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DEVICE FOR DISPENSING SOLID AGENTS AND METHOD FOR CONTROLLING THE DEVICE

Description

The present invention relates to a device for spreading solid active agents according to independent Claim 1 and to a method for the motion control and/or regulation of a device for spreading solid active agents according to Claim 12.

Field sprayers and spray booms hooked up to working machines such as tractors partly have very large working widths of more than 20 metres. For transport journeys, such wide spray booms are folded up. On the field, symmetrical outriggers of multiple meters in length are situated on both sides of the working machine, which depending on the surface condition and field relief have a variable distance from the ground. Since the nozzles arranged on the outriggers and directed downwards for spreading a spraying agent such as for example a pesticide, each have a defined spraying cone, a variable distance of the nozzles to the ground produces an uneven coverage of the field with spraying agent. In addition, the risk of the spraying agent drifting off also increases greatly with increasing distance of the spraying nozzles from the ground since the finely atomized drops are negatively influenced even by minor air movements.

For this reason there is the need with increasing outrigger dimensions and the accompanying working width to guide the spray boom at a distance to the ground that preferably stays the same since even minor tilts of the spray boom result in major distance differences of the nozzles to the ground.

To this end, it is known to suspend a spray boom about a central point at least rotatably about a rotation axis from a carrier vehicle. There, the rotation axis runs preferentially parallel to the longitudinal axis of the carrier vehicle. In order to ensure an even spreading of the spraying agent, the distance between upper edge of the crop and the spray nozzles has to be regulated constantly to a defined distance. On horizontal agricultural surfaces, this can basically be achieved through a selflevelling system in the case of which the spray boom aligns itself in the horizontal in that the centre of gravity of the spray boom is provided below the central point and the spray boom is suspended pivotably so as to swing freely. However, the desired effect does not materialize in the case of agricultural surfaces running along a slope.

In order to constantly regulate the distance between upper edge of the crop and the spray nozzles arranged on a spray boom rotatably suspended about a central point to a defined distance with any agricultural surface profiles, it is therefore known to rotate a spray boom raised for example to a desired distance from the ground about a rotation axis running through the central point so that this distance is optimized over the entire working width. To this end, an alignment-changing torque about a rotation axis running through the central point has to be exerted on the spray boom. This is effected by means of at least one actuator, which, at least when required, transmits a force or a force couple causing an alignment-changing torque about the rotation axis onto the spray boom in order to change the alignment of the same.

This alignment-changing torque accelerates the spray boom in a desired pivot direction. Even after the termination of the effect of the alignment-changing torque, the spray boom would continue pivoting about the rotation axis without countermeasures, since because of the mass moment of inertia it maintains its pivot impulse. In order to be able to again brake the spray boom, a brake torque that is opposite to the previous alignment-changing torque has to be induced. This brake torque counteracts the angular movement triggered by the alignment-changing torque and thus dampens the system of spray boom rotatably suspended about the central point.

To date, conventional mechanical dampers attached between carrier vehicle and spray boom are customarily used for generating the brake torque. Assuming that a relative movement between carrier vehicle and boom occurs in the form of a rotation about the rotation axis, a mechanical damper attached in between counteracts the relative rotation or the relative movement of the boom braking the same as desired. However when the carrier vehicle, for example because of irregularities, rotates about the rotation axis and the spray boom stands still, a relative rotation between carrier vehicle and spray boom likewise materializes. A mechanical damper arranged between carrier vehicle and spray boom would act counter to this relative rotation and thus transmit a torque acting about the rotation axis onto the spray boom as a result of which there is a coupling between carrier vehicle and spray boom.

This coupling exists similarly when as basis for a regulation of the torque a measurement system is used, which measures a relative angle and/or a relative rotation between the carrier vehicle and spray boom.

In addition to this, measurement systems are known which use tilt sensors arranged on the spray boom in order to determine the position of the spray boom. By time derivation of the tilt, the angular velocity of the spray boom can be obtained independently of the carrier vehicle. Tilt sensors however supply a faulty tilt in the case of transverse accelerations as occur for example when negotiating curves. Thus, a faulty angular velocity is also calculated.

By way of US2011/0282554A1 a device for spreading liquid agents is known. The device includes:

- a carrier vehicle,

- a centre part arranged on the spray boom including a centre part that is variably adjustable in its distance to the ground and two outriggers arranged on the same, moveably arranged independently of one another about its dedicated rotation axes running parallel to a longitudinal axis of the carrier vehicle, projecting laterally from the carrier vehicle,

- distance sensors for detecting the positions or distances of the outrigger ends to the ground arranged on the two outriggers,

- at least one distance sensor arranged on the centre part between the outriggers for detecting the distance of the centre part to the ground,

- a regulating device processing the output signals of the sensors into control signals,

- an actuator each acting on one of the two outriggers in the form of a hydraulic cylinder for the individual raising and lowering of each outrigger in dependence on control signals of the regulating device, and

- an angle of rotation sensor or angular rate sensor detecting the roll angle or the roll rate of the carrier vehicle about the longitudinal axis of the same arranged on the carrier vehicle independently of the spray boom.

The distance sensors can be LIDAR (light detection and ranging), RADAR (radio detection and ranging) or ultrasound sensors or sensors based on an interference measurement method or on radio frequency such as for example GPS sensors. The angle of rotation sensor or angular rate sensor can be a gyroscopic instrument. In order to keep the outrigger ends at the same distance to the ground as the centre part, an elevation error of the two outrigger ends is initially calculated by way of a comparison of the output signals of the distance sensors. If this elevation error is unequal to zero for one or for both outrigger ends, an initial control signal is generated in order to actuate an actuator assigned to the outrigger concerned and to adjust the outrigger end having an elevation error again to the default distance to the ground. When in the process one of the outriggers is raised, a rolling movement of the carrier vehicle in the direction of the outrigger to be raised follows from this, as a result of which the remaining outrigger would, without further measures, have an elevation error resulting in a lowering. In order for a regulating circuit composed of distance sensors, regulating device and actuators to be stable in terms of regulation, and not uncontrollably escalate and/or lead to a lateral toppling-over of the carrier vehicle it is provided, by means of the regulating device, to generate a compensation control signal counteracting an instability of the regulating circuit by way of the output signal of the angle of rotation sensor or angular rate sensor detecting the roll angle or the roll rate of the carrier vehicle about the longitudinal axis of the same and to output a control signal to the actuators determined by way of the initial control signal and the compensation control signal.

By way of WO2012/146255A1 a device likewise for outputting liquid agents is known. The device comprises:

- a carrier vehicle,

- a spray boom moveably arranged on the carrier vehicle about a rotation axis running parallel to a longitudinal axis of the carrier vehicle with outriggers projecting on both sides of the carrier vehicle,

- one or more sensors arranged on the spray boom in order to detect the distances of the outriggers to the ground such as for example one or more acceleration sensors, gyroscopes and/or distance sensors,

- a regulating device processing the output signals of the one or the multiple sensors into control signals,

- a stabilization device damping oscillations of the spray boom comprising two guides running along the two outriggers and a block each moveably arranged along one of the guides, and

- an actuation device influencing the positions of the two blocks along the guides in dependence on control signals of the regulating device. As an answer to undesirable vertical movements, which in an undamped regulating circuit can excite the spray boom into rotary oscillations about the longitudinal axis of the carrier vehicle, a damping and compensation through a shifting of mass by way of moving the blocks along the two outriggers is provided. Output signals of acceleration sensors detecting vertical oscillations of the spray boom that are attached to the outriggers serve as input variable of the regulating device being included in the control signals to the actuation device. A regulation of a constant distance of the outrigger to the ground is not disclosed.

By way of DE102007045846A1 a device for outputting liquid agents is known. The device includes:

- a carrier vehicle,

- a spray boom arranged about a rotation axis running parallel to a longitudinal axis of the carrier vehicle on a height-adjustable parallelogram boom on the carrier vehicle,

- an acceleration sensor arranged on the spray boom,

- an acceleration sensor arranged on the parallelogram boom, and

- a first reference sensor arranged on the carrier vehicle in the form of an acceleration sensor, and

- a second reference sensor in the form of a gyrostat or angular rate sensor arranged in the region of a frame of the carrier vehicle,

- a regulating device processing the output signals of the one or of the multiple sensors into control signals,

- an actuator in the form of a hydraulic cylinder influencing the angular position of the spray boom in dependence on control signals of the regulating device, and

- an actuator in the form of a hydraulic cylinder influencing the distance of the parallelogram boom to the ground in dependence on control signals of the regulating device.

The control signals generated by the regulating device avoid position changes of a position and orientation of the spray boom once manually set during braking, accelerating, spring compression and rebound of the carrier vehicle or even when travelling over ground irregularities. Errors creeping in by way of the different positioning of the acceleration sensors and the reference sensors can be more accurately compensated for by the reference sensors. A regulation of a continuous distance of the spray boom to the ground is not disclosed.

By way of JPA2008-29261 a device for spreading liquid or solid active agents is also known.

For the sake of completeness, it is mentioned that in addition to this, spray booms consisting of segments that are adjustable in relation to one another are known in order to make possible in the case of very large working widths an adaptation to the ground contour in sections. A spray boom, which has an outrigger composed of segments, is known through DE3202569A1. Here, individual segments are connected to one another, wherein the movement of the individual segments in relation to one another takes place passively. For this mechanism, a supporting element on the outside of each outrigger is necessary in order to make possible the pivoting operation.

The object of the invention is to develop a device for spreading solid active agents with a carrier vehicle and at least one boom that is pivotably arranged about a rotation axis running preferentially parallel to a longitudinal axis of the carrier vehicle with outriggers projecting on both sides of the carrier vehicle which, even with uneven grounds and moving or rolling carrier vehicle makes possible a preferably exact maintaining of the distances of the outriggers in relation to the ground surface, and to state a method for controlling such a device with the help of which a preferably exact maintaining of the distances of the outriggers in relation to the ground surface is made possible even with irregular grounds and moving or rolling carrier vehicle.

The object is solved in each case through the features of the independent claims.

Features of advantageous further developments of the invention are obtained from the dependent claims, the following general description parts, the drawings and the associated figure description parts.

A first subject of the invention accordingly relates to a device for spreading solid active agents. The device comprises:

- a carrier vehicle,

- at least one boom that is pivotably arranged about a rotation axis preferentially running parallel to a longitudinal axis of the carrier vehicle with outriggers projecting on both sides of the carrier vehicle and spreading means arranged on the same that are connected and/or connectable to a storage unit for at least one solid active agent,

- at least one sensor arrangement for detecting an angular velocity of the boom about the rotation axis in relation to a reference plane,

- at least one sensor arrangement for detecting an angular position of the boom about the rotation axis in relation to the reference plane,

- at least one sensor arrangement for detecting at least one average distance of the boom in relation to the ground,

- a regulating device processing output signals of the sensor arrangements into control signals,

- at least one actuator influencing the angular position of the boom about the rotation axis in relation to the carrier vehicle in dependence on control signals of the regulating device for example in the form of one or more hydraulic cylinders, which converts control signals into mechanical motion or another physical quantity, such as for example pressure and thus generates a force exerting a torque on the boom or a force couple generating a torque on the boom,

wherein the regulating device for determining an angular position of the boom about the rotation axis in relation to a starting orientation coinciding for example with the reference plane:

- through time integration of the angular velocity calculates the angular position of the boom in relation to the reference plane, by way of which on the one hand neither the carrier vehicle nor translational accelerations interferingly influence the calculation of the angular position, but on the other hand measuring errors are likewise integrated and cause a drift of the angular position referred to as angular drift in the following, and

- fuses the angular position of the boom calculated by way of the angular velocity for compensating for the angular drift with the detected angular position of the boom for determining the present angular position of the boom in relation to the reference plane in order to generate a control signal from this which returns the boom from its present angular position into a desired angular position in relation to the reference plane.

By way of a time integration of the angular rate referred to as angular velocity an angle of rotation reflecting an angular position of the boom in relation to the reference plane is obtained. Here, interferences by the carrier vehicle or through translational accelerations have no influence on the calculation, whereas measuring errors are likewise integrated and cause an angular drift of the rotation angle.

A measurement of the angular position in relation to the reference plane, for example through a measurement of the relative rotation between carrier vehicle and boom or a measurement of a tilt angle to the earth acceleration has the disadvantage of influencing interferences through angular movements of the carrier vehicle or through translational accelerations such as for example occur during cornering, but which is opposed by the advantage that this type of detection of the angular position is not subjected to any angular drift.

By fusing the calculated angular position and the measured angular position referred to as detected angular position, the present angular position in relation to the reference plane is very accurately determined, wherein only the advantages of the respective measuring methods are utilized without having to accept the disadvantages of the same.

Advantages compared with the prior art are the obtaining of a measuring system, which exists on the basis of the at least one sensor arrangement for detecting an angular velocity of the boom about the rotation axis in relation to a reference plane, on the basis of the at least one sensor arrangement for detecting an angular position of the boom about the rotation axis in relation to the reference plane, and on the basis of the regulating device which processes the output signals of the sensor arrangements into control signals, and which measuring system reflects the present angular position and angular movements of the boom based on the reference plane independently of the carrier vehicle and from this generates control signals for regulating a constant orientation of the boom in relation to the reference plane. For determining the present angular position, two measuring systems which are based on different physical fundamentals are used and fused. By way of this, the disadvantages of each measuring method are suppressed.

The at least one sensor arrangement for detecting an angular velocity of the boom about the rotation axis in relation to a reference plane can include an angular rate sensor arranged on the boom and detecting the angular velocity of the boom.

For detecting the angular velocity an angular rate sensor is employed here, which is directly mounted onto the boom. Angular movements of the carrier vehicles thus have no influence on determining the angular velocity of the boom. An output signal of an angular rate sensor that is proportional to the measuring variable or reflecting the same thus corresponds to the angular movement of the boom based on any reference plane, for example based on the surface of the earth or orthogonally to the earth acceleration or a long-term orientation of the carrier vehicle reflecting a mean ground profile.

This measuring variable or an output signal proportional to or reflecting the same serving as input variable of the regulating device influencing the control signal to the actuator or actuators of an angular rate sensor detecting angular velocities of the boom can be used in order to obtain an active damping of the boom in the form of an actively induced braking moment.

Alternatively or additionally, the at least one sensor arrangement for detecting an angular velocity of the boom about the rotation axis in relation to a reference plane can comprise at least one angular rate sensor arranged on the carrier vehicle, in order to measure angular velocities of the carrier vehicle at least about the longitudinal axis of the same and thus angular movements of the carrier vehicle representing interference movements.

In addition, the at least one sensor arrangement for detecting an angular velocity of the boom about the rotation axis in relation to a reference plane can include at least one angle of rotation sensor or rotational angular velocity sensor detecting the relative rotation between carrier vehicle and boom, so that from the two measurement values angular velocity of the carrier vehicle in relation to the longitudinal axis of the same and relative rotation between carrier vehicle and boom, the absolute angular velocity of the boom about the rotation axis can then be determined.

Alternatively or additionally to an angular rate sensor, the at least one sensor arrangement for detecting an angular velocity of the boom about the rotation axis in relation to a reference plane can include an angular acceleration sensor. Through time integration of the output signal of the same, a dimension for the angular velocity can be extracted.

Alternatively or additionally to an angular rate sensor and/or an angular acceleration sensor, the at least one sensor arrangement for detecting an angular velocity of the boom about the rotation axis in relation to a reference plane can typically include at least two acceleration sensors arranged in the region of the outriggers of the boom, for example at their ends. It is mentioned here however that even one sensor can already be sufficient, which can be arranged in the region of one of the outriggers of the boom, for example at one end. Output signal of the same or the output signals of multiple sensors reflect the translational accelerations at the ends of the outriggers. The difference of the output signals of two acceleration sensors arranged at the opposite ends of the outriggers, multiplied by the boom width, produces the angular accelerations through the time integration of which in turn the angular velocity is obtained.

In summary it is evident accordingly that the means for determining an angular velocity of the boom about the rotation axis in relation to a reference plane can include one or more inertial sensors arranged on the boom.

Inertial sensors serve for measuring accelerations and angular rates. By combining multiple inertial sensors in an inertial measuring unit also referred to as "inertial measurement unit", IMU, accelerations in up to 6 degrees of freedom which a rigid body can comprise (three translational and three rotational degrees of freedom) can be measured. An IMU is a main component of an inertia navigation system also referred to as inertial navigation system.

Examples of inertial sensors are acceleration sensors and angular rate sensors.

An angular rate detects the rotation or angular velocity of a body about a given rotation or pivot axis, wherein an output signal of an angular rate sensor is preferentially unambiguously proportional to a detected angular velocity.

By integration of the angular velocity over a time interval the angle by which a body has rotated within the time interval can be derived. The angular rates about the three space axes are referred to as:

- Yaw rate (rotation about vertical axis)

- Pitch rate (rotation about transverse axis)
- Roll rate (in the case of non-land-based vehicles also referred to as roll rate (rotation about longitudinal axis).

The measuring principle is substantially based on two measuring principles on the one hand the Coriolis force, which acts on a mechanically moving system, and on the other hand the Sagnac effect, which is observed with light.

Examples of mechanically moving systems utilizing the Coriolis force are:

- Foucault pendulum,
- Gyro compass,
- Dynamically tuned gyro (DTG), measuring error <1°/h,
- Vibrating gyroscope, measuring error <10°/h,
- Oscillating piston.

Examples of optical systems utilizing the Sagnac effect are:

- Ring laser (RLG), measuring error <0.001°/h,
- Fibreoptic gyroscope (FOG), measuring error <1°/h.

Inertial measuring units generally contain the following sensor types:

- Three orthogonally arranged acceleration sensors (also referred to as translation sensors) detect the linear acceleration in the x or y or z-axis. From this the translational movement can be calculated with twice-repeated integration.

- Three orthogonally arranged angular rate sensors (also referred to as gyroscopic sensors) measure the angular velocity about the x or y or z-axis. From this the angular movement can be calculated with easy integration.

For determining the integration constant and/or for improving the accuracy and/or in order to correct a drift of the sensors, for example magnetic field sensors such as for example compass sensors and/or for receiving signals of an existing and/or future global navigation satellite system also referred to as GNSS such as for example:

- GPS (Global Positioning System) of the United States of America, and/or
- GLONASS (GLObal NAvigation Satellite System) of the Russian Federation and/or
- Galileo of the European Union, and/or
- Beidou of the People's Republic of China

can be additionally employed.

The at least one sensor arrangement for detecting an angular position of a boom about the rotation axis regarding the reference plane can include at least one sensor detecting a relative rotation between carrier vehicle and boom based on the rotation axis.

At least one sensor for detecting a relative rotation between carrier vehicle and boom can be an angle of rotation sensor arranged between the boom and the carrier vehicle.

Alternatively or additionally, a detection of a relative rotation between carrier vehicle and boom can be realized by way of at least one tilt sensor detecting an angle between the carrier vehicle and the reference plane and by way of at least one tilt sensor detecting an angle between the boom and the reference plane, wherein the difference of the angle detected by the sensors between the carrier vehicle and the reference plane and of the angle between the boom and the reference plane is proportional to a relative rotation between carrier vehicle and boom.

By fusing the angular position of the boom calculated by means of a sensorially detected angular velocity with a relative rotation between carrier vehicle and boom sensorially detected by means of an angle of rotation sensor directly or by difference formation in relation to the reference plane reference can be made to a reference plane corresponding to a long-term orientation of the carrier vehicle reflecting a mean ground profile.

The at least one sensor arrangement for detecting an angular position of the boom about the rotation axis in relation to the reference plane can, alternatively or additionally, include at least one tilt sensor detecting an angle between the boom and the reference plane.

By fusing the angular position of the boom calculated by way of an angular velocity by way of an angular position of the boom detected by way of a detection of an angle between the boom and reference plane, reference can be made to a reference plane corresponding to an artificial horizon.

Although tilt sensors have the disadvantage that they are afflicted with transverse acceleration, this disadvantage is compensated for by the fusion with the angular position of the boom calculated by way of an angular velocity.

In summary, the reference plane accordingly can either be an artificial horizon, wherein the at least one sensor arrangement for detecting an angular position of the boom about the rotation axis with reference to a reference plane preferably includes a tilt sensor, or a long-term orientation of the carrier vehicle, wherein the at least one sensor arrangement for detecting an angular position of the boom about the rotation axis with reference to a reference plane preferably includes a detection of a relative rotation between carrier vehicle and boom for example by way of an angle of rotation sensor detecting the angle between boom and carrier vehicle.

For determining the present angular position of the boom about the rotation axis in relation to the reference plane by way of a fusion of the angular position of the boom calculated by way of an angular velocity with the angular position of the boom detected directly or indirectly sensorially by difference formation, the regulation device is preferentially provided with means carrying out a Kalman filtering.

Alternatively or additionally, the regulating device can be equipped for determining the present angular position of the boom about the rotation axis in relation to the reference plane by way of a fusion of the angular position of the boom calculated by means of an angular velocity with the angular position of the boom detected directly or indirectly sensorially through difference formation with means for low-pass filtering of the sensorially detected angular position and means for comparing the low-pass filtered sensorially detected angular position subject to continuous zero balance with the angular position calculated by way of an angular velocity, in order to compensate for the angular drift.

The regulating device regulates and/or controls by means of at least one actuator exemplarily including at least one hydraulic cylinder, the angular position of the boom about the rotation axis longitudinally in relation to the travelling direction of the carrier vehicle.

The regulating device can allow a manual operating state during which the actuator influencing the angular position of the boom about the rotation axis in relation to the carrier vehicle does not perform any active control and the boom is guided for example almost free of any actuating force.

In the manual operating state, at least one part of the boom, for example at least a centre part arranged between the outriggers follows, seen over an extended period of time, the movement of the carrier vehicle since the same basically follows the field relief and thus the contour of the field.

High frequency rolling movements of the carrier vehicle however should have no influence on the angular position of the boom with reference to a reference plane corresponding to the long-term orientation of the carrier vehicle or an artificial horizon.

In addition to this, the regulating device allows an automatic operating state in which the actuator carries out an active movement in order to thus adapt the angular position of the boom in relation to the reference plane.

The invention allows a very precise determination of a present angular position of the boom based on a reference plane. Compared with a determination of the angular position by way of multiple ultrasound sensors this is less complicated and cost intensive.

The device can additionally include an actuator influencing an average distance of the boom in relation to the ground or the crop in dependence on control signals of the regulating device for example in the form of one or more hydraulic cylinders, which converts control signals into mechanical motion or another physical quantity such as for example pressure, and thereby exerts a force on the boom lifting or lowering the boom. Basically, instead of the hydraulic cylinders, other suitable actuators can be employed for example pneumatic, electromechanical or electro-motoric actuators.

In addition to this, the device includes at least one sensor arrangement for detecting at least one average distance of the boom in relation to the ground. Preferentially, such a sensor arrangement includes in each case typically at least one distance sensor arranged at each end of the outriggers of the boom. By means of distance sensors arranged at the ends of the outriggers of the boom and a corresponding consideration of their output signals in generating control signals by means of the regulating device the reliability can be increased with which it can be prevented that the boom or spreading means for solid agents arranged thereon come into ground contact and/or in contact with the crop. It is pointed out that the sensor arrangement can optionally include only a single distance sensor at an end of one of the outriggers of the boom. By means of such a distance sensor arranged at an end of one of the outriggers of the boom and through a corresponding consideration of its output signal in generating control signals by means of the regulating device, the reliability can be increased with which it can be prevented that the boom or spreading means for solid agents arranged thereon, come into ground contact and/or in contact with the crop.

Alternatively or additionally, such a sensor arrangement can include at least one distance sensor arranged on the carrier vehicle in the part of the boom not exceeding the width of the said carrier vehicle.

By way of the distance signals of the sensors, the regulating device can generate control signals provided at least for the at least one actuator influencing an average distance of the boom in relation to the ground or the crop.

In order to preferably exclude influences of uneven mass distributions of the boom, the rotation axis preferentially runs through the centre of gravity of the boom.

The at least one boom can be arranged on the carrier vehicle permanently or so as to be exchangeable with another device for the agricultural soil and/or crop treatment.

Here, the carrier vehicle can be driven or pulled so that the device:

- in the case of a driven carrier vehicle with permanently arranged boom forms a self-propelled agricultural device or an agricultural self-propelled device,

- in the case of a pulled carrier vehicle with permanently arranged boom forms a pulled agricultural device, such as for example an agricultural trailer, and

- in the case of a driven carrier vehicle with a boom that is arranged interchangeably with another device for the agricultural soil and/or crop treatment for example on a three-point power lift or on a loading surface provided for this purpose, either forms an attachment device, or a superstructure device.

Advantages in addition to the already mentioned advantages in relation to the prior art are obtained through a complete solution of the set objective while eliminating all disadvantages of the prior art.

In addition it is reliably avoided by the exact maintaining of the distances of the outriggers in relation to the ground surface and/or the crop independently of the moving and/or rolling carrier vehicle that the outriggers come into ground contact.

A second object of the invention relates to a method for controlling a previously described device by way of a regulation of the angular position of the boom moveably arranged about a rotation axis on a carrier vehicle in dependence on a present angular position, wherein for determining the present angular position it is provided:

- to detect an angular velocity of the boom about the rotation axis in relation to a reference plane,

- to detect an angular position of the boom about the rotation axis in relation to the reference plane independently of the angular velocity,

- to calculate by time integration of the angular velocity the angular position of the boom in relation to the reference plane, by way of which on the one hand neither the carrier vehicle of the device, nor translational accelerations can interferingly influence the calculation of the angular position, but on the other hand measuring errors are likewise integrated and cause a drift of the angular position referred to as angular drift in the following, and

- to fuse the angular position of the boom calculated by way of the angular velocity for compensating for the angular drift with the detected angular position of the boom for determining the present angular position of the boom in relation to the reference plane.

By fusing the calculated measured angular position referred to as detected angular position, the present angular position in relation to the reference plane is very accurately determined, wherein only the advantages of the respective measuring methods are utilized without having to accept their disadvantages.

The method preferably provides, by way of the fusion of the angular position of the boom calculated by means of the angular velocity with the angular position of the boom detected independently of the angular velocity, in each case based on the reference plane, to generate, in each case based on the reference plane, a control signal returning the boom from its present angular position to a desired angular position in relation to the reference plane.

The method can provide to detect the angular velocity by way of an angular rate sensor arranged on the boom detecting the angular velocity of the boom.

For detecting the angular velocity, an angular rate sensor is employed here, which is directly mounted on the boom. Angular movements of the carrier vehicle thus have no influence on determining the angular velocity of the boom. An output signal of an angular rate sensor that is proportional to the measuring variable or reflecting the same thus corresponds to the angular movement of the boom based on any reference plane, for example based on the surface of the earth or orthogonally to the earth acceleration or a long-term orientation of the carrier vehicle reflecting an averaged ground profile.

This measuring variable or an output signal that is proportional to this measuring variable or reflects the same included in the control signal or control signals of an angular rate sensor detecting angular velocities of the boom can be used in order to obtain an active damping of the boom in the form of an actively induced braking moment.

Alternatively or additionally the method can provide to detect the angular velocity of the boom by way of an angular velocity of the carrier vehicle about the longitudinal axis of the same running parallel to the rotation axis accompanied by a relative rotation between carrier vehicle and boom, so that from the two measuring values angular velocity of the carrier vehicle in relation to the longitudinal axis of the same and relative rotation between carrier vehicle and boom the absolute angular velocity of the boom about the rotation axis can then be determined.

To this end it can be provided to arrange on the carrier vehicle of device an angular rate sensor in order to detect the angular velocity of the carrier vehicle about its longitudinal axis also referred to as yaw rate, and to provide an angle of rotation sensor or rotational angular velocity sensor between carrier vehicle and boom.

Alternatively or additionally it can be provided for this purpose to detect an angular acceleration and extract the angular velocity through time integration.

Alternatively or additionally it can be provided to detect translational accelerations in the region of the outriggers of the boom, preferentially at the opposite ends of the boom and by way of a difference of the translational accelerations at the opposite ends of the outriggers, initially calculate the angular acceleration of the boom and, by time integration, again the angular velocity.

Additionally or in place of the preceding exemplary embodiments including a detection of relative rotation between carrier vehicle and boom the method can additionally provide to detect relative rotation between carrier vehicle and boom by way of the difference between the angular position of the boom about the rotation axis in relation to the reference plane and the angular position of the carrier vehicle about the longitudinal axis of the same running parallel to the rotation axis in relation to the reference plane, wherein the difference of the angle detected by the sensors between the carrier vehicle and the reference plane and the angle between the boom and the reference plane is proportional to a relative rotation between carrier vehicle and boom. For detecting the angular position of the boom about the rotation axis in relation to the reference plane and the angular position of the carrier vehicle about the longitudinal axis of the same running parallel to the rotation axis in relation to the reference plane, tilt sensors detecting tilt angles between the boom and the vertical and/or the horizontal or between the carrier vehicle and the vertical and/or the horizontal can be provided in each case on the boom and on the carrier vehicle.

The method can provide to make reference by way of a fusion of the angular position of the boom calculated by means of a detected angular velocity with a calculated and/or detected relative rotation between carrier vehicle and boom, to a reference plane corresponding to a long-term orientation of the carrier vehicle reflecting an averaged ground profile.

For detecting an angular position of the boom about the rotation axis in relation to the reference plane, the method can provide, for example by means of a tilt sensor, to detect a tilt angle reflecting an angle between the boom and the reference plane.

By fusing the angular position of the boom calculated by way of an angular velocity with an angular position of the boom detected by detecting an angle between the boom and the reference plane, reference can be made to a reference plane corresponding to an artificial horizon.

The method can provide, for determining the present angular position of the boom about the rotation axis in relation to the reference plane, to perform a Kalman filtering by fusing the angular position of the boom calculated by way of an angular velocity with the angular position of the boom detected directly or indirectly by difference formation.

Alternatively or additionally, the method can provide, for determining the present angular position of the boom about the rotation axis in relation to the reference plane by way of a fusion of the angular position of the boom calculated by way of an angular velocity with the angular position of the boom detected directly or indirectly by difference formation, to carry out a low-pass filtering of the detected angular position and a comparison of the low-pass filtered detected angular position subject to continuous zero balance with the angular position calculated by way of an angular velocity in order to compensate for the angular drift.

The method allows to make all advantages of the described device utilizable.

The method is suitable, besides usage in connection with a previously described device for spreading liquid and/or solid active agents, for use with any devices for agricultural soil and/or crop treatment, during which – be it for protecting the soil or the crop – equipment supported in relation to the ground is omitted and yet a highly accurate guidance in a predetermined angular position, for example vertically or parallel to the ground, is required.

Both the device and also the method can alternatively or additionally comprise individual features or a combination of multiple features described as introductory in conjunction with the prior art and/or mentioned in one or more of the documents mentioned regarding the prior art.

In addition to this, the device, alternatively or additionally, can have individual features or a combination of multiple features previously described in connection with the method; similarly, the method, alternatively or additionally, have individual features or a combination of multiple features previously described in conjunction with the device.

It is evident that the invention can be realized through a spray boom regulation by means of at least one inertial sensor such as for example an angular rate sensor, for example a gyroscope, which is provided on or in the spray boom and/or a part of a spray boom, for example a centre part. The inertial sensor detects an effective angular velocity of the spray boom and/or a part of a spray boom independently of a movement of the carrier vehicle. Based on the detected angular velocity an active damping and/or regulation takes place. By means of a time integral over the angular velocity, an actual twist angle referred to as angular position in relation to a reference plane can be calculated.

By means of an angle sensor, for example an angle of rotation encoder, the angular position of the spray boom and/or of a part of a spray boom in relation to the carrier vehicle is additionally detected, as a result of which the absolute rotation angle position of the spray boom or of a part of a spray boom to the carrier vehicle is determined.

By fusing the sensor data extracted by way of the output signals of the sensors, angular velocity or angular rate and absolute rotation angle position or angular position and corresponding filtering, for example by means of a Kalman filter, it is possible to guide the spray boom or the part of a spray boom provided with an inertial sensor with the carrier vehicle without high-frequency rolling movements disturbing the position and orientation of the spray boom or the part of a spray boom.

Alternatives to an angular rate sensor for example in the form of a gyroscope can be one or more angular acceleration sensors or symmetrically arranged angular acceleration sensors whose output signals are counterbalanced. When for example two symmetrically arranged angular acceleration sensors in different directions are provided, the angular acceleration in a direction can in each case be detected by way of the angular acceleration of the one and of the other angular acceleration sensor and calculated by a time integral over the detected angular acceleration, the angular velocity in the corresponding direction can be calculated.

In summary, the invention accordingly provides to base the actual position of the boom to a reference plane in order to be able to regulate the angular position of the boom or regulate the boom to a defined angle regardless of the movements of the carrier vehicle. This reference plane can be a horizontal plane running orthogonally to the earth acceleration, or a long-term orientation of the carrier vehicle.

For this purpose, the invention provides a fusion of two measuring signals extracted by way of measuring methods that are independent of one another, on the one hand a calculated angular position of the boom and on the other hand a measured or detected angular position of the boom into a fused control or measuring signal.

The fused measuring signal represents the present angular position of the boom based on a reference plane, corresponding to a rotation angle between the boom and the reference plane. Here, the reference plane preferentially corresponds to an artificial horizon or a long-term orientation of the carrier vehicle. The result is insensitive to rotational and translational movements of the carrier vehicle and is not subject to any angular drift. In addition to this, this fused measuring signal is not lagging in time to the actual angular movement either and thus excellently suitable for a regulation which not undesirably is coupled, in particular high-frequency coupled, to the carrier vehicle.

It is important to emphasize that the at least one pivotable arrangement of the boom on the carrier vehicle preferentially running parallel to the longitudinal axis of the carrier vehicle includes both at least one pivotable arrangement, preferentially running parallel to the longitudinal axis of the carrier vehicle, of a boom that is rigid within itself or articulated, and also at least one pivotable arrangement of two outriggers of a boom each being pivotably arranged on the carrier vehicle or on a boom centre part about dedicated rotation axes each preferentially running parallel to the longitudinal axis of the carrier vehicle.

The invention and its advantages are explained in more detail in the following by way of exemplary embodiments shown in the figures, wherein the application of liquid active agents does not fall within the scope of the patent claims. The size relationships of the individual elements in relation to one another do not always correspond to the real size relationships in the figures, since in the figures some forms are shown in simplified fashion and other forms for better illustration are shown in enlarged fashion in relation to other elements. Identical reference numbers are used for elements of the invention that are the same or have the same effect. Further, for the sake of clarity, only reference numbers are shown in the individual figures which are necessary for the description of the respective figure. The shown embodiments represent merely examples as to how the transfer gear according to the invention can be equipped and do not constitute any conclusive limitation. In a schematic representation:

Fig. 1 shows a perspective view of a device embodied as self-propelled field sprayer for spreading liquid and/or solid active agents,

Fig. 2 shows an isometric view of a boom of a device for spreading liquid and/or solid active agents,

Fig. 3 shows a perspective detailed view of an arrangement of a boom of a device for spreading liquid and/or solid active agents that is pivotable about a rotation axis preferentially running parallel to a longitudinal axis of the carrier vehicle,

Fig. 4 shows a front view of a boom of a device for spreading liquid and/or solid active agents,

Fig. 5 shows a detailed view of an arrangement of a boom of a device for spreading liquid and/or solid active agents that is pivotable about a rotation axis preferentially running parallel to a longitudinal axis of the carrier vehicle in a front view,

Fig. 6 shows a detailed view of a part of a device for spreading liquid and/or solid active agents of an arrangement of a boom of a device for spreading liquid and/or solid active agents that is pivotable about a rotation axis preferentially running parallel to a longitudinal axis of the carrier vehicle in a perspective view,

Fig. 7 shows a first exemplary embodiment of a sequence of determining a present angular position of the boom in relation to a reference plane according to a method for controlling a device for spreading liquid and/or solid active agents by way of a regulation of the angular position of the boom of the device moveably arranged about a rotation axis on a carrier vehicle in dependence on a present angular position,

Fig. 8 shows a second exemplary embodiment of a sequence of determining a present angular position of the boom in relation to a reference plane according to a method for controlling a device for spreading liquid and/or solid active agents by way of a regulation of the angular position of the boom of the device moveably arranged about a rotation axis on a carrier vehicle in dependence on a present angular position.

A device 01 shown wholly or in parts in Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5, Fig. 6 for spreading liquid and/or solid active agents includes:

- a carrier vehicle 10,

- at least one boom 02 that is pivotably arranged about a rotation axis 20 preferentially running parallel to a longitudinal axis of the carrier vehicle 10, such as for example a spray boom, having outriggers 21, 22 projecting on both sides of the carrier vehicle 10 and spreading means arranged on the same and connected and/or connectable to a reservoir 11 for at least one liquid and/or solid active agent, such as for example spray nozzles connected and/or connectable to a spraying agent tank,

- at least one sensor arrangement for detecting an angular velocity of the boom or of parts of the boom 02, such as for example the outriggers 21, 22 of the same about the at least one rotation axis 20 in relation to a reference plane,

- at least one sensor arrangement for detecting an angular position of the boom 02 about the rotation axis 20 in relation to the reference plane,

- a regulating device processing output signals of the sensor arrangements into control signals,

- at least one actuator 03, also referred to as actuator, influencing the angular position of the boom 02 about the rotation axis in relation to the carrier vehicle 10 in dependence on control signals of the regulating device, for example in the form of one or more hydraulic cylinders, which converts control signals into mechanical motion or another physical quantity such as for example pressure and thereby generates a force exerting a torque on the boom 02 or a force couple exerting a torque on the boom 02,

wherein the regulating device for determining an angular position of the boom 02 calculates an angular position of the boom 02 about the rotation axis 20 in relation to an initial orientation corresponding for example with the reference plane:

- through time integration of the angular velocity w calculates the angular position alpha2 of the boom 02 in relation to the reference plane, as a result of which on the one hand neither the carrier vehicle 10 nor translational accelerations interferingly influence the calculation of the angular position, but on the other hand measuring errors are likewise integrated and cause a drift of the angular position referred to as angular drift, and

- fuses the angular position alpha2 calculated by way of the angular velocity w of the boom 02 for compensating for the angular drift with the detected angular position alpha1 or d_alpha1 of the boom 02 for determining the present angular position of the boom 02 in relation to the reference plane, in order to generate from this a control signal returning the boom 02 from its present angular position into a desired angular position in relation to the reference plane.

The at least one sensor arrangement for detecting an angular velocity w of the boom 02 or of parts of the boom 02, such as for example the outriggers 21, 22 of the same with reference to a reference plane can include one or more angular rate sensors 25, 26 arranged on the boom 02, detecting the angular velocity w of the boom 02 or of parts of the boom 02, such as for example the outriggers 21, 22 of the same about the at least one rotation axis 20.

For detecting the angular velocity, at least one angular rate sensor 25, 26 is preferentially employed here, which is directly mounted on the boom 02, or the centre part of the same, or on a part of the boom 02 pivotably arranged about a dedicated rotation axis 20, such as for example an outrigger 21, 22 of the boom 02 pivotably arranged about a dedicated rotation axis 20. Thus, angular movements of the carrier vehicle 10 have no influence on determining the angular velocity of the boom 02 or of the angular velocities of parts of the boom 02. An output signal that is proportional to or reflecting the measuring variable of an angular rate sensor 25, 26 thus corresponds to the angular movement of the boom 02 or of a part of the boom 02 formed for example by an outrigger 21, 22 based on any reference plane, for example based on the earth surface or orthogonally to the earth acceleration or a long-term orientation of the carrier vehicle 10 reflecting an averaged ground profile.

This measuring variable or an output signal that is proportional to or reflecting the same serving as input variable of the regulating device being included in the control signals to the actuator or actuators 03 of an angular rate sensor 25, 26 detecting angular velocities of the boom 02 or of parts of the boom 02 formed by the outriggers 21, 22 can be used in order to obtain an active damping of the boom 02 in the form of an actively induced braking moment.

The at least one sensor arrangement for detecting an angular velocity of the boom 02 or of parts of the boom 02, such as for example the outriggers 21, 22 of the same about at least one rotation axis 20 with reference to a reference plane, can include at least two acceleration sensors 27, 28 arranged in the region of the outriggers 21, 22 of the boom 20, for example at their ends 23, 24. The output signals of these reflect the translational accelerations at the ends 23, 24 of the outriggers 21, 22. The difference of the output signals of two acceleration sensors 27, 28 arranged at the opposite ends 23, 24 of the outriggers 21, 22 multiplied by the working and/or boom width or by the distance between the two acceleration sensors 27, 28 produces the angular accelerations by way of which through the time integration of the same the angular velocity is again obtained.

The at least one sensor arrangement for detecting an angular velocity of the boom 02 or of parts of the boom 02, such as for example the outriggers 21, 22 of the same about at least one rotation axis 20 in relation to a reference plane can alternatively include at least one angular rate sensor also referred to as rotational angular velocity sensor arranged on the carrier vehicle 10, in order to measure angular velocities of the carrier vehicle 10 at least about the longitudinal axis of the same running parallel to the at least one rotation axis 20 and thereby angular movements of the carrier vehicle 10 representing interference movements. Here, the at least one sensor arrangement for detecting an angular velocity of the boom 02 about the rotation axis with reference to a reference plane preferentially includes additionally at least one angle of rotation sensor or rotational angular velocity sensor detecting a relative rotation between carrier vehicle 10 and boom 02 or between carrier vehicle 10 and for example parts of the boom 02 formed by the outriggers 21, 22, so that, out of the two measuring values, angular velocity of the carrier vehicle 10 in relation to its longitudinal axis and relative rotation between carrier vehicle 10 and boom 02 or between carrier vehicle 10 and for example parts of the boom 02 formed by the outriggers 21, 22, the absolute angular velocity of the boom 02 or of parts of the boom 02 formed for example by the outriggers 21, 22 about the respective at least one rotation axis 20 can be determined. By way of an angle of rotation sensor, the relative rotation between carrier vehicle 10 and boom 02, or of parts of the boom 02 formed for example by outriggers 21, 22 each pivotably arranged about dedicated rotation axes on the carrier vehicle 10 is directly detected, whereas by way of a rotational angular velocity sensor the relative rotation between carrier vehicle 10 and boom 02 or of parts of the boom 02 formed for example by outriggers 21, 22 which are each pivotably arranged about dedicated rotation axes on the carrier vehicle 10 is indirectly detected by time integration of the angular velocity.

The at least one sensor arrangement for detecting an angular velocity of the boom 02 or of parts of the boom 02, such as for example the outriggers 21, 22 of the same, about at least one rotation axis in relation to a reference plane includes an angular acceleration sensor in place of or in addition to an angle of rotation sensor. Through time integration of the output signal of the same, a dimension for the angular velocity can be extracted.

The at least one sensor arrangement for detecting an angular position of the boom 02 or of parts of the boom 02, such as for example the outriggers 21, 22 of the same, about the at least one rotation axis 20 in relation to the reference plane, can include at least one sensor detecting a relative rotation between carrier vehicle 10 and boom 02 or between carrier vehicle 10 and parts of the boom 02, such as for example the outriggers 21, 22 of the same based on the at least one rotation axis 20.

The at least one sensor for detecting a relative rotation between carrier vehicle 10 and boom 02 or between carrier vehicle 10 and parts of the boom 02, such as for example the outriggers 21, 22 of the same, can include:

- at least one angle of rotation sensor arranged between the boom 02 or parts of the boom 02, such as for example the outriggers 21, 22 of the same and the carrier vehicle 10 and/or

- at least one tilt sensor detecting an angle between the carrier vehicle 10 and the reference plane and at least one tilt sensor detecting an angle between the boom 02 or of parts of the boom 02, such as for example the outriggers 21, 22 of the same, and the reference plane.

Here, the difference of the angle detected by the tilt sensors between the carrier vehicle 10 and the reference plane and the angle between the boom 02 or parts of the boom 02, such as for example the outriggers 21, 22 of the same, and the reference plane, is proportional to a relative rotation between carrier vehicle 10 and boom 02 or to a relative rotation between carrier vehicle 10 and parts of the boom 02, such as for example the outriggers 21, 22 of the same arranged pivotably about dedicated rotation axes 20.

By way of fusing the angular position alpha2 of the boom 02 calculated by way of a sensorially detected angular velocity w or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same, with a relative rotation d_alpha1 detected directly by means of an angle of rotation sensor or indirectly sensorially detected through difference formation of the tilt alpha_g of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same and the tilt alpha_t of the carrier vehicle 10 in relation to the reference plane, between carrier vehicle 10 and boom 02 or between carrier vehicle 10 and parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same, reference can be made to a reference plane corresponding to a long-term orientation of the carrier vehicle 10 and reflecting an averaged ground profile.

The at least one sensor arrangement for detecting an angular position of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same, about the rotation axis 20 in relation to the reference plane can include at least one tilt sensor detecting an angle alpha_g between the boom 02 or parts of the boom 02 arranged pivotably about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same, and the reference plane.

By way of fusing the angular position alpha2 of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20 such as for example the outriggers 21, 22 of the same calculated by means of an angular velocity w, with an angular position alpha1 of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same detected by detecting an angle alpha between the boom 02 and the reference plane or between parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22 and the reference plane, reference can be made to a reference plane corresponding to an artificial horizon.

For determining the present angular position of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same, about the at least one rotation axis 20 in relation to the reference plane by fusing the angular position of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same calculated by way of a rotation velocity, with the angular position of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same directly or indirectly sensorially detected through difference formation, the regulating device can:

- include means carrying out a Kalman filtering, and/or
- include means for low-pass filtering of the sensorially detected angular position and means for comparing the low-pass filtered sensorially detected angular position subject to continuous zero balance with the angular position calculated by way of an angular velocity in order to compensate for the angular drift.

By means of at least one actuator 03 including for example at least one hydraulic cylinder the regulating device regulates and/or controls the angular position of the boom 02 or of parts of the boom 02 arranged pivotably about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same, about the at least one rotation axis 20 along the travelling direction of the carrier vehicle 10. Basically, instead of the hydraulic cylinders, other suitable actuators 03 can be employed at any time, for example pneumatic, electromechanical or electro-motoric actuators 03 or final control elements.

The regulating device allows an automatic operating state during which the actuator 03 in order to adjust the angular position of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same, in relation to the reference plane.

The invention allows a very exact determination of a present angular position of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same based on a reference plane. Compared with determining the angular position by way of multiple ultrasound sensors, this is less complex and cost-intensive.

The at least one boom 02 can be permanently arranged on the carrier vehicle 10 or so as to be interchangeable against another device for the agricultural soil and/or crop treatment.

Here, the carrier vehicle 10 can be driven or pulled so that the device 01:

- in the case of a driven carrier vehicle 10 with permanently arranged boom 02 forms a self-propelled agricultural device or an agricultural self-propelled device,

- in the case of a pulled carrier vehicle 10 with permanently arranged boom 02 forms a pulled agricultural device, such as for example an agricultural trailer, and

- in the case of a driven carrier vehicle 10 forms either an attachment device or an infrastructure device with a boom 02 that is arranged in a manner interchangeable with another device for the agricultural soil and/or crop treatment for example on a three-point power lift or on a loading surface provided for this purpose.

The device 01 allows carrying out a method for the control of the same by way of a regulation of the angular position of the boom 02 moveably arranged about a rotation axis 20 on a carrier vehicle 10 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22 in dependence on a present angular position.

For determining the present angular position shown in different exemplary embodiments in Fig. 7 and in Fig. 8 it is provided here:

- to detect an angular velocity w of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22, about the at least one rotation axis 20 in relation to a reference plane,

- to detect preferably independently of the angular velocity w an angular position alpha1 or d_alpha1 of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22, about the at least one rotation axis 20 in relation to the reference plane,

- to calculate through time integration of the detected angular velocity w the angular position alpha2 of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22, in relation to the reference plane, as a result of which on the one hand neither the carrier vehicle 10 of the device 01 nor translational accelerations interferingly influence the calculation of the angular position, but on the other hand measuring errors are likewise integrated and cause a drift of the angular position alpha1 or d_alpha1 referred to as angular drift, and

- to fuse the angular position alpha2 of the boom calculated by way of the angular velocity w for compensating for the angular drift with the detected angular position alpha1 or d_alpha1 of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22, for determining the present angular position alpha0 of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22, in relation to the reference plane.

By fusing the calculated angular position alpha2 with the measured angular position alpha1 or d_alpha1 referred to as detected angular position, the present angular position in relation to the reference plane is very accurately determined, wherein only the advantages of the respective measuring methods are utilized without having to accept their disadvantages.

By fusing the angular position alpha2 of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same calculated by means of the angular velocity w, with the angular position alpha1 or d_alpha1 of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same detected independently of the angular velocity w, in each case based on the reference plane, a control signal returning the boom 02 or parts of the boom 02 pivotably arranged about dedicated rotation axes 20 such as for example its outriggers 21, 22, from the present angular position alpha0 of the same into a desired angular position in relation to the reference plane can be generated.

According to the invention, the angular velocity w can be detected in multiple ways and manners.

For example, the angular velocity w can be detected by way of at least one angular rate sensor 25, 26 that is pivotably arranged on the boom 02 or on parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same detecting the angular velocity of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same.

Accordingly, an angular rate sensor 25, 26 can be employed for detecting the angular velocity w, which is mounted directly on the boom 02 or on parts of the boom 02 that are pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22. Angular movements of the carrier vehicle 10 thus have no influence on determining the angular velocity w of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22. Thus, an output signal of an angular rate sensor 25, 26 that is proportional to or reflects the measuring variable corresponds to the angular movement of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same, based on any reference plane, for example based on the earth surface or orthogonally to the earth acceleration or a long-term orientation of the carrier vehicle 10 reflecting an averaged ground profile.

This measuring variable or an output signal that is proportional to or reflects this measuring variable being included in the control signal or control signals of at least one angular rate sensor 25, 26 detecting angular velocities of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22 can be used in order to obtain an active damping of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22, in the form of an actively induced braking moment.

Alternatively or additionally, the angular velocity w can be detected by way of an angular velocity of the carrier vehicle 10 about the longitudinal axis of the same running parallel to the rotation axis 20 and a relative rotation between carrier vehicle 10 and boom 02 or between carrier vehicle 10 and parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22, so that, from the two measuring values, angular velocity of the carrier vehicle 10 in relation to its longitudinal axis and relative rotation between carrier vehicle 10 and boom 02 or relative rotation between carrier vehicle 10 and parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same, the absolute angular velocity w of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same, about the at least one rotation axis 20 can then be determined.

In order to detect the angular velocity w of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same, by way of an angular velocity of the carrier vehicle 10 about the longitudinal axis of the same running parallel to the rotation axis 20 and by way of a relative rotation d_alpha1 between carrier vehicle 10 and boom 02 or by way of one or more relative rotations d_alpha1 between carrier vehicle 10 and parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example the outriggers 21, 22 of the same, it can be provided to arrange an angle of rotation sensor on the carrier vehicle 10 of the device 01 in order to detect the angular velocity of the carrier vehicle 10 about its longitudinal axis also referred to as roll rate, and to provide an angle of rotation sensor or rotational angular velocity sensor between carrier vehicle 10 and boom 02 or an angle of rotation sensor or rotational angular velocity sensor each between carrier vehicle 10 and parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22.

Alternatively or additionally, the angular velocity w can be detected by way of a time integration of an angular acceleration and/or by way of a time integration of an angular acceleration determined by means of translational accelerations.

For example, in order to detect the angular velocity w, translational accelerations in the region of the outriggers 21, 22 of the boom 02, preferentially at the opposite ends 23, 24 of the outriggers 21, 22, can be detected and by way of a difference of the translational accelerations at the opposite ends 23, 24 of the outriggers 21, 22, knowing the boom width also referred to as working width, initially the angular acceleration of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22 and through time integration in turn the angular velocity w can be calculated.

The angular position alpha1 of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22 about the at least one rotation axis 20 in relation to the reference plane, can be detected by way of a tilt angle alpha between the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22 and the horizontal or vertical (Fig. 8).

The relative rotation d_alpha1 between carrier vehicle 10 and boom 02 or between carrier vehicle and parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22, can be for example detected directly by way of a twist angle d_alpha1 between boom 02 and carrier vehicle 10 or indirectly by way of the difference between the angular position alpha_g of the boom 02 about the rotation axis 20 with regard to the reference plane and the angular position alpha_t of the carrier vehicle 10 about its longitudinal axis running parallel to the rotation axis 20 in relation to the reference plane. The difference of the angle d_alpha1 detected by the sensors between the carrier vehicle 10 and the reference plane and of the angle between the boom and the reference plane is proportional to a relative rotation d_alpha1 between carrier vehicle 10 and boom 02. This relative rotation d_alpha1 corresponds to a tilt of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22 in relation to a reference plane formed by the carrier vehicle 10, for example the long-term orientation of the same. For detecting the angular position alpha_g of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22, about the at least one rotation axis 20 in relation to the reference plane and the angular position alpha_t of the carrier vehicle 10 about the longitudinal axis running parallel to the at least one rotation axis 20 of the same in relation to the reference plane, tilt angle sensors detecting tilt angle alpha_g between the boom 02 and the vertical and/or the horizontal or tilt angles alpha_t between the carrier vehicle 10 and the vertical and/or the horizontal each can be provided on the boom 02 and on the carrier vehicle 10 (Fig. 7).

For the direct detection of the relative rotation d_alpha1, an angle of rotation sensor can be provided between boom 02 or parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22 and carrier vehicle 10.

By fusing the angular position alpha2 of the boom 02 or parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22 calculated by means of a detected angular velocity w, with a calculated and/or detected relative rotation d_alpha1 between carrier vehicle 10 and boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22, reference is made to a reference plane corresponding to a long-term orientation of the carrier vehicle 10 and reflecting an averaged ground profile.

By fusing the angular position alpha2 of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22 calculated by means of a detected angular velocity w, with an angular position alpha1 of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20 such as for example its outriggers 21, 22 detected by detecting an angle alpha between the boom 02 or parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22 and the reference plane, reference is made to a reference plane corresponding to an artificial horizon.

For determining the present angular position alpha0 of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22, about the at least one rotation axis 20 in relation to the reference plane by way of fusing the angular position alpha2 of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22 calculated by way of an angular velocity w, with the angular position alpha1 or d_alpha1 of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22 detected directly or indirectly through difference formation, it is preferentially provided to carry out a Kalman filtering and/or – in order to compensate for the angular drift – a low-pass filtering of the detected angular position alpha1 or d_alpha1 and a comparison of the low-pass filtered detected angular position alpha1 or d_alpha1 subject to continuous zero balance with the angular position alpha2 calculated by way of an angular velocity w.

For detecting the angular velocity w, at least one angular rate sensor 25, 26 is preferably employed here, which is mounted directly on the boom 02 such as for example on its centre part or on parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22. Thus, angular movements of the carrier vehicle 10 have no influence on determining the angular velocity w of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22. An output signal that is proportional to or reflecting the measuring variable thus corresponds to the angular movement of the boom 02 or of parts of the boom 02 pivotably arranged about dedicated rotation axes 20, such as for example its outriggers 21, 22 based on any reference plane, for example based on the earth surface or orthogonally to the earth acceleration.

It is important to mention that for determining the angular velocity w an angular rate sensor 25, 26 is preferentially employed, which is directly mounted on the boom 02. Because of this, angular movements of the carrier vehicle 10 have no influence on the measurement. Thus, the measuring variable of these corresponds to the angular movement of the boom based on the earth surface or orthogonally to the earth acceleration.

The invention also includes an angular rate sensor 25, 26 on a carrier vehicle 10 for measuring the angular movements (interference movements) of the carrier vehicle, wherein in addition the relative rotation d_alpha1 between carrier vehicle 10 and a boom 02 preferentially formed as spray boom can be determined by an angle sensor referred to as angle of rotation encoder or sensor or an angular velocity sensor referred to as angular rate encoder or sensor, wherein from both measuring values the absolute angular velocity w of the spray boom can be determined.

Accordingly, the invention also includes a carrier vehicle 10 with a boom 02 and an angular rate sensor 25, 26 mounted thereon.

The invention is commercially applicable in particular in the region of the manufacture of agricultural devices for spreading solid active agents.

The invention was described making reference to a preferred embodiment. However, it is conceivable for a person skilled in the art that modifications or changes to the invention can be made without leaving the scope of protection of the following claims.

Patentkrav

1. Anordning (01) til udbringning af faste virksomme stoffer, omfattende:

- et trækkende køretøj (10),
- mindst en bom (02, 21, 22) fastgjort drejeligt om i det mindste en rotationsakse (20), med udkragninger, der rager ud på begge sider af det trækkende køretøj, samt udbringningsmidler, der er anbragt ved den mindst ene bom, og som er forbundet og/eller kan forbindes med et reservoir til mindst et fast stof, hvori rotationsaksen (20) er en rotationsakse, der løber parallelt med en længdeakse på det trækkende køretøj,
- mindst en sensorindretning (25, 26) til registrering af en rotationshastighed (w) og/eller acceleration af bommen (02, 21, 22) om rotationsaksen (20) i forhold til et referenceplan,
- mindst en sensorindretning til registrering af en rotationsposition (alpha1, d_alpha1) af bommen (02, 21, 22) om rotationsaksen (20) i forhold til referenceplanet,
- mindst en sensorindretning til registrering af mindst en gennemsnitsafstand af bommen i forhold til jorden;
- en reguleringsenhed, som forarbejder udgangssignaler (alpha0) fra sensorindretningerne til styringssignaler,
- i det mindste en aktuator (03), som afhængigt af styringssignaler fra reguleringsenheden påvirker bommens (02, 21, 22) aktuelle rotationsposition (alpha0) om rotationsaksen (20),

hvilken aktuator konverterer styringssignaler til mekanisk bevægelse eller en anden fysisk størrelse, hvormed der genereres en kraft, der udøver et drejningsmoment på bommen (02, 21, 22), eller et kraftpar, der udøver et drejningsmoment på bommen (02, 21, 22), og

hvor reguleringsenheden til bestemmelse af en rotationsposition (alpha0) af bommen (02, 21, 22) om rotationsaksen (20) i forhold til en starthældning:

- ved hjælp af tidsmæssig integration af rotationshastigheden (w) beregner i det mindste en rotationsposition (alpha2) af bommen (02, 21, 22) i forhold til referenceplanet.

2. Anordning ifølge krav 1, ved hvilken reguleringsenheden fusionerer den rotationsposition (alpha2), som er beregnet ved hjælp af rotationshastigheden (w), med den registrerede rotationsposition (alpha1, d_alpha1) til bestemmelse af den aktuelle rotationsposition (alpha0) af bommen (02, 21, 22) i forhold til referenceplanet,

for heraf at generere et styringssignal, der fører bommen (02, 21, 22) fra sin aktuelle rotationsposition (alpha0) tilbage til en ønsket rotationsposition i forhold til referenceplanet.

3. Anordning ifølge krav 1 eller 2, hvor den mindst ene sensorindretning til registrering af en rotationshastighed (w) af bommen (02, 21, 22) om rotationsaksen (20) i forhold til et referenceplan omfatter mindst en rotationshastighedssensor (25, 26) anbragt på bommen (02, 21, 22).

4. Anordning ifølge et af kravene 1 til 3, hvor den mindst ene sensorindretning til registrering af en rotationshastighed (w) af bommen (02, 21, 22) om rotationsaksen (20) i forhold til et referenceplan omfatter mindst en accelerationssensor (27, 28) anbragt i mindst et endeområde (23, 24) af bommen (02, 21, 22).

5. Anordning ifølge et af kravene 1 til 4, hvor den mindst ene sensorindretning til registrering af en rotationshastighed (w) af det trækkende køretøj (10) om rotationsaksen (20) i forhold til et referenceplan omfatter mindst en rotationshastighedssensor anbragt på det trækkende køretøj (10); og/eller
hvor den registrerede rotationshastighed (w) af bommen (02, 21, 22) om rotationsaksen (20), der som reguleringsenhedens inputstørrelse indgår i styringssignalet på den mindst ene aktuator, anvendes for at opnå en aktiv dæmpning af bommen (02) i form af et aktivt overført bremsemoment.

6. Anordning ifølge krav 5, hvor den mindst ene sensorindretning til registrering af en rotationshastighed (w) af bommen (02, 21, 22) om rotationsaksen (20) i forhold til et referenceplan omfatter mindst en rotationsvinkelsensor eller rotationsvinkelhastighedssensor, der registrerer en relativ rotation (d_alpha1) mellem det trækkende køretøj (10) og bommen (02, 21, 22).

7. Anordning ifølge et af kravene 4 til 6, hvor den mindst ene sensorindretning til registrering af en rotationshastighed (w) af bommen (02, 21, 22) om rotationsaksen (20) i forhold til et referenceplan omfatter en rotationsaccelerationssensor i stedet for eller i tillæg til en rotationshastighedssensor (25, 26).

8. Anordning ifølge et af de foregående krav, hvor den mindst ene sensorindretning til registrering af en rotationsposition (alpha1, d_alpha1) af bommen om rotationsaksen (20) i forhold til referenceplanet omfatter mindst en sensor, der registrerer en relativ rotation (d_alpha1) mellem det trækkende køretøj (10) og bommen (02,

21, 22).

9. Anordning ifølge krav 8, hvor den mindst ene sensor til registrering af en relativ rotation (d_alpha1) mellem det trækkende køretøj (10) og bommen (02, 21, 22) omfatter:

- mindst en rotationsvinkelsensor anbragt mellem bommen (02, 21, 22) og det trækkende køretøj (10) og/eller
- mindst en hældningssensor, der registrerer en vinkel (alpha_t) mellem det trækkende køretøj (10) og referenceplanet, og i det mindste en hældningssensor, der registrerer en vinkel (alpha_g) mellem bommen (02, 21, 22) og referenceplanet.

10. Anordning ifølge et af de foregående krav, hvor den mindst ene sensorindretning til registrering af en rotationsposition (alpha1, d_alpha1) af bommen (02, 21, 22) om rotationsaksen (20) i forhold til referenceplanet i det mindste omfatter en hældningssensor, der registrerer en vinkel (alpha) mellem bommen (02, 21, 22) og referenceplanet.

11. Anordning ifølge et af de foregående krav, hvor reguleringsenheden:

- omfatter midler, der udfører en Kalman-filtrering, og/eller
- omfatter midler til lavpasfiltrering af den sensorregistrerede rotationsposition (alpha1, d_alpha1) samt midler til sammenligning af den lavpasfiltrerede sensorregistrerede rotationsposition (alpha1, d_alpha1), ved permanent justering til nul, med rotationspositionen (alpha2) beregnet ved hjælp af en rotationshastighed (w).

12. Fremgangsmåde til styring af en anordning ifølge et af kravene 1 til 11 ved hjælp af en regulering af rotationspositionen af bommen (02, 21, 22) anbragt bevægeligt om en rotationsakse (20) på et trækkende køretøj (10) afhængigt af en aktuel rotationsposition (alpha0), med udkragninger, der rager ud på begge sider af det trækkende køretøj, samt udbringningsmidler, der er anbragt ved den mindst ene bom, og som er forbundet og/eller kan forbindes med et reservoir til mindst et fast stof, hvori rotationsaksen (20) er en rotationsakse, der løber parallelt med en længdeakse på det trækkende køretøj, hvor det til bestemmelse af den aktuelle rotationsposition (alpha0) er tilvejebragt:

- at registrere en rotationshastighed (w) af bommen (02, 21, 22) om rotationsaksen (20) i forhold til et referenceplan,

- at registrere en rotationsposition (alpha1, d_alpha1) af bommen (02, 21, 22) om rotationsaksen (20) i forhold til referenceplanet,

- hvor styresignaler konverteres til mekanisk bevægelse eller en anden fysisk størrelse, og der dermed genereres en kraft, der udøver et drejningsmoment på bommen (02, 21, 22), eller et kraftpar, der udøver et drejningsmoment på bommen (02, 21, 22); hvor det til bestemmelse af den aktuelle rotationsposition (alpha0) er tilvejebragt:

- ved hjælp af tidsmæssig integration af rotationshastigheden (w) at beregne en rotationsposition (alpha2) af bommen (02, 21, 22) i forhold til referenceplanet.

13. Fremgangsmåde ifølge krav 12, hvor det til bestemmelse af den aktuelle rotationsposition (alpha0) er tilvejebragt:

- at fusionere den rotationsposition (alpha2) af bommen (02, 21, 22), som er beregnet ved hjælp af rotationshastigheden (w), med den registrerede rotationsposition (alpha1, d_alpha1) af bommen (02, 21, 22) til bestemmelse af den aktuelle rotationsposition (alpha0) af bommen (02, 21, 22) i forhold til referenceplanet.

14. Fremgangsmåde ifølge krav 12 eller 13, hvor der ved hjælp af fusionen af rotationspositionen (alpha2) af bommen (02, 21, 22), beregnet ved hjælp af rotationshastigheden (w), med den registrerede rotationsposition (alpha1, d_alpha1) af bommen (02, 21, 22), hver i forhold til referenceplanet, genereres et styringssignal, der fører bommen (02, 21, 22) fra sin aktuelle rotationsposition (alpha0) tilbage til en ønsket rotationsposition i forhold til referenceplanet.

15. Fremgangsmåde ifølge et af kravene 12 til 14, hvor:

- rotationshastigheden (w) registreres ved hjælp af mindst en rotationshastighedssensor (25, 26) anbragt på bommen (02, 21, 22), og/eller

- hvor den registrerede rotationshastighed (w) af bommen (02, 21, 22) om rotationsaksen (20), der som reguleringsenhedens inputstørrelse indgår i styringssignalet på den mindst ene aktuator, anvendes for at opnå en aktiv dæmpning af bommen (02) i form af et aktivt overført bremsemoment; og/eller

- rotationshastigheden (w) af bommen (02, 21, 22) registreres ved hjælp af en rotationshastighed af det trækkende køretøj (10) om den længdeakse, der forløber parallelt med rotationsaksen (20), og ved hjælp af en relativ rotation (d_alpha1) mellem det trækkende køretøj (10) og bommen (02, 21, 22), og/eller
- rotationshastigheden (w) registreres ved hjælp af en tidsmæssig integration af en rotationsacceleration, og/eller
- rotationshastigheden (w) registreres ved hjælp af en tidsmæssig integration af en rotationsacceleration bestemt ved hjælp af translatoriske accelerationer (25, 26), og/eller
- rotationspositionen (alpha1) af bommen (02, 21, 22) om rotationsaksen (20) i forhold til referenceplanet registreres ved hjælp af en hældningsvinkel (alpha) mellem bommen (02, 21, 22) og det horisontale eller vertikale plan.

16. Fremgangsmåde ifølge et af kravene 12 til 15, hvor:
- der ved hjælp af en fusion af rotationspositionen (alpha2) af bommen (02, 21, 22), beregnet ved hjælp af en registreret rotationshastighed (w), med en relativ rotation mellem det trækkende køretøj (10) og bommen (02, 21, 22) tages højde for et referenceplan, der svarer til en langvarig orientering af det trækkende køretøj (10),

eller
- der ved hjælp af en fusion af rotationspositionen (alpha2) af bommen, beregnet ved hjælp af en registreret rotationshastighed (w), med en registreret rotationsposition (alpha1) af bommen (02, 21, 22) beregnet ved registrering af en vinkel (alpha) mellem bommen (02, 21, 22) og referenceplanet tages højde for et referenceplan, der svarer til en kunstig horisont.

17. Fremgangsmåde ifølge et af kravene 12 til 16, hvor der til bestemmelse af den aktuelle rotationsposition (alpha0) af bommen (02, 21, 22) om rotationsaksen (20) i forhold til referenceplanet ved hjælp af en fusion af rotationspositionen (alpha2) af bommen (02, 21, 22), beregnet ved hjælp af en rotationshastighed (w), med rotationspositionen (alpha1, d_alpha1) af bommen (02, 21, 22) registreret direkte eller indirekte ved differensdannelse:
- udføres en Kalman-filtrering

og/eller

- en lavpasfiltrering af den registrerede rotationsposition (alpha1, d_alpha1) samt en sammenligning af den lavpasfiltrerede registrerede rotationsposition (alpha1, d_alpha1), ved permanent justering til nul, med en rotationsposition (alpha2) beregnet ved hjælp af en rotationshastighed (w).

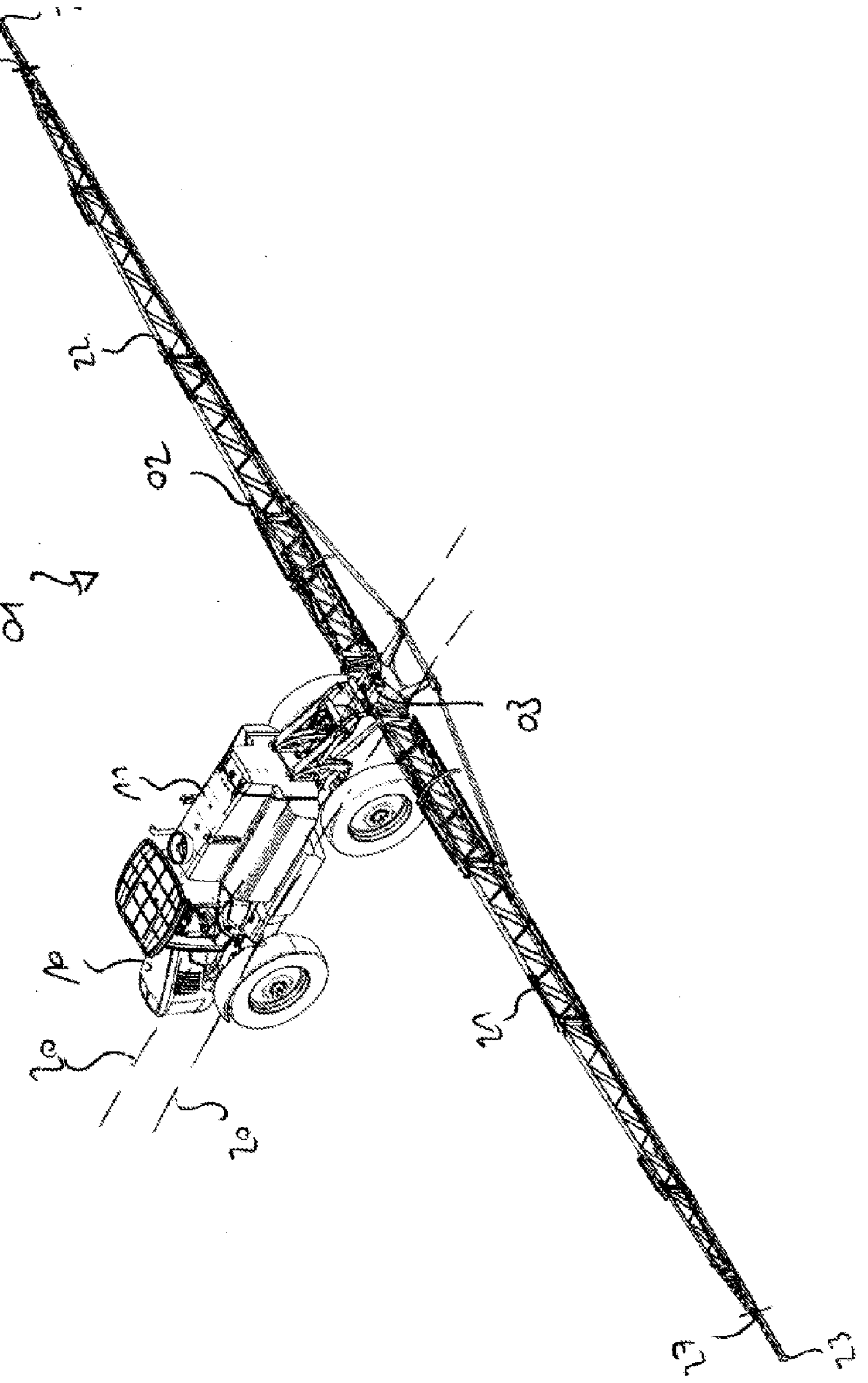


Fig. 1

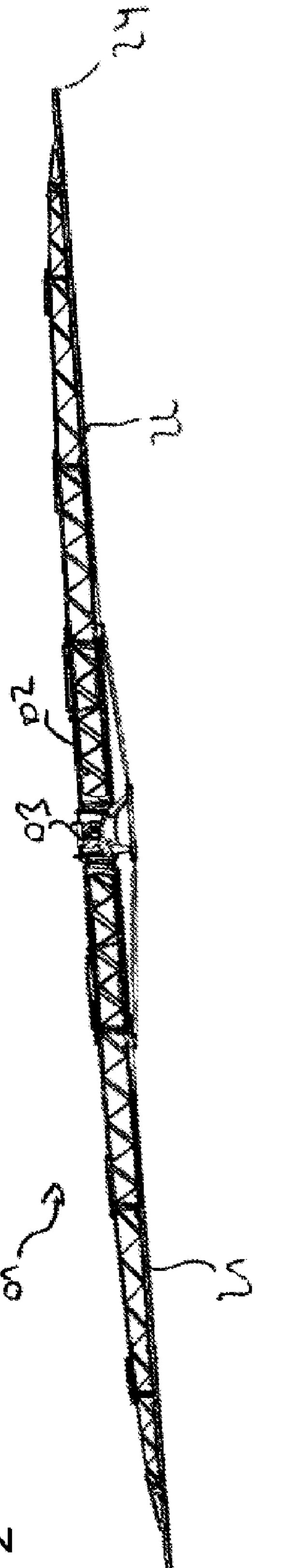


Fig. 2

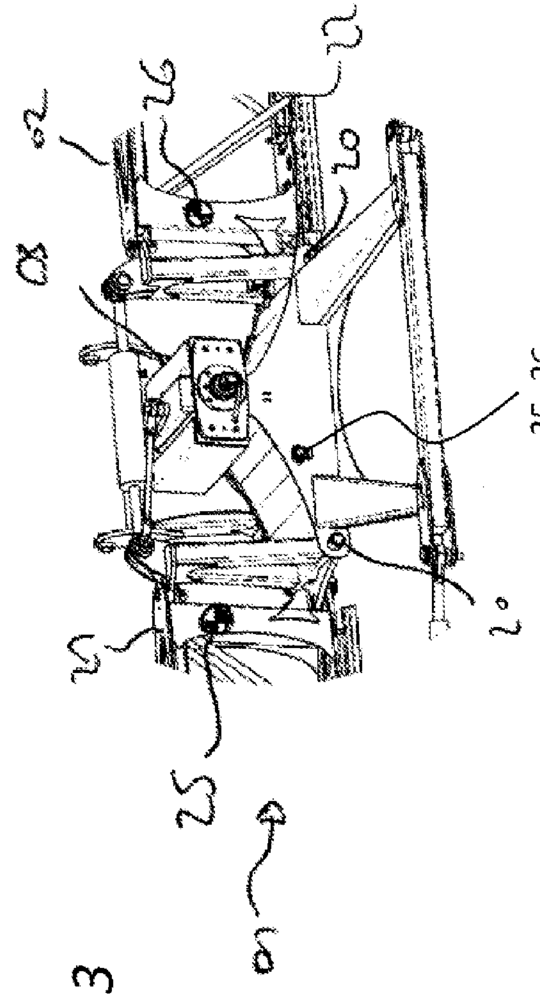


Fig. 3

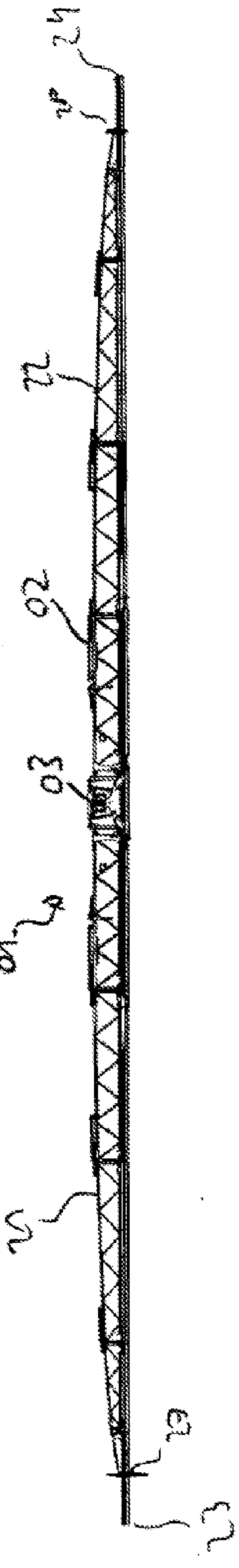


Fig. 4

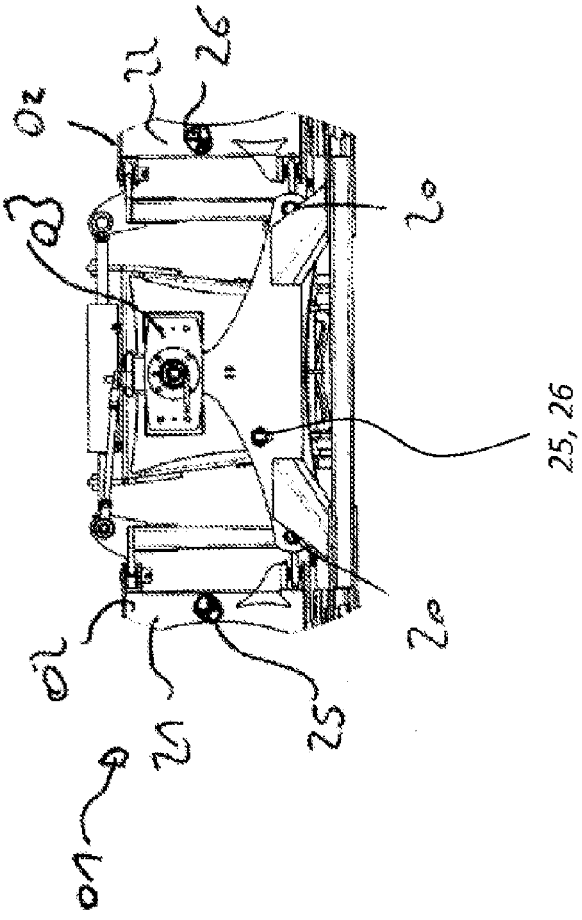


Fig. 5

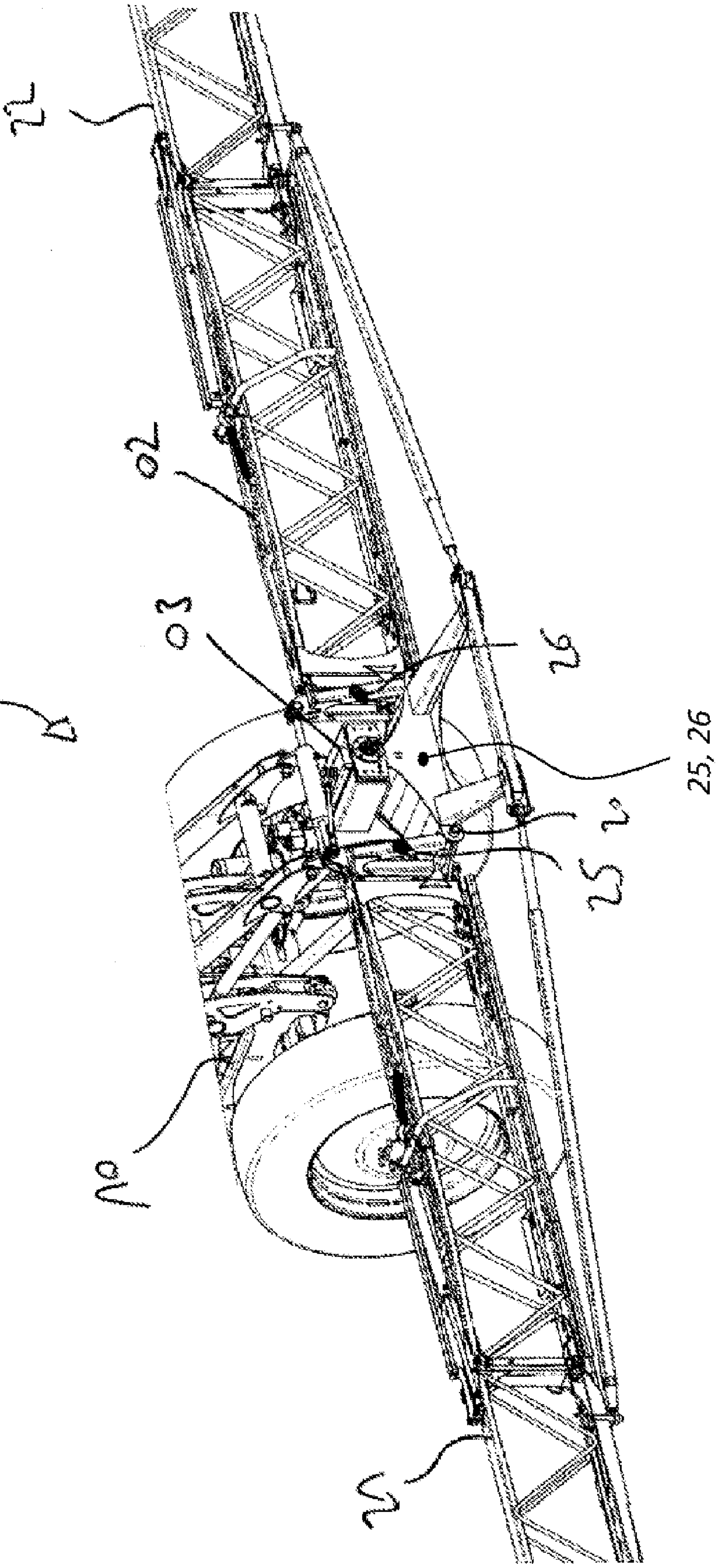


Fig. 6

Fig. 7

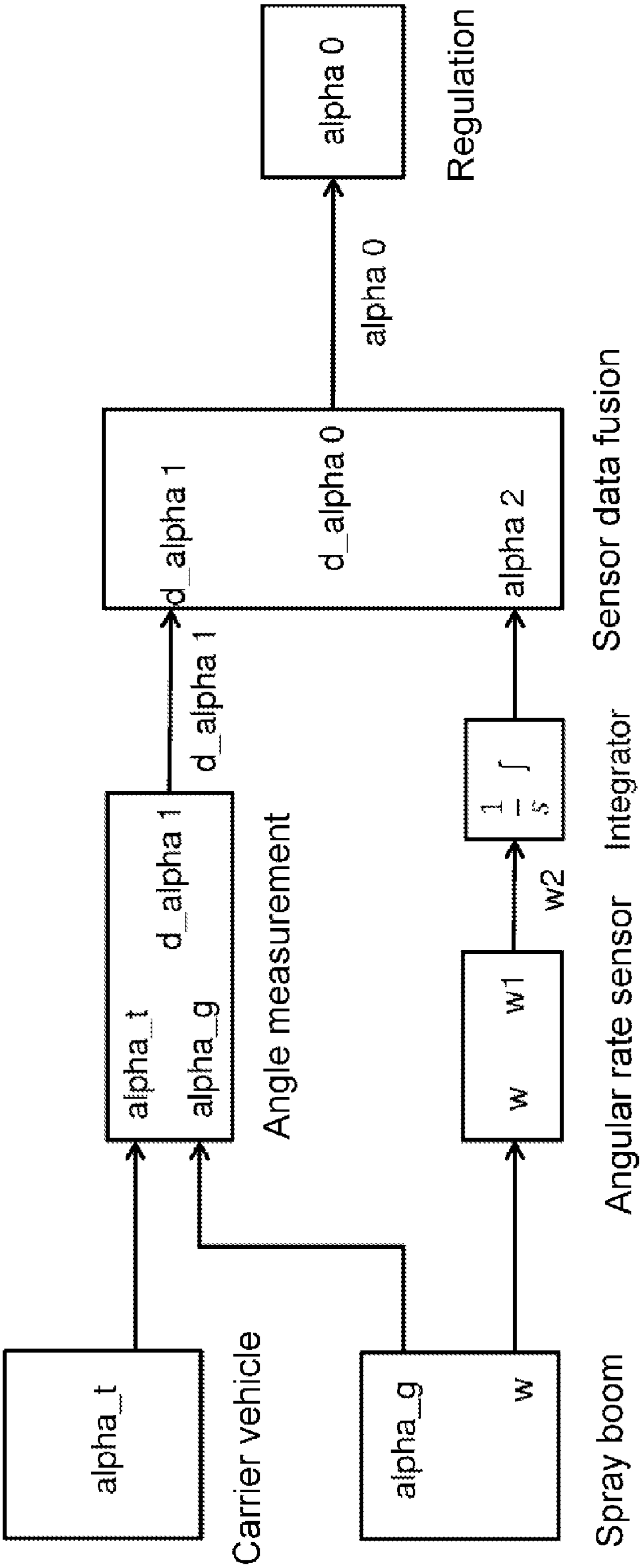
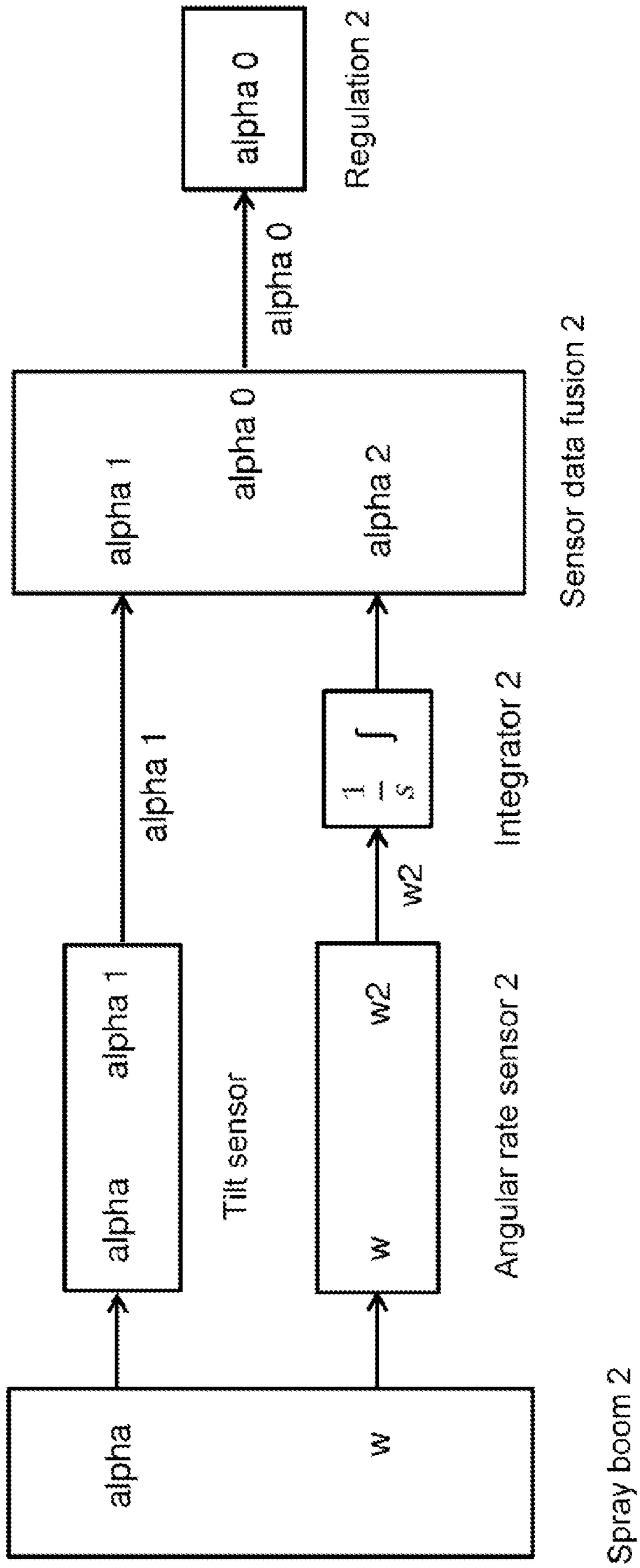

alpha_t
Carrier vehicle
alpha_g
w
Spray boom
alpha_t
alpha_g
d_alpha 1
Angle measurement
w
w1
Angular rate sensor
w2
1/s ∫
Integrator
d_alpha 1
d_alpha 1
d_alpha 0
alpha 2
Sensor data fusion
alpha 0
alpha 0
Regulation

Fig. 8


Spray boom 2
alpha
w
Tilt sensor
alpha
alpha 1
Angular rate sensor 2
w
w2
alpha 1
w2
Integrator 2
1/s
Sensor data fusion 2
alpha 1
alpha 0
alpha 2
alpha 0
Regulation 2
alpha 0