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(54) **COMPENSATED GANGWAY**

(57) The present invention is an articulated gangway. The gangway is adapted to be installed on a vessel, said vessel being adapted to be controlled by a dynamic positioning system. The articulated gangway comprises at least one actuator, and at least one sensor sensing at least one signal related to the articulated gangway. At least one joint in the articulated gangway is adapted to be controlled by a guidance system through at least one of the said at least one actuator, wherein the guidance system is capable of communicating with the dynamic positioning system for holding a distal end of a passageway of the articulated gangway to be substantially stationary with respect to a predetermined reference point. The present invention is also a vessel with such articulated gangway, a control system for the articulated gangway, and a method for control of the articulated gangway.

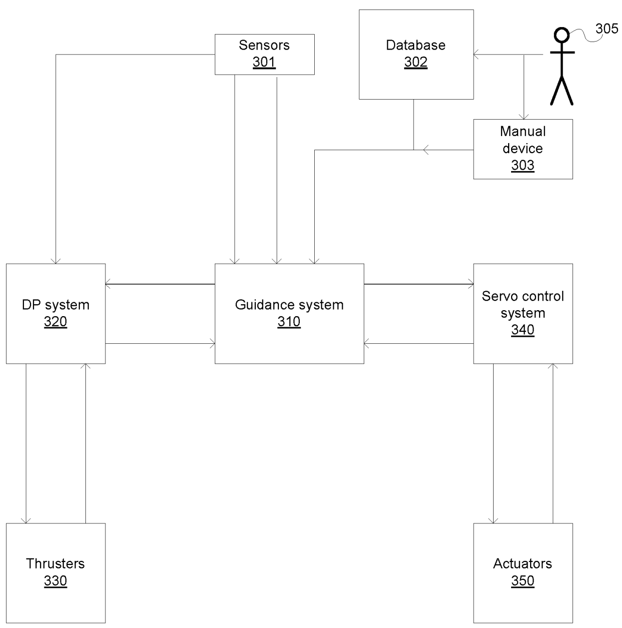


FIG. 3

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## Description

**[0001]** The present invention is related to a gangway for transferring personnel to or from a vessel. More specifically the present invention is related to a gangway for a watercraft.

**[0002]** Gangway operations are frequently used for transferring personnel and goods between floating vessels and other floating or fixed structures. In the wind energy business, gangway transfer is the most common way to transfer personnel and goods between a service vessel and wind turbines for maintenance tasks. It is also the common way of transferring personnel between offshore floatels and other fixed or floating structures.

**[0003]** There exist several proposed solutions in the technical field of compensated gangways, for example:

> WO2012021062A1 proposes a vessel including a motion compensation platform. The platform comprises a carrier and a multiple number of first actuators for moving the carrier relative to the vessel, however it is not shown how the number of first actuators, or the degrees of freedom can be less than three.

**[0004]** WO2012069825A1 proposes a bridge apparatus to transfer persons between a vessel and an offshore installation compensated mainly by using a motorized capstan.

**[0005]** WO2011154730A2 proposes a vessel with a roller assembly arranged to bear against a structure, and the vessel further comprising a gangway assembly so as to compensate for vertical movement of the vessel, and a base arranged to respond to and compensate for roll of the vessel.

**[0006]** None of the prior-art however proposes a harmonization of the vessel position control and the gangway compensation system. This and other problems inherent to the prior-art will be shown solved by the features of the present invention as stated in the independent claims.

**[0007]** In simple words, the present invention is a Dynamic Position ("DP") system integrated gangway control system. More specifically, the invention is a system and a method for an integrated DP and gangway control system for increased efficiency of bringing personnel or goods from a DP operated vessel to a fixed or floating structure via an articulated gangway. The present invention is a gangway system with integrated DP. The invention is also a vessel with an integrated gangway DP control, and the present invention is also a control system for integrated gangway DP control.

**[0008]** By coordinating the vessel's DP system with the control of the different joints of a multi degree of freedom ("DoF") gangway, the deployment of the gangway can be done more quickly and more accurately. The gangway and vessel is hence considered as one system.

**[0009]** A gangway ("GW") typically comprises a proximal end and a distal end. The proximal end is usually connected to a base or a platform on the vessel. Alternatively, the proximal end of gangway may be adjustably attached to a vertical section mounted on the vessel, with the height of the gangway being adjustable along the vertical section. Said vertical section can be a pedestal or such. The distal end of the gangway is positioned for contacting a target area. The target area could be an installation, or even another vessel. The gangway typically comprises one or even serval articulated joints with more degrees of freedom than the minimum required to be able to position the distal end at a predetermined- or desired- location, or a target area.

**[0010]** In a first aspect, the invention relates to a gangway system having a passageway with a distal end for positioning towards a target relative to a reference point, wherein the distal end of the passageway and/or the reference point may be subject to undesired motion caused by external factors, such as waves of the sea, and/or wind.

**[0011]** The general idea is to compensate undesired motion with respect to a reference point somewhere on earth. In offshore to onshore transfer applications, this reference point is usually a point on the land or on a fixed installation at sea. The fixed installation can for example be a wind turbine, a platform, or other types of installations anchored to the seabed. In such cases, the reference point is usually fixed in position coordinates (X, Y, Z). In vessel to vessel transfers, or even offshore to offshore transfers, the reference point may also be variable in terms of position coordinates (X, Y, Z), for example, the reference point may be defined as a fixed point on a target vessel, which may be moving due to waves and/or winds.

**[0012]** In this disclosure, the terms distal end of the gangway, distal end of the passageway, tip of the gangway, and tip of the passageway are used interchangeably. Furthermore, the terms walking bridge and passageway are used interchangeably without affecting the scope or generality of the invention.

**[0013]** The invention will now be described in a greater detail with reference to the following drawings that describe representative embodiments of the present invention by way of examples.

Fig. 1 shows an illustration of an articulated gangway with some available DoFs

Fig. 2 shows an illustration of an articulated gangway mounted on a vessel and DoFs of the vessel

Fig. 3 shows an embodiment of the integrated gangway control system according to the present invention

Fig. 4 shows yet another embodiment of the present invention showing an implementation architecture

Fig. 5 shows another overview of the system components according to one of the embodiments of the invention

**[0014]** Fig. 1 illustrates an example of a gangway, or more specifically an articulated gangway with five degrees of freedom (110, 120, 130, 140 and 150). The gangway comprises a pedestal 105 is mounted on a vessel 101, for example on a ship deck of the vessel 101. The gangway also comprises a passageway or a walking bride 102. The proximal end 102p of the passageway 102 is connected to the pedestal 105. The passageway 102 in this case is shown in two sections; 102a towards the proximal end 102p, and 102b at the distal end 102d of the passageway 102. The five degrees of freedom are,

- rotational motion 110 around the axis 103 of the pedestal,
- pivotal motion 120 of the pedestal 105 relative to a perpendicular to the surface of the vessel 101,
- vertical motion 130 along the axis of the pedestal 105,
- pivotal motion 140 of the passageway 102 relative and essentially perpendicular to the axis 103 of the pedestal 105, and
- linear motion 150 for adjusting the linear distance between the proximal end and the distal end of the passageway 102

**[0015]** To further elaborate the pivotal motion 140 of the passageway 102 relative and essentially perpendicular to the axis 103 of the pedestal 105, means here that the passageway, with its proximal end 102p attached or connected to the pedestal 105, moves relative to the pedestal 105 such that angle between the axis 103 of the pedestal and the passageway 102 is changed due to said pivotal motion 140 of the passageway. Similar comments apply also to the pivotal motion 120 of the pedestal. Further, by linear motion 150 for adjusting the linear distance between the proximal end and the distal end of the passageway 102, it is meant that the two sections 102a and 102b of the passageway or walking bridge can be extended or retracted with respect to each other.

**[0016]** The vertical motion 130 can either be achieved, for example, by an extendible pedestal, such as a telescopic type pedestal, or due to a passageway arrangement that can traverse vertically along the pedestal 105. By the passageway arrangement that can traverse vertically along the pedestal, it is meant that the proximal end 102p of the passageway 102 is capable of being moved and positioned vertically, along the axis 103 of the pedestal 105.

**[0017]** Three degrees of freedom are needed to position the distal end 102d of the passageway 102 at a given target position. The given target position can be a three dimensional location on a coordinate system with respect to a reference point, the reference point being fixed or variable with respect to the coordinate system.

**[0018]** A person skilled in the art will appreciate that different types of motions defined above can be realized using either or a combination of mechanical arrangements such as hydraulic, pneumatic or electric actuators, cable and winch mechanisms, gear box, or such. It should also be understood that the extension and retraction of the passageway 102 can be achieved, for example, by a telescopic type passageway, or even a lazy-tongs type structure. The passageway 102 may even have more than two sections. A particular choice of a mechanical arrangement or a structure limits neither the scope nor the generality of the present invention.

**[0019]** Now referring to Fig. 2, which shows the gangway comprising pedestal 105 and passageway 102 mounted on the vessel 101. The vessel 101 further has at least 3 degrees of freedom corresponding to the movements yaw 210 along the yaw axis z, pitch 220 along the pitch axis y, and roll 230 along the roll axis x respectively. The yaw axis z is essentially parallel to the axis 103 of the pedestal 105 when the pedestal is essentially perpendicular to horizontal deck of the vessel 101. Three degrees of freedom are available for control; rotation around 210, transversal movements 220 and 230. Control of these three degrees of freedom can be done using a dynamic positioning ("DP") system. Hence, according to one embodiment of the present invention, altogether at least eight degrees of freedom are available for manipulation to position the gangway distal end 102d at a desired position.

**[0020]** Alternatively, one can prioritize certain degrees of freedom, for example, depending upon marine activity, and/or environmental conditions to reduce the number of degrees of freedom that need to be manipulated. As an example, if undesired yaw movement is below a certain threshold, the system considers it as constant and instead manipulate the dominant movements. In other words, one does not need to use all DoFs unless required. For example, if unwanted movements are negligible along a certain axis, they system may decide not to act on such movements. The category of said environmental conditions includes wind activity. Using the term marine activity does not imply that the invention is suitable in marine environments only. Without limitation of scope and generality, the invention applies to all sorts of watercrafts, used in any kind of water body or watercourse.

**[0021]** In another embodiment, the system estimates different scenarios for the distribution of the compensation effort along different DoFs to find an optimized distribution of compensating movements. By optimized, it is meant, a distribution of compensating movements that results in consumption of a substantially reduced amount of energy as compared to other options for distributing the compensating movements to result in a compensation of the distal end 102d. A person skilled in the art will understand that the movement along the vessel axes x, y, and z may be effected by using propulsion devices such as thrusters, or propellers, or such. A choice of propulsion devices does not affect the scope of generality of the present invention. The system can further use estimation and/or prediction of the external influences for distribution and/or optimization of the compensating movements. By compensation of the distal end 102d it is meant that the distal end is positioned in contact with, or essentially in proximity to, an installation, such that unwanted movements in the distal end 102d, due to vessel and/or gangway movements, e.g., due to marine activity and/or environmental conditions are substantially reduced. The distal end 102d is thus held essentially stable with respect to a reference point. In addition, compensation of the distal end, can also mean that the walking bridge 102 is held at a predetermined angle with respect to a horizontal plane. Preferably, the predetermined angle is zero with respect to the horizontal plane, however it can also be of another value as per requirement. In addition, compensation of the distal end, can also mean that the overall unwanted movements in the walking bridge 102 are essentially reduced such that the walking bridge is substantially stationary with respect to a chosen reference point such that any personnel traversing the walking bridge 102 perceive substantially reduced movements of the walking bridge 102 despite turbulence in marine activity and/or environmental conditions.

**[0022]** Now referring to Fig. 3 which shows a functional embodiment of the proposed invention. More specifically, Fig. 3 shows main blocks of an integrated gangway control system. The system comprises at least one sensor 301, with at least some of the sensor outputs being transmitted to a guidance system 310. The at least some of the sensor outputs being transmitted to the guidance system 310 can comprise for example be either one or a combination of, yaw, pitch, roll, heave, and their rates, relative position of the distal end 102d, and speed of the distal end 102d. The guidance system 310 is capable of receiving inputs from at least one database 302. The guidance system is also capable of receiving input from an operator 305, for example through a manual control device 303. The at least one database 302 can also be manipulated by the operator 305. At least some of the outputs from the at least one sensor 301 are transmitted to a DP system 320. The DP system 320 is capable of transmitting signals to the guidance system 310, said transmitted signals comprising at least one of the following; vessel position and speed. The DP system 320 is further capable of receiving signals from the guidance system 310, the received signals comprising at least one of the following; setpoint of vessel position, and setpoint for vessel speed. The DP system 320 is capable of controlling at least one thruster 330 of the vessel. The DP system 320 is further capable of receiving at least one feedback signal from the at least one thruster 330. Said feedback signal from thruster is related to the operational parameter of the thruster. Said operational parameter of the thruster, for example, is propeller speed, power consumption, capacity, thrust, and such. The guidance system 310 is also capable of receiving signals from a servo control system 340. Said signals received by the guidance system 310 from the servo control system 340 can comprise for example either one or a combination of, speed, and position related to the joint associated with the respective servo. The guidance system 310 may receive signals related to a plurality of joints in the gangway system. The guidance system 310 is also capable of transmitting signals to the servo control system 340. Said signals transmitted to the servo control system 340 from the guidance system 310 can comprise either one or a combination of position setpoint, and speed setpoint; the setpoints being related to the respective joint the guidance system intends controlled. The servo control system 340 is further capable of sending at least one control signal to at least one actuator 350. An example, of at least one control signal sent to at least one actuator 350 by servo control system 340 is start, stop, speed, or their combination. Combination here means, for example, that the servo control system 340 sends a start command to an actuator and a command to maintain a certain speed and/or to obtain a certain joint displacement or angle. Said at least one actuator 350, can either be hydraulic type actuator, pneumatic type actuator, electrical type actuator, or their combination. Said at least one actuator 350 can also be a plurality of actuators, in which case the actuators can also be of different types depending upon suitability. The servo control system 340 is also capable of receiving feedback signals from the at least one actuator. The feedback signals received from the at least one actuator are typically operational parameters related to the specific actuator.

**[0023]** In another embodiment, the servo control system 340 is a part of the guidance system 310. In yet another embodiment, the DP system 320, the guidance system 310, and the servo control system 340 are a part of the same control system.

**[0024]** The position of the distal end 102d of the passageway 102 relative to a target position, is measured by a sensor or a plurality of sensors 310. Said sensor can, for example be a camera. The camera output may further be handled by an image-processing module.

**[0025]** The joints of the gangway may be equipped with sensors, for example, displacement sensor, angular sensor, speed sensor, acceleration sensor or their likes such that the output of the sensor is dependent upon the parameters of the respective joint of the gangway that the sensor is supposed to measure. The parameters of the joint can for example be, position, angle, velocity, acceleration or such. By knowing the actual gangway configuration by design and/or through joint position signal from the sensor, the position of the distal end 102d relative, for example to the base of the pedestal 105 can be calculated. Knowing the location of the pedestal base, the vessel position, and attitude (pitch, roll and heave), the position of the distal end 102d with respect to a reference point may be derived. The difference between the derived distal end position and the directly measured distal end relative position is used for improving the accuracy of measured relative position. Said difference is also used for simultaneously correcting the calculated gangway joint velocities (in the following denoted the gangway states). Said improving the accuracy of the measured relative position and the gangway joint states is preferably done using an algorithm. Typical examples of algorithms that can be used here are Observer or Estimator algorithms, as known in the art of control theory. Gangway may be equipped with additional sensors, e.g, accelerometer/gyro based local motion and altitude sensors, as e.g. motion reference unit ("MRU"). In this case, the additional sensor readings are applied together with the said position sensor in the observer. Speed of the distal end is usually a function of the gangway states and the vessel motion.

**[0026]** The target position for the distal end 102d may be fetched for example, from a database 302, the database comprising a plurality of geographical locations for target positions. The target position may even be set manually by an operator 305 through the use of a manual control device 303. Manual control device can be any sort of human interaction system such as keyboard, mouse, touchscreen, or such. Alternatively, the user 305 can even be an interface to another control system. The another control system being capable of manipulating the at least one database 302, or providing direct inputs to the guidance system 310. In such a case, i.e., when another control system provides direct input to the guidance system 310, in that case the manual device 303 is correspondingly a communication interface between the guidance system 310 and the another control system.

**[0027]** Gangway joint setpoints, such as position and speed setpoints, are calculated by a Guidance system 310 by optimization with the constraint that the distal end position shall essentially be "equal" to the target position. Main optimization criterion is to keep the walking bridge 102 as horizontal as possible and to minimize joint motions and rates of change. The results of the optimization are translated into setpoints for one or more of the gangway joints. The setpoints for one or more of the gangway joints can be position/angle and corresponding speed. The results of the optimization can also result in changes to the DP system's desired position and the vessel velocities to achieve that position.

**[0028]** The servo control 340 system can take care of the control of the individual servo actuators to realize the required movements of the gangway joints. Similarly, the DP control system 320 can control at least one of the at least one thruster 330 to move the vessel to the desired location.

**[0029]** By thrusters, it is meant any sort of propulsion device, without affecting the scope or generality of the invention.

**[0030]** Now referring to Fig. 4, which shows an alternative embodiment of the system, it is shown how in an application the proposed system can be arranged. The DP control computer 420 is essentially equivalent to the DP system 320, the guidance computer 410 is essentially equivalent to the guidance system 310, the servo control computer 440 is essentially equivalent to the servo control system 340. The at least one database 302 including geographical locations values of the target locations is also shown communicating with the guidance computer 410. The at least one sensor 301 is shown differently; here the DP system related sensors are included in 401 that provides position and heading inputs to the DP system. The local gangway motion and attitude sensors are included in 420, providing position of the distal end 102d with respect to a reference point, and preferably also pitch, roll and heave motions of the vessel 101. Gangway actuators and sensors are essentially included in 403. A person skilled in the art will understand that the various computers, e.g., 410, 420 and 440, in Fig. 4 can actually be included in the same controller. They may be realized either as a software or hardware separation within the same physical machine. Furthermore, the at least one database 302 could also be located within either of the computers. An architectural choice does not affect the generality or scope of the present invention.

**[0031]** Now reverting to the functional aspects of the invention, especially relevant towards a method according to the present invention, the main goal of a combined DP-gangway ("DP-GW") control system is to control the gangway distal end 102d to preserve contact with or closed proximity to a desired target or landing point. As the system can have several redundant degrees of freedom, a multi-task control approach is applied according to the present invention. Such an approach is mostly found in robotics applications to achieve additional goals. According to the present invention, the use of a multi-task control approach is proposed for keeping the walking bridge 102 as horizontal as possible or for limiting the excursion or movement of the joints.

**[0032]** Given the available degrees of freedom, the control system aims to solve the following tasks, preferably in the specified priority order:

1. Controlling the distal end 102d position to match the desired landing or target point
2. Controlling the walking bridge 102 altitude to match the desired landing point altitude, or enforcing horizontality
3. Controlling the DP position setpoint to achieve the optimal geographic position of the vessel which minimizes the joint displacements, for enabling the system to operate as far from the physical mechanical limits as possible
4. Minimizing the rate of change of all joints and the DP setpoint speed

**[0033]** The system is thus also able to maintain a favorable headroom for control of the gangway system, for example, by optimal geographic position or alignment of the vessel such that joint displacements are minimized and that sufficient excursion in the joints is available for compensating the unwanted movements.

**[0034]** In order to define the tasks, in a formal mathematical sense, differential kinematics modelling is adopted. A task can be considered as a mathematical function which is dependent on vessel and gangway states. In multi-task control, for each task there will be a corresponding task function, which represents the ultimate value and/or the time-domain trajectory to follow in order to achieve the task.

**[0035]** When the distal end 102d of the gangway, and other point of interests, are geometrically established, the task functions can be defined as functions of generalized joint space variables, which is typically the union of DP and gangway states. The DP related generalized joint space variables include:

1. North Position of vessel
2. East Position of vessel
3. Vertical Position of vessel, or heave
4. Yaw Angle, or heading
5. Pitch Angle, and
6. Roll Angle

**[0036]** The North position, the East position, and the Yaw angle ("NEY") are assumed to be freely perturbable. This will result as additional degrees of freedom for improving the proposed multi-task control. The North, East, Yaw perturbation is used by the DP system only.

**[0037]** For the gangway system the generalized joint space variable set comprises:

1. Slew angle
2. Pedestal angle
3. Bridge elevation
4. Boom angle
5. Telescopic displacement

**[0038]** According to the invention, a task is represented as an analytical function of the combined DP-GW joint space variable set. In addition, MRU data are used, preferably in a feed forward sense, to model the vessel's induced motion contributing to the task.

**[0039]** The method according to the present invention combines singular value decomposition ("SVD") and quadratic programming ("QP") optimization, for achieving a regularized task-oriented solution for a single task. The SVD algorithm is applied to calculate the setup for a QP problem. In order to link lower priority tasks with the higher ones, the null-space control ("NSC") paradigm from classic robotics is adopted. The QP problem is adjusted to include information of the higher priority tasks and physical or operational boundary conditions. Once an optimal solution is found for a given task, the method is re-applied to next task. The NSC paradigm will prevent a lower task solution to compromise a higher one. The overall solution, as a result of a series of QP iterations, yields a set of generalized joint speeds, including both North, East, Yaw DP-speed and GW joint rates of change.

**[0040]** The proposed method essentially guarantees that any solution is feasible with respect to generalized joint speed and position limits, such as mechanical hard limits or actuator limitations.

**[0041]** The solution is numerically integrated over time to generate setpoints. The setpoins generated are preferably a pair of speed and position set-points for the high speed servo loops controlling the actuators in the gangway.

**[0042]** For taking into account the difference between the DP system and the gangway system in terms of bandwidth, the following steps are used:

1. The integrated gangway and DP setup ("GW+DP"), which typically comprises 8 controllable DoFs, is considered

    a. The multi-task optimization problem is solved to obtain the GW+DP solution, including DP-North, East and Yaw perturbation and gangway joint setpoints

    b. The gangway joint setpoints are neglected, while the DP controllable DoFs (North, East and Yaw) are selected to be delivered to the DP system

2. The gangway setup, which comprises 5 controllable DoFs, is considered

    a. The multi-task optimization problem is solved to obtain the sole gangway solution given actual DP- North, East and Yaw

    b. The gangway joint setpoints are delivered to the gangway servo control system

**[0043]** By the term considered, as used above, it is meant that the system evaluates the case of the integrated system, as in step 1 above, separately from the case of the gangway system alone, as in step 2 above.

**[0044]** The above steps can also use feed forward information coming from MRU or similar devices for including a parameters related to the actual vessel motion contributing to the differential form of the task functions.

**[0045]** Such a hybrid solution according to the present invention provides a compromise between reactiveness of the controlled gangway system itself and a slow adaptation to scenario changes due to the integrated gangway and DP solution.

**[0046]** Step 1 above, is used for generating a long-term reference, or a slowly varying setpoint, for the slower of the two control systems. Step 2 is used for generating a short-term reference, or a relatively rapidly varying setpoint, for the faster control system. In these, the DP system is typically the slower system, and gangway servo control system is typically the faster control system.

**[0047]** Asymptotically the solution will converge into the optimal integrated gangway and DP solution when the slower DP system will reach its steady state.

**[0048]** As mentioned earlier in this disclosure, the controllable DoFs can be minimized based upon the marine and environmental activity or conditions. Said conditions may either be prevailing, or even predicted, estimated, or forecasted. Accordingly, the step 1 and/or step 2 mentioned above may hence, each decide to utilize fewer than 8 and 5 DoFs respectively. If the gangway is realized with more than 5 DoFs, the system and method according to the present invention can be adapted accordingly without affecting the scope or generality of the invention.

**[0049]** The main blocks of the integrated gangway control system are illustrated in Fig. 3.

**[0050]** Fig. 5 shows an embodiment illustrating an organizational overview of the system components of the invention. The system comprises two multi task controllers ("MTCs"). The first MTC 501 does multi task control for the gangway. The second MTC 502 does multi task control for the integrated DP and gangway systems. Both MTCs receive one or more inputs from the DP system 320 and gangway sensors 503.

**[0051]** The MTCs 501 and 502 are configured to handle at least one task. An example of a first task, Task1, is control of the position of the distal end 102d of the passageway. Task 1 will be considered by the first MTC 501 and the second MTC 502. The second task, Task 2, can be the control of altitude of the walking bridge or passageway 102, also being handle by both the first MTC 501 and the second MTC 502. The third task, Task 3, can be the control of DP setpoints for optimizing gangway joint location. Since tasks such as the control of DP setpoints is outside the scope of the GW MTC 501, because the required DoFs are not included into the setup for MTC 501, such tasks are exclusively handled by the DP+GW MTC 502. The fourth task, Task 4, can be minimization of rate of change of the available degrees of freedom handled by both the first MTC 501 and the second MTC 502. The first MTC 501 is further adapted to control the gangway joint velocity setpoints 504. The first MTU 501 is further capable of controlling at least one gangway servo or actuator 505, either through setpoint manipulation 505, or even directly. The second MTU 502 is capable of controlling the DP system 320, preferably through setpoint manipulation 506. The DP setpoints 506 are setpoints for DP related parameters; e.g, position, velocity, or such.

**[0052]** To summarize the inventions in other words, the present invention is an articulated gangway adapted to be installed on a vessel. The vessel is adapted to be controlled by a dynamic positioning system. The articulated gangway comprises at least one actuator. The articulated gangway also comprises at least one sensor sensing at least one signal related to the articulated gangway. At least one joint in the articulated gangway is adapted to be controlled by a guidance system. The guidance system controls at least one of the at least one joint through at least one of the at least one actuator. The guidance system is capable of communicating with the dynamic positioning system for holding a distal end of a passageway of the articulated gangway to be substantially stationary with respect to a predetermined reference point. By being capable of communicating with, here it is meant that the guidance system is capable of sending as well as receiving signals including sensor signals and control signals.

**[0053]** Alternatively, or in combination, to above the guidance system is capable of communicating with the dynamic positioning system for aligning the vessel such that said articulated gangway is operated away from at least some of the mechanical limits of the articulated gangway.

**[0054]** By alternatively, we mean, the present invention is an articulated gangway adapted to be installed on a vessel. The vessel is adapted to be controlled by a dynamic positioning system. The articulated gangway comprises at least one actuator. The articulated gangway also comprises at least one sensor sensing at least one signal related to the articulated gangway. At least one joint in the articulated gangway is adapted to be controlled by a guidance system. The guidance system controls at least one of the at least one joint through at least one of the at least one actuator. The guidance system is capable of communicating with the dynamic positioning system for aligning the vessel such that said articulated gangway is operated away from at least some of the mechanical limits of the articulated gangway.

**[0055]** According to one embodiment, the guidance system is adapted to generate a long-term reference for the dynamic positioning system. The long-term reference is preferably a relatively slowly moving setpoint for the DP system.

**[0056]** In another embodiment, the guidance system is adapted to generate a short-term reference for the control of the articulated gangway. The short-term reference is preferably a relatively fastly moving setpoint for the control of the articulated gangway. The terms relatively as used in context of the relative response speeds of the DP control system, and gangway control system with respect to each other.

**[0057]** In another embodiment, the articulated gangway has at least 3 degrees of freedom. In another embodiment, the articulated gangway has at least 4 degrees of freedom. In yet another embodiment, the articulated gangway has at least 5 degrees of freedom. In the preferred embodiment, the articulated gangway has 5 degrees of freedom. The articulated gangway can have more than 5 degrees of freedom without affecting the scope of generality of the invention. The invention may even reduce and/or certain DoFs in computation and control.

**[0058]** In the preferred embodiment, the vessel has 3 degrees of freedom, however, depending upon operating conditions, the degrees of freedom either be more or less, also for the articulated gangway. Operating conditions can be prevailing marine activity and/or environmental conditions. In another embodiment, the operating conditions can also be predicted or forecasted marine activity and/or environmental conditions.

**[0059]** In the preferred embodiment, an observer algorithm is used for calculating a velocity at least one of the joints of the articulated gangway.

**[0060]** In another preferred embodiment, an estimator algorithm is used for calculating a velocity at least one of the joints of the articulated gangway.

**[0061]** In yet another embodiment, the guidance system has access to at least one database. At least one of the at least one database is adapted to store a plurality of target positions. The target positions or target areas may include geographical conditions. The target positions can also include elevations and/or angles.

**[0062]** In another embodiment, the guidance system is adapted to maintain the passageway substantially close to a predetermined angle with respect to a horizontal plane. By substantially close to a predetermined angle it is meant here that the passageway is set at or close to a predetermined angle value with respect to a horizontal plane, and the guidance system maintains the angle between the passageway and the horizontal plane substantially close to the predetermined angle value. The predetermined angle is in most cases equal to or essentially close to zero degrees. The predetermined angle can also be a non-zero value such that it does not result in safety problems or discomfort for the personnel traversing the gangway. A non-zero angle can for example be helpful in moving goods across the passageway, depending upon a favorable inclination.

**[0063]** In another embodiment, at least the guidance system is adapted to use kinematic modelling, defining a task as an analytical function of a joint space variable set of dynamic positioning system and articulated gangway parameters. By at least the guidance system adapted to use kinematic modelling, it is here meant that at least some part of the kinematic modelling can also be run on the DP system.

**[0064]** In another embodiment, at least some data from a motion reference unit are adapted to be used in feedforward sense for modeling the vessel's induced motion contributing to the task. In another embodiment, when there are a plurality of tasks, at least the guidance system is adapted to apply null-space control for linking lower priority tasks with the higher one. By at least the guidance system adapted to apply null-space control, it is here meant that the DP system can also adapted to apply null-space control. Such cases are especially relevant when the DP controller and the guidance system are encompassed within a same controller, either as software implementation, or as hardware, or their combinations.

**[0065]** The present invention is also a vessel with an articulated gangway. The vessel is adapted to be controlled by a dynamic positioning system. The articulated gangway comprises at least one actuator. The articulated gangway also comprises at least one sensor sensing at least one signal related to the articulated gangway. At least one joint in the articulated gangway is adapted to be controlled by a guidance system. The guidance system controls at least one of the at least one joint through at least one of the at least one actuator. The guidance system is capable of communicating with the dynamic positioning system for holding a distal end of a passageway of the articulated gangway to be substantially stationary with respect to a predetermined reference point.

**[0066]** Alternatively, or in combination, to above the guidance system is capable of communicating with the dynamic positioning system for aligning the vessel such that said articulated gangway is operated away from at least some of the mechanical limits of the articulated gangway.

**[0067]** The present invention is also a method for control of an articulated gangway. Said articulated gangway is adapted to be installed on a vessel. The vessel adapted to be controlled by a dynamic positioning system. The articulated gangway has a passageway with a distal end. The method comprising the steps of

- Controlling the distal end position to match a desired target point
- Controlling the passageway altitude to match the desired landing point altitude
- Controlling a position setpoint of the dynamic positioning system to achieve an optimal geographic position of the vessel such that at least one joint displacement of the articulated gangway is essentially minimized, and
- Minimizing the rate of change of at least one joint of the articulated gangway

**[0068]** In another embodiment, the method also comprises,

- Minimizing the speed of the dynamic positioning system setpoint.

**[0069]** The present invention is also a control system for an articulated gangway. The articulated gangway is adapted to be installed on a vessel. The vessel is adapted to be controlled by a dynamic positioning system. The articulated gangway comprises at least one actuator. The articulated gangway also comprises at least one sensor sensing at least one signal related to the articulated gangway. At least one joint in the articulated gangway is adapted to be controlled by the control system. The control system controls at least one of the at least one joint through at least one of the at least one actuator. The control system is capable of communicating with the dynamic positioning system for holding a distal end of a passageway of the articulated gangway to be substantially stationary with respect to a predetermined reference point.

**[0070]** Alternatively, or in combination, to above the control system is capable of communicating with the dynamic positioning system for aligning the vessel such that said articulated gangway is operated away from at least some of the mechanical limits of the articulated gangway.

**[0071]** The actuator or servo can be of any type, for example, electric, hydraulic, pneumatic, or their combinations.

## Claims

1. An articulated gangway adapted to be installed on a vessel, said vessel adapted to be controlled by a dynamic positioning system, the articulated gangway comprising,

    at least one actuator, and
    at least one sensor sensing at least one signal related to the articulated gangway,

    at least one joint in the articulated gangway being adapted to be controlled by a guidance system through at least one of the said at least one actuator, wherein the guidance system is capable of communicating with the dynamic positioning system for holding a distal end of a passageway of the articulated gangway to be substantially stationary with respect to a predetermined reference point.

2. The articulated gangway according to claim 1, wherein the guidance system is adapted to align the vessel such that said articulated gangway is operated away from at least some of the mechanical limits of the articulated gangway.

3. The articulated gangway according to any of the above claims, wherein the guidance system is adapted to generate a long-term reference for the dynamic positioning system.

4. The articulated gangway according to any of the above claims, wherein the guidance system is adapted to generate a short-term reference for the control of the articulated gangway.

5. The articulated gangway according to any of the above claims, wherein the articulated gangway has at least 3 degrees of freedom.

6. The articulated gangway according to any of the above claims, wherein the articulated gangway has at least 4 degrees of freedom.

7. The articulated gangway according to any of the above claims, wherein the articulated gangway has at least 5 degrees of freedom.

8. The articulated gangway according to any of the above claims, wherein the vessel has at least 3 degrees of freedom.

9. The articulated gangway according to any of the above claims, wherein an observer algorithm is used for calculating a velocity at least one of the joints of the articulated gangway.

10. The articulated gangway according to any of the above claims, wherein an estimator algorithm is used for calculating a velocity at least one of the joints of the articulated gangway.

11. The articulated gangway according to any of the above claims, wherein the guidance system has access to at least one database adapted to store a plurality of target positions.

12. The articulated gangway according to any of the claims 2 - 11, wherein the guidance system is adapted to maintain the passageway substantially close to a predetermined angle with respect to a horizontal plane.

13. The articulated gangway according to claim 12, wherein the predetermined angle is essentially zero degrees.

14. The articulated gangway according to any of the above claims, wherein at least the guidance system is adapted to use kinematic modelling, defining a task as an analytical function of a joint space variable set of dynamic positioning system and articulated gangway parameters.

15. The articulated gangway according to claim 14, wherein at least some data from a motion reference unit are adapted to be used in feedforward sense for modeling the vessel's induced motion contributing to the task.

16. The articulated gangway according to any of the claims 14 or 15, wherein at least the guidance system achieves a regularized task-oriented solution for the task by combining singular value decomposition and quadratic programming optimization.

17. The articulated gangway according to any of the claims 14 - 16, wherein with a plurality of tasks, at least the guidance system is adapted to apply null-space control for linking lower priority tasks with the higher one.

18. A vessel with an articulated gangway, said vessel adapted to be controlled by a dynamic positioning system, the articulated gangway comprising,

    at least one actuator, and
    at least one sensor sensing at least one signal related to the articulated gangway,

at least one joint in the articulated gangway being adapted to be controlled by a guidance system through at least one of the said at least one actuator, wherein the guidance system is capable of communicating with the dynamic positioning system for holding a distal end of a passageway of the articulated gangway to be substantially stationary with respect to a predetermined reference point.

**19.** A method for control of an articulated gangway adapted to be installed on a vessel, said vessel adapted to be controlled by a dynamic positioning system, the articulated gangway having a passageway with a distal end; the method comprising the steps of,

- Controlling the distal end position to match a desired target point
- Controlling the passageway altitude to match the desired landing point altitude
- Controlling a position setpoint of the dynamic positioning system to achieve an optimal geographic position of the vessel such that at least one joint displacement of the articulated gangway is essentially minimized, and
- Minimizing the rate of change of at least one joint of the articulated gangway

**20.** The method according to claim 19, also comprising the step,

- Minimizing the speed of the dynamic positioning system setpoint.

**21.** A control system for an articulated gangway, said articulated gangway adapted to be installed on a vessel, said vessel adapted to be controlled by a dynamic positioning system, the articulated gangway comprising,

at least one actuator, and
at least one sensor sensing at least one signal related to the articulated gangway,

at least one joint in the articulated gangway being adapted to be controlled by the control system through at least one of the said at least one actuator, wherein the control system is capable of communicating with the dynamic positioning system for holding a distal end of a passageway of the articulated gangway to be substantially stationary with respect to a predetermined reference point.

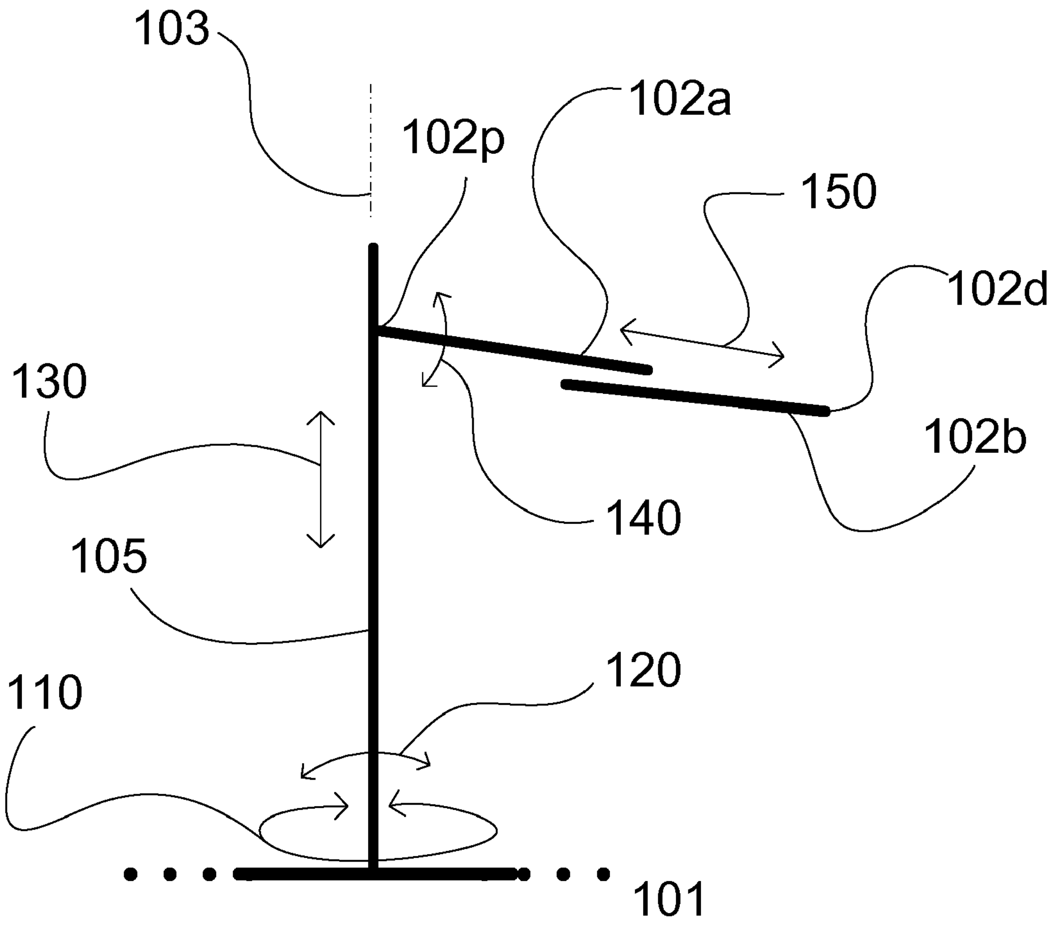


FIG. 1

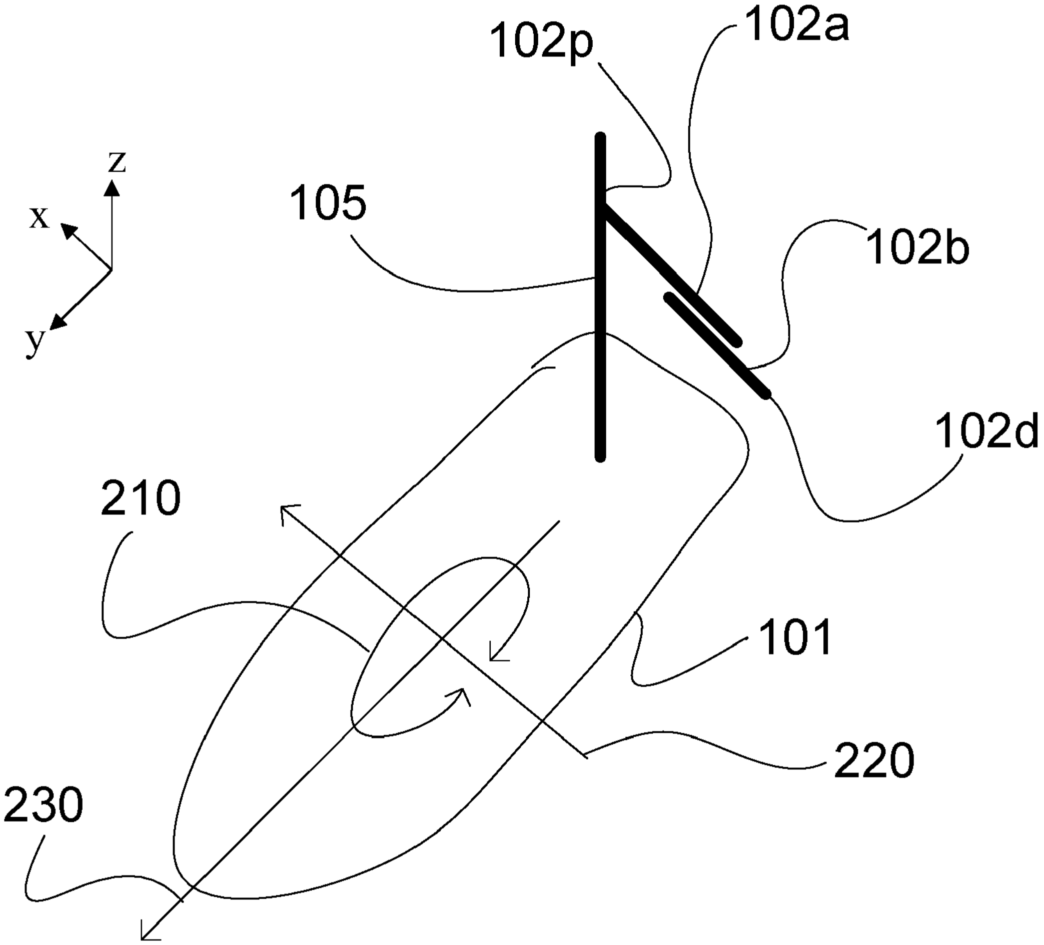


FIG. 2

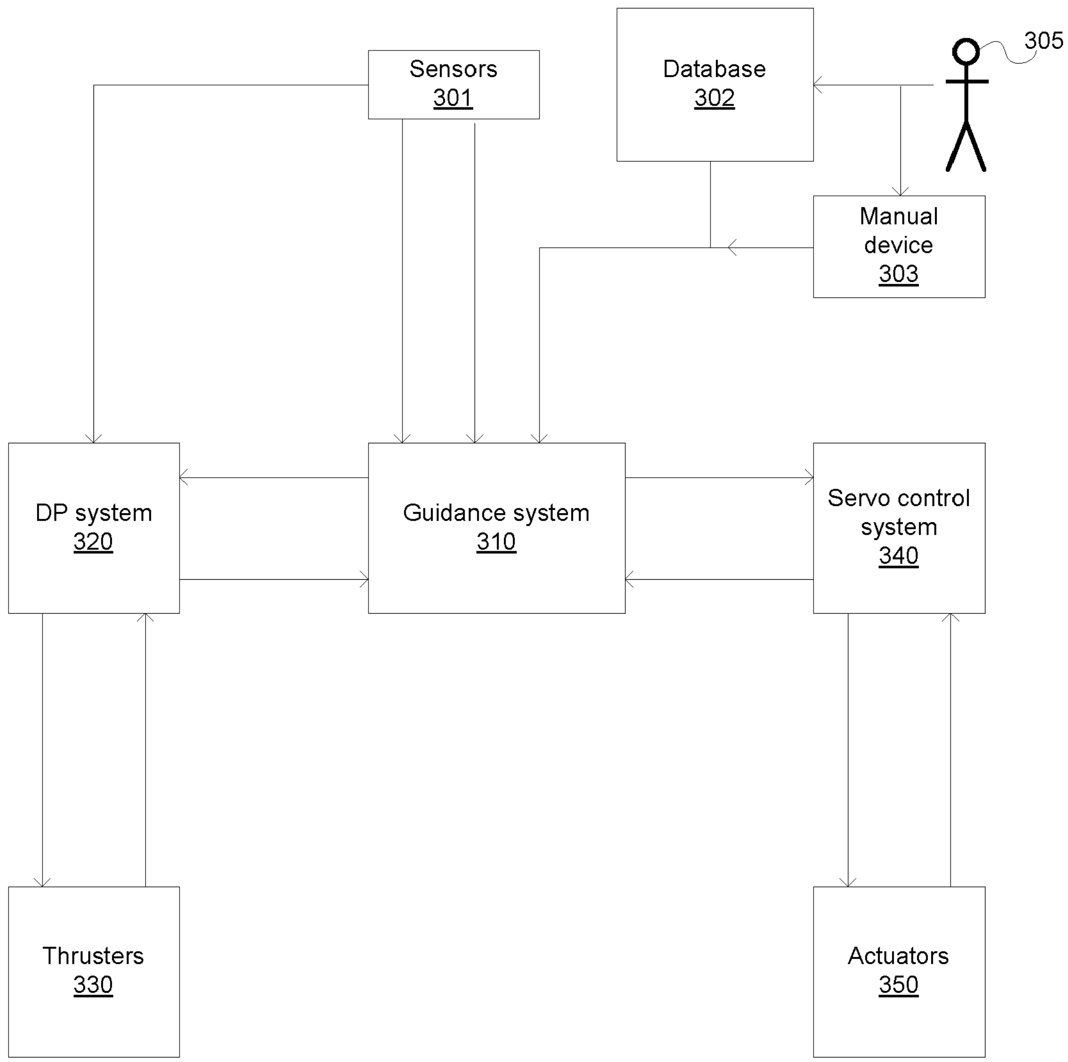
Sensors
301
Database
302
305
Manual
device
303
DP system
320
Guidance system
310
Servo control
system
340
Thrusters
330
Actuators
350

FIG. 3

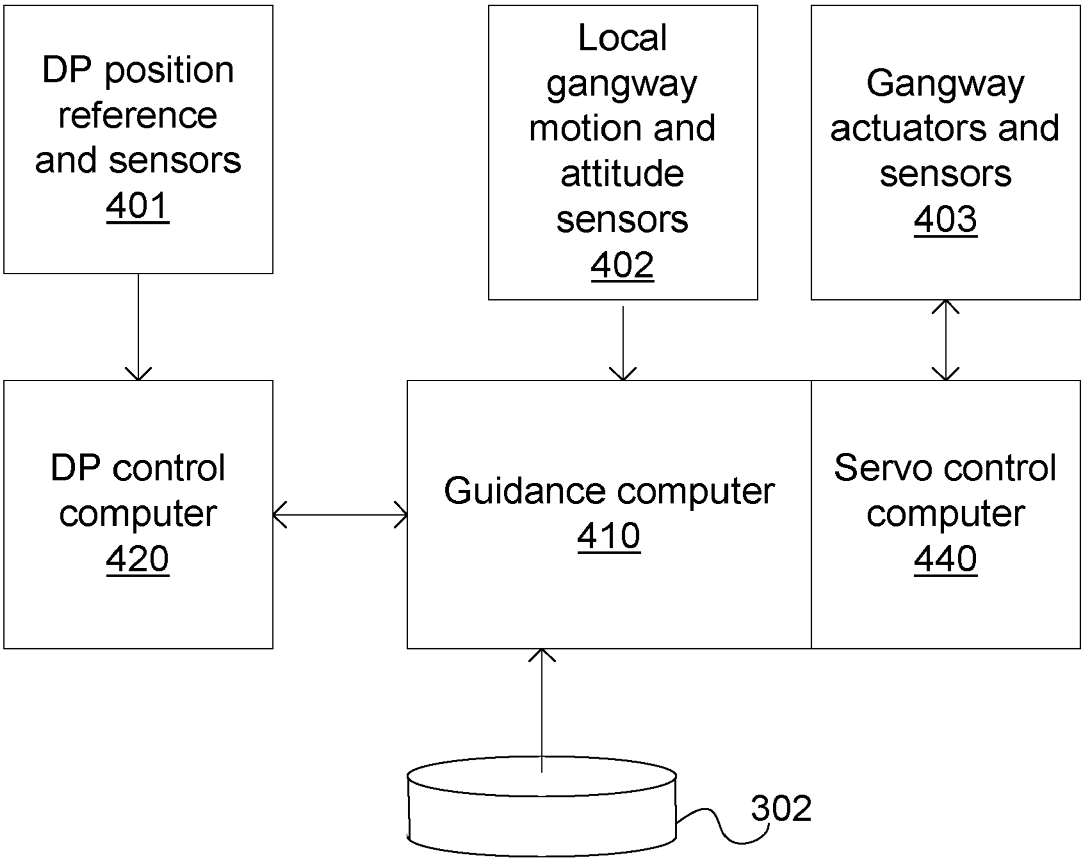
DP position reference and sensors 401
Local gangway motion and attitude sensors 402
Gangway actuators and sensors 403
DP control computer 420
Guidance computer 410
Servo control computer 440
302

FIG. 4

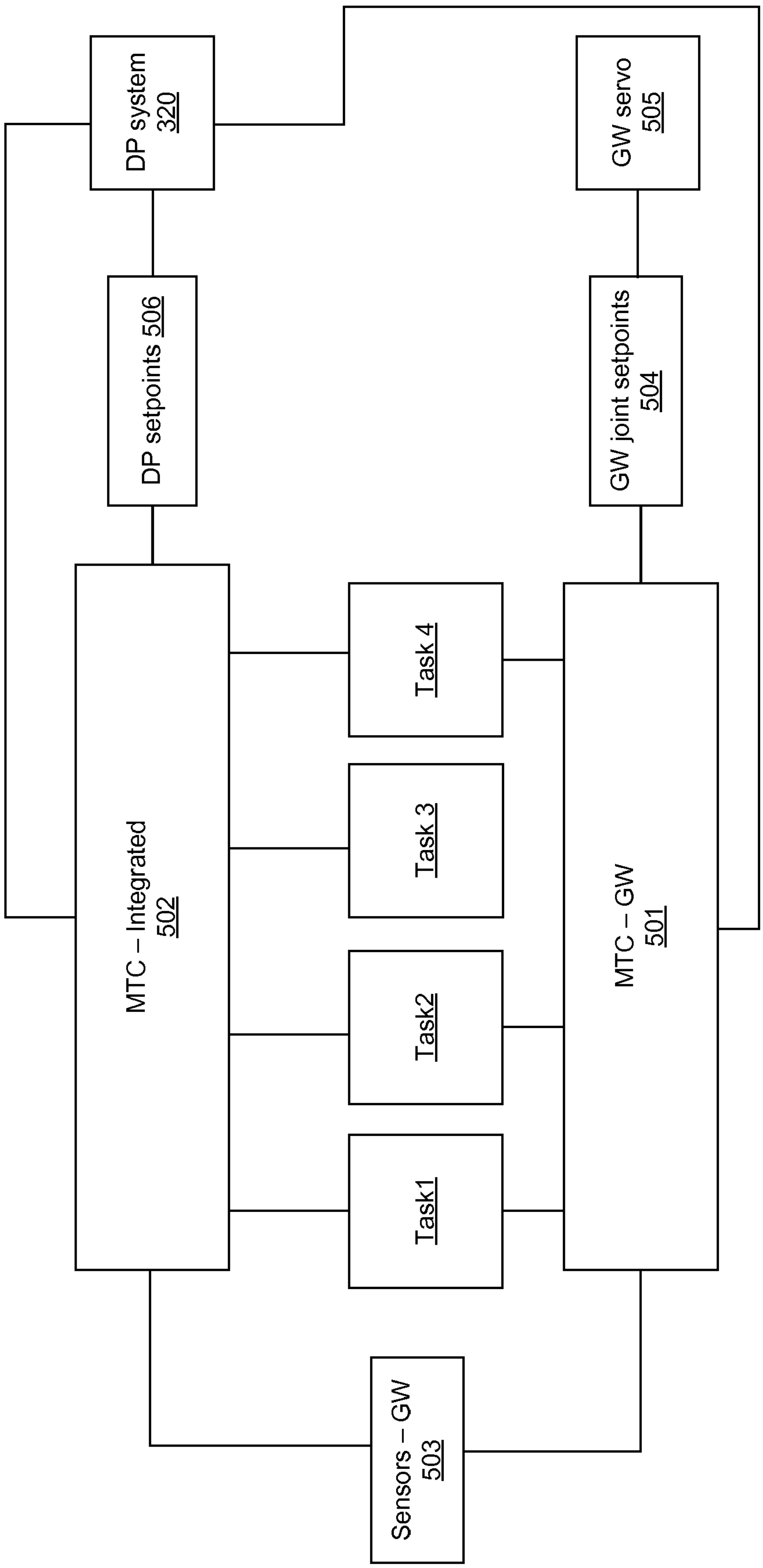
DP system
320
DP setpoints 506
MTC – Integrated
502
Task 4
Task 3
Task2
Task1
GW servo
505
GW joint setpoints
504
MTC – GW
501
Sensors – GW
503

FIG. 5

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# EUROPEAN SEARCH REPORT

Application Number
EP 17 19 2799

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B63B
E01D

The present search report has been drawn up for all claims

2

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 7 March 2018 | Martínez, Felipe |

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07-03-2018

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