

DESCRIPTION

Title of Invention: DETECTION SYSTEM FOR DETECTING ENTRANCE OF AIRCRAFT

Technical Field

[0001] The present disclosure relates to a detection system for detecting an entrance of an aircraft.

Background Art

[0002] Conventionally, a passenger boarding bridge is known as equipment that forms a passenger walkway between an aircraft and a terminal building of an airport. The passenger boarding bridge includes: a rotunda connected to the terminal building and supported in a horizontally rotatable manner; an extendable and retractable tunnel unit whose proximal end is connected to the rotunda; a cab rotatably provided at the distal end of the tunnel unit and docked with an entrance of the aircraft; and a drive column provided at the distal side of the tunnel unit, the drive column serving as a support leg. The drive column includes: a lifting/lowering device configured to support the tunnel unit and move the tunnel unit upward/downward; and a travel device provided under the lifting/lowering device, the travel device including a pair of travel wheels. It has been proposed to automatically move such a passenger boarding bridge (see, for example, Patent Literatures 1 and 2 indicated below).

[0003] For example, Patent Literature 1 discloses that a camera to capture an image of the entrance of the aircraft is mounted to the cab. When the cab is at a predetermined standby position, horizontal positional information about the entrance is calculated based on the image of the entrance captured by the camera, and based on the calculated horizontal positional information, a destination target position to which the cab is to be moved and at which the cab is to be docked with the entrance is calculated. Then, the cab at the standby position is caused to move toward the target position.

[0004] Patent Literature 2 discloses a configuration in which a head part (i.e., the cab) that is connectable to the entrance of the aircraft is provided with two cameras, i.e., first and second cameras. When an input to start driving is performed with an operating panel, traveling by the wheels is started by a travel drive unit, and when the head part has reached a position that is several meters away from the aircraft, the first camera and the second camera start capturing images of a first characteristic part and a second characteristic part of the aircraft. Then, by using the images captured by the first and second cameras, the position of a target point on the entrance of the aircraft is calculated, and a relative position and a relative angle of the head part

with respect to the entrance of the aircraft are calculated. Based on these, a control correction amount is calculated, and based on the calculated control correction amount, various drive units are driven to move the head part toward the target point on the aircraft.

Citation List

Patent Literature

- [0005] PTL 1: Japanese Patent No. 6720414
PTL 2: Japanese Laid-Open Patent Application Publication No. 2020-175727

Summary of Invention

Technical Problem

[0006] In order to automatically move such a passenger boarding bridge, it is necessary to precisely detect the position of the entrance of the aircraft from a captured image captured by a camera provided on the distal end part of the passenger boarding bridge. In particular, the position of the entrance of the aircraft may significantly vary depending on, for example, the type and size of the aircraft that is parked. Moreover, the gate arrangement at the airport also varies from airport to airport, and it is troublesome to preset an entrance position detection mode for each combination of the parked aircraft and the gate arrangement. Thus, the above Patent Literatures 1 and 2 have a room for improvement in terms of precisely detecting the position of the entrance of each of a plurality of types of aircrafts for various gate arrangements.

[0007] The present disclosure has been made to solve the above-described problems. An object of the present disclosure is to provide a detection system that is capable of precisely detecting, for various gate arrangements, the position of an entrance of an aircraft by using captured images captured by cameras provided on the distal end part of a passenger boarding bridge.

Solution to Problem

[0008] A detection system according to one aspect of the present disclosure is a detection system for detecting an entrance of an aircraft, the detection system including: a passenger boarding bridge connected to a terminal building; a first camera and a second camera that are provided on the passenger boarding bridge; a height changing mechanism configured to change a height position of each of the first camera and the second camera; a controller that controls an operation of the height changing mechanism; and an image processor that detects the entrance of the aircraft from a first captured image captured by the first camera and a second captured image

captured by the second camera. The first camera and the second camera are arranged such that a first angle of a first virtual line relative to a horizontal plane is different from a second angle of a second virtual line relative to the horizontal plane, the first virtual line connecting between an optical center of the first camera and a predetermined position on a physical object whose image is to be captured by the first camera, the second virtual line connecting between an optical center of the second camera and the predetermined position. The image processor generates a first search area image from the first captured image and a second search area image from the second captured image. The first search area image includes a wider area in an up-down direction than the second search area image does. In a case where the image processor has detected the entrance from the first search area image and has not detected the entrance from the second search area image, the controller controls the height changing mechanism to change the height position of each of the first camera and the second camera.

Advantageous Effects of Invention

[0009] The present disclosure makes it possible to precisely detect, for various gate arrangements, the position of an entrance of an aircraft by using captured images captured by cameras provided on the distal end part of a passenger boarding bridge.

Brief Description of Drawings

[0010] FIG. 1 is a schematic plan view showing one example of a passenger boarding bridge to which a detection system according to an embodiment of the present invention is applied.

FIG. 2 shows a positional relationship between a first camera and a second camera in the present embodiment.

FIG. 3 is a block diagram showing a schematic configuration of the detection system that is applied to the passenger boarding bridge shown in FIG. 1.

FIG. 4 is a flowchart showing a flow of a search process in the present embodiment.

FIG. 5 is a flowchart showing a flow of the search process in the present embodiment.

FIG. 6 shows an example of a captured image in the present embodiment.

FIG. 7 is a conceptual diagram for setting a first area and a second area on the captured image shown in FIG. 4.

FIG. 8 shows a comparison, in the present embodiment, between an image in which projective transformation has been performed on the first area on a first captured image and the

image in which the projective transformation has not yet been performed on the first area.

FIG. 9 shows a comparison, in the present embodiment, between an image in which projective transformation has been performed on the second area on a second captured image and the image in which the projective transformation has not yet been performed on the second area.

FIG. 10 illustratively shows the degree of image-capturing area overlap between a first search area image and a second search area image in the present embodiment.

FIG. 11 shows a positional relationship between the first camera and the second camera in Variation 1.

FIG. 12 shows a positional relationship between the first camera and the second camera in Variation 2.

Description of Embodiments

[0011] Hereinafter, a preferred embodiment of the present disclosure is described with reference to the drawings. In the drawings, the same or corresponding elements are denoted by the same reference signs, and repeating the same descriptions is avoided below. The drawings show each component schematically in order to facilitate the understanding thereof. Therefore, in some cases, the drawings may not display accurate shapes, accurate dimensional ratios, etc. The present disclosure is not limited to the embodiment described below.

[0012] FIG. 1 is a schematic plan view showing one example of a passenger boarding bridge to which a detection system according to the present embodiment is applied.

[0013] A passenger boarding bridge 11 includes: a rotunda (a proximal-end round room) 4 connected to an entrance of a terminal building 2 of an airport; a tunnel unit 5, whose proximal end is connected to the rotunda 4 in such a manner that the tunnel unit 5 is liftable and lowerable, the tunnel unit 5 being configured to be extendable and retractable in the longitudinal direction of the tunnel unit 5; and a cab (a distal-end round room) 6 connected to the distal end part of the tunnel unit 5. The rotunda 4 is configured to be horizontally rotatable about a first rotational axis R4, which extends in the vertical direction. The cab 6 is configured to be horizontally rotatable about a second rotational axis R6, which extends in a direction orthogonal to the bottom surface of the cab 6.

[0014] The tunnel unit 5 forms a passenger walkway, and includes a plurality of tubular tunnels 5a and 5b, which are fitted together in a nested manner, such that the tunnel unit 5 is extendable and retractable in the longitudinal direction thereof. In the description herein, the tunnel unit 5 is formed by the two tunnels 5a and 5b as one example. The tunnel unit 5 is

formed by at least two tunnels. The proximal end part of the tunnel unit 5 is connected to the rotunda 4 in such a manner that the proximal end part is swingable (up and down) about a rotational axis that extends in the horizontal direction. That is, the proximal end part of the tunnel unit 5 is connected to the rotunda 4 in such a manner that the tunnel unit 5 is liftable and lowerable.

[0015] The distal end part of the tunnel unit 5 (specifically, the tunnel 5a on the distal end side of the tunnel unit 5) is provided with a drive column 7, which serves as a support leg. It should be noted that the drive column 7 may be mounted to the cab 6. The drive column 7 includes a lifting/lowering device 8, which lifts and lowers the cab 6 and the tunnel unit 5. Accordingly, the cab 6 and the tunnel unit 5 can be swung in the up-down direction with respect to the rotunda 4. Therefore, the orientation of the second rotational axis R6, which is the rotational axis of the cab 6, changes in accordance with an inclination of the bottom surface of the cab 6 relative to a horizontal plane. In other words, the second rotational axis R6 extends in a direction crossing the horizontal plane, and the extending direction of the second rotational axis R6 changes in accordance with up-down swinging of the cab 6 and the tunnel unit 5.

[0016] The drive column 7 further includes a travel device 9, which causes the tunnel unit 5 to rotate about the rotunda 4 (i.e., about the first rotational axis R4) and also causes the tunnel unit 5 to extend/retract. The travel device 9 is provided under the lifting/lowering device 8. The travel device 9 includes, for example, two travel wheels, each of which can be independently driven to rotate in regular and reverse directions. By causing the two travel wheels to rotate in the same direction (regular rotation or reverse rotation), the travel device 9 can travel forward or backward. Also, by causing the two travel wheels to rotate in opposite directions to each other, the travel direction (the facing direction of the travel wheels) can be changed on the spot. It should be noted that the present embodiment illustratively describes the configuration in which the tunnel unit 5 rotates about the first rotational axis R4 as a result of the rotunda 4 rotating about the first rotational axis R4. However, as an alternative, the rotunda 4 may be fixed to the terminal building 2, and the tunnel unit 5 may be connected to the rotunda 4 in such a manner that the tunnel unit 5 is rotatable about the first rotational axis R4.

[0017] The distal end part of the cab 6 includes a connector 6a to be connected to an entrance D1 or D2 of an aircraft 3. The connector 6a includes components such as a closure, a bumper, and a distance sensor. By rotating of the cab 6 about the second rotational axis R6, the position of the connector 6a (the direction in which the connector 6a is to be connected to the entrance D1 or D2) can be changed. It should be noted that instead of rotating the cab 6, the connector 6a may be rotated about the second rotational axis R6 relative to the cab 6.

[0018] Cameras 21a and 21b are installed on the cab 6. Each of the cameras 21a and 21b is a camera to capture an image of a side surface of the aircraft 3. Each of the cameras 21a and 21b is provided on the distal end part of the cab 6. In the example of FIG. 1, the first camera 21a is installed on the upper inner side of the connector 6a of the cab 6. The second camera 21b is installed on the lower inner side of the connector 6a of the cab 6. That is, the first camera 21a is disposed above the second camera 21b. Further, the position of the first camera 21a in the front-back direction of the cab 6 (i.e., a first distance K1 shown in FIG. 2, which is a distance from the connector 6a) is the same as the position of the second camera 21b in the front-back direction of the cab 6 (i.e., a second distance K2 shown in FIG. 2, which is a distance from the connector 6a).

[0019] It should be noted that each of the first camera 21a and the second camera 21b need not be positioned on the inner side of the cab 6, but may be installed at any position on the distal end part of the cab 6, so long as the cameras 21a and 21b can each capture an image of the side surface of the aircraft 3. For example, the first camera 21a and the second camera 21b may be installed on the upper outer side and the lower outer side of the cab 6, respectively.

[0020] In the present embodiment, the positional relationship between the first camera 21a and the second camera 21b is set as follows. FIG. 2 shows the positional relationship between the first camera and the second camera in the present embodiment. FIG. 2 shows a first virtual line V1 and a second virtual line V2. The first virtual line V1 connects between the optical center of the first camera 21a and a predetermined position VO on a physical object whose image is to be captured by the first camera 21a, and the second virtual line V2 connects between the optical center of the second camera 21b and the predetermined position VO. The first camera 21a and the second camera 21b are arranged such that a first angle $\delta 1$ of the first virtual line V1 relative to a horizontal plane H is different from a second angle $\delta 2$ of the second virtual line V2 relative to the horizontal plane H.

[0021] The predetermined position VO on the physical object may be set, for example, as a predetermined three-dimensional position in a three-dimensional coordinate system in which the first camera 21a serves as the origin. Alternatively, the predetermined position VO on the physical object may be set, for example, as a predetermined three-dimensional position in a three-dimensional coordinate system in which a predetermined point on an apron EP serves as the origin. The three-dimensional position of the predetermined position VO may be set to an expected detected position on the entrance D1 of the aircraft 3 (i.e., a below-described reference point on a door of the entrance D1) in a case where the entrance D1 is positioned in front of the connector 6a. In the present embodiment, the predetermined position VO is set as a position

below the cab 6. Accordingly, the first angle $\delta 1$ is greater than the second angle $\delta 2$.

[0022] In the present embodiment, based on a first captured image G1 and a second captured image G2 captured by the first camera 21a and the second camera 21b, respectively, which are provided on the distal end part of the passenger boarding bridge 11, the entrance D1 of the aircraft 3, to which the passenger boarding bridge 11 is to be connected, is searched for.

[0023] FIG. 3 is a block diagram showing a schematic configuration of the detection system that is applied to the passenger boarding bridge shown in FIG. 1. As shown in FIG. 3, a detection system 20 in the present embodiment includes the aforementioned cameras 21a and 21b and an image processor 23. The image processor 23 detects the entrance D1 of the aircraft 3 from the captured images G1 and G2 captured by the respective cameras 21a and 21b. The detection system 20 further includes a storage 24 and an outputter 25. The storage 24 stores data of, for example, the captured images, an image processing program, and so forth. The outputter 25 outputs, for example, detection results. These components 21a, 21b, 23, 24, and 25 can transmit and receive data to and from each other via a bus 26.

[0024] A controller 30, which controls the passenger boarding bridge 11, is also connected to the bus 26. The controller 30 is, for example, provided in the cab 6 or in the frontmost tunnel 5a. The controller 30 controls rotation of the cab 6 as well as lifting/lowering and traveling of the drive column 7 for the passenger boarding bridge 11. The controller 30 further controls a height changing mechanism 36 and rotation of an image-capturing direction changing mechanism 34 for the cameras 21a and 21b.

[0025] The height positions of the respective cameras 21a and 21b are changeable. Accordingly, the detection system 20 includes the height changing mechanism 36, which is configured to change the height position of each of the cameras 21a and 21b. In the present embodiment, the lifting/lowering device 8 of the drive column 7, which lifts and lowers the cab 6, serves as the height changing mechanism 36. That is, the cameras 21a and 21b are changed in height together with the cab 6, to which the cameras 21a and 21b are mounted. Alternatively, the height changing mechanism 36 may be configured to change the height of each of the cameras 21a and 21b with respect to the cab 6. For example, the cameras 21a and 21b may be mounted outside the cab 6 via a height-adjusting rail that extends in the height direction, and the positions of the respective cameras 21a and 21b on the height-adjusting rail may be made adjustable by the height changing mechanism 36.

[0026] The image-capturing direction of each of the cameras 21a and 21b (i.e., the orientation of an image-capturing center axis L1) is changeable within a horizontal plane. Accordingly, the detection system 20 includes the image-capturing direction changing

mechanism 34, which changes the image-capturing direction of each of the cameras 21a and 21b by rotating about a predetermined rotational axis that extends in a direction crossing the horizontal plane.

[0027] The image-capturing direction changing mechanism 34 may be configured as a camera rotating mechanism to rotate the cameras 21a and 21b relative to the cab 6. In this case, the image-capturing direction changing mechanism 34 can change the image-capturing direction of the first camera 21a and the image-capturing direction of the second camera 21b independently of each other. Alternatively, the cab 6 may serve as the image-capturing direction changing mechanism 34. For example, the cameras 21a and 21b may be fixed to the cab 6, and the image-capturing direction of each of the cameras 21a and 21b (i.e., the orientation of the image-capturing center axis L1) may be changed as a result of the cab 6 rotating about the second rotational axis R6, which extends in a direction crossing the horizontal plane.

[0028] The controller 30 and the image processor 23 are realized by a computer that performs various calculations and processing based on the data stored in the storage 24. For example, the controller 30 and the image processor 23 include a CPU, a main memory (RAM), a communication interface, etc. It should be noted that the controller 30 and the image processor 23 may be realized by the same computer, or may be realized by different computers, respectively.

[0029] The outputter 25 outputs, for example, results of calculations or processing by the controller 30 or the image processor 23. The outputter 25 is configured, for example, as a monitor that displays calculation results and so forth or as a communication device that transmits data to a server or to a communication terminal via a communication network. It should be noted that the image processor 23 and the storage 24 of the detection system 20 may be configured as a server that is connected to the cameras 21a and 21b via a communication network. Specifically, the server may: obtain captured images captured by the respective cameras 21a and 21b; perform a below-described search process on the server; and display results thereof on a monitor provided in, for example, a control room of the passenger boarding bridge 11, or on a display of a communication terminal.

[0030] The controller 30 and the image processor 23 use, for example, a predetermined three-dimensional coordinate system such as an XYZ orthogonal coordinate system to recognize in real time the position coordinates of various parts of the passenger boarding bridge 11. For example, as absolute coordinates, the intersection point of the first rotational axis R4 of the rotunda 4 and the plane of the apron EP is set as the origin (0, 0, 0), and the position coordinates of each part of the passenger boarding bridge 11 are expressed as position coordinates in a three-

dimensional coordinate system in which an X-axis, a Y-axis, and a Z-axis that are orthogonal to each other are set with respect to the origin. Of the position coordinates, an X coordinate value, a Y coordinate value, and a Z coordinate value each indicate a distance (e.g., in units of [mm]) from the origin (0, 0, 0), which is the position of the first rotational axis R4 of the rotunda 4. The controller 30 and the image processor 23 express the positions of various parts of the aircraft 3 and various parts of the passenger boarding bridge 11 as position coordinates by using such a three-dimensional orthogonal coordinate system.

[0031] The image processor 23 includes the following function blocks to perform the below-described search process: a search area image generator 31; a search performer 32; and a search range determiner 33. Part of, or the entirety of, these function blocks include circuitry including integrated circuitry. Therefore, these components 31, 32, and 33 can be considered as circuitry. These function blocks are hardware that carry out or are programmed to perform the recited functionality. The hardware may be any hardware disclosed herein or otherwise known which is programmed or configured to carry out the recited functionality. When the hardware is a processor which may be considered a type of circuitry, these function blocks are a combination of hardware and software, the software being used to configure the hardware or processor. The image processor 23 reads out, from the storage 24, a program for performing a search process to perform the search process, which will be described below.

[0032] Hereinafter, the search process to search for the entrance D1 in the present embodiment is described. Each of FIG. 4 and FIG. 5 is a flowchart showing a flow of the search process in the present embodiment. The search process is performed in a case where the aircraft 3 has arrived at a predetermined arrival position. Accordingly, the passenger boarding bridge 11 is, as shown in FIG. 1, at an initial position (standby position) to avoid the aircraft 3.

[0033] The storage 24 prestores data of search ranges that are preset for the respective first and second cameras 21a and 21b. Each search range is set as an area extending along the direction of an aircraft axis AL. The storage 24 further prestores initial angles of the respective cameras 21a and 21b (i.e., image-capturing direction data). The initial angles of the cameras 21a and 21b are, when the passenger boarding bridge 11 is at its initial position, set to such angles that the angle of view of each of the cameras 21a and 21b includes at least one end portion of the search range, which is preset for each of the cameras 21a and 21b, in the direction of the aircraft axis AL.

[0034] The search process according to the present embodiment is performed in a manner to sequentially shift from the front side toward the back side of the aircraft 3 in the direction of the aircraft axis AL. Accordingly, the initial angles of the cameras 21a and 21b are, when the

passenger boarding bridge 11 is at its initial position, set to such angles that the angle of view of each of the cameras 21a and 21b includes a front end portion of the search range, which is preset for each of the cameras 21a and 21b, in the direction of the aircraft axis AL.

[0035] In the search process, first, the controller 30 controls the image-capturing direction changing mechanism 34 to adjust the angle of each of the cameras 21a and 21b to their initial angle (step S1). The controller 30 further controls the height changing mechanism 36 to adjust the height of each of the cameras 21a and 21b to their initial height. Each of the cameras 21a and 21b performs image capturing at the initial angle (step S2). The image processor 23 obtains the first captured image G1 captured by the first camera 21a at the initial angle and the second captured image G2 captured by the second camera 21b at the initial angle. The obtained captured images G1 and G2 are stored in the storage 24. It should be noted that the image processor 23 may perform, in advance, predetermined image processing on the captured images G1 and G2, such as distortion correction that may be necessary due to the camera lens or brightness correction. A position on each of the captured images G1 and G2 is expressed as position coordinates in a two-dimensional coordinate system in which one vertex of each of the captured images G1 and G2 (e.g., the upper-left vertex) is set as the origin and a U-axis and a V-axis that are orthogonal to each other are set with respect to the origin.

[0036] The search area image generator 31 demarcates a first area E_{ai} ($i = 1, 2, 3, \dots$) including a part of the first captured image G1 to generate a first search area image C_{ai} (see FIG. 8, which will be referred to below) including a partial area of the first captured image G1, the partial area being demarcated based on the first area E_{ai} . In order to do this, first, the search area image generator 31 sets, on the first captured image G1, the first area E_{ai} corresponding to a virtual rectangular frame B_i in a three-dimensional space that is an actual space (step S3). An area including a front end portion of the search range in the direction of the aircraft axis AL is set as an initial first area E_{a1} in the search process. Similarly, the search area image generator 31 demarcates a second area E_{bi} ($i = 1, 2, 3, \dots$) including a part of the second captured image G2 to generate a second search area image C_{bi} (see FIG. 9, which will be referred to below) including a partial area of the second captured image G2, the partial area being demarcated based on the second area E_{bi} .

[0037] FIG. 6 shows an example of a captured image in the present embodiment. FIG. 7 is a conceptual diagram for setting first and second areas on the captured image shown in FIG. 6. It should be noted that in the description below with reference to FIG. 6 and FIG. 7, a mode of generating the first search area image C_{ai} from the first captured image G1 is mainly described. The second search area image C_{bi} is generated from the second captured image G2 in the same

manner. That is, a mode of generating the second search area image Cbi from the second captured image G2 is indicated by replacing, in FIGS. 6 and 7 as well as in the description below, the first camera 21a, the first captured image G1, the first area Eai, and the first search area image Cai with the second camera 21b, the second captured image G2, the second area Ebi, and the second search area image Cbi, respectively. It should be noted that the first area Eai and the second area Ebi are, in an actual space, set to the same area (i.e., set as areas both corresponding to the same virtual rectangular frame Bi).

[0038] In the present embodiment, the search area image generator 31 sets, on the first captured image G1, a virtual plane VP perpendicular to a horizontal plane (apron EP) and parallel to the aircraft axis AL. Here, the aircraft axis AL is preset at a position that is a predetermined distance above a marshall line 13 drawn on the apron EP, assuming that the aircraft 3 is to be parked on the marshall line 13. It should be noted that, in the present specification and the claims, the front side and the back side in the direction of the aircraft axis AL mean the front side and the back side of the aircraft 3 parked on the marshall line 13.

[0039] The virtual plane VP is set at a position that is offset from the aircraft axis AL toward one side in the fuselage width direction (specifically, toward one side closer to the boarding bridge 11) by an offset amount W. That is, the virtual plane VP is defined as a plane including a reference axis VL, which is offset from the aircraft axis AL toward the one side in the fuselage width direction by the offset amount W, the plane being perpendicular to the horizontal plane. The offset amount W is preset in consideration of the fuselage width of the aircraft 3, such that the distance between the virtual plane VP and the outer surface of the entrance D1 is small (less than a predetermined distance).

[0040] The search area image generator 31 sets the virtual rectangular frame Bi in a three-dimensional space on the virtual plane VP. For example, the virtual rectangular frame Bi may be configured as a square frame on the virtual plane VP. The center of the square frame is a reference point Pi on the reference axis VL, and each side of the square frame has a length of 4 m. In many cases, the image-capturing direction of the first camera 21a (i.e., the image-capturing center axis L1) is not perpendicular to the virtual plane VP. Therefore, it is often the case that the virtual rectangular frame Bi is, on the first captured image G1, in a distorted quadrangular shape as shown by the first area Eai of FIG. 6. Three-dimensional coordinates Bi (xi, yi, zi) in the actual space have one-to-one correspondence with two-dimensional coordinates Eai (ui, vi) on the first captured image G1 captured by the first camera 21a. Conversion between the three-dimensional coordinate system in the actual space and the two-dimensional coordinate system on the first captured image G1 is performed by perspective projective

transformation.

[0041] It should be noted that, desirably, the quadrangular shape (first area) Eai on the first captured image G1, which corresponds to the virtual rectangular frame Bi, is entirely shown on the captured image G1. However, it will suffice, so long as at least a part of the quadrangular shape is shown on the first captured image G1.

[0042] The search area image generator 31 performs projective transformation on the virtual plane VP in the first area Eai (i.e., the area including a part of the first captured image G1) set in the above-described manner to transform the virtual plane VP into an image that is seen from a direction perpendicular to the virtual plane VP (step S4).

[0043] Hereinafter, the projective transformation is described in more detail. FIG. 8 shows a comparison, in the present embodiment, between an image in which the projective transformation has been performed on the first area on the first captured image and the image in which the projective transformation has not yet been performed on the first area. FIG. 9 shows a comparison, in the present embodiment, between an image in which the projective transformation has been performed on the second area on the second captured image and the image in which the projective transformation has not yet been performed on the second area. Each of FIG. 8 and FIG. 9 illustratively shows a case where the virtual rectangular frame Bi is set near the entrance D1. In each of FIG. 8 and FIG. 9, a part of the outer surface of the aircraft 3 is indicated by two-dot chain line.

[0044] As mentioned above, it is often the case that the first area Eai including a part of the first captured image G1 is in a distorted quadrangular shape. In the first search area image Cai, which is a projective-transformed image, the virtual rectangular frame Bi has the same rectangular shape as the shape set in the three-dimensional space. For example, if the virtual rectangular frame Bi has a square shape, then after the projective transformation, a first area Eapi corresponding to the virtual rectangular frame Bi also has a square shape. In accordance therewith, in the projective-transformed image, correction is made such that it is brought closer to an image in which a part of the aircraft 3 near the virtual plane VP is seen from a direction perpendicular to the aircraft axis AL of the aircraft 3. It should be noted that, to be exact, the correction is to be made only on a physical object that is present on the virtual plane VP. Therefore, the greater the distance from the virtual plane VP, the greater the correction error remaining.

[0045] In FIG. 8, the image-capturing direction (the image-capturing center axis L1) of the first camera 21a is inclined relative to the aircraft axis AL. Accordingly, the door included in the first area Eai, which is the entrance D1, is shown in such a manner that the lower end portion

and the upper end portion of the door are inclined relative to the horizontal line of the first captured image G1. As described below, in the search for the entrance D1 (e.g., in the aforementioned AI image recognition), the reference point on the door is set, for example, on the door sill or on a reinforcing plate provided on the door sill. In this case, in the image used in the search for the entrance D1, preferably, the lower end portion (the door sill or the reinforcing plate) of the entrance D1 (the door) extends horizontally.

[0046] In the present embodiment, as shown in FIG. 8, the projective transformation is performed on the first area Eai, which includes a part of the first captured image G1, so that the virtual rectangular frame Bi, which is set on the virtual plane VP parallel to the aircraft axis AL and perpendicular to the horizontal plane (the apron EP), is displayed as a rectangle. Also, a change in the size of the entrance D1, the change depending on the distance between the first camera 21a and the entrance D1, is suppressed by the projective transformation. That is, regardless of the distance between the first camera 21a and the entrance D1, the size of the entrance D1 after the projective transformation can be made about constant in each projective-transformed image. This makes it possible to precisely detect the entrance D1 in the projective-transformed image.

[0047] As shown in FIG. 9, also for the second captured image G2 captured by the second camera 21b, the projective transformation is similarly performed on the second area Ebi, which includes a part of the second captured image G2, so that the virtual rectangular frame Bi, which is set on the virtual plane VP parallel to the aircraft axis AL and perpendicular to the horizontal plane (the apron EP), is displayed as a rectangle.

[0048] The search area image generator 31 adjusts each of the search area images Cai and Cbi by trimming each projective-transformed image (step S5). The search area image generator 31 performs the trimming of each projective-transformed image, so that the first search area image Cai, which is a partial area of the first captured image G1, includes a wider area in the up-down direction than the second search area image Cbi does, the second search area image Cbi being a partial area of the second captured image G2.

[0049] In the present embodiment, as shown in FIG. 8, the first search area image Cai includes the entire first area Eapi that has been projective-transformed, and the first search area image Cai is set as an area having a length Wah between a pair of horizontal boundary lines Bah, which demarcate the area in the up-down direction, and also having a length Wav between a pair of vertical boundary lines Bav, which demarcate the area in the left-right direction. The length Wah is greater than the length Wav. On the other hand, as shown in FIG. 9, the second search area image Cbi includes an entire second area Ebpi that has been projective-transformed, and the

second search area image Cbi is set as an area having a length Wbh between a pair of horizontal boundary lines Bbh, which demarcate the area in the up-down direction, and also having a length Wbv between a pair of vertical boundary lines Bbv, which demarcate the area in the left-right direction. The length Wbh is less than the length Wbv.

[0050] Here, the length Wah of the first search area image Cai in the up-down direction is greater than the length Wbh of the second search area image Cbi in the up-down direction.

Also, the length Wbv of the second search area image Cbi in the left-right direction is greater than the length Wav of the first search area image Cai in the left-right direction. By performing such trimming, even if the captured images G1 and G2, which are captured by the respective first and second cameras 21a and 21b having the same angle of view, are used, the first search area image Cai can be made wider than the second search area image Cbi in the up-down direction. This makes it possible to readily determine whether or not the height positions of the respective first and second cameras 21a and 21b are proper positions.

[0051] The search area image generator 31 further performs predetermined extrapolation processing on the images that have been adjusted. For example, the extrapolation processing includes such processing as filling the pixels out of the ranges of the respective captured images G1 and G2 with a single color (e.g., black color) or copying the pixels of edge portions. Also, the generated search area images Cai and Cbi are enlarged such that the entire virtual rectangular frame Bi is shown as large as possible in each of the search area images Cai and Cbi.

[0052] For each of the search area images Cai and Cbi, which have been generated in the above-described manner, the search performer 32 performs a search to determine whether or not a door that is potentially the entrance D1 is present within each of the search area images Cai and Cbi (step S6). A method adopted to search for the door is not particularly limited, so long as the adopted method is an image recognition process by which the door is detectable. For example, AI image recognition using a learned model generated by deep learning can be used.

[0053] In the door image recognition process, the door and a reference point on the door are detected based on, for example, a contour-painted portion of the door and the shape of the reinforcing plate provided on the door sill. The reference point on the door is set, for example, on a middle portion of the door sill or on a middle portion of the reinforcing plate.

[0054] In a case where the search performer 32 has detected the door in the first search area image Cai and has also detected the door in the second search area image Cbi (Yes in both steps S7 and S8), the search performer 32 calculates three-dimensional coordinates of the reference point on the door (step S9). The three-dimensional coordinates on the door are obtained, for example, by converting two-dimensional coordinates on the search area images Cai and Cbi into

two-dimensional coordinates on the original captured images G1 and G2 and then converting the two-dimensional coordinates on the first captured image G1 and the two-dimensional coordinates on the second captured image G2 into three-dimensional coordinates in the actual space. It should be noted that the three-dimensional coordinates in the actual space may be calculated only from the two-dimensional coordinates on either one of the search area image Cai or the search area image Cbi. In this case, for example, the three-dimensional coordinates in the actual space may be determined by calculations approximating the reference point on the door to be on the virtual plane VP.

[0055] Based on the three-dimensional coordinates on the detected door, the search performer 32 determines whether or not the detected door is the entrance D1, with which the passenger boarding bridge 11 is to be docked (step S10). The storage 24 prestores a search range that includes all of various aircraft doors with which the passenger boarding bridge 11 is to be docked. In a case where the three-dimensional coordinates on the detected door are within the search range stored in the storage 24, the search performer 32 determines that the entrance D1 has been detected. In a case where it is determined that the entrance D1 has been detected (Yes in step S10), the search performer 32 outputs a result indicative of successful search (step S11).

[0056] In a case where the search performer 32 has detected the door in the first search area image Cai, but has not detected the door in the second search area image Cbi (Yes in step S7 and No in step S8), the controller 30 controls the height changing mechanism 36 to change the height position of each of the first camera 21a and the second camera 21b.

[0057] In the present embodiment, as described above, the first camera 21a is installed on the upper inner side of the connector 6a of the cab 6. The second camera 21b is installed on the lower inner side of the connector 6a of the cab 6. Further, in the search for the entrance D1, the reference point on the door is set on the door sill positioned on the lower end portion of the door, or set on the reinforcing plate provided on the door sill. Accordingly, if the height position of the second camera 21b disposed on the lower inner side of the connector 6a of the cab 6 is located above the height position of the reference point on the door of the entrance D1 of the aircraft 3, then as shown in FIG. 9, it is possible that the reference point on the door is not shown in the image-capturing range of the second camera 21b (i.e., not shown in the second captured image G2) since a floor surface X of the cab 6 blocks the view of the lower part.

[0058] Accordingly, in a case where the door has been detected in the first search area image Cai generated based on the first captured image G1 captured by the first camera 21a, but has not been detected in the second search area image Cbi generated based on the second

captured image G2 captured by the second camera 21b, it is considered that the height position of the second camera 21b is located above the height position of the reference point on the door of the entrance D1 of the aircraft 3.

[0059] Therefore, the controller 30 controls the height changing mechanism 36 to change the height position of each of the first camera 21a and the second camera 21b into a lower position. In the present embodiment, the controller 30 lowers the cab 6 for a predetermined distance by the lifting/lowering device 8 of the drive column 7. A change amount of the height is set such that the captured image before the height is changed and the captured image after the height is changed partly overlap each other. Accordingly, it is unnecessary to additionally install a mechanism to change the height position of each of the first camera 21a and the second camera 21b, and also, at the time of connecting the connector 6a of the passenger boarding bridge 11 to the entrance D1 of the aircraft 3, the amount of adjustment of the height position of the passenger boarding bridge 11 to align it with the position of the entrance D1 can be reduced.

[0060] Here, since the first search area image Cai includes a wider area in the up-down direction than the second search area image Cbi does, so long as the door is included within the range of the first search area image Cai in the horizontal direction, the first search area image Cai can be obtained as an image within which the reference point on the door is present.

[0061] After the heights of the respective cameras 21a and 21b are changed, the cameras 21a and 21b perform the image capturing again (step S2). Thereafter, the above-described search process is performed in the same manner on the captured images G1 and G2 whose heights have been changed (step S3 to step S11).

[0062] In a case where the door has not been detected in the first search area image Cai (No in step S7) or in a case where it is determined that the detected door is not the entrance D1 (No in step S10), the search area image generator 31 shifts the first area Eai from one side toward the other side of the aircraft 3 in the direction of the aircraft axis AL to sequentially generate the first search area image Cai, and also shifts the second area Ebi from the one side toward the other side of the aircraft 3 in the direction of the aircraft axis AL to sequentially generate the second search area image Cbi. In the present embodiment, the search area image generator 31 shifts each of the first area Eai and the second area Ebi from the front side toward the back side in the direction of the aircraft axis AL.

[0063] In order to do this, first, the search area image generator 31 shifts the virtual rectangular frame Bi in the three-dimensional space from the one side toward the other side of the aircraft 3 in the direction of the aircraft axis AL by a predetermined distance. The search area image generator 31 calculates the first area Eai, on the first captured image G1,

corresponding to the virtual rectangular frame B_i that has been shifted, and also calculates the second area E_{bi} , on the second captured image G_2 , corresponding to the virtual rectangular frame B_i that has been shifted. In this manner, the search area image generator 31 shifts, on the first captured image G_1 , the first area E_{ai} from the one side toward the other side of the aircraft 3 in the direction of the aircraft axis AL , and also shifts, on the second captured image G_2 , the second area E_{bi} from the one side toward the other side of the aircraft 3 in the direction of the aircraft axis AL (step S13).

[0064] For example, in the three-dimensional space, on the reference axis VL , a reference point $P_i + 1$ is set at a position that is a predetermined distance away from the position of the reference point P_i toward the back side in the direction of the aircraft axis AL , and a virtual rectangular frame $B_i + 1$ is set with reference to the reference point $P_i + 1$. The distance between the reference point P_i and the reference point $P_i + 1$ is preferably not greater than the length of one horizontal side of the virtual rectangular frame B_i , and more preferably, not less than $1/4$ and not greater than $1/2$ of the length of the one horizontal side of the virtual rectangular frame B_i . In this manner, in the search for a door, the same door can be detected multiple times (about two or three times).

[0065] The search range determiner 33 determines whether or not the first area E_{ai} and the second area E_{bi} that have been shifted are each within a predefined search range, i.e., whether or not the search has been performed over the entire search range (step S14). It should be noted that, at the time of determining whether or not the first area E_{ai} and the second area E_{bi} that have been shifted are each within the search range, the search range determiner 33 may determine whether or not the corresponding virtual rectangular frame B_i in the three-dimensional space is within the search range. In a case where the first area E_{ai} and the second area E_{bi} that have been shifted are each within the search range (Yes in step S14), the search range determiner 33 further determines whether or not the first area E_{ai} that has been shifted is within the range of the first captured image G_1 used in the previous search, and also determines whether or not the second area E_{bi} that has been shifted is within the range of the second captured image G_2 used in the previous search (step S15).

[0066] In a case where the first area E_{ai} that has been shifted is within the range of the first captured image G_1 and the second area E_{bi} that has been shifted is within the range of the second captured image G_2 (Yes in step S15), the search area image generator 31 sets (updates) the first area E_{ai} that has been shifted as the first area E_{ai} for generating the first search area image C_{ai} , and sets (updates) the second area E_{bi} that has been shifted as the second area E_{bi} for generating the second search area image C_{bi} (step S3).

[0067] Based on the updated first area Eai and second area Ebi, the search area image generator 31 generates (updates) the first search area image Cai and the second search area image Cbi in the same manner as that described above. The search performer 32 searches for the entrance D1 in each of the updated first search area image Cai and second search area image Cbi. In this manner, while changing the first search area image Cai by shifting the first area Eai from the front side toward the back side in the direction of the aircraft axis AL, the search performer 32 repeatedly performs the search for the entrance D1 by using a plurality of first search area images Cai, which are sequentially generated. Similarly, while changing the second search area image Cbi by shifting the second area Ebi from the front side toward the back side in the direction of the aircraft axis AL, the search performer 32 repeatedly performs the search for the entrance D1 by using a plurality of second search area images Cbi, which are sequentially generated.

[0068] In a case where the first area Eai that has been shifted is within the search range, but is not within the range of the first captured image G1, or in a case where the second area Ebi that has been shifted is within the search range, but is not within the range of the second captured image G2 (No in step S15), the search range determiner 33 transmits, to the controller 30, an instruction signal to change the image-capturing direction of each of the cameras 21a and 21b. Based on the instruction signal, the controller 30 controls the corresponding image-capturing direction changing mechanism 34 to change the image-capturing direction of each of the cameras 21a and 21b (step S16). A change amount of the image-capturing direction is set such that the captured image before the image-capturing direction is changed and the captured image after the image-capturing direction is changed partly overlap each other.

[0069] In the example of FIG. 7, by rotating the cab 6 about the second rotational axis R6 by a predetermined angle θ , the image-capturing center axis L1 of the cameras 21a and 21b is changed into an image-capturing center axis L1a. The image-capturing center axis L1a crosses the reference axis VL of the virtual plane VP at a position that is shifted, toward the back side in the direction of the aircraft axis AL, from the position at which the image-capturing center axis L1 crosses the reference axis VL. It should be noted that, as previously described, a method adopted to change the image-capturing direction of each of the cameras 21a and 21b is not limited to this. For example, each of the first and second cameras 21a and 21b itself may be rotated relative to the cab 6 about a predetermined rotational axis that extends in a direction crossing the horizontal plane.

[0070] The first camera 21a and the second camera 21b perform the image capturing again after their image-capturing direction is changed (step S2). Thereafter, the search process is

performed in the same manner on the updated captured images (steps S3 to S11).

[0071] In a case where the first area Eai that has been shifted or the second area Ebi that has been shifted is not within the search range (No in step S14), if the number of retries that have been done is less than a preset reference value (No in step S17), the search range determiner 33 increments the number of retries by 1, and starts over the search process again. That is, the angle of each of the cameras 21a and 21b is brought back to the initial angle and then the image capturing is performed, and the search is performed based on each of the captured images G1 and G2. In a case where the number of retries that have been done has become the reference value or greater (Yes in step S17), the search performer 32 determines that the entrance D1 has not successfully been detected, and outputs a result indicative of failed search (step S18).

[0072] As described above, according to the present embodiment, the first search area image Cai, on which the determination as to whether or not the entrance D1 of the aircraft 3 has been detected is performed, is generated from the image captured by the first camera 21a, and the second search area image Cbi, on which the determination as to whether or not the entrance D1 of the aircraft 3 has been detected is performed, is generated from the image captured by the second camera 21b.

[0073] In a case where the entrance D1 has been detected from the first search area image Cai, but has not been detected from the second search area image Cbi, the height position of each of the first camera 21a and the second camera 21b is changed. The first search area image Cai includes a wider area in the up-down direction than the second search area image Cbi does. Accordingly, in a case where the entrance D1 can be detected in the first search area image Cai, but cannot be detected in the second search area image Cbi, it means that the heights of the respective first and second cameras 21a and 21b are not proper heights.

[0074] According to the above configuration, also in a case where the height positions of the respective first and second cameras 21a and 21b are not proper positions for detecting the entrance D1 of the aircraft 3 due to a positional relationship between the aircraft 3 and the passenger boarding bridge 11, the height position of each of the first camera 21a and the second camera 21b is changed automatically. Accordingly, the height position of the search area to search for the entrance D1 can be changed automatically in accordance with the position of the entrance D1 of the aircraft 3. This makes precise detection of the position of the entrance D1 of the aircraft 3 possible for various gate arrangements.

[0075] In a case where the entrance D1 has not been detected from the first search area image Cai, then regarding the direction of the aircraft axis AL of the aircraft 3, it is determined that the entrance D1 is not present in the current search area (the position of the virtual

rectangular frame Bi), and the areas Eai and Ebi are shifted.

[0076] FIG. 10 illustratively shows the degree of image-capturing area overlap between the first search area image and the second search area image in the present embodiment. In the example of FIG. 10, determination areas including the first search area image Cai and the second search area image Cbi include a first determination area Q1, a second determination area Q2, and third determination areas Q3.

[0077] The first determination area Q1 is an area where the upper area of the first search area image Cai and the middle area of the second search area image Cbi in the left-right direction overlap each other. In a case where the entrance D1 has been detected in the first determination area Q1, it is determined that the entrance D1 to be searched for has been detected. The second determination area Q2 is the lower area of the first search area image Cai, and does not overlap the second search area image Cbi. In a case where the entrance D1 has been detected in the second determination area Q2, it is determined that the cameras 21a and 21b need height adjustment. The third determination areas Q3 are end areas of the second search area image Cbi on both ends of the second search area image Cbi in the left-right direction, and do not overlap the first search area image Cai. In a case where the entrance D1 has been detected in either of the third determination areas Q3 or in a case where the entrance D1 has not been detected in any of the determination areas Q1, Q2, and Q3, it is determined that the search area needs to be shifted in the direction of the aircraft axis AL.

[0078] Thus, based on whether the entrance D1 is detected in one of the determination areas Q1, Q2, and Q3, which are included in the first and second search area images Cai and Cbi, or the entrance D1 is detected in none of the determination areas Q1, Q2, and Q3, the flow of the search process is branched, which makes it possible to automatically perform the determination as to how the search area should be changed.

[0079] Further, a plurality of search area images Cai are generated from the captured image G1 captured by the camera 21a and a plurality of search area images Cbi are generated from the captured image G2 captured by the camera 21b, the cameras 21a and 21b being provided on the distal end part of the passenger boarding bridge 11. Each of the plurality of search area images Cai is demarcated to include its corresponding area Eai including a part of the captured image G1. Each of the plurality of search area images Cbi is demarcated to include its corresponding area Ebi including a part of the captured image G2. Each of the plurality of search area images Cai is generated by shifting the area Eai from one side toward the other side of the aircraft 3 in the direction of the aircraft axis AL. Each of the plurality of search area images Cbi is generated by shifting the area Ebi from the one side toward the other side of the aircraft 3 in the

direction of the aircraft axis AL. Accordingly, the search for the entrance D1 is repeatedly performed while changing the search area image Cai by using the plurality of search area images Cai, which are sequentially generated. Similarly, the search for the entrance D1 is repeatedly performed while changing the search area image Cbi by using the plurality of search area images Cbi, which are sequentially generated. In this manner, the search for the entrance D1 can be performed over the entirety of each of the captured images G1 and G2 while shifting the search area in a direction along the aircraft axis AL of the aircraft 3.

[0080] This makes it possible to perform the search for the entrance D1 in a uniform manner regardless of the type of the aircraft 3 or the gate arrangement. A conventional way of detection of the position of the entrance D1, which depends solely on three-dimensional positions, cannot achieve proper detection for a certain gate arrangement. However, even for such gate arrangement, the present embodiment makes it possible to perform proper detection of the entrance D1, with which the passenger boarding bridge 11 is to be docked. In addition, in the search for the entrance D1, onerous operations such as inputting information corresponding to the parked aircraft 3 can be made unnecessary. That is, merely by a button operation by an operator to start the search process, the search process and a below-described automatic docking control process can be performed for any of various types of aircrafts 3.

[0081] Further, according to the present embodiment, the search area images Cai and Cbi are each generated as an image parallel to the aircraft axis AL by projective transformation. Therefore, even in a case where each of the captured images G1 and G2 is an image captured from a diagonal direction relative to the aircraft 3, shape distortion of the entrance D1 to be searched for can be suppressed in each of the search area images Cai and Cbi. This makes it possible to improve the precision of the search for the entrance D1 in each of the search area images Cai and Cbi.

[0082] Further, according to the present embodiment, each time the search area image generator 31 demarcates the area Eai, which includes a part of the captured image G1, the search area image generator 31 performs projective transformation on the captured image G1 in the area Eai. Similarly, each time the search area image generator 31 demarcates the area Ebi, which includes a part of the captured image G2, the search area image generator 31 performs projective transformation on the captured image G2 in the area Ebi. Thus, for each area Eai, the projective transformation (as well as trimming) is performed on the captured image G1, and for each area Ebi, the projective transformation (as well as trimming) is performed on the captured image G2. In this manner, a reduction in image resolution can be suppressed compared to a case where the projective transformation is performed on the entire captured image G1, and then

from the resulting projective-transformed image, the predetermined area Eai is demarcated and enlarged, and also to a case where the projective transformation is performed on the entire captured image G2, and then from the resulting projective-transformed image, the predetermined area Ebi is demarcated and enlarged.

[0083] Further, according to the present embodiment, in a case where it is determined that the area Eai that has been shifted is within the search range, but is not within the captured image G1, or it is determined that the area Ebi that has been shifted is within the search range, but is not within the captured image G2, the image-capturing direction of each of the cameras 21a and 21b is changed by the image-capturing direction changing mechanism 34, and the cameras 21a and 21b perform the image capturing again. Thus, while changing the image-capturing direction of each of the cameras 21a and 21b, the image capturing is performed multiple times. As a result, a captured image of the entire search range can be obtained as a plurality of captured images G1 and also as a plurality of captured images G2. Accordingly, an image-capturing range for each time of image capturing can be made relatively narrow, which makes it possible to increase the resolution of the search area images Cai and Cbi obtained from the captured images G1 and G2, or makes it possible to set the search range to be wider than the field of view of each of the cameras 21a and 21b.

[0084] [Variations]

Although the embodiment of the present disclosure has been described above, the present disclosure is not limited to the above embodiment, and various improvements, alterations, and modifications can be made to the above embodiment without departing from the scope of the present disclosure.

[0085] For example, the above embodiment has illustratively described a mode in which the first camera 21a and the second camera 21b have the same angle of view, and when generating the search area images Cai and Cbi from the respective captured images G1 and G2, the adjustment is made such that the first search area image Cai includes a wider area in the up-down direction than the second search area image Cbi does (by differentiating the cutout shape of the first search area image Cai and the cutout shape of the second search area image Cbi from each other). However, this is a non-limiting example. For example, the first camera 21a may have a greater angle of view than that of the second camera 21b. In this case, even if an area, in the first captured image G1, from which the first search area image Cai is generated and an area, in the second captured image G2, from which the second search area image Cbi is generated have the same square measure, the area of the actual space included in the first search area image Cai is wider than the area of the actual space included in the second search area image Cbi.

[0086] The above embodiment has illustratively described a mode in which the adjustment is made such that the second search area image Cbi includes a wider area in the left-right direction than the first search area image Cai does. However, this is a non-limiting example. For example, the width of the first search area image Cai in the left-right direction and the width of the second search area image Cbi in the left-right direction may be the same. Further, the aspect ratio ($Wah : Wav$) of the first search area image Cai is not limited to the above embodiment (i.e., not limited to $Wah > Wav$). Similarly, the aspect ratio ($Wbh : Wbv$) of the second search area image Cbi is not limited to the above embodiment (i.e., not limited to $Wbv > Wbh$).

[0087] The above embodiment has illustratively described a mode in which if the entrance D1 has not been detected in the first search area image Cai, then regardless of whether or not the entrance D1 has been detected in the second search area image Cbi (in either of the third determination areas Q3 shown in FIG. 10), the search area images Cai and Cbi are shifted in the direction of the aircraft axis AL. However, alternatively, between a case where the entrance D1 has been detected only in the second search area image Cbi and a case where the entrance D1 has not been detected in either of the first and second search area images Cai and Cbi, the process to be performed thereafter may be differentiated.

[0088] For example, the search area image generator 31 may differentiate the amount of shifting of the first area Eai and the second area Ebi in the direction of the aircraft axis AL between a case where the entrance D1 has been detected only in the second search area image Cbi and a case where the entrance D1 has not been detected in either of the first and second search area images Cai and Cbi. For example, in a case where the entrance D1 has not been detected in either of the first and second search area images Cai and Cbi, the amount of shifting of the first area Eai and the second area Ebi in the direction of the aircraft axis AL may be made greater than in a case where the entrance D1 has been detected only in the second search area image Cbi.

[0089] More specifically, in a case where the entrance D1 has been detected only in the second search area image Cbi, i.e., in a case where the entrance D1 has been detected in either of the third determination areas Q3, the search area image generator 31 may shift the first area Eai and the second area Ebi so that the entrance D1 will be positioned in the first determination area Q1. Also, in a case where the entrance D1 has not been detected in either of the first and second search area images Cai and Cbi, the search area image generator 31 may shift the first area Eai and the second area Ebi so that an area positioned outside the third determination areas Q3 in the direction of the aircraft axis AL will be positioned in the first determination area Q1.

[0090] The above embodiment has illustratively described a mode in which the position of the first camera 21a and the position of the second camera 21b are the same in the front-back direction of the cab 6, but the position of the first camera 21a is higher than the position of the second camera 21b. However, this is a non-limiting example. FIG. 11 shows a positional relationship between the first camera and the second camera in Variation 1. As shown in FIG. 11, the first camera 21a and the second camera 21b may be arranged such that the height position of the first camera 21a and the height position of the second camera 21b are the same, but the position of the first camera 21a and the position of the second camera 21b are different from each other in the front-back direction of the cab 6. The position of the first camera 21a in the front-back direction of the cab 6 is located (near the connector 6a) forward of the position of the second camera 21b in the front-back direction of the cab 6. Also in this case, the first virtual line V1 connects between the optical center of the first camera 21a and the predetermined position VO on the physical object whose image is to be captured by the first camera 21a, and the second virtual line V2 connects between the optical center of the second camera 21b and the predetermined position VO; and the first angle $\delta 1$ of the first virtual line V1 relative to the horizontal plane H is different from the second angle $\delta 2$ of the second virtual line V2 relative to the horizontal plane H (specifically, the first angle $\delta 1$ is greater than the second angle $\delta 2$). The first camera 21a and the second camera 21b may be arranged such that the height position of the first camera 21a and the height position of the second camera 21b are different from each other, and such that the position of the first camera 21a and the position of the second camera 21b are different from each other in the front-back direction of the cab 6.

[0091] The above embodiment has illustratively described a mode in which the first camera 21a, by which the first captured image G1 for generating the first search area image Cai including a wider area in the up-down direction is captured, is disposed above (or forward of) the second camera 21b. Alternatively, as shown in FIG. 12, the first camera 21a may be disposed below (or backward of) the second camera 21b. FIG. 12 shows a positional relationship between the first camera and the second camera in Variation 2. The example of FIG. 12 is different from the above-described embodiment (i.e., the example of FIG. 2) in that the position of the first camera 21a and the position of the second camera 21b are switched with each other. In the example of FIG. 12, the predetermined position VO is set as a position above the cab 6. Accordingly, also in this example, the first angle $\delta 1$ is greater than the second angle $\delta 2$.

[0092] For example, in a case where the reference point on the door is set on the upper end portion of the door, if the height position of the second camera 21b disposed on the upper inner side of the connector 6a of the cab 6 is located below the height position of the reference point

on the door of the entrance D1 of the aircraft 3, then it is possible that the reference point on the door is not shown in the image-capturing range of the second camera 21b (i.e., not shown in the second captured image G2) since the ceiling of the cab 6 blocks the view of the upper part. Accordingly, in a case where the door has been detected in the first search area image Cai generated based on the first captured image G1 captured by the first camera 21a, but has not been detected in the second search area image Cbi generated based on the second captured image G2 captured by the second camera 21b, it is considered that the height position of the second camera 21b is located below the height position of the reference point on the door of the entrance D1 of the aircraft 3. In this case, the controller 30 controls the height changing mechanism 36 to change the height position of each of the cameras 21a and 21b to a higher position.

[0093] The above embodiment has illustratively described a mode in which the search is performed from the front side toward the back side in the direction of the aircraft axis AL of the aircraft 3. However, this is a non-limiting example. Alternatively, the search may be performed from the back side toward the front side in the direction of the aircraft axis AL of the aircraft 3. For example, at the time of connecting the connector 6a of the passenger boarding bridge 11 to an entrance D2 positioned on the back side of the aircraft 3, it is preferable to perform the search from the back side toward the front side in the direction of the aircraft axis AL of the aircraft 3.

[0094] The above embodiment has illustratively described a system including one passenger boarding bridge 11. Alternatively, the detection system 20 may include two or more passenger boarding bridges. For example, the detection system 20 of the present disclosure is applicable also to a system including two passenger boarding bridges that are a first boarding bridge and a second boarding bridge.

[0095] For example, the connector 6a of the cab 6 of the first boarding bridge is connected to the entrance D1 on the front side of the aircraft 3, and the connector 6a of the cab 6 of the second boarding bridge is connected to the entrance D2 on the back side of the aircraft 3. In this case, in the search process to search for the entrance D1, to which the first boarding bridge is to be connected, the search is performed from the front side toward the back side in the direction of the aircraft axis AL within a search range predefined for the first boarding bridge. That is, in the search process to search for the entrance D1, to which the first boarding bridge is to be connected, as described above, the areas Eai and Ebi are, on the respective captured images G1 and G2, shifted from the front side toward the back side in the direction of the aircraft axis AL. Further, as necessary, the image-capturing direction of each of the cameras 21a and 21b is changed from the front side of the aircraft 3 toward the back side thereof, and the image

capturing is performed again.

[0096] On the other hand, in the search process to search for the entrance D2, to which the second boarding bridge is to be connected, the search is performed from the back side toward the front side in the direction of the aircraft axis AL within a search range predefined for the second boarding bridge. That is, in the search process to search for the entrance D2, to which the second boarding bridge is to be connected, the areas Eai and Ebi are, on the respective captured images G1 and G2, shifted from the back side toward the front side in the direction of the aircraft axis AL. Further, as necessary, the image-capturing direction of each of the cameras 21a and 21b is changed from the back side of the aircraft 3 toward the front side thereof, and the image capturing is performed again.

[0097] In this manner, based on the captured images G1 and G2 captured by the respective cameras 21a and 21b installed on the first boarding bridge, the entrance D1, which is positioned on the front side of the aircraft 3, can be detected preferentially, and based on the captured images G1 and G2 captured by the respective cameras 21a and 21b installed on the second boarding bridge, the entrance D2, which is positioned on the back side of the aircraft 3, can be detected preferentially. This makes it possible to reduce the possibility of detecting the same entrance for the plurality of boarding bridges. Therefore, the entrance D1, to which the first boarding bridge is to be connected, and the entrance D2, to which the second boarding bridge is to be connected, can be precisely searched out within a short period of time.

[0098] Further, for example, the detection system 20 of the present disclosure is applicable also to a system including three boarding bridges. In this case, it can be assumed that the aircraft 3 has first and second decks and entrances that are positioned on the first and second decks.

[0099] In this case, for example, in order to connect the first boarding bridge to a first-deck entrance positioned on the front side in the direction of the aircraft axis AL, a first search is performed from the front side toward the back side in the direction of the aircraft axis AL within a first search range. Also, in order to connect the second boarding bridge to another first-deck entrance positioned on the back side in the direction of the aircraft axis AL, a second search is performed from the back side toward the front side in the direction of the aircraft axis AL within a second search range. Further, in order to connect a third boarding bridge to a second-deck entrance, a third search is performed from the front side toward the back side in the direction of the aircraft axis AL within a third search range that is set at a higher elevation than the first search range for the first search.

[0100] It should be noted that, similar to the search for the entrance D1, to which the first

boarding bridge is to be connected, the search for the entrance D2, to which the second boarding bridge is to be connected, may be performed from the front side toward the back side in the direction of the aircraft axis AL.

[0101] The above embodiment has illustratively described a mode in which one controller 30 controls the operations of all of the following components: the passenger boarding bridge 11, the image-capturing direction changing mechanism 34, and the height changing mechanism 36. Alternatively, some of these components 11, 34, and 36 may be controlled by a different controller(s), or all of these components 11, 34, and 36 may be controlled by respective controllers that are different from each other.

[0102] [Summary of Disclosure]

The following items each disclose a preferred embodiment.

[0103] [Item 1]

A detection system according to one aspect of the present disclosure is a detection system for detecting an entrance of an aircraft, the detection system including: a passenger boarding bridge connected to a terminal building; a first camera and a second camera that are provided on the passenger boarding bridge; a height changing mechanism configured to change a height position of each of the first camera and the second camera; a controller that controls an operation of the height changing mechanism; and an image processor that detects the entrance of the aircraft from a first captured image captured by the first camera and a second captured image captured by the second camera. The first camera and the second camera are arranged such that a first angle of a first virtual line relative to a horizontal plane is different from a second angle of a second virtual line relative to the horizontal plane, the first virtual line connecting between an optical center of the first camera and a predetermined position on a physical object whose image is to be captured by the first camera, the second virtual line connecting between an optical center of the second camera and the predetermined position. The image processor generates a first search area image from the first captured image and a second search area image from the second captured image. The first search area image includes a wider area in an up-down direction than the second search area image does. In a case where the image processor has detected the entrance from the first search area image and has not detected the entrance from the second search area image, the controller controls the height changing mechanism to change the height position of each of the first camera and the second camera.

[0104] According to the above configuration, the first search area image, on which the determination as to whether or not the entrance of the aircraft has been detected is performed, is generated from the image captured by the first camera, and the second search area image, on

which the determination as to whether or not the entrance of the aircraft has been detected is performed, is generated from the image captured by the second camera. In a case where the entrance has been detected from the first search area image, but has not been detected from the second search area image, the height position of each of the first camera and the second camera is changed. The first search area image includes a wider area in the up-down direction than the second search area image does. Accordingly, in a case where the entrance can be detected in the first search area image, but cannot be detected in the second search area image, it means that the heights of the respective first and second cameras are not proper heights. According to the above configuration, also in a case where the height positions of the respective first and second cameras are not proper positions for detecting the entrance of the aircraft due to a positional relationship between the aircraft and the passenger boarding bridge, the height position of each of the first camera and the second camera is changed automatically. Accordingly, the height position of the search area to search for the entrance can be changed automatically in accordance with the position of the entrance of the aircraft. This makes precise detection of the position of the entrance of the aircraft possible for various gate arrangements.

[0105] [Item 2]

In the detection system according to item 1, the image processor may demarcate a first area including a part of the first captured image to generate the first search area image including a partial area of the first captured image, the partial area being demarcated based on the first area, and demarcate a second area including a part of the second captured image to generate the second search area image including a partial area of the second captured image, the partial area being demarcated based on the second area. The first area and the second area may be set to a same area in an actual space. The partial area of the first captured image may include a wider area in the up-down direction than the partial area of the second captured image does.

[0106] According to the above configuration, even if the first camera and the second camera that are used have the same angle of view, whether or not the height positions of the respective first and second cameras are proper positions can be readily determined.

[0107] [Item 3]

In the detection system according to item 2, the image processor may: in a case where the entrance has not been detected from the first search area image, shift the first area on the first captured image from one side toward the other side of the aircraft in a direction of an axis of the aircraft to sequentially generate the first search area image, and shift the second area on the second captured image from the one side toward the other side of the aircraft in the

direction of the axis of the aircraft to sequentially generate the second search area image; and repeatedly perform the search while changing the first search area image by using a plurality of the first search area images that are sequentially generated, and repeatedly perform the search while changing the second search area image by using a plurality of the second search area images that are sequentially generated.

[0108] According to the above configuration, a plurality of first search area images are generated from the first captured image captured by the first camera, and each of the plurality of first search area images is demarcated to include its corresponding first area including a part of the first captured image. Similarly, a plurality of second search area images are generated from the second captured image captured by the second camera, and each of the plurality of second search area images is demarcated to include its corresponding second area including a part of the second captured image. Each of the plurality of first search area images is generated by shifting the first area from one side toward the other side of the aircraft in the direction of the axis of the aircraft, and each of the plurality of second search area images is generated by shifting the second area from the one side toward the other side of the aircraft in the direction of the axis of the aircraft. Accordingly, the search for the entrance is repeatedly performed while changing the search area image by using the plurality of search area images that are sequentially generated. In this manner, the search for the entrance can be performed over the entirety of each of the captured images while shifting the search area in a direction along the aircraft axis of the aircraft. This makes it possible to perform the search for the entrance in a uniform manner regardless of the type of the aircraft or the gate arrangement. This makes precise detection of the position of the entrance of the aircraft possible for various gate arrangements.

[0109] [Item 4]

In the detection system according to any one of items 1 to 3, the first camera may be disposed above the second camera.

[0110] [Item 5]

In the detection system according to any one of items 1 to 4, the passenger boarding bridge may include: a cab including a connector to be connected to the entrance of the aircraft; and a lifting/lowering device that lifts and lowers the cab. The first camera and the second camera may be provided on the cab, and the lifting/lowering device may serve as the height changing mechanism.

[0111] According to the above configuration, it is unnecessary to additionally install a mechanism to change the height position of each of the first camera and the second camera, and also, at the time of connecting the connector of the passenger boarding bridge to the entrance of

the aircraft, the amount of adjustment of the height position of the passenger boarding bridge to align it with the position of the entrance can be reduced.

[0112] [Item 6]

The detection system according to item 3 may include an image-capturing direction changing mechanism that changes an image-capturing direction of each of the first camera and the second camera by rotating about a predetermined rotational axis that extends in a direction crossing the horizontal plane. The image processor may determine whether or not the first area that has been shifted is within a predefined search range and within the first captured image. In a case where it is determined that the first area that has been shifted is within the search range, but is not within the first captured image, the controller may cause the image-capturing direction changing mechanism to change the image-capturing direction of each of the first camera and the second camera, and cause each of the first camera and the second camera to perform image capturing again.

[0113] According to the above configuration, while changing the image-capturing direction of each camera, the image capturing is performed multiple times. As a result, a captured image of the entire search range can be obtained as a plurality of captured images. Accordingly, an image-capturing range for each time of image capturing can be made relatively narrow, which makes it possible to increase the resolution of the search area image obtained from each captured image, or makes it possible to set the search range to be wider than the field of view of each camera.

Reference Signs List

- [0114] 2 terminal building
- 3 aircraft
- 6 cab
- 8 lifting/lowering device
- 11 passenger boarding bridge
- 12 second boarding bridge
- 20 detection system
- 21a first camera
- 21b second camera
- 23 image processor
- 30 controller
- 34 image-capturing direction changing mechanism

36 height changing mechanism

D1,D2 entrance

CLAIMS

[Claim 1] A detection system for detecting an entrance of an aircraft, the detection system comprising:

- a passenger boarding bridge connected to a terminal building;
- a first camera and a second camera that are provided on the passenger boarding bridge;
- a height changing mechanism configured to change a height position of each of the first camera and the second camera;
- a controller that controls an operation of the height changing mechanism; and
- an image processor that detects the entrance of the aircraft from a first captured image captured by the first camera and a second captured image captured by the second camera, wherein

- the first camera and the second camera are arranged such that a first angle of a first virtual line relative to a horizontal plane is different from a second angle of a second virtual line relative to the horizontal plane, the first virtual line connecting between an optical center of the first camera and a predetermined position on a physical object whose image is to be captured by the first camera, the second virtual line connecting between an optical center of the second camera and the predetermined position, and

- the image processor generates a first search area image from the first captured image and a second search area image from the second captured image,

- the first search area image includes a wider area in an up-down direction than the second search area image does, and

- in a case where the image processor has detected the entrance from the first search area image and has not detected the entrance from the second search area image, the controller controls the height changing mechanism to change the height position of each of the first camera and the second camera.

[Claim 2] The detection system according to claim 1, wherein

- the image processor demarcates a first area including a part of the first captured image to generate the first search area image including a partial area of the first captured image, the partial area being demarcated based on the first area, and demarcates a second area including a part of the second captured image to generate the second search area image including a partial area of the second captured image, the partial area being demarcated based on the second area,

- the first area and the second area are set to a same area in an actual space, and

the partial area of the first captured image includes a wider area in the up-down direction than the partial area of the second captured image does.

[Claim 3] The detection system according to claim 2, wherein
the image processor:

in a case where the entrance has not been detected from the first search area image, shifts the first area on the first captured image from one side toward the other side of the aircraft in a direction of an axis of the aircraft to sequentially generate the first search area image, and shifts the second area on the second captured image from the one side toward the other side of the aircraft in the direction of the axis of the aircraft to sequentially generate the second search area image; and

repeatedly performs the search while changing the first search area image by using a plurality of the first search area images that are sequentially generated, and repeatedly performs the search while changing the second search area image by using a plurality of the second search area images that are sequentially generated.

[Claim 4] The detection system according to any one of claims 1 to 3, wherein
the first camera is disposed above the second camera.

[Claim 5] The detection system according to any one of claims 1 to 3, wherein
the passenger boarding bridge includes:

a cab including a connector to be connected to the entrance of the aircraft; and
a lifting/lowering device that lifts and lowers the cab,

the first camera and the second camera are provided on the cab, and
the lifting/lowering device serves as the height changing mechanism.

[Claim 6] The detection system according to claim 3, comprising:

an image-capturing direction changing mechanism that changes an image-capturing direction of each of the first camera and the second camera by rotating about a predetermined rotational axis that extends in a direction crossing the horizontal plane, wherein

the image processor determines whether or not the first area that has been shifted is within a predefined search range and within the first captured image, and

in a case where it is determined that the first area that has been shifted is within the search range, but is not within the first captured image, the controller causes the image-capturing

direction changing mechanism to change the image-capturing direction of each of the first camera and the second camera, and causes each of the first camera and the second camera to perform image capturing again.