYNCHRONIZED CONTROL OF A HARVESTER AND TRANSPORT VEHICLE**

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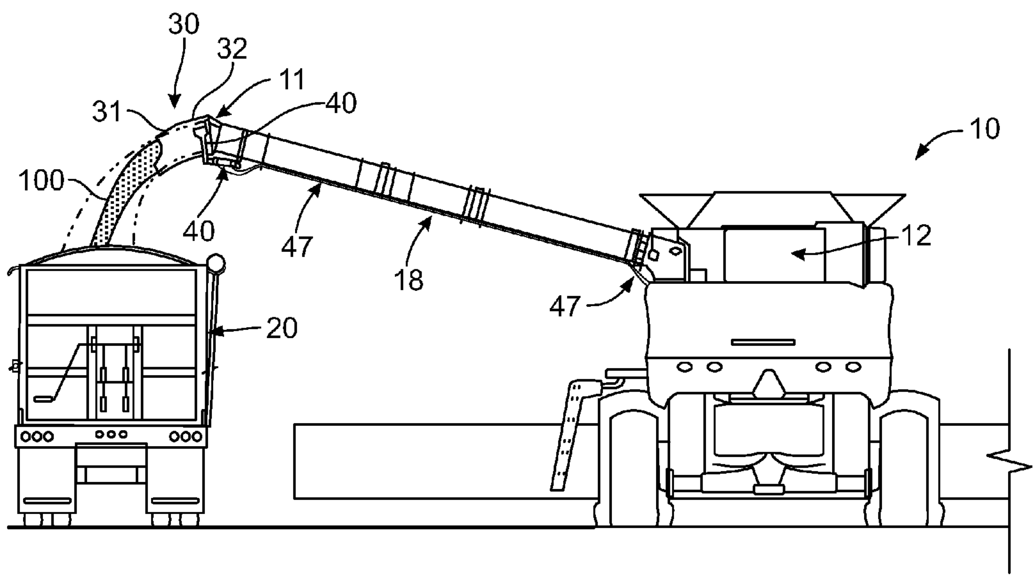
(57) **ABSTRACT**

A control system and method is provided to control a longitudinal position of a transport vehicle relative to a harvester during an unload on the go operation and to control both the lateral position and the longitudinal position of a transport vehicle relative to a harvester during an unload on the go operation to evenly fill a receiving area of the transport vehicle with crop material from the harvester. The longitudinal position of the transport vehicle is maintained within an acceptable range by adjusting the velocity of the transport vehicle. The receiving area of the transport vehicle can be more evenly filled with crop material by adjusting the lateral position and the longitudinal position of the transport vehicle within predetermined trim distances associated with the receiving area of the transport vehicle.



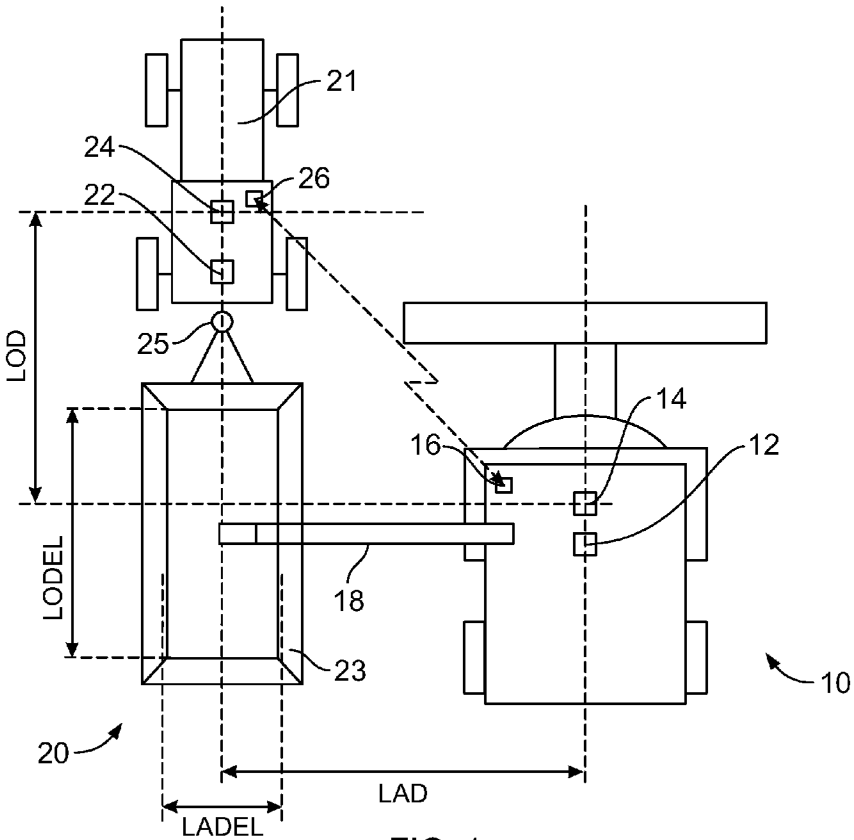

21
24
26
22
25
LOD
LODEL
14
16
12
18
23
10
20
LAD
LADEL

FIG. 1

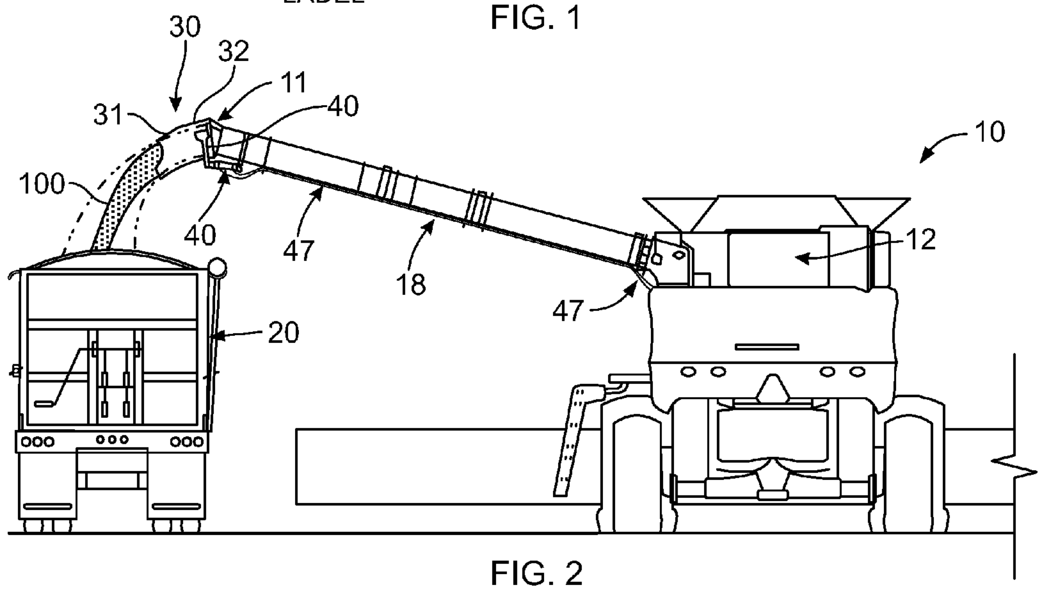

30
32
11
40
31
100
40
47
18
10
12
47
20

FIG. 2

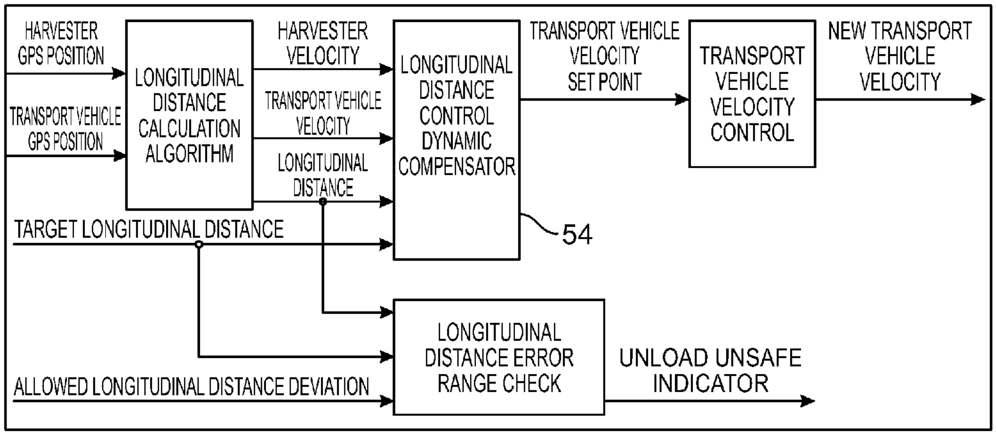

HARVESTER GPS POSITION
TRANSPORT VEHICLE GPS POSITION
LONGITUDINAL DISTANCE CALCULATION ALGORITHM
HARVESTER VELOCITY
TRANSPORT VEHICLE VELOCITY
LONGITUDINAL DISTANCE
LONGITUDINAL DISTANCE CONTROL DYNAMIC COMPENSATOR
TRANSPORT VEHICLE VELOCITY SET POINT
TRANSPORT VEHICLE VELOCITY CONTROL
NEW TRANSPORT VEHICLE VELOCITY
TARGET LONGITUDINAL DISTANCE
54
LONGITUDINAL DISTANCE ERROR RANGE CHECK
ALLOWED LONGITUDINAL DISTANCE DEVIATION
UNLOAD UNSAFE INDICATOR

FIG. 3

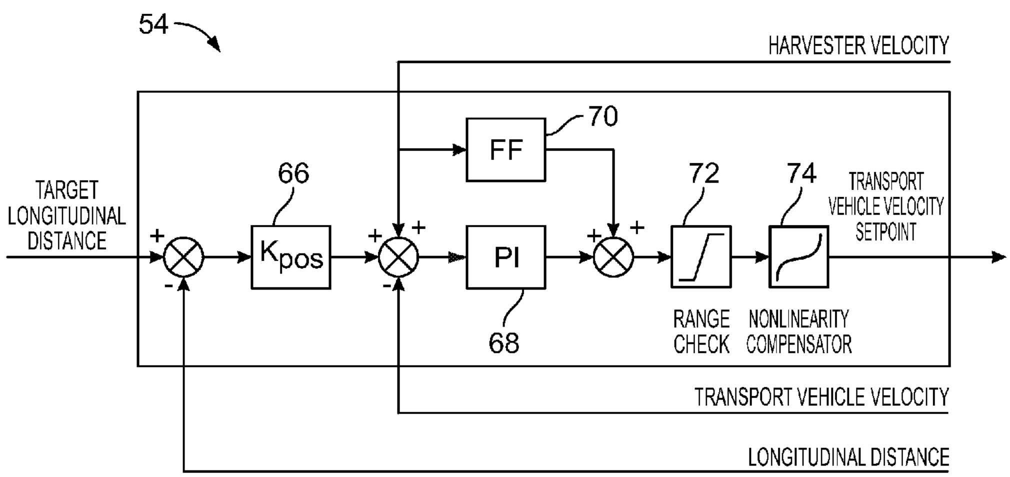

54
HARVESTER VELOCITY
70
FF
66
72
74
TARGET LONGITUDINAL DISTANCE
Kpos
PI
TRANSPORT VEHICLE VELOCITY SETPOINT
68
RANGE CHECK
NONLINEARITY COMPENSATOR
TRANSPORT VEHICLE VELOCITY
LONGITUDINAL DISTANCE

FIG. 5

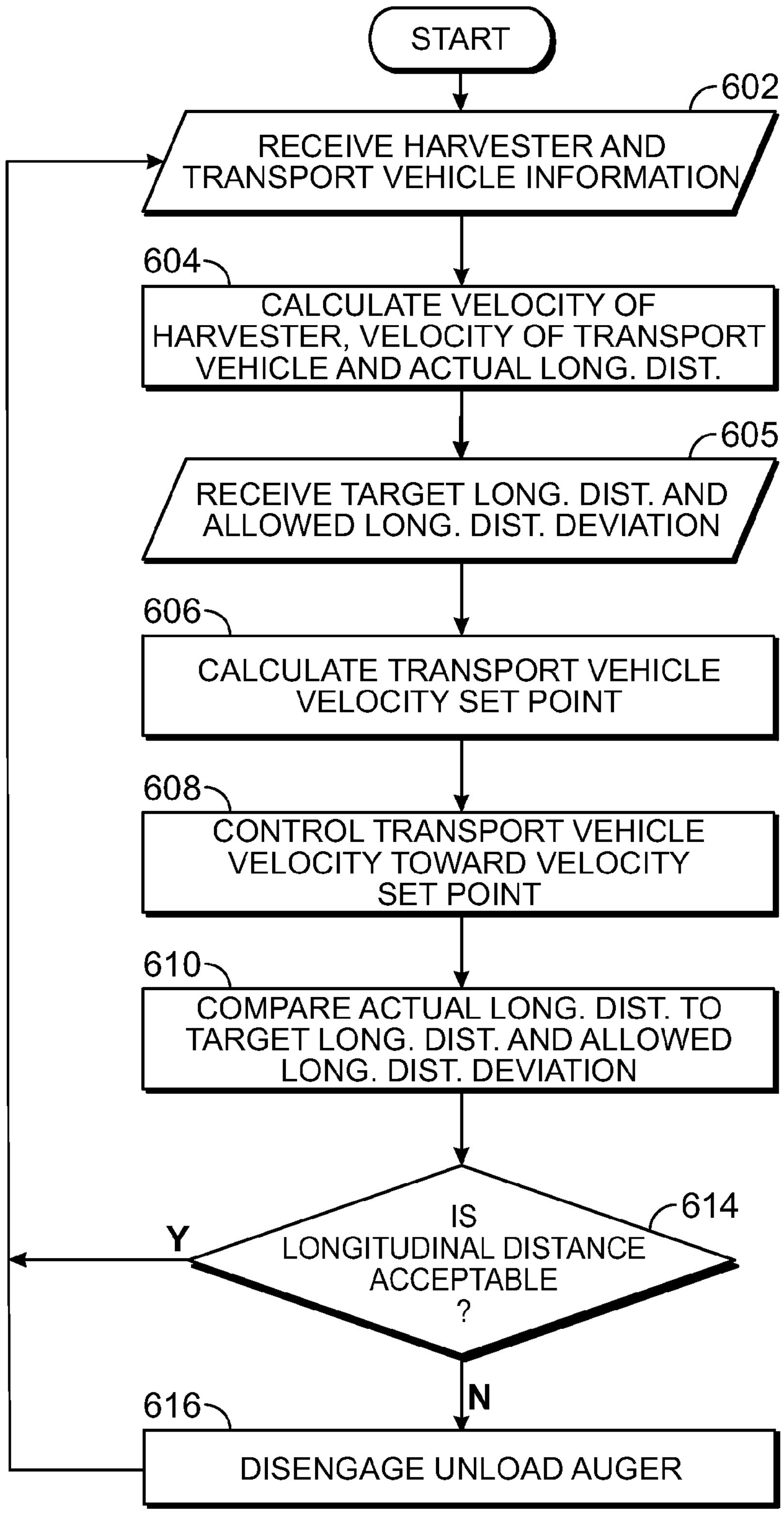

START
602
RECEIVE HARVESTER AND TRANSPORT VEHICLE INFORMATION
604
CALCULATE VELOCITY OF HARVESTER, VELOCITY OF TRANSPORT VEHICLE AND ACTUAL LONG. DIST.
605
RECEIVE TARGET LONG. DIST. AND ALLOWED LONG. DIST. DEVIATION
606
CALCULATE TRANSPORT VEHICLE VELOCITY SET POINT
608
CONTROL TRANSPORT VEHICLE VELOCITY TOWARD VELOCITY SET POINT
610
COMPARE ACTUAL LONG. DIST. TO TARGET LONG. DIST. AND ALLOWED LONG. DIST. DEVIATION
614
IS LONGITUDINAL DISTANCE ACCEPTABLE ?
Y
N
616
DISENGAGE UNLOAD AUGER

FIG. 4

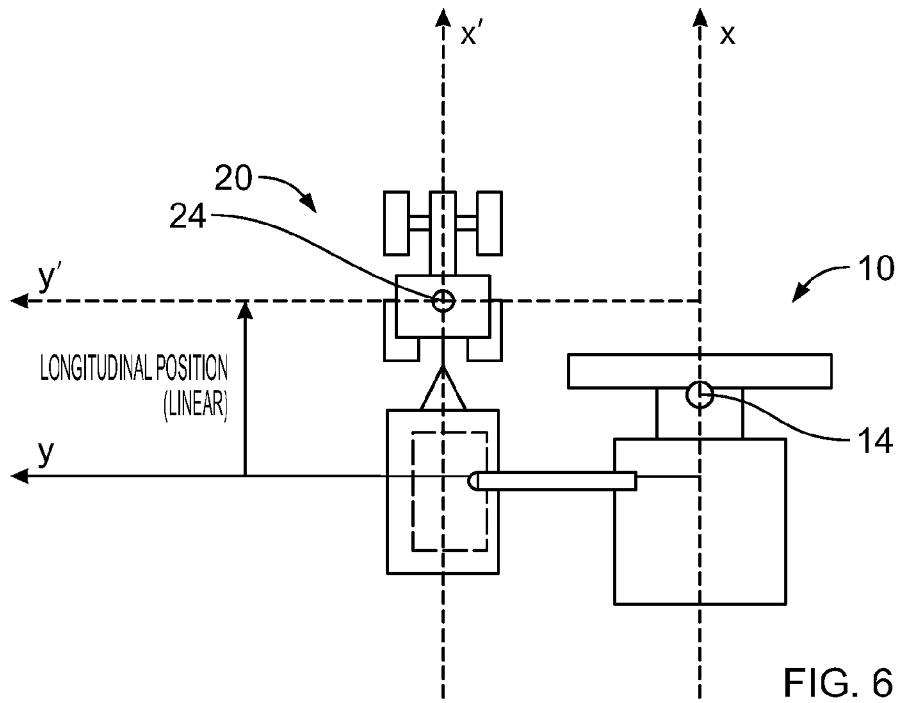

x′
x
20
24
y′
10
LONGITUDINAL POSITION
(LINEAR)
y
14

FIG. 6

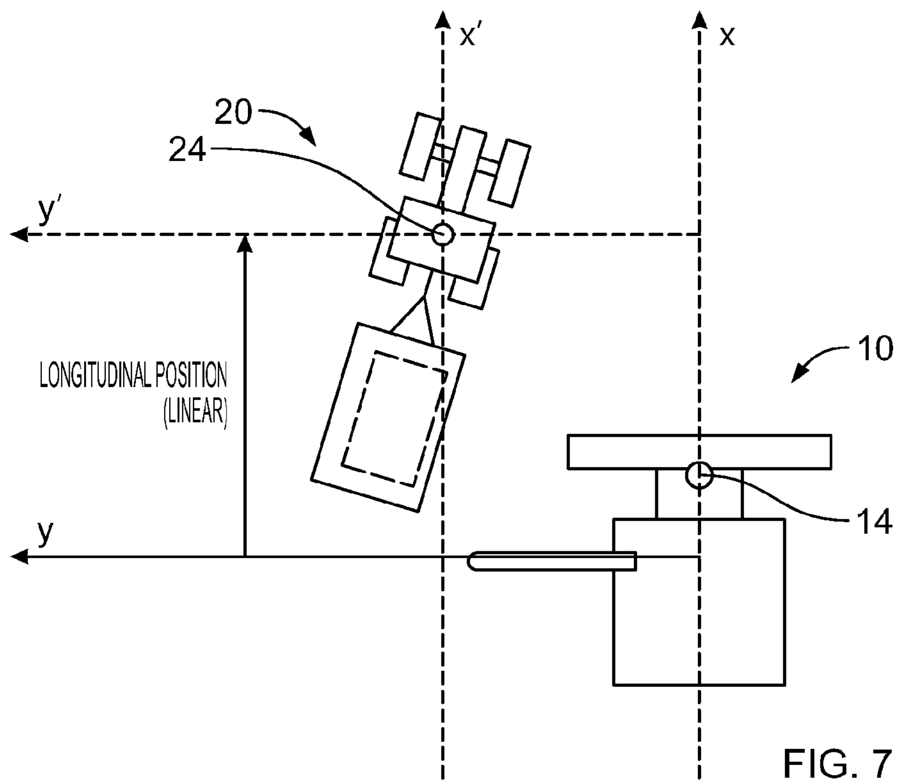

x′
x
20
24
y′
10
LONGITUDINAL POSITION
(LINEAR)
y
14

FIG. 7

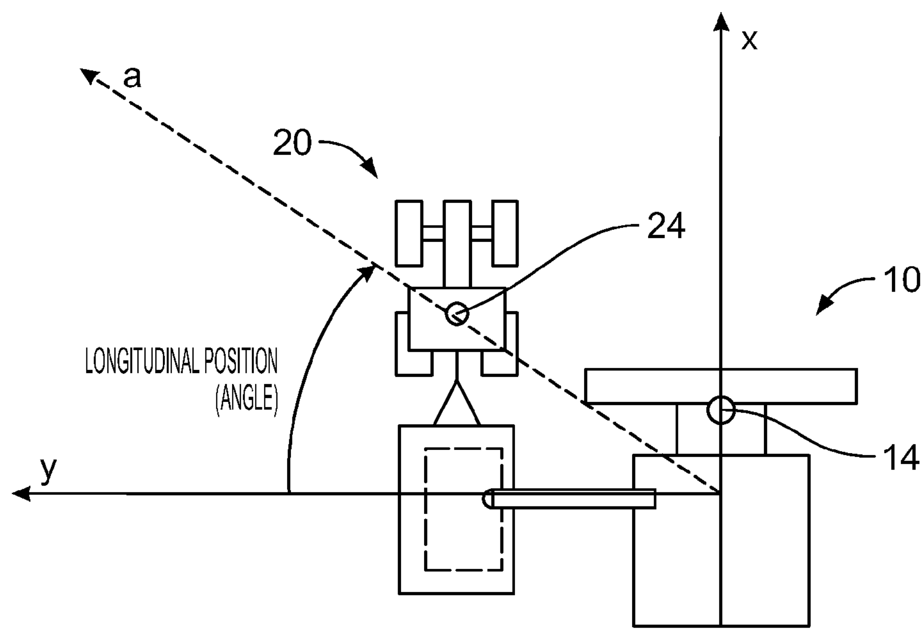

x
a
20
24
10
LONGITUDINAL POSITION
(ANGLE)
y
14

FIG. 8

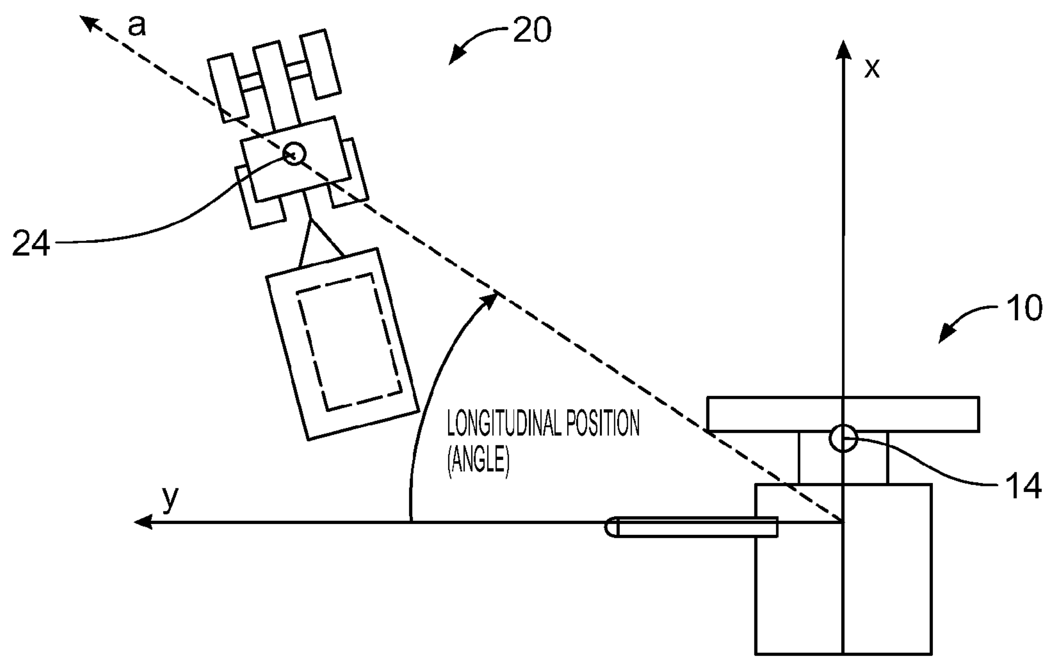

a
20
x
24
10
LONGITUDINAL POSITION
(ANGLE)
y
14

FIG. 9

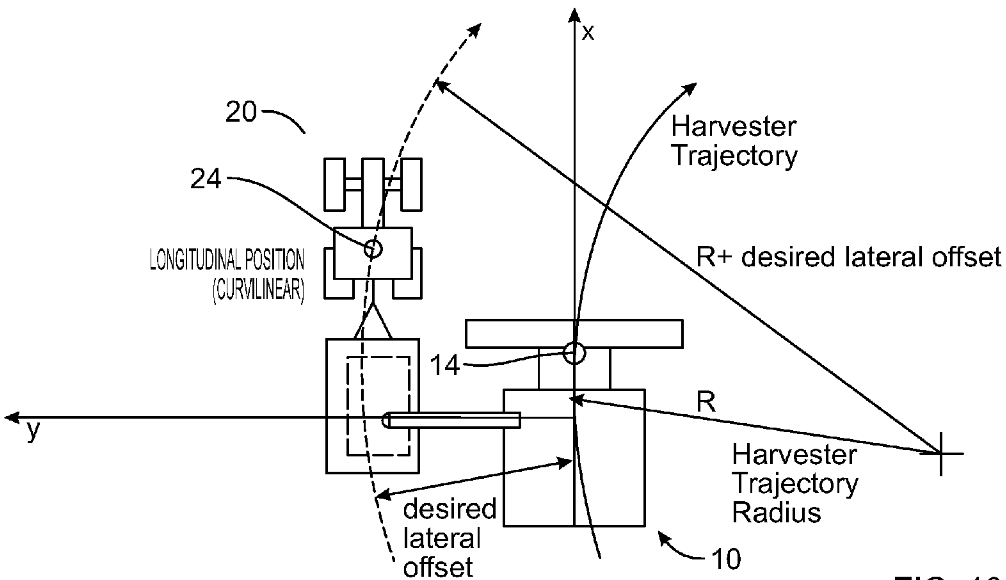


FIG. 10

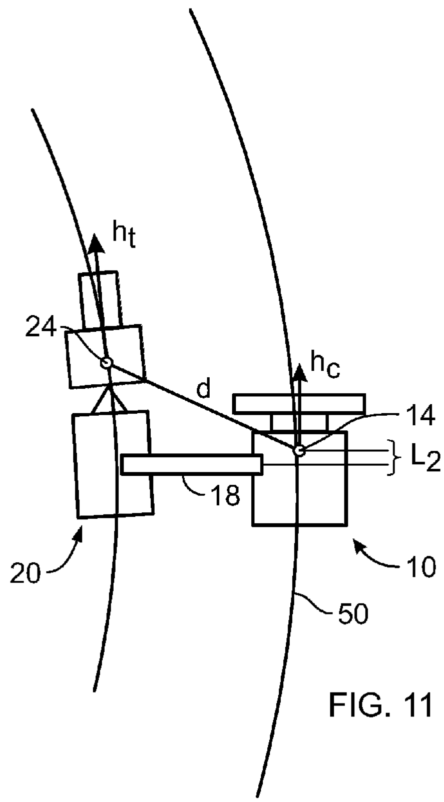


FIG. 11

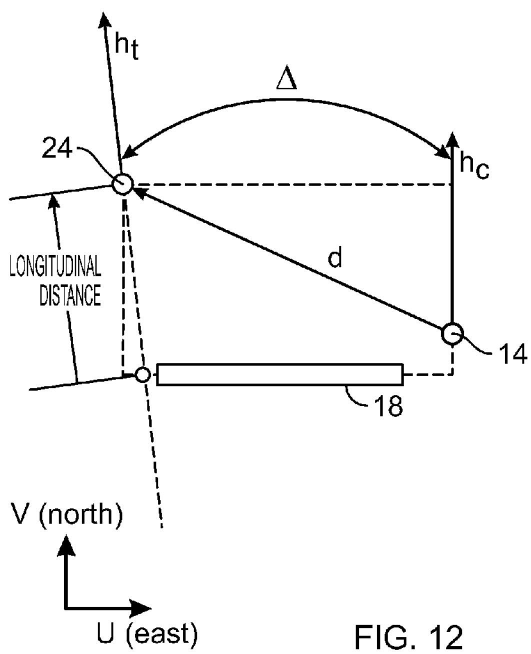


FIG. 12

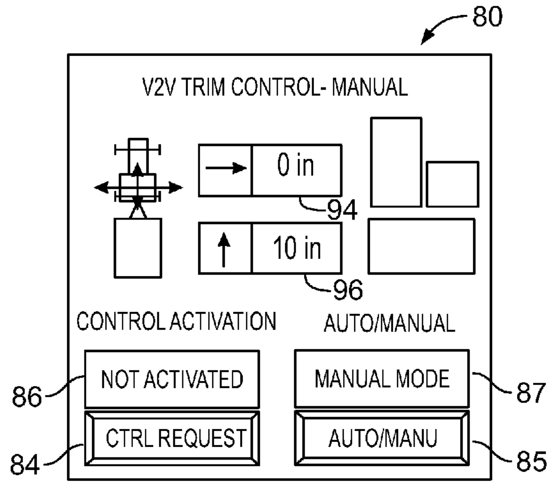


FIG. 13

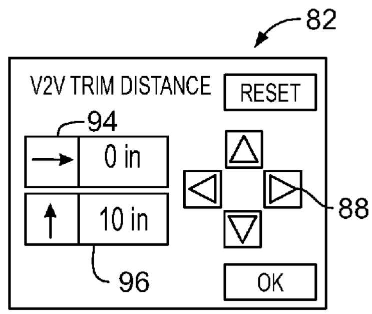


FIG. 14

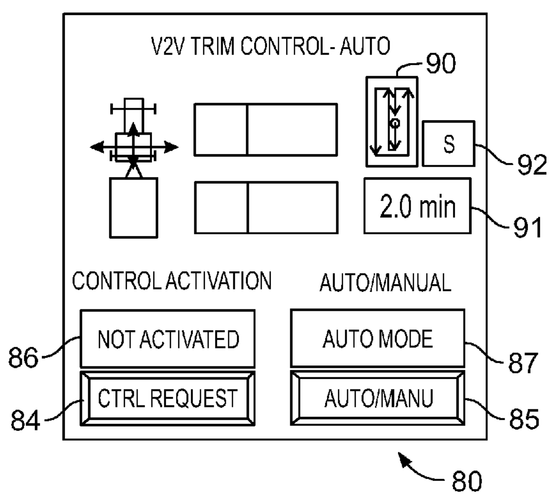


FIG. 15

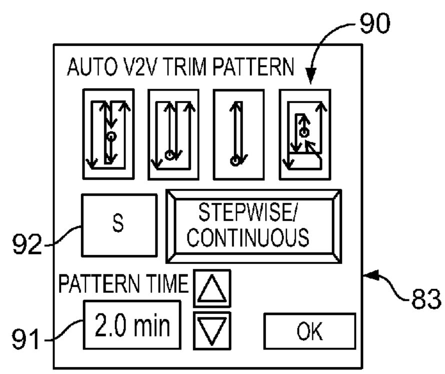


FIG. 16

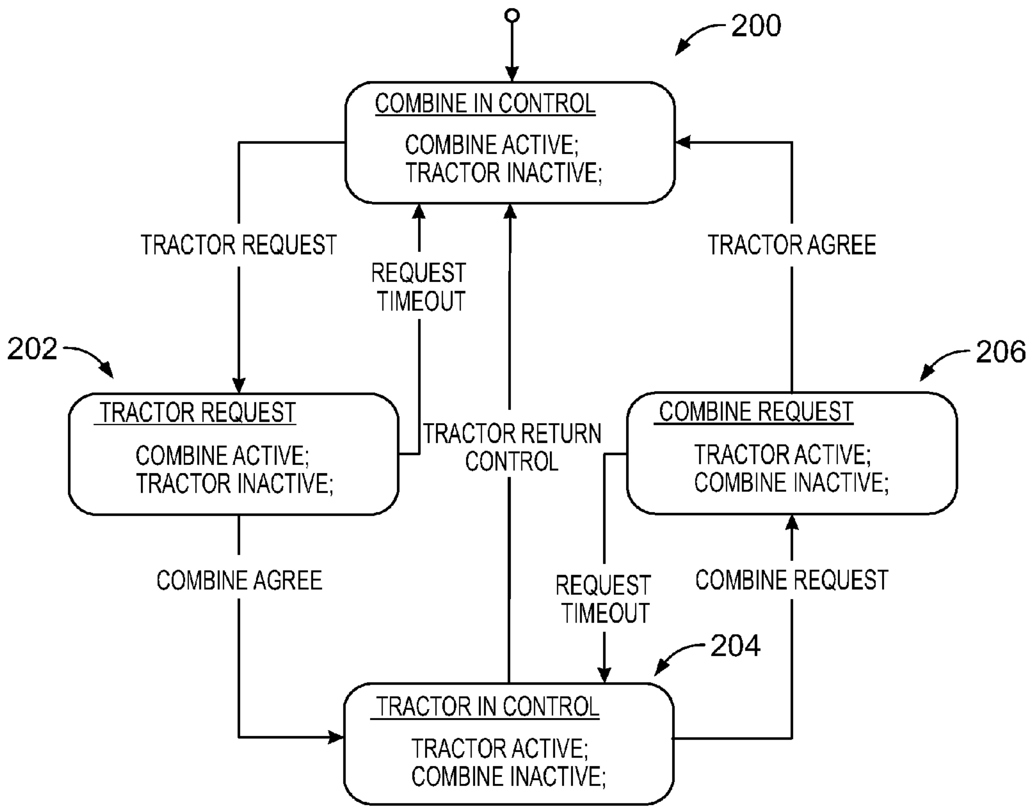

200
COMBINE IN CONTROL
COMBINE ACTIVE;
TRACTOR INACTIVE;
TRACTOR REQUEST
REQUEST TIMEOUT
TRACTOR AGREE
202
TRACTOR REQUEST
COMBINE ACTIVE;
TRACTOR INACTIVE;
TRACTOR RETURN CONTROL
206
COMBINE REQUEST
TRACTOR ACTIVE;
COMBINE INACTIVE;
COMBINE AGREE
REQUEST TIMEOUT
COMBINE REQUEST
204
TRACTOR IN CONTROL
TRACTOR ACTIVE;
COMBINE INACTIVE;

FIG. 17

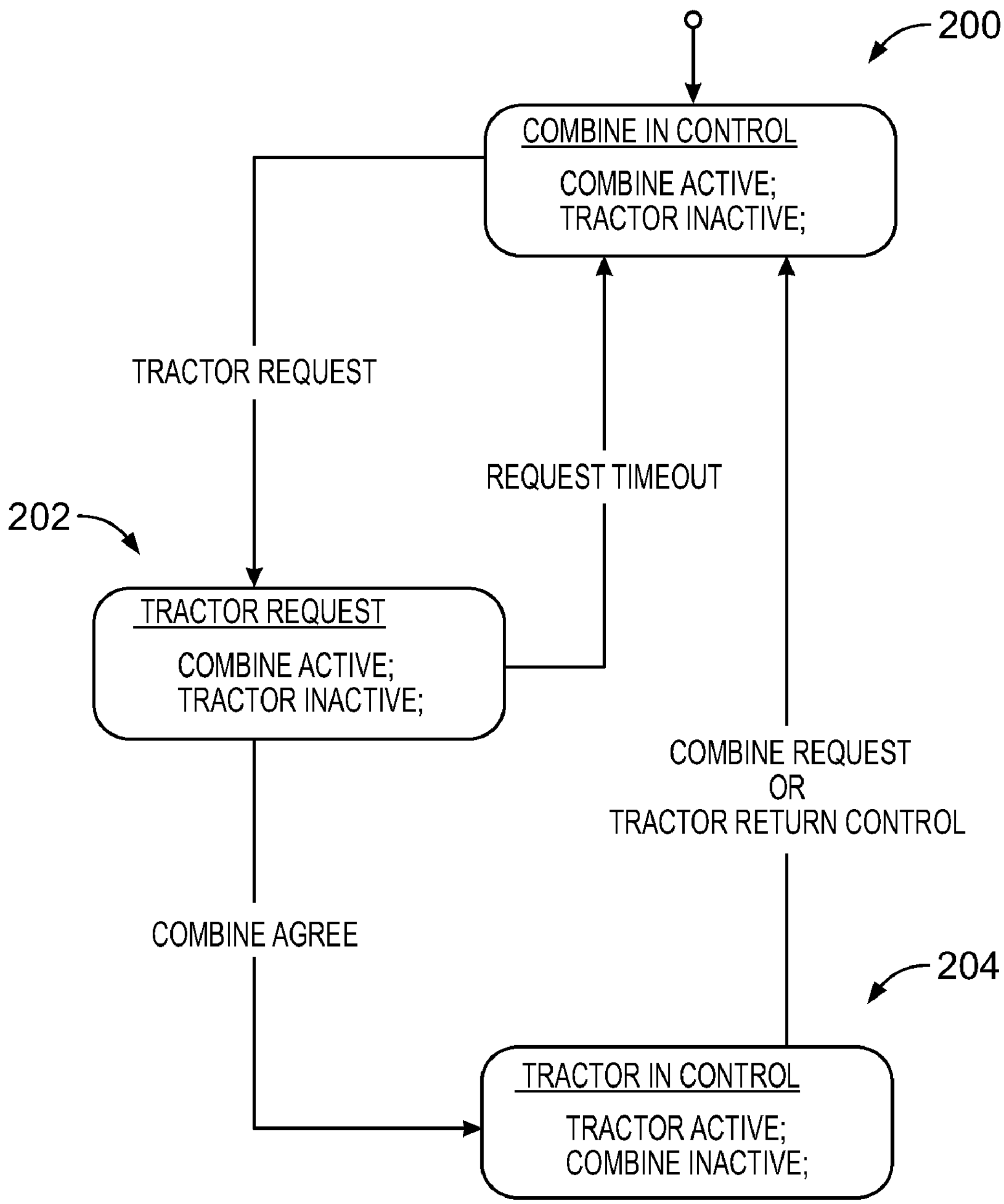

200
COMBINE IN CONTROL
COMBINE ACTIVE;
TRACTOR INACTIVE;
TRACTOR REQUEST
REQUEST TIMEOUT
202
TRACTOR REQUEST
COMBINE ACTIVE;
TRACTOR INACTIVE;
COMBINE REQUEST
OR
TRACTOR RETURN CONTROL
COMBINE AGREE
204
TRACTOR IN CONTROL
TRACTOR ACTIVE;
COMBINE INACTIVE;

FIG. 18

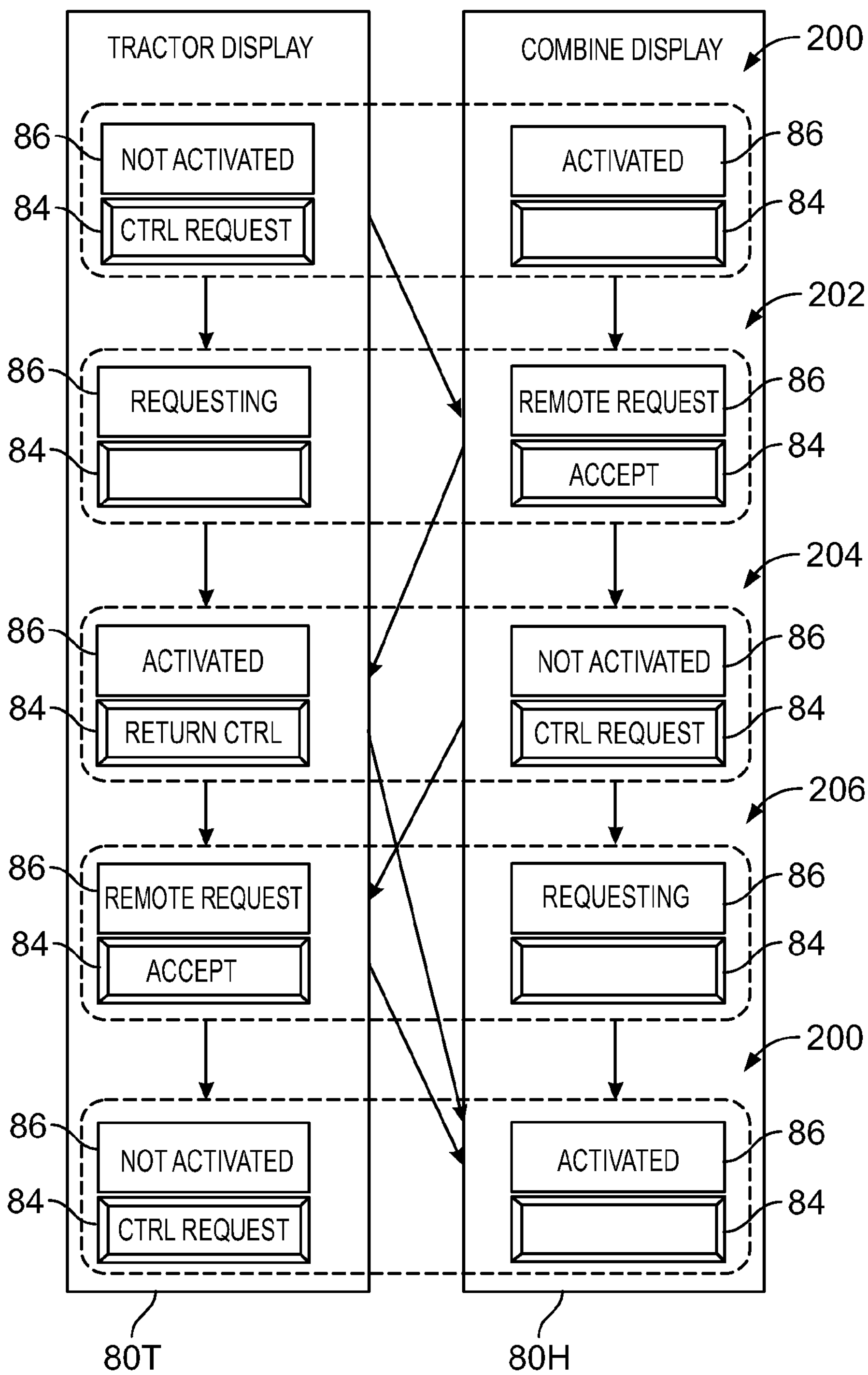

TRACTOR DISPLAY
COMBINE DISPLAY
200
86
84
NOT ACTIVATED
CTRL REQUEST
ACTIVATED
202
REQUESTING
REMOTE REQUEST
ACCEPT
204
ACTIVATED
RETURN CTRL
NOT ACTIVATED
CTRL REQUEST
206
REMOTE REQUEST
ACCEPT
REQUESTING
200
NOT ACTIVATED
CTRL REQUEST
ACTIVATED
80T
80H

FIG. 19

SYSTEM AND METHOD FOR SYNCHRONIZED CONTROL OF A HARVESTER AND TRANSPORT VEHICLE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61/444,526, entitled “SYSTEM AND METHOD FOR SYNCHRONIZED CONTROL OF A HARVESTER AND TRANSPORT VEHICLE,” filed Feb. 18, 2011, which application is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] The present application relates generally to a system and method for automating or synchronizing the control of a harvester and transport vehicle engaging in “unload on the go” operation.

[0003] Harvesters or harvesting machines pick up crop material, treat the crop material, e.g., remove any undesirable portions or residue, and discharge the crop material. Harvesters can discharge the crop material, either continuously as with a forage harvester or after intermediate storage as with a combine harvester, to a transport or transfer vehicle. The transport vehicle may be a tractor or truck pulling a cart, wagon, or trailer, or a truck or other vehicle capable of transporting harvested crop material. The harvested crop material is loaded into the transport vehicle via a crop discharging or unloading device, such as a spout or discharge auger, associated with the harvester.

[0004] During “unload on the go” operation of the harvester, the harvested crop material is transferred from the harvester to the transport vehicle while both vehicles are moving. The transport vehicle can travel next to and/or behind the harvester during unload on the go operation. Unload on the go operation is required for a forage harvester, since the forage harvester constantly discharges the harvested crop material. While unload on the go operation is not required for a combine harvester due to the combine harvester’s intermediate storage capability, unload on the go operation is commonly used for a combine harvester to maximize the operating efficiency of the combine harvester.

[0005] To effectively implement unload on the go operation, the operation of the harvester and transport vehicle is coordinated to maintain the relative distance between the harvester and transport vehicle within an acceptable range. By maintaining the relative distance of the harvester and transport vehicle within an acceptable range, the position and orientation of the harvester unload spout and the position of the transport vehicle, specifically the portion of the transport vehicle receiving crop material, relative to the harvester unload spout position are maintained within an acceptable distance range to permit harvester unload on the go operation, i.e., the discharged crop material can be provided into the transport vehicle without loss to the ground. That is, discharged crop material is directed to collect in the transport vehicle and is substantially prevented from being misdirected to miss the transport vehicle and collecting on the ground resulting in waste or loss of crop material. In order to maintain an acceptable distance range between the harvester and the transport vehicle, both the lateral (side to side) distance and longitudinal (fore and aft) distance between the harvester and transport vehicle have to be maintained within acceptable ranges.

[0006] Using a global positioning system (GPS) based auto-guidance system, auto-steering of the harvester and transport vehicle can maintain lateral distance between the harvester and transport vehicle within an acceptable range. With a wireless communication link between the harvester and transport vehicle, each machine can communicate its position provided by a GPS device to the other machine. A master machine, such as a harvester, operates in a way to best perform the harvesting operation, while the slave machine, such as a transport vehicle, follows using the GPS auto-guidance system’s auto-steering function to maintain an acceptable lateral distance from the master machine. While the use of the auto-steering function of a GPS-based auto-guidance system can maintain a lateral distance between the harvester and transport vehicle, the auto-steering function cannot maintain a longitudinal distance between the harvester and transport vehicle during unload on the go operations.

[0007] Further, when maintaining acceptable lateral and longitudinal distances during unload on the go operation, the transport vehicle can be filled with crop material in the center, which can result in underutilization of the transport vehicle’s capacity since the transport vehicle is not being evenly filled. Another problem in unload on the go operations is the variation of grain shoot-out distance from the unload spout to the transport vehicle. The variation in shoot-out distance is mainly due to different grain shoot-out speeds and directions, but the wind direction and velocity can also affect the grain shoot-out distance.

[0008] Therefore, what is needed is a system and method during unload on the go operations to maintain a longitudinal distance between the harvester and transport vehicle and to adjust the position of the transport vehicle relative to the harvester for more even filling of the transport vehicle with crop material.

SUMMARY

[0009] The present application is directed to a system and method for automated or synchronized control of a harvester and transport vehicle during unload on the go operations.

[0010] The present application relates to a method for controlling a transport vehicle to bring the transport vehicle into alignment with a harvester for unload on the go operation. The method includes determining a position and velocity of the transport vehicle and determining a position and velocity of the harvester. The method includes calculating a lateral distance error between the transport vehicle and the harvester and calculating a longitudinal distance error between the transport vehicle and the harvester for an auto-guidance control system and a longitudinal position control system to control the corresponding distances to obtain distance errors of zero. The method includes providing selective operator control of the distance between the transport vehicle and the harvester within a predetermined longitudinal distance error limit and a predetermined lateral distance error limit.

[0011] The present application further relates to a method of controlling a transport vehicle to enable substantially even loading of the crop material into the transport vehicle during an unload on the go operation with a harvester. The method includes determining a current lateral position for a transport vehicle relative to a harvester and a current longitudinal position for the transport vehicle relative to the harvester. The current lateral position is based on a predetermined path for the transport vehicle and a current lateral position adjustment. In one embodiment, the current lateral position is on an adjusted path which offsets in parallel from the predetermined path by the current lateral position adjustment. The predetermined path for the transport vehicle can be based on a predetermined path of the harvester and a predetermined desired lateral distance from the harvester. The current longitudinal position is based on a predetermined desired longitudinal distance from the harvester and a current longitudinal position adjustment. The method further includes calculating a future adjustment to at least one of the current lateral position or the current longitudinal position and calculating a future lateral position for the transport vehicle relative to a harvester and a future longitudinal position for the transport vehicle relative to the harvester using the current lateral position, the current longitudinal position, the predetermined path and the calculated future adjustment to the at least one of the current lateral position or the current longitudinal position. The method also includes generating a steering control signal to steer the transport vehicle to the future lateral position with an auto-guidance system for the transport vehicle and generating a speed control signal to control the transport vehicle to the future longitudinal position with an automated speed control in a longitudinal position control system for the transport vehicle, and applying the generated steering control signal and the generated speed control signal to transport vehicle components to automatically control the steering and speed of the transport vehicle and provide for substantially even filling of the transport vehicle with crop material from the harvester.

[0012] The present application also relates to a control system to control a transport vehicle to enable substantially even loading of crop material into the transport vehicle during an unload on the go operation with a harvester. The control system includes a global positioning system device to determine a current lateral position of a transport vehicle and a current longitudinal position of the transport vehicle and a user interface for an operator to enter information. The control system also includes a first controller having a microprocessor to execute a computer program to operate an auto-guidance system for the transport vehicle to steer the transport vehicle along a predetermined path or an adjusted path which offsets in parallel from the predetermined path by a lateral position adjustment and a second controller having a microprocessor to execute a computer program to calculate an adjustment to at least one of the current lateral position or the current longitudinal position of the transport vehicle based on information entered by the operator and to determine a future lateral position for the transport vehicle and a future longitudinal position for the transport vehicle using the current lateral position, the current longitudinal position, the predetermined path and the calculated adjustment to the at least one of the current lateral position or the current longitudinal position. The control system further includes a third controller having a microprocessor to execute a computer program to operate a longitudinal position control system for the transport vehicle. The longitudinal position control system for the transport vehicle is operated to control the transport vehicle to the future longitudinal position relative to the harvester. The auto-guidance system and longitudinal position control system for the transport vehicle are operated to control the transport vehicle to the future lateral position and the future longitudinal position through automated steering control and speed control and provide for substantially even filling of the transport vehicle with crop material from a harvester. In one embodiment, at the power-up of the control systems, the initial lateral position adjustment and longitudinal position adjustment can be preset to zero.

[0013] The present application relates to a method of controlling a transport vehicle to maintain a longitudinal distance between the transport vehicle and a corresponding harvester during an unload on the go operation. The method includes determining a global positioning system position for each of a transport vehicle and a harvester, calculating a velocity for the transport vehicle and a velocity for the harvester using the determined global positioning system positions for the transport vehicle and the harvester and calculating a longitudinal distance between the harvester and the transport vehicle using the determined global positioning system positions for the transport vehicle and the harvester. The method also includes calculating a transport vehicle velocity set point using the calculated velocity for the transport vehicle, the calculated velocity for the harvester, the calculated longitudinal distance between the harvester and the transport vehicle and a predetermined longitudinal distance and controlling a velocity of the transport vehicle in response to the calculated transport vehicle velocity set point to control the longitudinal distance between the transport vehicle and the harvester to be within a predetermined distance deviation from the predetermined longitudinal distance.

[0014] The present application additionally relates to a control system to control a velocity of a transport vehicle during an unload on the go operation with a harvester. The control system includes a first global positioning system device to determine a position of a transport vehicle, a second global positioning system device to determine a position of a harvester and a first controller having a microprocessor to execute a computer program to calculate a velocity of the transport vehicle, a velocity of the harvester and a longitudinal distance between the harvester and the transport vehicle using the determined positions of the transport vehicle and the harvester. The control system further includes a second controller having a microprocessor to execute a computer program to calculate a transport vehicle velocity set point using the calculated velocity for the transport vehicle, the calculated velocity for the harvester, the calculated longitudinal distance between the harvester and the transport vehicle and a predetermined longitudinal distance and a third controller having a microprocessor to execute a computer program to control a velocity of the transport vehicle in response to the calculated transport vehicle velocity set point.

[0015] The present application further relates to a method of controlling movement of an unload tube spout of a harvester. The method includes determining an activation region for a harvester. The activation region is based on a preselected lateral distance range relative to the harvester and a preselected longitudinal distance range relative to the harvester. The method further includes determining a position of a transport vehicle to receive crop material from the harvester. The determined position of the transport vehicle is relative to the harvester. The method also includes comparing the determined activation region and the determined position of the transport vehicle, disabling movement of an unload tube spout of a harvester in response to the determined position of the transport vehicle being outside of the determined activation region and enabling movement of an unload tube spout of a harvester between an open position and a closed position in response to the determined position of the transport vehicle being within the determined activation region.

[0016] One advantage of the present application is the ability to more evenly fill the transport vehicle with crop material during an unload on the go operation of the harvester and transport vehicle.

[0017] Another advantage of the present application is the ability to maintain a longitudinal distance between the harvester and the transport vehicle within an acceptable range.

[0018] Other features and advantages of the present application will be apparent from the following more detailed description of the exemplary embodiments, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE FIGURES

[0019] FIG. **1** shows a schematic top view of an embodiment of a harvester and transport vehicle during unload on the go operation.

[0020] FIG. **2** shows a rear view of an embodiment of a harvester and transport vehicle during unload on the go operation.

[0021] FIG. **3** shows schematically an embodiment of a control system for longitudinal position control.

[0022] FIG. **4** shows a flowchart of a control process for the control system of FIG. **3**.

[0023] FIG. **5** shows schematically an embodiment of the longitudinal distance control dynamic compensator of FIG. **3**.

[0024] FIGS. **6** and **7** show different longitudinal positions of a transport vehicle relative to a harvester using a Cartesian coordinate system.

[0025] FIGS. **8** and **9** show different longitudinal positions of a transport vehicle relative to a harvester using a Polar coordinate system.

[0026] FIG. **10** shows a longitudinal position of a transport vehicle relative to a harvester using a curvilinear approach.

[0027] FIGS. **11** and **12** show another exemplary embodiment for determining a longitudinal position of a transport vehicle relative to a harvester.

[0028] FIGS. **13-16** show exemplary embodiments of user interfaces associated with a V2V distance trim control system.

[0029] FIGS. **17-18** show exemplary embodiments of control activation logic for implementing a V2V distance trim control between a combine operator and a tractor operator.

[0030] FIG. **19** shows display screens for the harvester and transport vehicle when executing the control activation logic of FIG. **17**.

[0031] Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0032] In the present application, a vehicle to vehicle (V2V) operation refers to an unload on the go operation, and a V2V combine and a V2V tractor refer to a harvester and transport vehicle performing the unload on the go operation.

[0033] FIGS. **1** and **2** show the relative positions of a harvester **10** and transport vehicle **20** during an unload on the go or V2V operation. In one exemplary embodiment, the harvester or V2V combine **10** and the transport vehicle or V2V tractor **20** can be controlled by a global positioning system (GPS) based auto-guidance control system(s) in order to maintain a desired lateral distance (LAD) and a desired longitudinal distance (LOD) between the harvester **10** and the transport vehicle **20**. As described in more detail with respect to FIGS. **3-4**, the GPS based auto-guidance control system can include a longitudinal distance control function or system to adjust the speed of the transport vehicle in following the harvester to maintain a desired longitudinal distance.

[0034] An exemplary embodiment of the reference points used for measuring the desired or target lateral distance and the desired or target longitudinal distance is shown in FIG. **1**. However, any suitable reference points for measuring lateral distance and longitudinal distance can be used. The desired lateral distance and desired longitudinal distance can both be a preselected distance plus or minus a predetermined offset that ensures that crop material discharged from the harvester **10** is received and stored by the transport vehicle **20**. As shown in FIG. **1**, the lateral distance error limits (LADEL), together with the desired lateral distance (LAD), define the maximum and minimum lateral distances that can be used for unload on the go operation. The defined maximum and minimum lateral distance can be the LAD plus and minus one half of the LADEL range. As further shown in FIG. **1**, the longitudinal distance error limits (LODEL), together with the desired longitudinal distance (LOD), similarly define the maximum and minimum longitudinal distances that can be used for unload on the go operation. The preselected or desired lateral and longitudinal distances and the corresponding predetermined offsets can be related to the particular harvesters and transport vehicles being used, specifically the distance from the distal end of the harvester unload spout to the centerline of the harvester, the size of the storage area in the transport vehicle and an estimate of the shoot-out distance of the crop material from the harvester unload spout to the transport vehicle.

[0035] The desired lateral distance and desired longitudinal distance can be control targets. During an unload on the go operation, the actual lateral and longitudinal distances are measured and compared to the corresponding desired lateral and longitudinal distances for calculating distance errors, and then used by the corresponding control and auto-guidance systems to adjust the relative positions of the transport vehicle **20** and harvester **10** to attempt to obtain distance errors of zero. In one embodiment, the LADEL and LODEL, or portions thereof, can define an activation region related to the particular harvester **10** and transport vehicle **20** being used and/or the relative speeds at which the transport vehicle **20** and harvester **10** can be operated. Once the transport vehicle **20** has entered the activation region, the unload tube for the harvester **10** may be opened or closed and/or unload on the go operation may be initiated. The limiting of the opening and closing of the unload tube to times when the transport vehicle is in the activation region can be used as a safety feature to prevent damage to the unload tube. In another embodiment, the size of the activation region associated with the unload tube opening/closing may be different than the size of the activation region associated with initiation of the unload on the go operation.

[0036] The harvester **10** can have: a controller **12** that includes a display unit or user interface and a navigation controller; a GPS device **14** that includes an antenna and receiver; and a wireless communication unit or device (WCU) **16** that can include a power control switch. Similarly, the transport vehicle **20** can have: a controller **22** that can include a display unit or user interface, a navigation controller and tractor vehicle to vehicle control unit (TV2V); a GPS device **24** that can include an antenna and receiver; and a wireless communication unit or device (WCU) **26** that can include a power control switch. The controllers can be used to control operation and/or steering and/or speed of the harvester **10** and/or transport vehicle **20**, regardless of the machine in which the controller may be installed. The GPS device can be used to determine the position of the harvester **10** or transport vehicle **20** and the wireless communication device can be used to send and receive information, data and control signals between the harvester **10** and the transport vehicle **20**. In one embodiment, an additional GPS antenna may be positioned on the receiving area of the transport vehicle, e.g., a grain cart. The TV2V control unit can execute one or more computer programs to operate a longitudinal position control system for the transport vehicle. The TV2V control unit also can be integrated into a GPS based auto-guidance control system.

[0037] In the exemplary embodiment shown in FIG. **1**, the transport vehicle **20** can include a fraction device **21** and a loading receptacle **23**. A hitch angle sensor **25** can be used to determine the relative angle or hitch angle between the fraction device **21** and the loading receptacle **23**. As shown in FIG. **1**, the traction device **21** can be a tractor and the loading receptacle **23** can be a wagon or grain cart. However, in other embodiments, the traction device **21** may be a truck or other self-propelled vehicle sufficient to transport the loading receptacle **23** and the loading receptacle **23** may be a bin or other similar storage/transport vehicle. In another embodiment, the transport vehicle **20** may be a truck, semi-trailer truck, tractor-trailer or other similar self-propelled container vehicle.

[0038] Referring now to FIG. **2**, the combine harvester **10** has an unloading tube or spout **18** transversely extending and fully deployed as it unloads crop material **100** through the discharge boot **30** and into the transport vehicle **20**. The boot **30** can have any convenient and suitable shape. In one exemplary embodiment, the boot **30** can be generally cylindrical, but can be more boxy with edges, or venturi-shaped, etc. The opening of the unloading tube or spout **18** at its distal end is peripherally sealed by a joint member **11** which hingedly engages portion **32** of the boot **30**, which portion **32** interfaces the distal end of the unloading tube or spout **18**. The joint member **11** can be rounded or spherical, but can also be cylindrical on a horizontal axis, as long as the interface between the tube or spout **18** and the boot **30** is adequately sealed. Angularly extending from portion **32** of the boot **30** is a spout end **31** of the boot **30**. Signals from the controller **12** of the combine harvester **10**, travel through conduits **47** for controlling the actuators **40**, which actuators **40** can pivotally move the boot **30** up and down and back and forth in hinging relationship to the unloading tube or spout **18**, via the spherical joint **11**. The joint **11** also serves to seal the interface at the end **31** of the boot **30**.

[0039] The controllers **12**, **22** can include a microprocessor, a non-volatile memory, an interface board, an analog to digital (A/D) converter, and a digital to analog (D/A) converter to control operation of the harvester and/or transport vehicle. The controllers **12**, **22** can execute one or more control algorithms to control operation, guidance and/or steering of the harvester **10** and/or transport vehicle **20**, to control the speed of the transport vehicle and/or harvester and to implement harvester spout control. In one embodiment, the control algorithm(s) can be computer programs or software stored in the non-volatile memory of the controllers **12**, **22** and can include a series of instructions executable by the corresponding microprocessor of the controllers **12**, **22**. While it is preferred that the control algorithm be embodied in a computer program(s) and executed by the microprocessor, it is to be understood that the control algorithm may be implemented and executed using digital and/or analog hardware by those skilled in the art. If hardware is used to execute the control algorithm, the corresponding configuration of the controllers **12**, **22** can be changed to incorporate the necessary components and to remove any components that may no longer be required.

[0040] Further, the controllers **12**, **22** can be connected to or incorporate a display unit or user interface that permits an operator of the harvester **10** or transport vehicle **20** to interact with the controllers **12**, **22**. The operator can select and enter commands for the controllers **12**, **22** through the display unit or user interface. In addition, the display unit or user interface can display messages and information from the controllers **12**, **22** regarding the operational status of the harvester **10** and/or transport vehicle **20**. The display units or user interfaces can be located locally to the controllers **12**, **22**, or alternatively, the display units or user interfaces can be located remotely from the controllers **12**, **22**. In another exemplary embodiment, the controllers **12**, **22** can each include one or more subcontrollers under the control of a master controller. Each subcontroller and the master controller can be configured similar to the controllers **12**, **22**.

[0041] In one exemplary embodiment, the controllers **12**, **22** can execute a V2V auto-guidance control system that can automatically steer a V2V tractor to follow the travel path of a V2V combine during unload on the go operations. The auto-guidance control system can steer the V2V tractor in a controlled manner during unload on the go operations to maintain the lateral distance between the V2V tractor and the V2V combine within the specified lateral distance error limits. In order to steer the V2V tractor, the auto-guidance control system can provide control signals to a steering control valve to adjust the steering position of the V2V tractor (and ultimately the path of the V2V tractor) and receive signals from a steering sensor to determine the current steering position of the V2V tractor.

[0042] Referring now to FIGS. **3-4**, an embodiment of a longitudinal position control system and algorithm utilized to control the longitudinal distance between the transport vehicle and the harvester is shown. The longitudinal distance between the transport vehicle and the harvester can be controlled to be within an acceptable range with respect to a target or desired longitudinal distance so that automatic unload on the go operations can be permitted. The longitudinal position control system and method can be implemented either on the harvester controller **12** or on the transport vehicle controller **22** because of the wireless communication between the harvester **10** and transport vehicle **20**. A harvester GPS position and a transport vehicle GPS position can be input to the longitudinal position control system (step **602**). A longitudinal distance calculation algorithm can then calculate a harvester velocity, a transport vehicle velocity, and a current longitudinal distance between the harvester **10** and transport vehicle **20** (step **604**) using the harvester GPS position and a transport vehicle GPS position. The actual or current longitudinal distance may be estimated or calculated by using the following information: the GPS positions of the transport vehicle and the harvester, crab angles of the transport vehicle and the harvester (a vehicle crab angle can be defined as the angle between the vehicle's orientation and its travel course), grain cart or transport vehicle pivot angle (may be used with a tractor pulling a corresponding grain cart) and/or a harvester steering angle.

[0043] A target longitudinal distance and an allowed longitudinal distance deviation can be input to the longitudinal position control system (step **605**). The target longitudinal distance may be defined as a function of a longitudinal offset distance of the unload spout distal end position to the GPS position of the harvester, a longitudinal offset distance of the center of the receiving area of the transport vehicle to the GPS position of the transport vehicle, and/or an estimate of the longitudinal grain shoot-out distance from the unload tube of the harvester to the receiving area of the transport device. An acceptable or allowed longitudinal distance deviation range from the target longitudinal distance is determined by the size of the receiving area of the transport vehicle or the grain cart.

[0044] A longitudinal distance control dynamic compensator **54** calculates a transport vehicle velocity set point (step **606**) from the harvester velocity, the transport vehicle velocity, the current longitudinal distance and the target longitudinal distance. The transport vehicle velocity set point is provided to a transport vehicle velocity control system that controls the transport vehicle at a new velocity based on the received transport vehicle velocity set point (step **608**). The transport vehicle velocity control system can use an automatic engine rpm (revolutions per minute) control system, a transport vehicle auto-shift control system, or a transport vehicle continuously variable transmission (CVT) control system to control or adjust the transport vehicle velocity based on the transport vehicle velocity set point. In one embodiment, the transport vehicle velocity control system can control the transport vehicle velocity to match the harvester velocity when the longitudinal distance error is zero.

[0045] A longitudinal distance error range check algorithm generates an "unload unsafe" indicator. In one embodiment, when the "unload unsafe" indicator is a zero (0), the longitudinal distance is within an acceptable range, and when the "unload unsafe" indicator is a one (1), the longitudinal distance is outside of an acceptable range. The "unload unsafe" indicator is generated by comparing the actual longitudinal distance from the longitudinal distance calculation algorithm to the target longitudinal distance and the acceptable longitudinal distance deviation (step **610**) and determining whether the actual longitudinal distance is within an acceptable range based on the target longitudinal distance and the acceptable longitudinal distance deviation (step **614**). If the actual longitudinal distance is not within an acceptable range, the discharge auger of the harvester is disengaged or shut down (step **616**). If the actual longitudinal distance is within the acceptable range, the discharge auger of the harvester is enabled to be engaged. An engagement of the discharge auger depends on other conditions, such as the harvester unload spout being filly deployed.

[0046] FIG. **5** shows schematically components of the longitudinal distance control dynamic compensator of FIG. **3**. The longitudinal distance control dynamic compensator **54** can calculate a difference between target longitudinal distance and the actual longitudinal distance. The longitudinal distance difference is provided to a proportional distance control gain device or amplifier K_{pos} **66** that can provide a signal used to adjust the transport vehicle speed or velocity when the distance error is not zero. The longitudinal distance control dynamic compensator **54** includes a proportional-integral (PI) dynamic compensator **68**, and a feed-forward (FF) dynamic compensator **70**. A range check **72** limits the velocity or speed command (i.e., the velocity set point) to a transport vehicle velocity or speed range, and a nonlinearity compensator **74** compensates for a nonlinear relationship between the velocity command and transport vehicle speed or velocity response. The integral control in the longitudinal distance control dynamic compensator **54** maintains the transport vehicle velocity command when both the velocity control error and distance control error equal zero.

[0047] The longitudinal position control system is a unified distance-speed control system, designed for controlling the longitudinal distance and transport vehicle speed to match the target distance and harvester speed simultaneously. The system operates on a V2V tractor or transport vehicle, and is a closed loop distance control system with an inner speed control loop. The longitudinal position control system can be designed to be able to integrate different transport vehicle speed control systems, such as Auto Productivity Management (APM), Continuously Variable Transmissions (CVTs), and engine speed control systems.

[0048] FIGS. **6-10** show different longitudinal positions of a transport vehicle relative to a harvester. The different approaches for defining the longitudinal position can be used to quantify the transport vehicle's longitudinal distance from the harvester unloading point. The harvester's reference frame for the approaches in FIGS. **6-10** can be defined by an x-y axis. FIGS. **6-7** show a linear approach for measuring the longitudinal distance between the harvester and the transport vehicle using a Cartesian coordinate system. In FIGS. **6-7**, the transport vehicle's reference frame can be defined by an x'-y' axis and the longitudinal distance can be defined as the distance between the y axis and the y' axis. FIGS. **8-9** show an angular approach for determining the longitudinal distance between the harvester and the transport vehicle using a Polar coordinate system. In FIGS. **8-9**, the transport vehicle's reference frame can be defined by an a axis. The longitudinal position for the transport vehicle can be defined as the angle between the y axis and the a axis and the distance along the a axis from the origin of the x-y axis to the GPS position of the transport vehicle. In one embodiment, a lateral distance, i.e., a distance along the y axis, may also be used to determine longitudinal position using the angular approach. FIG. **10** shows a curvilinear approach for measuring the longitudinal distance between the harvester and the transport vehicle by taking into account trajectory curvatures of the harvester and transport vehicle. The longitudinal position for the transport vehicle can be defined as the portion of the transport vehicle's trajectory from the y axis. In one embodiment, the transport vehicle's trajectory can be defined by the harvester trajectory radius plus a predetermined or desired lateral offset. The desired lateral offset or distance can be determined by the lateral distance from the distal end of the harvester spout to the longitudinal centerline of the harvester (i.e., the x axis). FIGS. **6**, **8** and **10** show the transport vehicle in proper longitudinal alignment with the harvester unloading point or spout for unload on the go operation and FIGS. **7** and **9** show the transport vehicle out of proper longitudinal alignment with the harvester unloading point or spout for unload on the go operation.

[0049] In an alternate embodiment, as disclosed and further shown in FIGS. **11-12**, a longitudinal distance can be defined as the distance from the discharge or unload tube outlet to the transport vehicle GPS position along the transport vehicle longitudinal centerline (i.e., the transport vehicle heading direction). The defined longitudinal distance is a function of the GPS positions of the two vehicles, i.e., the harvester **10** and transport vehicle **20**, the headings of the two vehicles, and the offset distance L_2 from the harvester discharge tube outlet to the harvester GPS position along the harvester longitudinal centerline **50** (i.e., the harvester heading direction).

[0050] The harvester position and transport vehicle position are sensed by respective GPS units or devices **14**, **24** on each vehicle. The distance between the two vehicles is a function of the GPS positions of the two vehicles, and can be represented by a vector d in terms of east (u) and north (v) coordinates. The harvester heading and transport vehicle heading are represented by unit vectors h_c and h_t, respectively. The harvester heading and the transport vehicle heading can be calculated separately and may not be the same, especially during curved path travel. A difference or angular displacement between the two headings can be represented by an angle Δ. An offset distance from the outlet of the harvester discharge or unload tube **18** to the harvester GPS device or position **14** in the harvester heading direction is represented by L_2, which value can be defined positive if the harvester GPS device or position **14** is ahead of the harvester discharge or unload tube **18** and defined negative if the harvester GPS device or position **14** is behind the discharge or unload tube **18**. The longitudinal distance can be calculated using a vector dot product as set forth in Equation 1. By the sign convention of L_2 defined above, the calculated longitudinal distance d_{LON} is positive when the transport vehicle GPS device or position **24** is ahead of the discharge tube **18**.

$$d_{LON}=(d\cdot h_c+L_2)/|h_t\cdot h_c|, \quad (1)$$

[0051] When $|\Delta|\geqq 90°$, the transport vehicle and harvester are in opposite or perpendicular directions to each other. Thus, unload on the go operation would not be performed and the calculation of the longitudinal distance using Equation 1 would not be valid for longitudinal position control.

[0052] A predetermined longitudinal distance can be defined as the distance from the center of the receiving area of the transport vehicle or the loading receptacle, e.g., a grain cart, to the transport vehicle GPS position, as measured in the transport vehicle heading direction, when the receiving area of the transport vehicle or the grain cart is aligned with the transport vehicle, i.e., the transport vehicle, including any connected grain cart, is travelling in an essentially straight direction. Stated differently, the receiving area of the transport vehicle is aligned with the transport vehicle when the pivot angle between the corresponding fraction device and the loading receptacle or grain cart is zero. In one embodiment, the predetermined longitudinal distance can be set as a default target or desired longitudinal distance.

[0053] In another embodiment, when the pivot angle between the corresponding traction device and grain cart is not zero, such as during travel along a curved path, the predetermined longitudinal distance can be equal to the sum of the following two distances: the distance from the center of the grain cart to the pivot point in the direction of the grain cart's longitudinal centerline, and the distance from the pivot point to the transport vehicle GPS position in the transport vehicle's heading direction. However, a target longitudinal distance error is introduced when travelling along a curved path, i.e., the pivot angle is not zero. For a small pivot angle, which can be the case for most unload on the go operations, the error is tolerable and can be ignored. For example, if the heading difference or angular displacement (angle Δ) is 10 deg and pivot angle is within +/−5 deg, then the error of the target longitudinal distance is within 2% of the distance from the center of the grain cart to the pivot point. For a large pivot angle, not a usual situation, the longitudinal position controller can adjust or compensate the target longitudinal distance by the target longitudinal distance error. Calculation of the target longitudinal distance error can be calculated using basic geometry and algebra principles.

[0054] Alternatively, the direction of a planned or predetermined path or swath for the transport vehicle, in replacement of the transport vehicle heading h_t, can be used for calculation of the longitudinal distance. The planned path or swath provides a defined direction for the transport vehicle which doesn't introduce the disturbance signal caused by a heading sensing signal noise or back and forth vehicle steering corrections. The planned path can be used when the transport vehicle uses an auto-guidance system to follow the planned path in that the transport vehicle heading is exactly at or very close to the path direction.

[0055] As a further alternative, the direction of a planned or predetermined path or swath of the harvester, in replacement of the harvester heading h_c, can be used for calculation of the longitudinal distance. The planned path can be used when the harvester uses an auto-guidance system to follow the planned path.

[0056] In the case of a straight line path, the direction of the planned path is the line direction. In the case of a curved path, the direction of the planned path is tangent to the path at a current path point. The current path point is on the planned path and is either coincident with or nearest to the current vehicle position, depending on whether the vehicle is exactly on the planned path or not.

[0057] In one embodiment, a straight path can be viewed as a special situation when the curvatures of the curved paths in FIG. **11** become zero, that is, the curves (or desired paths) in FIG. **11** become straight lines. Points A and B (not shown) can be defined as any two ground points marked with GPS positions to define a straight line on the desired straight harvester path, or any two points on the desired straight transport vehicle path, or any two points on a straight line parallel to the desired straight harvester and transport vehicle paths. When both the harvester and the transport vehicle are following straight paths parallel to the straight AB line (not shown) and the angle Δ≈0, the longitudinal distance can be calculated in the direction of the AB line using a simplified version of Equation (1) as set forth in Equation (2):

$$d_{LON}=(d\cdot h_{AB})\cdot \mathrm{sng}(h_{AB}\cdot h_t)+L_2, \quad (2)$$

[0058] In Equation (2), h_{AB} is a unit vector in the direction from point A to point B. The sgn function, i.e., $\mathrm{sgn}(h_{AB}\cdot h_t)$, returns the sign of the dot product $h_{Ab}\cdot h_t$, meaning a value of +1 when the transport vehicle heading is in the direction from A to B or within +/−90 degrees from the direction from A to B, or a value of −1 when the transport vehicle heading is in the direction from B to A or within +/−90 degrees from the direction from B to A.

[0059] In one embodiment, (u_A, v_A), (u_B, v_B), (u_{tr}, v_{tr}), (u_{cmb}, v_{cmb}) can represent Cartesian coordinates of point A, point B, transport vehicle position (tr) and harvester position (cmb), respectively. The dot product $d\cdot h_{AB}$ in Equation (2) can be expressed in the form of Equation (3):

$$d\cdot h_{AB}=[(u_{tr}-u_{cmb})(u_B-u_A)+(v_{tr}-v_{cmb})(V_B-V_A)]/[(u_B-u_A)^2+(v_B-v_A)^2]^{1/2} \quad (3)$$

[0060] Returning now to FIG. **1**, each of the harvester **10** and the transport vehicle **20** can travel along its own path or swath during an unload on the go operation. In other words, the path or swath for the transport vehicle **20** does not have to be the same as for the harvester **10**. In one embodiment, the path for the transport vehicle **20** can be based on the path for the harvester **10**. The lateral distance error limits (LADEL) define the maximum and minimum lateral distances for the transport vehicle path from a desired or target lateral distance (LAD) that can be used for unload on the go operation between the harvester **10** and the transport vehicle **20**. As further shown in FIG. **1**, the longitudinal distance error limits (LODEL) define the maximum and minimum longitudinal distances along the transport vehicle path from a desired or target longitudinal distance (LOD) that can be used for unload on the go operation between the harvester **10** and the transport vehicle **20**. In one exemplary embodiment, the auto-guidance system with an integrated longitudinal position control system for the transport vehicle **20** calculates the target lateral distance (LAD) and the target longitudinal distance (LOD) based on a predetermined lateral offset distance and a predetermined longitudinal offset distance from the distal end of the unloading spout to the GPS device **14** of the harvester, a predetermined longitudinal offset distance from the center of the loading receptacle **23** to the GPS device **24** of the transport vehicle and an estimate of crop shoot-out distance, and controls the transport vehicle to maintain those distances. In another embodiment, the lateral distance error limits (LADEL) and longitudinal distance error limits (LODEL), or at least portions of each of the LADEL and LODEL may be utilized to achieve V2V distance trim control. In other words, the LADEL and LODEL, including portions thereof, may be used to re-position the transport vehicle with respect to the unload tube of the harvester for more even filling of the transport vehicle and to compensate for variations of grain shoot-out distance. The LADEL and LODEL, including portions thereof, can sometimes be referred to as the "trim" or the "trim distance."

[0061] FIGS. **13-16** show exemplary embodiments of user interfaces associated with a V2V distance trim control system. Specifically, FIGS. **13** and **14** show exemplary touch-screen user interfaces for a manual implementation of the V2V distance trim control system and FIGS. **15** and **16** show exemplary touch-screen user interfaces for an automated implementation of the V2V distance trim control system. The V2V distance trim control system includes a main window or control display **80** and popup windows or sub-control displays **82**, **83**, which are accessed from the main window **80**, depending on the selected implementation mode, i.e., manual or automated. The main window **80** and the popup windows **82**, **83** provide an operator, such as the harvester operator or the transport vehicle operator, with an opportunity to not only achieve both lateral and longitudinal trim control (in either direction of each of the lateral and longitudinal directions), but also with the ability to adjust the trim value, i.e., the distance from the desired or center point, if desired. Additionally, the V2V distance trim control system provides control activation negotiation between the harvester and the transport vehicle to establish which operator, i.e., the harvester operator or the transport vehicle operator, can perform the trim control.

[0062] As shown in FIGS. **13** and **15**, the main window **80** can include an icon of a tractor pulling a grain cart with repositioning direction arrows from an overview vantage point. Additional control buttons or status displays **84-87** can be provided for control activation, i.e., engagement and disengagement of the V2V distance trim control system command capabilities, and the selection function between automated and manual implementation of trim control. Specifically, an activation or control button **84** and an activation status message box **86** are provided for V2V distance trim control system activation and a mode control or activation button **85** and a mode status message box **87** are provided for the selection between manual and automated mode of implementation. The activation status message box **86** indicates whether the operator viewing the display has the ability to make adjustment to the trim control. Only when the activation status message box **86** indicates "Activated" can the operator make adjustments to the trim control through the mode control activation button **85** and popup windows **82**, **83**. Otherwise, the operator has to request control from the other vehicle by using the activation or control button **84** as described below with respect to FIGS. **17-19**.

[0063] As shown in FIG. **13**, when manual mode of operation or implementation is selected for trim control, the mode status message box **87** indicates "Manual Mode" and a lateral distance display **94** and a longitudinal distance display **96** become active. The lateral distance and longitudinal distance displays **94**, **96**, can include message boxes and/or control buttons with associated symbols and text to indicate current re-positioning directions for the adjustment of the lateral and longitudinal position of the transport vehicle. When an operator touches either of the lateral distance and longitudinal distance displays **94**, **96**, the popup window **82**, as shown in FIG. **14**, can be provided or displayed to permit the operator to change one or both of the two control variables, i.e., the lateral and longitudinal positions. The four directional control buttons **88** provide the operator with stepwise distance trim control in four directions. Pressing a directional button **88** once causes a trim distance to change by one step size in that direction, which change is reflected in the lateral distance and longitudinal distance displays **94**, **96**. The step size may differ depending upon equipment type and application, and in a further embodiment, the step size may vary as the edges of the LODEL and/or LADEL are approached to provide for improved grain retention control. Pressing the "RESET" button resets the trim distances to zeros. Pressing the "OK" button accepts the trim adjustments and closes the popup window. The left-right trim distance (some or all of LADEL) adjustment as entered by the operator is then implemented by the transport vehicle lateral position control system or auto-guidance control system to steer the transport vehicle accordingly, with a new target lateral distance being the predetermined lateral distance (LAD) plus the left-right trim distance and the fore-aft trim distance (some or all of LODEL) adjustment as entered by the operator is implemented by the transport vehicle longitudinal position control system to control the longitudinal distance accordingly, with a new target longitudinal distance being the predetermined longitudinal distance (LOD) plus the fore-aft trim distance.

[0064] As shown in FIG. **15**, when automated or auto mode of operation or implementation is selected for trim control, the mode status message box **87** indicates "Auto Mode" and a trim pattern type display **90**, a trim pattern time display **91**, and a trim pattern travel display **92**, become active. The trim pattern type, trim pattern time and trim pattern travel displays **90**, **91**, **92**, can include message boxes and/or control buttons with associated symbols to indicate an icon of a grain cart repositioning pattern, the time period it takes to cycle though or complete one path of the pattern, and a character display for the manner of travelling the pattern, e.g., an "S" for a stepwise travelling of the pattern or a "C" for continuous travelling of the pattern. When an operator touches any of the trim pattern type, trim pattern time and trim pattern travel displays **90**, **91**, **92**, the popup window **83**, as shown in FIG. **16**, can be provided or displayed to permit the operator to change any or all of the three control variables related to the automated adjustment of the longitudinal and lateral positions. In the popup window **83**, the operator has the option to setup or configure an automatic V2V distance trim control pattern by selecting a pattern type to be indicated in the trim pattern display **90**, a stepwise or continuous execution of the pattern to be indicated in the trim pattern travel display **92**, and a pattern cycle time to be indicated in the trim pattern time display **91**. The pattern type for trim control shows the movement of the relative position of the crop material from the harvester in the receiving area. The starting point for the pattern can be located in the center of the receiving area or at an end of the receiving area. In one embodiment, a step size of V2V distance trim control, such as 10 inches or 0.25 meter, may be utilized, although other distances may be used. Once a selected pattern type, pattern time and/or pattern travel is highlighted or selected, pressing the "OK" button can close the popup window **83** and complete a setup of an automatic V2V distance trim control. The pattern type, pattern time and/or pattern travel adjustments are automatically implemented by the transport vehicle lateral position control system or auto-guidance control system and the transport vehicle longitudinal position control system to reposition the transport vehicle with respect to the unloading spout of the harvester accordingly using automated steering control and speed control. The new target lateral distance can be the predetermined lateral distance (LAD) plus the left-right trim distance (some or all of LADEL), if any, as established by the selected pattern type. The new target longitudinal distance can be the predetermined longitudinal distance (LOD) plus the fore-aft trim distance (some or all of LODEL), if any, as established by the selected pattern type.

[0065] FIG. **17** is a state flow chart for implementing the V2V distance trim control activation logic between the harvester or combine and the transport vehicle or tractor. FIG. **18** is an alternative control activation logic that is similar to FIG. **17**, but with a difference that the harvester has authority to take over control activation from the transport vehicle without the condition of the transport vehicle's agreement. FIG. **19** shows an example of the V2V trim control activation buttons **84** and activation status message boxes **86** on both a tractor display **80**T and a combine display **80**H when progressing through the different control states from FIG. **17**.

[0066] On initialization of the V2V distance trim control system as shown in FIG. **17**, the initial control state is in the "Combine" state **200**, wherein the V2V trim distance is controlled by the combine or harvester operator, and the V2V lateral distance trim value and longitudinal distance trim value are initialized to be zero on both the harvester or combine and the transport vehicle or tractor. In the "Combine" state **200**, the harvester or combine is active for distance trim control, and the transport vehicle or tractor is inactive, or passive, i.e., the tractor operator cannot make any trim distance adjustments. On the combine display **80**H, "Activated" is shown in the text message box **86**, and the control button **84** is deactivated and shown as a grayed-out button. A harvester or combine operator can manually change the lateral and longitudinal distance trim values by using the control buttons **94**, **96**, **88** or change the automated trim control variables by using buttons **90**, **91**, **92** on the combine display **80**H or popup windows **82**, **83**. After the combine operator hits the "OK" button, a stored lateral or longitudinal distance trim value in the combine display **80**H is updated in response to a change in the lateral or longitudinal distance trim value by the combine operator. On the tractor display **80**T, "Not Activated" is shown in text message box **86**, and the control button **84** is activated with a "Ctrl Request" message. The displays and control buttons **94** and **96**, **90**, **91** and **92** on the tractor touch-screen display **80**T shown in FIG. **13** and FIG. **15** are functioning as displays only with the functions of control buttons being deactivated so that the tractor operator cannot use them to change the distance trim values. The tractor operator can use the "Ctrl Request" button **84** to request the control authority from the combine operator.

[0067] If a tractor operator presses the "Ctrl Request" button **84**, then control state transitions from the "Combine" state **200** to a "Tractor Request" state **202**. In the "Tractor Request" state **202**, on the tractor display **80**T, the message box **86** shows the message "Requesting" and the control button **84** is deactivated and is shown as a grayed-out button. On the combine display **80**H, the message box **86** shows the message "Remote Request," meaning an operator on the other side of the V2V control is requesting for control of V2V distance trim values, and the control button **84** is activated for the combine operator to accept the request. In the "Tractor Request" state, the combine remains active and the tractor remains passive for making trim distance adjustment.

[0068] In the "Tractor Request" state **202**, if a combine operator doesn't accept the request during a preset period of time, then the "Tractor Request" state **202** is timed out and the control state returns back to the "Combine" state **200**. Otherwise, if a combine operator accepts the request by pressing the "Accept" control button **84** on the combine display **80**H, then the control state transitions to the "Tractor" state **204**, wherein the V2V distance trim values are controlled by the tractor operator.

[0069] In the "Tractor" state **204**, the tractor display **80**T is active for distance trim control, and the combine display **80**H is inactive, or passive, i.e., the combine operator cannot make any trim distance adjustments. On the tractor display **80**T, message box **86** shows "Activated' and control button **84** is activated with a "Return Ctrl" message. On the combine display **80**H, message box **86** shows "Not Activated" and control button **84** is activated with a "Ctrl Request" message. A tractor operator can manually change the lateral and longitudinal distance trim values by using the control buttons **94**, **96**, **88** or change the automated trim control variables by using buttons **90**, **91**, **92** on the tractor display **80**T or popup windows **82**, **83**. After a tractor operator selects the "OK" button, a stored lateral or longitudinal distance trim value in the tractor display **80**T is updated in response to a change in lateral or longitudinal distance trim value by the tractor operator. In the "Tractor" state **204**, either a combine operator can request for control of V2V distance trim or a tractor operator can return the control to the combine operator.

[0070] If the tractor operator presses the "Return Ctrl" button **84** on the tractor display **80**T, then the control state transitions from the "Tractor" state **204** to the "Combine" state **200**. Otherwise, if a combine operator presses the "Ctrl Request" button **84** on the combine display **80**H, then the control state transitions from the "Tractor" state **204** to the "Combine Request" state **206**, wherein the combine operator is requesting control of the V2V distance trim. In an unusual case when the tractor operator control event and combine operator control event happen at exactly the same time, then the tractor "Return Ctrl" event overrides the combine "Ctrl Request" event.

[0071] In the "Combine Request" state **206**, the V2V distance trim control operation is similar to the operation in "Tractor Request" state **202**. The difference is that control button functions and display messages are now exchanged between the combine display **80**H and the tractor display **80**T. If a tractor operator doesn't accept the request during a preset period of time, then the "Combine Request" state **206** is timed out and the control state returns back to the "Tractor" state **204**. Otherwise, if a tractor operator accepts the request by pressing the "Accept" control button **84**, then the control state transitions to the "Combine" state **200**. For any one of the state transitions described above, a wireless communication link between a V2V combine and a V2V tractor is established for communicating actions on the control button **84** of the combine display **80**H and actions on the control button **84** of the tractor display **80**T.

[0072] During a V2V control engagement between the V2V combine and a V2V tractor, if the V2V distance trim control state is the "Combine" state **200** or the "Tractor Request" state **202**, the lateral and longitudinal distance trim values in the combine display **80**H are sent to the tractor to update the distance trim values in the tractor display **80**T. Then, the tractor V2V autoguidance control system updates the tractor path in response to an updated lateral distance trim value, and the tractor longitudinal position control system updates the target longitudinal distance in response to an updated longitudinal distance trim value. Otherwise, if the V2V distance trim control state is the "Tractor" state **204** or the "Combine Request" state **206**, the lateral and longitudinal distance trim values in the tractor display **80**T are used to update the tractor path and the target longitudinal distance, and are sent to the combine to update the distance trim values in the combine display **80**H.

[0073] FIG. **18** is an alternative control activation logic. The difference is that there is no "Combine Request" state **206**. Otherwise, the V2V distance trim control operations are basically the same. In the "Tractor" state **204** of this control activation logic, if a combine operator press the "Ctrl Request" button **84** on the combine display **80**H, then the control state transitions to "Combine" state **200** without the condition of a tractor operator accepting the request.

[0074] In FIG. **19**, a grayed-out control button is deactivated for that state. A control request is accompanied by a preset time period. If the preset time period runs out without acceptance of the request, then the request is aborted and the control state does not change.

[0075] During operation, exchange of control button signals between the combine and tractor is through the wireless communication link. A multi-function handle is an alternative to the popup window for operator control of trim distances. The handle has four directional control buttons and one reset button, similar to those in the popup window. The reset button is positioned in the center of the four directional buttons, and can be labeled "H" for home, i.e., the start point of V2V trim distance adjustments.

[0076] The automatic trim control popup window can include, but is not limited to, the control patterns shown in the popup window. The trim distance limits for a pattern can be dependent on the lateral distance error limits (LADEL), and the longitudinal distance error limits (LODEL), which in turn are associated with the receiving area size. The control button **85** and associated text display is for the operator to select an auto or manual V2V distance trim control mode. In auto mode, a time step is calculated and then executed for a stepwise pattern, or a relative speed is calculated and then executed for a continuous pattern, based on the following: selected pattern type, pattern time, LADEL and LODEL, and distance step size (for stepwise pattern only).

[0077] Harvester unloading on the go automation allows greater accuracy during the unloading process and greater utilization of grain cart capacity. The accuracy improvements come from making sure all the grain/material being unloaded makes it into the grain cart being pulled by the tractor. It also allows more farmers to perform unloading on the go operations due to a reduction in the level of skill drivers may need to perform the operation. The ability to adjust grain cart position in the system allows maximization of the fill process.

[0078] It should be understood that the application is not limited to the details or methodology set forth in the following description or illustrated in the figures. It should also be understood that the phraseology and terminology employed herein is for the purpose of description only and should not be regarded as limiting.

[0079] The present application contemplates methods, systems and program products on any machine-readable media for accomplishing its operations. The embodiments of the present application may be implemented using existing computer processors, or by a special purpose computer processor for an appropriate system, or by a hardwired system.

[0080] Embodiments within the scope of the present application include program products comprising machine-readable media for carrying or having machine-executable instructions or data structures stored thereon. Machine-readable media can be any available non-transitory media that can be accessed by a general purpose or special purpose computer or other machine with a processor. By way of example, machine-readable media can include RAM, ROM, EPROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer or other machine with a processor. When information is transferred or provided over a network or another communications connection (either hardwired, wireless, or a combination of hardwired or wireless) to a machine, the machine properly views the connection as a machine-readable medium. Combinations of the above are also included within the scope of machine-readable media. Machine-executable instructions comprise, for example, instructions and data which cause a general purpose computer, special purpose computer, or special purpose processing machines to perform a certain function or group of functions.

[0081] Although the figures herein may show a specific order of method steps, the order of the steps may differ from what is depicted. Also, two or more steps may be performed concurrently or with partial concurrence. Variations in step performance can depend on the software and hardware systems chosen and on designer choice. All such variations are within the scope of the application. Likewise, software implementations could be accomplished with standard programming techniques with rule based logic and other logic to accomplish the various connection steps, processing steps, comparison steps and decision steps.

[0082] In the further consideration of the drawings of this application and the discussion of such drawings and the elements shown therein, it should also be understood and appreciated that, for purposes of clarity in the drawings, pluralities of generally like elements positioned near to one another or extending along some distance may sometimes, if not often, be depicted as one or more representative elements with extended phantom lines indicating the general extent of such like elements. In such instances, the various elements so represented may generally be considered to be generally like the representative element depicted and generally operable in a like manner and for a like purpose as the representative element depicted.

[0083] Many of the fastening or connection processes and components utilized in the application are widely known and used, and their exact nature or type is not necessary for an understanding of the application by a person skilled in the art. Also, any reference herein to the terms "left" or "right" is used as a matter of mere convenience, and is determined by standing at the rear of the machine facing in its normal direction of travel. Furthermore, the various components shown or described herein for any specific embodiment in the application can be varied or altered as anticipated by the application and the practice of a specific embodiment of any element may already be widely known or used by persons skilled in the art.

[0084] It will be understood that changes in the details, materials, steps and arrangements of parts which have been described and illustrated to explain the nature of the application will occur to and may be made by those skilled in the art upon a reading of this disclosure within the principles and scope of the application. The foregoing description illustrates an exemplary embodiment of the invention; however, concepts, as based upon the description, may be employed in other embodiments without departing from the scope of the application.

[0085] While the application has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the application. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the application without departing from the essential scope thereof. Therefore, it is intended that the application not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this application, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A method of controlling a transport vehicle to enable substantially even loading of crop material into the transport vehicle during an unload on the go operation with a harvester, the method comprising:

determining a current lateral position for a transport vehicle relative to a harvester, the current lateral position being based on a predetermined path for the transport vehicle and a current lateral position adjustment;

determining a current longitudinal position for a transport vehicle relative to a harvester, the current longitudinal position being based on a predetermined longitudinal distance from the harvester and a current longitudinal position adjustment;

calculating a future adjustment to at least one of the current lateral position or the current longitudinal position;

calculating a future lateral position for the transport vehicle relative to a harvester and a future longitudinal position for the transport vehicle relative to the harvester using the current lateral position, the current longitudinal position, the predetermined path and the calculated future adjustment to the at least one of the current lateral position or the current longitudinal position;

generating a steering control signal to steer the transport vehicle to the future lateral position with an auto-guidance system for the transport vehicle;

generating a speed control signal to control the transport vehicle to the future longitudinal position with an automated speed control in a longitudinal position control system for the transport vehicle; and

applying the generated steering control signal and the generated speed control signal to transport vehicle components to automatically control the steering and speed of the transport vehicle and provide for substantially even filling of the transport vehicle with crop material from the harvester.

2. The method of claim **1** wherein calculating a future adjustment to at least one of the current lateral position or the current longitudinal position comprises manually entering by an operator the adjustment to the at least one of the current lateral position or the current longitudinal position.

3. The method of claim **2** wherein manually entering by an operator the adjustment comprises manually entering by the operator at least one of a lateral distance deviation or a longitudinal distance deviation.

4. The method of claim **1** wherein calculating a future adjustment to at least one of the current lateral position or the current longitudinal position comprises entering by an operator at least one control variable to enable automated adjustment of the at least one of the current lateral position or the current longitudinal position.

5. The method of claim **4** wherein entering by an operator at least one control variable comprises entering at least one of a trim pattern type, a trim pattern cycle time or a trim pattern travel manner.

6. The method of claim **1** wherein calculating a future adjustment to at least one of the current lateral position or the current longitudinal position comprises:

limiting an adjustment to the current lateral position to be within a predetermined maximum lateral distance adjustment and a predetermined minimum lateral distance adjustment; and

limiting an adjustment to the current longitudinal position to be within a predetermined maximum longitudinal distance adjustment and a predetermined minimum longitudinal distance adjustment.

7. The method of claim **6** wherein in the predetermined maximum lateral distance adjustment, the predetermined minimum lateral distance adjustment, the predetermined maximum longitudinal distance adjustment and the predetermined minimum longitudinal distance adjustment correspond to boundaries for a receiving area for crop material in the transport vehicle.

8. The method of claim **6** wherein:

the current lateral position corresponds to a position which offsets from the predetermined path by a current lateral position adjustment;

the current longitudinal position corresponds to a predetermined longitudinal distance from the harvester plus a current longitudinal position adjustment;

the predetermined maximum lateral distance adjustment and the predetermined minimum lateral distance adjustment are boundaries of a range centered on the predetermined lateral position; and

the predetermined maximum longitudinal distance adjustment and the predetermined minimum longitudinal distance adjustment are boundaries of a range centered on the predetermined longitudinal position.

9. The method of claim **1** wherein calculating a future adjustment to at least one of the current lateral position or the current longitudinal position comprises selecting one of a harvester operator or a transport vehicle operator to have control of the adjustment to the at least one of the current lateral position or the current longitudinal position.

10. A control system to control a transport vehicle to enable substantially even loading of crop material into the transport vehicle during an unload on the go operation with a harvester, the control system comprising:

a global positioning system device to determine a current lateral position of a transport vehicle and a current longitudinal position of the transport vehicle;

a user interface for an operator to enter information;

a first controller comprising a microprocessor to execute a computer program to operate an auto-guidance system for the transport vehicle to steer the transport vehicle along a predetermined path or an adjusted path with a parallel offset to the predetermined path by a lateral position adjustment;

a second controller comprising a microprocessor to execute a computer program to calculate an adjustment to at least one of the current lateral position or the current longitudinal position of the transport vehicle based on information entered by the operator and to determine a future lateral position for the transport vehicle and a future longitudinal position for the transport vehicle using the current lateral position, the current longitudinal position, the predetermined path and the calculated adjustment to the at least one of the current lateral position or the current longitudinal position;

a third controller comprising a microprocessor to execute a computer program to operate a longitudinal position control system for the transport vehicle to control the transport vehicle to the future longitudinal position relative to the harvester; and

wherein the auto-guidance system and longitudinal position control system for the transport vehicle being operated to control the transport vehicle to the future lateral position and the future longitudinal position through automated steering control and speed control and to provide for substantially even filling of the transport vehicle with crop material from a harvester.

11. The control system of claim **10** further comprising a first wireless communication device located on the harvester and a second wireless communication device located on the transport vehicle, the first wireless communication device and the second wireless communication device being operational to permit communication between the harvester and the transport vehicle.

12. A method of controlling a transport vehicle to maintain a longitudinal distance between the transport vehicle and a corresponding harvester during an unload on the go operation, the method comprising:

determining a global positioning system position for each of a transport vehicle and a harvester;

calculating a velocity for the transport vehicle and a velocity for the harvester using the determined global positioning system positions for the transport vehicle and the harvester;

calculating a longitudinal distance between the harvester and the transport vehicle using the determined global positioning system positions for the transport vehicle and the harvester;

calculating a transport vehicle velocity set point using the calculated velocity for the transport vehicle, the calculated velocity for the harvester, the calculated longitudinal distance between the harvester and the transport vehicle and a predetermined longitudinal distance; and

controlling a velocity of the transport vehicle in response to the calculated transport vehicle velocity set point to control the longitudinal distance between the transport vehicle and the harvester to be within a predetermined distance deviation from the predetermined longitudinal distance.

13. The method of claim **12** further comprising:

comparing the calculated longitudinal distance between the harvester and the transport vehicle to a predetermined distance range based on the predetermined longitudinal distance and the predetermined distance deviation;

generating an indicator to enable engagement of a discharge auger of the harvester in response to the calculated longitudinal distance between the harvester and the transport vehicle being within the predetermined distance range; and

generating an indicator to disengage the discharge auger of the harvester in response to the calculated longitudinal distance between the harvester and the transport vehicle being outside of the predetermined distance range.

14. The method of claim **12** wherein calculating a longitudinal distance between the harvester and the transport vehicle comprises including at least one of crab angles for the harvester and the transport vehicle, a pivot angle for the transport vehicle or a harvester steering angle in the calculation of the longitudinal distance between the harvester and the transport vehicle.

15. The method of claim **12** wherein calculating a longitudinal distance between the harvester and the transport vehicle comprises calculating a longitudinal position of the transport vehicle using at least one of a linear approach based on a Cartesian coordinate system, an angular approach based on a Polar coordinate system or a curvilinear approach based on a harvester trajectory.

16. The method of claim **12** wherein calculating a transport vehicle velocity set point comprises setting the transport vehicle velocity set point equal to a harvester velocity in response to the calculated longitudinal distance between the harvester and transport vehicle being equal to the predetermined longitudinal distance.

17. The method of claim **12** wherein calculating a transport vehicle velocity set point comprises:

calculating a distance error between the calculated longitudinal distance between the harvester and transport vehicle and the predetermined longitudinal distance;

providing the calculated distance error to a gain device to generate a first signal;

calculating a second signal by adding the first signal to the calculated velocity for the harvester and subtracting the calculated velocity for the transport vehicle;

providing the second signal to a proportional-integral dynamic compensator to generate a third signal;

providing the calculated velocity for the harvester through a feed-forward dynamic compensator to generate a fourth signal;

calculating a fifth signal by adding the third signal and the fourth signal;

adjusting the fifth signal to be within a transport vehicle velocity range in response to the fifth signal being outside the transport vehicle velocity range; and

applying the adjusted fifth signal to a nonlinearity compensator to generate the transport vehicle velocity set point.

18. The method of claim **12** wherein controlling a velocity of the transport vehicle in response to the calculated transport vehicle velocity set point comprises controlling the velocity of the transport vehicle using at least one of an auto-shift control system, a continuously variable transmission or an automatic engine speed control system.

19. The method of claim **12** wherein controlling a velocity of the transport vehicle in response to the calculated transport vehicle velocity set point comprises controlling the velocity of the transport vehicle to position the transport vehicle the predetermined longitudinal distance from the harvester.

20. A control system to control a velocity of a transport vehicle during an unload on the go operation with a harvester, the control system comprising:

a first global positioning system device to determine a position of a transport vehicle;

a second global positioning system device to determine a position of a harvester;

a first controller comprising a microprocessor to execute a computer program to calculate a velocity of the transport vehicle, a velocity of the harvester and a longitudinal distance between the harvester and the transport vehicle using the determined positions of the transport vehicle and the harvester;

a second controller comprising a microprocessor to execute a computer program to calculate a transport vehicle velocity set point using the calculated velocity for the transport vehicle, the calculated velocity for the harvester, the calculated longitudinal distance between the harvester and the transport vehicle and a predetermined longitudinal distance; and

a third controller comprising a microprocessor to execute a computer program to control a velocity of the transport vehicle in response to the calculated transport vehicle velocity set point.

21. The control system of claim **20** wherein the first controller, the second controller and the third controller are located on one of the harvester or the transport vehicle.

22. The control system of claim **20** further comprising a first wireless communication device located on the harvester and a second wireless communication device located on the transport vehicle, the first wireless communication device and the second wireless communication device being operational to permit communication between the harvester and the transport vehicle.

23. A method of controlling movement of an unload tube spout of a harvester, the method comprising:

determining an activation region for a harvester, the activation region being based on a preselected lateral distance range relative to the harvester and a preselected longitudinal distance range relative to the harvester;

determining a position of a transport vehicle to receive crop material from the harvester, the determined position of the transport vehicle being relative to the harvester;

comparing the determined activation region and the determined position of the transport vehicle;

disabling movement of an unload tube spout of a harvester in response to the determined position of the transport vehicle being outside of the determined activation region; and

enabling movement of an unload tube spout of a harvester between an open position and a closed position in response to the determined position of the transport vehicle being within the determined activation region.

24. The method of claim **23** wherein the determined activation region is based on a lateral distance range relative to the harvester and a longitudinal distance range relative to the harvester for a receiving area of the transport vehicle, the receiving area of the transport vehicle being an area to receive crop material from the harvester.

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