# Claims

[Claim 1]

An automatic landing system for controlling a position of a vertical take-off and landing aircraft in order to land the vertical take-off and landing aircraft on a target landing point provided on a marine vessel during flight, the automatic landing system comprising:

an imaging device mounted on the vertical take-off and landing aircraft;

a relative-position acquisition unit configured to perform image processing on an image, of a marker provided on a target landing point, captured by the imaging device, and configured to acquire a relative position between the vertical take-off and landing aircraft and the target landing point;

a relative-altitude acquisition unit configured to acquire a relative altitude between the vertical take-off and landing aircraft and the target landing point;

a guidance calculation unit configured to acquire a relative heading between the aircraft heading of the VTOL and the ship heading of the marine vessel; and

a control unit configured to control the vertical take-off and landing aircraft in a plurality of control modes such that the relative position becomes zero, wherein

the plurality of control modes include a hovering mode and a landing mode,

the hovering mode is executed within a first threshold value at which the relative position is within a range of the target landing point, the relative altitude of the vertical take-off and landing aircraft is lowered to a predetermined relative altitude in the hovering mode, the relative heading becomes zero, and when a predetermined condition including a condition that the relative position is within a predetermined threshold value that is less than the first threshold value is satisfied, the control mode is shifted from the hovering mode to the landing mode, and

in the landing mode, the relative heading becomes zero, and the relative altitude of the vertical take-off and landing aircraft is further lowered to land the vertical take-off and landing aircraft on the target landing point,

wherein

the hovering mode includes a high altitude hovering mode and a low altitude hovering mode,

in the high altitude hovering mode, the relative altitude of the vertical take-off and landing aircraft is maintained at a first relative altitude that is higher than the predetermined relative altitude, and when a first condition including a condition that the relative position is

within a second threshold value is satisfied, and an operator inputs an instruction to shift to the low altitude hovering mode, the control mode is shifted to the low altitude hovering mode, and

in the low altitude hovering mode, the relative altitude of the vertical take-off and landing aircraft is lowered to the predetermined relative altitude, and when a second condition as the predetermined condition including a condition that the relative position is within the predetermined threshold value is satisfied, and the operator inputs an instruction to shift to the landing mode, the control mode is shifted to the landing mode,

the automatic landing system further comprising:

a relative-velocity acquisition unit configured to acquire a relative velocity between the vertical take-off and landing aircraft and the target landing point, wherein

the control unit controls the vertical take-off and landing aircraft in a plurality of control modes such that the relative velocity is within a predetermined velocity.

[Claim 2]

The automatic landing system for a vertical take-off and landing aircraft according to claim 1, wherein

in the landing mode, when the relative altitude is less than or equal to a predetermined value, the vertical take-off and landing aircraft is caused to descend without changing an attitude angle of the vertical take-off and landing aircraft.

[Claim 3]

The automatic landing system for a vertical take-off and landing aircraft according to claim 1, wherein

the first condition and the second condition include a condition that a mode transition is instructed by an operator.

[Claim 4]

The automatic landing system for a vertical take-off and landing aircraft according to claim 1, wherein

the first condition includes a condition that an attitude rate of the vertical take-off and landing aircraft and a relative velocity between the vertical take-off and landing aircraft and the target landing point are within corresponding first determination threshold values.

[Claim 5]

The automatic landing system for a vertical take-off and landing aircraft according to claim 1 or 4, wherein

the second condition includes a condition that an attitude angle of the vertical take-off and landing aircraft, an attitude rate, a relative velocity between the vertical take-off and landing aircraft and the target landing point, an angle in a horizontal direction of the target landing point, and the relative altitude are within corresponding second determination threshold values.

[Claim 6]

The automatic landing system for a vertical take-off and landing aircraft according to claim 1, wherein

the marker has a marker shape being variable, and

the first condition and the second condition include a condition that the marker shape is a shape indicating a mode transition.

[Claim 7]

An automatic landing system for controlling a position of a vertical take-off and landing aircraft in order to land the vertical take-off and landing aircraft on a target landing point provided on a marine vessel during flight, the automatic landing system comprising:

an imaging device mounted on the vertical take-off and landing aircraft;

a relative-position acquisition unit configured to perform image processing on an image, of a marker provided on a target landing point, captured by the imaging device, and configured to acquire a relative position between the vertical take-off and landing aircraft and the target landing point;

a relative-altitude acquisition unit configured to acquire a relative altitude between the vertical take-off and landing aircraft and the target landing point;

a guidance calculation unit configured to acquire a relative heading between the aircraft heading of the VTOL and the ship heading of the marine vessel;

a control unit configured to control the vertical take-off and landing aircraft in a plurality of control modes such that the relative position becomes zero;

a position measuring unit configured to acquire position coordinates of the vertical take-off and landing aircraft;

a data transmission device configured to exchange data between the vertical take-off and landing aircraft and a facility provided with the target landing point; and

a second relative-position acquisition unit configured to calculate a relative position between a position of the vertical take-off and landing aircraft acquired by the position measuring unit and a position of the target landing point based on the position coordinates of the vertical take-off and landing aircraft acquired by the position measuring unit and position coordinates of the facility provided with the target landing point acquired by the data transmission device, wherein

the plurality of control modes include an approach mode, a hovering mode and a landing mode,

in the approach mode, the vertical take-off and landing aircraft is caused to fly toward the target landing point so that the relative position acquired by the second relative-position acquisition unit is falls within a predetermined range and, when the relative position acquired by the second relative position acquisition unit is falls within the predetermined range and the relative position acquired by the relative-position acquisition unit is within the first threshold value, the control mode is shifted to the hovering mode,

the hovering mode is executed within a first threshold value at which the relative position is within a range of the target landing point, the relative altitude of the vertical take-off and landing aircraft is lowered to a predetermined relative altitude in the hovering mode, the relative heading becomes zero, and when a predetermined condition including a condition that the relative position is within a predetermined threshold value that is less than the first threshold value is satisfied, the control mode is shifted from the hovering mode to the landing mode, and

in the landing mode, the relative heading becomes zero, and the relative altitude of the vertical take-off and landing aircraft is further lowered to land the vertical take-off and landing aircraft on the target landing point,

wherein

the automatic landing system further comprising:

a relative-velocity acquisition unit configured to acquire a relative velocity between the vertical take-off and landing aircraft and the target landing point, wherein

the control unit controls the vertical take-off and landing aircraft in a plurality of control modes such that the relative velocity is within a predetermined velocity.

[Claim 8]

The automatic landing system for a vertical take-off and landing aircraft according to any one of claims 1 to 7, wherein

when a time period for which the marker cannot be captured by the imaging device continues longer than or equal to a predetermined time period during execution of the hovering mode, the control unit shifts the control mode to an emergency mode in which an altitude of the vertical take-off and landing aircraft is raised to a predetermined altitude.

[Claim 9]

A vertical take-off and landing aircraft comprising:

the automatic landing system for a vertical take-off and landing aircraft according to any one of claims 1 to 8.

[Claim 10]

An automatic landing method for controlling a position of a vertical take-off and landing aircraft in order to land the vertical take-off and landing aircraft on a target landing point provided on a marine vessel during flight, the automatic landing method comprising:

mounting an imaging device on the vertical take-off and landing aircraft;

performing image processing on an image, of a marker provided on a target landing point, captured by the imaging device;

acquiring a relative position between the vertical take-off and landing aircraft and the target landing point;

acquiring a relative altitude between the vertical take-off and landing aircraft and the target landing point;

acquiring a relative heading between the aircraft heading of the VTOL and the ship heading of the marine vessel;

controlling the vertical take-off and landing aircraft in a plurality of control modes such that the relative position becomes zero, wherein the plurality of control modes include a hovering mode and a landing mode;

executing the hovering mode within a first threshold value at which the relative position is within a range of the target landing point;

lowering the relative altitude of the vertical take-off and landing aircraft to a predetermined relative altitude and becoming the relative heading zero, in the hovering mode;

when a predetermined condition including a condition that the relative position is within a predetermined threshold value that is less than the first threshold value is satisfied, shifting the control mode from the hovering mode to the landing mode;

in the landing mode, becoming the relative heading zero and further lowering the relative altitude of the vertical take-off and landing aircraft to land the vertical take-off and landing aircraft on the target landing point, wherein the hovering mode includes a high altitude hovering mode and a low altitude hovering mode,

in the high altitude hovering mode, maintaining the relative altitude of the vertical take-off and landing aircraft at a first relative altitude that is higher than the predetermined relative altitude;

when a first condition including a condition that the relative position is within a second threshold value is satisfied, and an operator inputs an instruction to shift to the low altitude hovering mode, shifting the control mode to the low altitude hovering mode, and

in the low altitude hovering mode, lowering the relative altitude of the vertical take-off and landing aircraft to the predetermined relative altitude;

when a second condition as the predetermined condition including a condition that the relative position is within the predetermined threshold value is satisfied, and the operator inputs an instruction to shift to the landing mode, shifting the control mode to the landing mode,

acquiring a relative velocity between the vertical take-off and landing aircraft and the target landing point;

controlling the vertical take-off and landing aircraft in a plurality of control modes such that the relative velocity is within a predetermined velocity.