Claims

[Claim 1]

An automatic landing system for a vertical take-off and landing aircraft, 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; 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, 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 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.

[Claim 2]

The automatic landing system for a vertical take-off and landing aircraft according to claim 1, 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 3]

The automatic landing system for a vertical take-off and landing aircraft according to claim 1 or 2, 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 4]

The automatic landing system for a vertical take-off and landing aircraft according to any one of claims 1 to 3, 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, 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, the control mode is shifted to the landing mode.

[Claim 5]

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

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

[Claim 6]

The automatic landing system for a vertical take-off and landing aircraft according to claim 4, 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 7]

The automatic landing system for a vertical take-off and landing aircraft according to claim 4 or 6, 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 8]

The automatic landing system for a vertical take-off and landing aircraft according to claim 4, 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 9]

The automatic landing system for a vertical take-off and landing aircraft according to any one of claims 1 to 8, further comprising:

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, and

in the approach mode, the vertical take-off and landing aircraft is caused to fly toward the target landing point based on the relative position acquired by the second relative-position acquisition unit and, when 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.

[Claim 10]

The automatic landing system for a vertical take-off and landing aircraft according to any one of claims 1 to 9, 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 11]

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 10.

[Claim 12]

A landing control method for a vertical take-off and landing aircraft, the method comprising:

performing image processing on an image, of a marker provided to a target landing point, captured by an imaging device mounted on the vertical take-off and landing aircraft, and 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; and

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,

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, 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 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.