

HYDROFOIL HEIGHT CONTROL DEVICE, HYDROFOIL CRAFT, HYDROFOIL HEIGHT CONTROL METHOD, PROGRAM, AND MODEL CONSTRUCTION DEVICE

TECHNICAL FIELD

5 [0001] The present disclosure relates to a hydrofoil height control device, a hydrofoil craft, a hydrofoil height control method, a program, and a model construction device.

BACKGROUND ART

[0002] In recent years, hydrofoils have been proposed that automatically control flaps so
10 that the height relative to the water surface is kept constant. For example, Patent Document 1 discloses a hydrofoil craft configured to predict an arrival ocean wave form and calculate a manipulated variable of the angle of a flap based on the predicted wave form.

Citation List

15 Patent Literature

[0003] Patent Document 1: JP2005-306188A

SUMMARY

[0004] However, the length and height of actual waves may change as time elapses from
20 the observation, and consequently, the wave form may irregularly change. Accordingly, the automatic control by predicting the wave form and controlling the flap may not deal with a case where the wave form irregularly changes. To deal with such a case, an operator of the hydrofoil craft (craft operator) manually adjusts the height of the hydrofoil craft when the automatic control is insufficient.

25 [0005] Such a manual operation with the prediction of change in the wave form requires skill and experience. Moreover, as the frequency of the manual operation increases, the burden on an operator who performs the manual operation increases.

[0006] In view of the above, an object of at least one embodiment of the present invention

is to reduce the burden on the operator of the hydrofoil craft due to a manual operation.

[0007] (1) A hydrofoil height control device according to at least one embodiment of the present invention is configured to control a flap for adjusting a height of a hydrofoil craft from a water surface, and comprises: a normal-manipulated-variable acquisition unit configured to acquire a normal manipulated variable of the flap used in a normal operation of the hydrofoil craft, the normal manipulated variable being determined based on a deviation between an actual height of the hydrofoil craft from the water surface and a target height of the hydrofoil craft from the water surface; a target wave image acquisition unit configured to acquire a target wave image of a wave captured from at least one imaging position on the hydrofoil craft; a determination unit configured to determine whether an additional operation is necessary for the flap in addition to the normal operation, based on the determined normal manipulated variable and the target wave image; an additional-manipulated-variable acquisition unit configured to, if it is determined that the additional operation is necessary, acquire an additional manipulated variable of the flap according to the target wave image, based on an additional-manipulated-variable derivation model learned with learning data including a relationship between a manual operation image of the wave captured from a position corresponding to the imaging position when an operator performs a manual operation and a manual manipulated variable in the manual operation; and an operation unit configured to output an actual manipulated variable of the flap, based on the normal manipulated variable and the additional manipulated variable.

[0008] In the above configuration (1), the additional manipulated variable is acquired based on the additional-manipulated-variable derivation model learned with the learning data including a relationship between a manual operation image captured from a position corresponding to the imaging position when the operator performs a manual operation and a manual manipulated variable in this manual operation. In this case, it is possible to reflect the additional manipulated variable in the actual manipulated variable when the normal manipulated variable is insufficient. Thus, it is possible to reduce the burden on the operator of the hydrofoil craft due to a manual operation.

[0009] (2) In some embodiments, in the above configuration (1), the additional-manipulated-variable derivation model derives a value adjusted from the normal manipulated variable as the additional manipulated variable.

[0010] With the above configuration (2), it is possible to derive a value adjusted from the normal manipulated variable as the additional manipulated variable, based on the additional-manipulated-variable derivation model.

[0011] (3) In some embodiments, in the above configuration (1) or (2), the learning data further includes a non-operation image of the wave captured from a position corresponding to the imaging position when the operator does not perform the manual operation, and the determination unit determines whether the additional operation is necessary for the target wave image, based on a necessary determination model learned with the learning data including the non-operation image.

[0012] In the above configuration (3), if it is determined that the additional operation is necessary as a result of determination of the necessity of the additional operation by the determination unit, the operation unit outputs an actual manipulated variable based on the additional manipulated variable acquired by the additional-manipulated-variable acquisition unit. Accordingly, if it is determined that the additional operation is unnecessary as a result of determination of the necessity of the additional operation by the determination unit, the additional-manipulated-variable acquisition unit does not need to acquire the additional manipulated variable. Thus, it is possible to reduce a processing burden.

[0013] (4) In some embodiments, in any one of the above configurations (1) to (3), the device further comprises a model correction unit configured to correct the additional-manipulated-variable derivation model based on a comparison result between the additional manipulated variable obtained by inputting the target wave image to the additional-manipulated-variable derivation model and the manual manipulated variable of the operator for the target wave image input to the additional-manipulated-variable derivation model.

[0014] In the above configuration (4), with the use of the hydrofoil height control device, it is possible to correct and optimize the additional-manipulated-variable derivation model.

For instance, by optimization based on a long-term use, conditions such as weather and season can be reflected in the additional-manipulated-variable derivation model.

[0015] (5) In some embodiments, in any one of the above configurations (1) to (4), the target wave image acquisition unit is configured to acquire a plurality of the target wave images captured at a plurality of the imaging positions, and the additional-manipulated-variable acquisition unit is configured to acquire the additional manipulated variable, based on one or more target wave images having no halation among the plurality of target wave images.

[0016] With the above configuration (5), it is possible to reduce a risk of reducing the accuracy of the additional manipulated variable acquired by the additional-manipulated-variable acquisition unit due to the influence of halation.

[0017] (6) In some embodiments, in any one of the above configurations (1) to (5), the additional-manipulated-variable derivation model outputs one of a plurality of previously classified additional-manipulated-variable candidates as the additional manipulated variable.

[0018] With the above configuration (6), since one of the plurality of previously classified additional-manipulated-variable candidates is output as the additional manipulated variable, it is possible to increase the response speed compared with the case where the additional manipulated variable is calculated each time.

[0019] (7) In some embodiments, in any one of the above configurations (1) to (6), the device further comprises an output unit configured to output a manipulated variable that preferentially controls the flap, instead of or in addition to the actual manipulated variable of the flap output from the operation unit.

[0020] With the above configuration (7), it is possible to control the flap in an emergency upon operation by the operator. Thus, safety is improved.

[0021] (8) A hydrofoil craft according to at least one embodiment of the present invention comprises: the hydrofoil height control device described in any one of the above (1) to (7); at least one imaging device for acquiring a target wave image of a wave captured from at least one imaging position on the hydrofoil craft; and one or more flaps controlled by the hydrofoil height control device for adjusting a height of the hydrofoil craft from a water surface.

[0022] With the above configuration (8), since the hydrofoil height control device described in any one of the above (1) to (7) is included, it is possible to reduce the burden on the operator of the hydrofoil craft due to a manual operation.

[0023] (9) A hydrofoil height control method according to at least one embodiment of the present invention is a method for controlling a flap for adjusting a height of a hydrofoil craft from a water surface, comprising: a normal-manipulated-variable acquisition step of acquiring a normal manipulated variable of the flap used in a normal operation of the hydrofoil craft, the normal manipulated variable being determined based on a deviation between an actual height of the hydrofoil craft from the water surface and a target height of the hydrofoil craft from the water surface; a target wave image acquisition step of acquiring a target wave image of a wave captured from at least one imaging position on the hydrofoil craft; a determination step of determining whether an additional operation is necessary for the flap in addition to the normal operation, based on the determined normal manipulated variable and the target wave image; an additional-manipulated-variable acquisition step of, if it is determined that the additional operation is necessary, acquiring an additional manipulated variable of the flap according to the target wave image, based on an additional-manipulated-variable derivation model learned with learning data including a relationship between a manual operation image of the wave captured from a position corresponding to the imaging position when an operator performs a manual operation and a manual manipulated variable in the manual operation; and an operation step of outputting an actual manipulated variable of the flap, based on the normal manipulated variable and the additional manipulated variable.

[0024] In the above method (9), the additional manipulated variable is acquired based on the additional-manipulated-variable derivation model learned with the learning data including a relationship between a manual operation image captured from a position corresponding to the imaging position when the operator performs a manual operation and a manual manipulated variable in this manual operation. In this case, it is possible to reflect the additional manipulated variable in the actual manipulated variable when the normal manipulated variable is insufficient. Thus, it is possible to reduce the burden on the operator

of the hydrofoil craft due to a manual operation.

[0025] (10) A program according to at least one embodiment of the present invention is configured to cause a computer to function as: a normal-manipulated-variable acquisition unit configured to acquire a normal manipulated variable of the flap used in a normal operation of the hydrofoil craft, the normal manipulated variable being determined based on a deviation between an actual height of the hydrofoil craft from the water surface and a target height of the hydrofoil craft from the water surface; a target wave image acquisition unit configured to acquire a target wave image of a wave captured from at least one imaging position on the hydrofoil craft; a determination unit configured to determine whether an additional operation is necessary for the flap in addition to the normal operation, based on the determined normal manipulated variable and the target wave image; an additional-manipulated-variable acquisition unit configured to, if it is determined that the additional operation is necessary, acquire an additional manipulated variable of the flap according to the target wave image, based on an additional-manipulated-variable derivation model learned with learning data including a relationship between a manual operation image of the wave captured from a position corresponding to the imaging position when an operator performs a manual operation and a manual manipulated variable in the manual operation; and an operation unit configured to output an actual manipulated variable of the flap, based on the normal manipulated variable and the additional manipulated variable.

[0026] In the above configuration (10), the additional manipulated variable is acquired based on the additional-manipulated-variable derivation model learned with the learning data including a relationship between a manual operation image captured from a position corresponding to the imaging position when the operator performs a manual operation and a manual manipulated variable in this manual operation. In this case, it is possible to reflect the additional manipulated variable in the actual manipulated variable when the normal manipulated variable is insufficient. Thus, it is possible to reduce the burden on the operator of the hydrofoil craft due to a manual operation.

[0027] (11) A model construction device according to at least one embodiment of the

present invention is configured to construct an additional-manipulated-variable derivation model used for acquiring an additional manipulated variable of a flap for adjusting a height of a hydrofoil craft from a water surface, and comprises: a manual operation image acquisition unit configured to acquire a manual operation image of a wave captured from one or more positions on the hydrofoil craft; an analysis unit configured to analyze a relationship between the manual operation image of the wave captured on the hydrofoil craft when at least one operator performs a manual operation and a manual manipulated variable in the manual operation; and a model construction unit configured to construct the additional-manipulated-variable derivation model for acquiring the additional manipulated variable of the flap according to the target wave image, based on an analysis result of the analysis unit.

[0028] With the above configuration (11), it is possible to construct the manipulated-variable derivation model usable in the hydrofoil height control device. When the constructed manipulated-variable derivation model is used in the hydrofoil height control device, it is possible to reduce the burden on the operator of the hydrofoil craft due to a manual operation.

[0029] According to at least one embodiment of the present invention, it is possible to reduce the burden on an operator of the hydrofoil craft due to a manual operation.

BRIEF DESCRIPTION OF DRAWINGS

[0030] FIG. 1 is a schematic configuration diagram of a hydrofoil craft according to an embodiment of the present invention.

FIG. 2 is a schematic block configuration diagram of a hydrofoil height control device according to an embodiment.

FIG. 3 is a schematic diagram for describing a function of a hydrofoil height control device according to an embodiment.

FIG. 4 is a flow chart showing an example of control processing executed by a hydrofoil height control device according to an embodiment.

FIG. 5 is a schematic block configuration diagram of a model construction device

according to an embodiment.

FIG. 6 is a conceptual diagram for describing a function of a model construction device according to an embodiment.

5 DETAILED DESCRIPTION

[0031] Embodiments of the present invention will now be described in detail with reference to the accompanying drawings. It is intended, however, that unless particularly identified, dimensions, materials, shapes, relative positions and the like of components described in the embodiments shall be interpreted as illustrative only and not intended to limit
10 the scope of the present invention.

For instance, an expression of relative or absolute arrangement such as “in a direction”, “along a direction”, “parallel”, “orthogonal”, “centered”, “concentric” and “coaxial” shall not be construed as indicating only the arrangement in a strict literal sense, but also includes a state where the arrangement is relatively displaced by a tolerance, or by an angle or a distance
15 whereby it is possible to achieve the same function.

For instance, an expression of an equal state such as “same” “equal” and “uniform” shall not be construed as indicating only the state in which the feature is strictly equal, but also includes a state in which there is a tolerance or a difference that can still achieve the same function.

20 Further, for instance, an expression of a shape such as a rectangular shape or a cylindrical shape shall not be construed as only the geometrically strict shape, but also includes a shape with unevenness or chamfered corners within the range in which the same effect can be achieved.

On the other hand, an expression such as “comprise”, “include”, “have”, “contain” and
25 “constitute” are not intended to be exclusive of other components.

[0032] FIG. 1 is a schematic configuration diagram of a hydrofoil craft 5 according to an embodiment of the present invention. As shown in FIG. 1, the hydrofoil craft 5 includes a hydrofoil height control device 100, at least one imaging device 1 for capturing an image of a

wave from at least one imaging position on the hydrofoil craft 5, one or more flaps 3 (3A, 3B), and a height sensor 4 for measuring an actual height.

[0033] The one or more flaps 3 (3A, 3B) may include a front foil flap 3A and a rear foil flap 3B. The hydrofoil height control device 100 controls at least one of the front foil flap 3A or the rear foil flap 3B. More specifically, the hydrofoil height control device 100 sends a control signal to a drive device 2 (2A, 2B) of the flap 3 (3A, 3B) and controls the angle of the flap 3 (3A, 3B) via the drive device 2 (2A, 2B). The height H of the hydrofoil craft 5 from the water surface is thus adjusted.

[0034] The at least one imaging device 1 is disposed at the at least one imaging position on the hydrofoil craft 5. The imaging position may be, for example, a bridge of the hydrofoil craft 5. The at least one imaging position may be any position that is suitable for capturing an image of wave on the hydrofoil craft 5, for example, may be one or more positions of a bridge, a deck, and a hull of the hydrofoil craft 5.

[0035] The height sensor 4 may be disposed on the bridge of the hydrofoil craft 5 to measure the height H of the hydrofoil craft 5 from the water surface. Thereby, the actual height is obtained.

[0036] The hydrofoil height control device 100 according to an embodiment will now be described in detail. FIG. 2 is a schematic block configuration diagram of the hydrofoil height control device 100 according to an embodiment.

[0037] As shown in FIG. 2, the hydrofoil height control device 100 includes a communication unit 11 configured to communicate with another device, a storage unit 12 configured to store various data, an input unit 13 configured to receive an input from an operator, an output unit 14 configured to output information to the operator, and a control unit 15 configured to control the entire device. These components are connected to each other by a bus line 16.

[0038] The communication unit 11 includes a communication interface for communication with another device. For instance, the communication unit 11 communicates with at least one imaging device 1, the height sensor 4, and the drive device 2 (2A, 2B),

receives a target wave image from the imaging device 1, receives information on the actual height from the height sensor 4, and transmits a control signal to the drive device 2 (2A, 2B). The transmission and reception of the information may be performed through the input unit 13 and the output unit 14. Accordingly, the hydrofoil height control device 100 may not include the communication unit 11.

[0039] The storage unit 12 includes, for example, a random access memory (RAM) and a read only memory (ROM). The storage unit 12 stores a program for executing various control processing and various data. For instance, the storage unit 12 stores information such as an additional-manipulated-variable derivation model, a necessity determination model, a set value of target height, and multiple previously classified additional-manipulated-variable candidates.

[0040] The input unit 13 includes a device such as an operation button and an operation lever, for example. The input unit 13 is an input interface used for the operator to input an instruction. Further, the input unit 13 acquires a manipulated variable when the operator performs operation.

[0041] The output unit 14 includes an output device such as a display and a speaker, for example. The output unit 14 is an output interface for providing information about operation to the operator.

[0042] The control unit 15 includes, for instance, a processor such as a central processing unit (CPU) and a graphics processing unit (GPU). The control unit 15 performs control processing, which will be described later, by executing a program stored in the storage unit 12.

[0043] A functional configuration of the control unit 15 will now be described. The control unit 15 functions as a normal-manipulated-variable acquisition unit 151, a target wave image acquisition unit 152, an additional-manipulated-variable acquisition unit 153, an operation unit 154, a determination unit 155, a model correction unit 156, and an emergency operation unit 157 (output unit).

[0044] The normal-manipulated-variable acquisition unit 151 acquires a normal manipulated variable of the flap 3 (3A, 3B) used in a normal operation of the hydrofoil craft 5.

More specifically, the normal-manipulated-variable acquisition unit 151 acquires a normal manipulated variable determined based on a deviation between an actual height of the hydrofoil craft 5 from the water surface and a target height of the hydrofoil craft 5 from the water surface.

5 [0045] The target wave image acquisition unit 152 acquires a target wave image of a wave captured from at least one imaging position on the hydrofoil craft 5. More specifically, the target wave image acquisition unit 152 acquires a target wave image by receiving the target wave image from the imaging device 1 via the communication unit 11. This operation is periodically or continuously performed when the hydrofoil craft 5 is operating. The target
10 wave image may be still image data acquired at short intervals not longer than one second, or may be moving image data acquired continuously. The same shall apply to a manual operation image and a non-operation image described later.

[0046] The additional-manipulated-variable acquisition unit 153 acquires an additional manipulated variable of the flap 3 (3A, 3B) used in an additional operation of the hydrofoil
15 craft 5. The additional-manipulated-variable acquisition unit 153 acquires an additional manipulated variable according to the target wave image acquired by the target wave image acquisition unit 152 based on an additional-manipulated-variable derivation model stored in the storage unit 12.

[0047] The additional-manipulated-variable derivation model is a model learned with
20 learning data including a relationship between a manual operation image of a wave captured from a position corresponding to the imaging position when the operator performs a manual operation and a manual manipulated variable in this manual operation if it is determined that an additional operation is necessary. The additional-manipulated-variable derivation model is configured to derive a value adjusted from the normal manipulated variable as the
25 additional manipulated variable. The learning data further includes a non-operation image of a wave captured from a position corresponds to the imaging position when at least one operator does not perform a manual operation. The “position corresponding to the imaging position” means a position that is substantially the same as the imaging position of the target

wave image. In other words, the imaging position at the use of the model (imaging position of target wave image) may be the same as the imaging position at the construction of the model (imaging position of manual operation image), or may be changed from the imaging position at the construction of the model, within a range that does not affect the derivation of the additional manipulated variable. For instance, even when the imaging position at the use of the model is changed from the imaging position at the construction of the model to be away from the wave, the influence on the additional manipulated variable may be eliminated by changing the zoom setting.

[0048] The manual manipulated variable used in the learning data may be associated with a manual operation in an automatic operating mode (i.e., a temporary manual operation performed by the operator when the automatic operating mode is insufficient), or a manual operation in a manual operating mode (i.e., a manual operation performed by the operator continuously without the automatic operating mode. In this case, for instance, the manual operation time includes a time during which the angle of the flap 3 (3A, 3B) is fixed).

[0049] The operation unit 154 outputs an actual manipulated variable of the flap 3 (3A, 3B), based on the normal manipulated variable acquired by the normal-manipulated-variable acquisition unit 151 and the additional manipulated variable acquired by the additional-manipulated-variable acquisition unit 153.

[0050] The determination unit 155 determines whether an additional operation is necessary for the target wave image based on a necessity determination model learned with learning data including the non-operation image. The determination unit may determine whether the additional operation is necessary for the flap 3 (3A, 3B) in addition to the normal operation, based on the determined normal manipulated variable and the target wave image. The necessity determination model is a model to determine whether an additional operation is necessary for the input target wave image. In order to realize such a determination, a relationship between the manual operation image and the non-operation image is machine-learned in advance by the necessity determination model based on learning data including these images. Thereby, it is possible to determine whether the additional operation is

necessary for the input wave image. The additional-manipulated-variable derivation model is a model to calculate the additional manipulated variable necessary for the input target wave image. In order to realize such a calculation, a relationship between the manual operation image and a corresponding manual manipulated variable is machine-learned in advance by the additional-manipulated-variable derivation model based on learning data including these images and values. Thereby, it is possible to calculate the additional manipulated variable for the input wave image.

[0051] The necessity determination model and the additional-manipulated-variable derivation model may be configured by analyzing the manual operation image and the non-operation image included in the learning data and acquiring features such as the height of wave, the extension of wave, the estimated distance to wave, and the direction to wave contained in these images. When a target wave image is input to these models, the necessity determination model and the additional-manipulated-variable derivation model may also perform image analysis on this target wave image, and acquire the above features of the target wave image, to determine the necessity of an additional operation or derive an additional manipulated variable based on comparison with the features of the manual operation image and the non-operation image included in the learning data. The necessity determination model is configured to perform classification into two classes (determination whether an additional operation is necessary) using a classifier such as a binary tree or a support vector machine (SVM). Specific methods of constructing the necessity determination model and the additional-manipulated-variable derivation model will be described later in conjunction with a model construction device 200.

[0052] The model correction unit 156 corrects the additional-manipulated-variable derivation model based on a comparison result between the additional manipulated variable obtained by inputting the target wave image to the additional-manipulated-variable derivation model and the manual manipulated variable of the operator for the target wave image input to the additional-manipulated-variable derivation model.

[0053] The emergency operation unit 157 (output unit) outputs a manipulated variable

that preferentially controls the flap 3 (3A, 3B), instead of or in addition to the actual manipulated variable of the flap 3 (3A, 3B) output from the operation unit 154. In other words, the emergency operation unit 157 enables the operator to perform a manual operation in an emergency via the emergency operation unit 157.

5 [0054] A function of the hydrofoil height control device 100 and details of control processing will now be described. FIG. 3 is a schematic diagram for describing a function of the hydrofoil height control device 100 according to an embodiment. FIG. 4 is a flow chart showing an example of control processing executed by the hydrofoil height control device 100 according to an embodiment.

10 [0055] As shown in FIG. 4, the hydrofoil height control device 100 acquires a normal manipulated variable (step S1). Specifically, as shown in FIG. 3, the normal-manipulated-variable acquisition unit 151 acquires the normal manipulated variable based on a deviation between an actual height, which is an actual value of the height (controlled variable) of the hydrofoil craft 5 from the water surface measured by the height sensor 4, and a target height
15 of the hydrofoil craft 5 from the water surface. The normal manipulated variable acquired by the normal-manipulated-variable acquisition unit 151 is input to the operation unit 154. The target height is generally set constant.

[0056] As shown in FIG. 4, the hydrofoil height control device 100 acquires a target wave image (step S2). Specifically, as shown in FIG. 3, the target wave image acquisition unit
20 152 acquires the target wave image from the imaging device 1. The target wave image acquired by the target wave image acquisition unit 152 is input to the determination unit 155 and the additional-manipulated-variable acquisition unit 153.

[0057] As shown in FIG. 4, the hydrofoil height control device 100 determines whether an additional operation is necessary (step S3). Specifically, as shown in FIG. 3, the
25 determination unit 155 determines whether the additional operation is necessary for the input target wave image based on the necessity determination model. The determination result is input to the additional-manipulated-variable acquisition unit 153.

[0058] If the determination unit 155 determines that the additional operation is necessary

for the target wave image (step S3; Yes), the additional-manipulated-variable acquisition unit 153 acquires an additional manipulated variable (step S4). In this case, the additional manipulated variable acquired by the additional-manipulated-variable acquisition unit 153 is input to the operation unit 154. Conversely, if the determination unit 155 determines that the additional operation is unnecessary for the target wave image (step S3; No), step S4 is skipped. Alternatively, when the additional operation is unnecessary, in step S4, a signal indicating that the additional manipulated variable is zero may be output without skipping step S4.

[0059] As shown in FIG. 4, the operation unit 154 outputs an actual manipulated variable for operating the flap 3 (3A, 3B) based on the input normal manipulated variable and additional manipulated variable (step S5). Specifically, the operation unit 154 transmits a control signal indicating the actual manipulated variable to the drive device 2 (2A, 2B) to control the flap 3 (3A, 3B) to be controlled. In FIG. 3, the drive device 2 (2A, 2B) is not depicted.

[0060] As shown in FIG. 4, when the operation unit 154 outputs the actual manipulated variable in step S5, the control processing returns to step S1, and the processing is executed again. In the meantime, as shown in FIG. 3, the height of the hydrofoil craft 5 from the water surface, which is the controlled variable, changes due to the influence of waves as disturbance. The changed height of the hydrofoil craft 5 from the water surface is measured by the height sensor 4, and is fed back as the actual height.

[0061] In the example shown in FIG. 3, the operation unit 154 outputs the sum of the normal manipulated variable and the additional manipulated variable as the actual manipulated variable. However, the configuration of the operation unit 154 is not limited thereto, and may be configured to output either one of the normal manipulated variable or the additional manipulated variable as the actual manipulated variable. For instance, the operation unit 154 may output the additional manipulated variable as the actual manipulated variable if the additional manipulated variable is input, and may output the normal manipulated variable as the actual manipulated variable if the additional manipulated variable

is not input. Thus, the operation unit 154 is configured to output the actual manipulated variable based on the normal manipulated variable and the additional manipulated variable.

[0062] In the example shown in FIG. 4, an emergency operation is not performed by the operator. However, as shown in FIG. 3, when the operator performs an emergency operation, the emergency operation unit 157 (output unit) outputs a manipulated variable that preferentially controls the flap 3 (3A, 3B), instead of or in addition to the actual manipulated variable of the flap 3 (3A, 3B) output from the operation unit 154.

[0063] As described above, for instance as shown in FIGs. 1 to 3, the hydrofoil height control device 100 according to at least one embodiment of the present invention includes: the normal-manipulated-variable acquisition unit 151 configured to acquire a normal manipulated variable of the flap 3 (3A, 3B) used in a normal operation of the hydrofoil craft 5, and configured to acquire the normal manipulated variable determined based on a deviation between an actual height of the hydrofoil craft 5 from the water surface and a target height of the hydrofoil craft 5 from the water surface; the target wave image acquisition unit 152 configured to acquire a target wave image of a wave captured from at least one imaging position on the hydrofoil craft 5; the determination unit 155 configured to determine whether an additional operation is necessary for the flap 3 (3A, 3B) in addition to the normal operation, based on the determined normal manipulated variable and the target wave image; the additional-manipulated-variable acquisition unit 153 configured to, if it is determined that the additional operation is necessary, acquire an additional manipulated variable according to the target wave image, based on the additional-manipulated-variable derivation model learned with learning data including a relationship between a manual operation image of the wave captured from a position corresponding to the imaging position when the operator performs a manual operation and a manual manipulated variable in the manual operation; and the operation unit 154 configured to output an actual manipulated variable of the flap 3 (3A, 3B), based on the normal manipulated variable acquired by the normal-manipulated-variable acquisition unit 151 and the additional manipulated variable acquired by the additional-manipulated-variable acquisition unit 153.

[0064] In this configuration, the additional manipulated variable is acquired based on the additional-manipulated-variable derivation model learned with the learning data including a relationship between a manual operation image captured from a position corresponding to the imaging position when the operator performs a manual operation and a manual manipulated variable in this manual operation. In this case, it is possible to reflect the additional manipulated variable in the actual manipulated variable when the normal manipulated variable is insufficient. Thus, it is possible to reduce the burden on the operator of the hydrofoil craft 5 due to a manual operation.

[0065] In some embodiments, the additional-manipulated-variable derivation model may be configured to derive a value adjusted from the normal manipulated variable as the additional manipulated variable.

[0066] With this configuration, it is possible to derive a value adjusted from the normal manipulated variable as the additional manipulated variable, based on the additional-manipulated-variable derivation model.

[0067] In some embodiments, the learning data further includes a non-operation image captured from a position corresponding to the imaging position when the operator does not perform a manual operation, and the determination unit 155 determines whether an additional operation is necessary for the target wave image based on a necessity determination model learned with the learning data including the non-operation image.

[0068] In this configuration, if it is determined that the additional operation is necessary as a result of determination of the necessity of the additional operation by the determination unit 155, the operation unit 154 outputs an actual manipulated variable based on the additional manipulated variable acquired by the additional-manipulated-variable acquisition unit 153. Accordingly, if it is determined that the additional operation is unnecessary as a result of determination of the necessity of the additional operation by the determination unit 155, the additional-manipulated-variable acquisition unit 153 does not need to acquire the additional manipulated variable. Thus, it is possible to reduce a processing burden.

[0069] In some embodiments, for instance, as shown in FIG. 2, the hydrofoil height

control device 100 includes the model correction unit 156 configured to correct the additional-manipulated-variable derivation model based on a comparison result between the additional-manipulated variable obtained by inputting the target wave image to the additional-manipulated-variable derivation model and the manual manipulated variable of the operator
5 for the target wave image input to the additional-manipulated-variable derivation model.

[0070] In this configuration, with the use of the hydrofoil height control device 100, it is possible to correct and optimize the additional-manipulated-variable derivation model. For instance, by optimization based on a long-term use, conditions such as weather and season can be reflected in the additional-manipulated-variable derivation model.

10 [0071] In some embodiments, for instance, in the configuration shown in FIGs. 2 and 3, the target wave image acquisition unit 152 may be configured to acquire a plurality of the target wave images obtained at a plurality of the imaging positions, and the additional-manipulated-variable acquisition unit 153 may be configured to acquire the additional-manipulated variable, based on one or more target wave images having no halation among the
15 plurality of target wave images. Whether halation has occurred may be determined by whether the luminance of the target wave image is equal to or greater than a threshold.

[0072] With this configuration, it is possible to reduce a risk of reducing the accuracy of the additional manipulated variable acquired by the additional-manipulated-variable acquisition unit 153 due to the influence of halation. Further, since the additional
20 manipulated variable can be acquired by comprehensive evaluation based on the plurality of target wave images, the accuracy is improved.

[0073] In some embodiments, the additional-manipulated-variable derivation model used by the additional-manipulated-variable acquisition unit 153 may be configured to output one of a plurality of additional-manipulated-variable candidates that are previously classified, as
25 the additional manipulated variable. The additional-manipulated-variable candidates are predetermined discrete values of magnitude of the manipulated variable, for example, including a first value (large manipulated variable), a second value (medium manipulated variable), and a third value (small manipulated variable).

[0074] With this configuration, since the additional-manipulated-variable acquisition unit 153 outputs one of the plurality of previously classified additional-manipulated-variable candidates as the additional manipulated variable, it is possible to increase the response speed compared with the case where the additional manipulated variable is calculated each time.

5 [0075] In some embodiments, for instance as shown in FIGs. 2 and 3, the hydrofoil height control device 100 further includes an output unit (emergency operation unit 157) configured to output a manipulated variable that preferentially controls the flap 3 (3A, 3B), instead of or in addition to the actual manipulated variable of the flap 3 (3A, 3B) output from the operation unit 154.

10 [0076] With this configuration, it is possible to control the flap 3 (3A, 3B) in an emergency upon operation by the operator. Thus, safety is improved.

[0077] The model construction device 200 according to an embodiment will now be described in detail. FIG. 5 is a schematic block configuration diagram of the model construction device 200 according to an embodiment. The model construction device 200 according to an embodiment is a device for constructing the additional-manipulated-variable derivation model and the necessity determination model. The model construction device 200 may be a device for constructing either one of the additional-manipulated-variable derivation model or the necessity determination model.

[0078] As shown in FIG. 5, the model construction device 200 includes a communication unit 21 configured to communicate with another device, a storage unit 22 configured to store various data, an input unit 23 configured to receive an input from an operator, an output unit 24 configured to output information to the operator, and a control unit 25 configured to control the entire device. These components are connected to each other by a bus line 26.

[0079] An operator for constructing the model preferably has skill and experience. Further, the operator for constructing the model may be different from the operator who uses the hydrofoil height control device 100. In the following description, the imaging device 1, the height sensor 4, and the drive device 2 (2A, 2B) may be different from those when the hydrofoil height control device 100 is used. However, these devices preferably have

substantially the same functions as those when the hydrofoil height control device 100 is used. Further, imaging conditions, such as position, imaging direction, and imaging area of the imaging device 1 at the construction of the model are preferably not much different from imaging conditions of the imaging device 1 at the use of the model. This is to prevent a reduction in accuracy due to a difference in environmental conditions between model construction and model use.

[0080] The communication unit 21 includes a communication interface for communication with another device. For instance, the communication unit 21 communicates with at least one imaging device 1, the height sensor 4, and the drive device 2 (2A, 2B), receives a target wave image from the imaging device 1, receives information on the actual height from the height sensor 4, and transmits a control signal to the drive device 2 (2A, 2B). The transmission and reception of the information may be performed through the input unit 23 and the output unit 24. Accordingly, the model construction device 200 may not include the communication unit 21.

[0081] The storage unit 22 may include RAM and ROM. The storage unit 22 stores a program for executing various control processing and various data. For instance, the storage unit 22 stores information such as a learning algorithm 203 (see FIG. 6 described later), a constructed additional-manipulated-variable derivation model, a constructed necessity determination model, and multiple previously classified additional-manipulated-variable candidates. Further, the storage unit 22 stores information such as input information including the manual operation image and the non-operation image, and correct information corresponding to the input information, including the presence or absence of a manual operation and a manual manipulated variable in the manual operation. The input information is stored as an input DB 201 (see FIG. 6 described below), and the correct information is stored as a correct DB 202 (see FIG. 6 described below).

[0082] The input unit 23 includes a device such as an operation button and an operation lever, for example. The input unit 23 is an input interface used for the operator to input an instruction. Further, the input unit 23 acquires a manipulated variable when the operator

performs operation. The acquired manual manipulated variable may not be identical to an actual manipulated variable provided by the operator, but may be converted to one of previously classified additional-manipulated-variable candidates (e.g., large manipulated variable, medium manipulated variable, and small manipulated variable) according to the magnitude of the actual manipulated variable.

[0083] The output unit 24 includes an output device such as a display and a speaker, for example. The output unit 24 is an output interface for providing information about operation to the operator.

[0084] The control unit 25 may include a processor such as CPU and GPU. The control unit 25 performs control processing, which will be described later, by executing a program stored in the storage unit 22.

[0085] A functional configuration of the control unit 25 will now be described. The control unit 25 functions as a manual-operation-image acquisition unit 251, a non-operation-image acquisition unit 252, a manual-manipulated-variable acquisition unit 253, an analysis unit 254, and a model construction unit 255.

[0086] The manual-operation-image acquisition unit 251 acquires a manual operation image of a wave captured from one or more imaging positions on the hydrofoil craft 5. The manual operation image is an image of a wave when the operator performs a manual operation.

[0087] The non-operation-image acquisition unit 252 acquires a non-operation image of a wave captured from one or more imaging positions on the hydrofoil craft 5. The non-operation image is an image of a wave when the operator does not perform a manual operation.

[0088] The manual-manipulated-variable acquisition unit 253 acquires a manual manipulated variable in a manual operation corresponding to the manual operation image. The manual-manipulated-variable acquisition unit 253 also acquires the presence or absence of a manual operation according to whether the manual manipulated variable is zero. The acquired manual manipulated variable may be an additional manipulated variable (only

addition) added to the normal manipulated variable in the automatic control, or may be a manipulated variable (total manipulated variable) applied instead of the normal manipulated variable in the automatic control.

[0089] The analysis unit 254 analyzes a relationship between the manual operation image
5 obtained on the hydrofoil craft 5 and the manual manipulated variable in that manual operation.

[0090] The model construction unit 255 constructs the additional-manipulated-variable derivation model and the necessity determination model, based on the analysis result of the analysis unit 254.

10 [0091] A function of the model construction device 200 will now be described in detail. FIG. 6 is a conceptual diagram for describing a function of the model construction device 200 according to an embodiment.

[0092] As shown in FIG. 6, the model construction device 200 acquires the manual operation image and the non-operation image as the input information from the imaging
15 device 1. The images may be identified as the manual operation image or the non-operation image according to whether the operator performs a manual operation for the image acquired as the target wave image by the imaging device 1. The acquired input information is accumulated in the input DB 201.

[0093] The model construction device 200 acquires the presence or absence of the manual
20 operation of the operator and the manual manipulated variable as the correct information corresponding to the input information via the input unit 23. The information accumulated in the input DB 201 is input to the learning algorithm 203. In FIG. 6, the learning algorithm 203 includes algorithms for generating the necessity determination model or the additional-manipulated-variable derivation model to be generated and a model for generating the
25 necessity determination model or the additional-manipulated-variable derivation model. The analysis unit 254 shown in FIG. 5 analyzes the information accumulated in the input DB 201 using the learning algorithm 203, and the model construction unit 255 temporarily constructs the additional-manipulated-variable derivation model and the necessity determination model,

based on the analysis result.

[0094] Then, as shown in FIG. 6, the model construction device 200 inputs the target wave image acquired by the imaging device 1 to the learning algorithm 203, and outputs an additional manipulated variable or a determination result regarding the necessity of an additional operation, based on the temporarily constructed additional-manipulated-variable derivation model and the necessity determination model. Further, the model construction device 200 acquires information regarding whether the operator performs a manual operation for the target wave image and a manual manipulated variable in the manual operation as the correction information.

[0095] The output obtained by the temporarily constructed additional-manipulated-variable derivation model and the necessity determination model and the correct information acquired from the correct DB 202 are input to an evaluation unit 204. The evaluation unit 204 feeds back a result of comparing them to the learning algorithm 203. As a result, an error of the output of the temporarily constructed additional-manipulated-variable derivation model and the necessity determination model from the correction information is gradually corrected, and when the error is brought into a predetermined range, the additional-manipulated-variable derivation model and the necessity determination model are finally constructed. The learning algorithm 203 and the evaluation unit 204 shown in FIG. 6 are implemented by cooperation of the analysis unit 254 and the model construction unit 255 shown in FIG. 5.

[0096] <Necessity determination model>

For constructing the necessity determination model, a previously acquired target wave image (manual operation image or non-operation image) and binary information indicating whether the operator performs a manual operation in this wind wave state are used. The input DB 201 stores data of N-number of target wave images previously acquired (N is any natural number). The correct DB 202 stores binary information indicating whether there is an additional operation corresponding to the N target wave images on a one-to-one basis. The binary information may be expressed as “1” when an operation is performed and “0”

when no operation is performed, for instance.

[0097] In FIG. 6, X_i represents data of the target wave image extracted from the input DB 201. X_i is, for example, RGB information in an image of $m \times n$ pixels (m and n are any natural numbers). In this case, X_i is $m \times n \times 3$ real-valued data indicating values of red, green, and blue components of each pixel. Y_i is binary information extracted as correct information corresponding to X_i .

[0098] The necessity determination model is, for example, a function y_i that outputs 0 or 1 when X_i is input. For example, the function is $y_i = f(X_i, a)$. “ a ” represents a parameter group. For example, when X_i is $m \times n \times 3$ real values, X_i is expressed as follows: $X_i = [X_{i1}, X_{i2}, X_{i3}, \dots, X_{im \times n \times 3}]$. When the parameter group is expressed as follows: $a = [a_1, a_2, a_3, \dots, a_N]$, the following nonlinear function is obtained: $y_i = a_1 \times X_{i1} + a_2 \times X_{i2} + \dots + a_i \times X_{i1} \times X_{i1} + a_{i+1} \times X_{i1} \times X_{i2} + \dots$. The evaluation unit 204 compares and evaluates the value obtained from the function y_i with the correct information Y_i , and according to the evaluation result, the learning algorithm 203 adjusts the parameter group such that the output value y_i of the function y_i of the temporary necessity determination model approximates the correct information Y_i . Consequently, the final necessity determination model is constructed.

[0099] <Additional-manipulated-variable derivation model>

For constructing the additional-manipulated-variable derivation model, a wave image when the operator performs a manual operation (i.e., manual operation image) among a plurality of previously acquired target wave images, and an additional manipulated variable at that time (i.e., total manipulated variable included in the manual manipulated variable or a manipulated variable to be added) are used.

[0100] The input DB 201 stores data of N -number of target wave images previously acquired (N is any natural number). The correct DB 202 stores additional manipulated variables corresponding to the N target wave images on a one-to-one basis. The additional manipulated variable may be expressed by a real number of 0 to 100.

[0101] In the construction of the additional-manipulated-variable derivation model, as with the case of constructing the necessity determination model, X_i is data of the target wave

image extracted from the input DB 201, for example, $m \times n \times 3$ real-valued data. Y_i is an additional manipulated variable extracted as correct information corresponding to X_i .

[0102] The additional-manipulated-variable derivation model is, for example, a function y_i that outputs a value of the additional manipulated variable in a range of 0 to 100 when X_i is input. For example, the function is $y_i = f(X_i, a)$. “a” represents a parameter group. The parameter group of the additional-manipulated-variable derivation model may be different from the parameter group of the necessity determination model. In the construction of the additional-manipulated-variable derivation model, as with the case of constructing the necessity determination model, the learning algorithm 203 and the evaluation unit 204 adjust the parameter group. Consequently, the final additional-manipulated-variable derivation model is constructed.

[0103] As described above, the model construction device 200 according to an embodiment is configured to construct the additional-manipulated-variable derivation model used for acquiring an additional manipulated variable of one or more flap 3 (3A, 3B) for adjusting the height of the hydrofoil craft 5 from the water surface. The model construction device 200 includes the manual operation image acquisition unit 251 configured to acquire a manual operation image of a wave captured from one or more positions on the hydrofoil craft 5, the analysis unit 254 configured to analyze a relationship between the manual operation image of the wave captured on the hydrofoil craft 5 when at least one operator performs a manual operation and a manual manipulated variable in the manual operation, and a model construction unit 255 configured to construct the additional-manipulated-variable derivation model for acquiring an additional manipulated variable of the flap 3 (3A, 3B) according to the target wave image, based on the analysis result of the analysis unit 254.

[0104] With this configuration, it is possible to construct the additional-manipulated-variable derivation model usable in the hydrofoil height control device 100. When the constructed additional-manipulated-variable derivation model is used in the hydrofoil height control device 100, it is possible to reduce the burden on the operator of the hydrofoil craft 5 due to a manual operation.

[0105] The present invention is not limited to the embodiments described above, but includes modifications to the embodiments described above, and embodiments composed of combinations of those embodiments.

[0106] For instance, the hydrofoil height control device 100 and the model construction
5 device 200 may be configured to take into consideration other information such as speed, acceleration, weather conditions (e.g., air volume and wind direction) of the hydrofoil craft 5 when the necessity determination model or the additional-manipulated-variable derivation model is constructed or used. The model construction device 200 may be configured to use
10 a virtual space image with VR technology to produce a state as if the operator operates the hydrofoil craft 5, and learn the presence or absence of the manual operation by the operator or the manual manipulated variable.

[0107] The hydrofoil height control device 100 and the model construction device 200 may be combined as appropriate. For instance, the function of the model construction device 200 to construct the model may be implemented in the hydrofoil height control device
15 100 so that the model used for control of the hydrofoil height control device 100 can be constructed. Further, the function of the model correction unit 156 of the hydrofoil height control device 100 may be implemented in the model construction device 200 so that the model construction device 200 can both construct and correct the model.

CLAIMS

1. A hydrofoil height control device configured to control a flap for adjusting a height of a hydrofoil craft from a water surface, comprising:

5 a normal-manipulated-variable acquisition unit configured to acquire a normal manipulated variable of the flap used in a normal operation of the hydrofoil craft, the normal manipulated variable being determined based on a deviation between an actual height of the hydrofoil craft from the water surface and a target height of the hydrofoil craft from the water surface;

10 a target wave image acquisition unit configured to acquire a target wave image of a wave captured from at least one imaging position on the hydrofoil craft;

a determination unit configured to determine whether an additional operation is necessary for the flap in addition to the normal operation, based on the determined normal manipulated variable and the target wave image;

15 an additional-manipulated-variable acquisition unit configured to, if it is determined that the additional operation is necessary, acquire an additional manipulated variable of the flap according to the target wave image, based on an additional-manipulated-variable derivation model learned with learning data including a relationship between a manual operation image of the wave captured from a position corresponding to the imaging position when an operator
20 performs a manual operation and a manual manipulated variable in the manual operation; and

an operation unit configured to output an actual manipulated variable of the flap, based on the normal manipulated variable and the additional manipulated variable.

2. The hydrofoil height control device according to claim 1,

25 wherein the additional-manipulated-variable derivation model derives a value adjusted from the normal manipulated variable as the additional manipulated variable.

3. The hydrofoil height control device according to claim 1 or 2,

wherein the learning data further includes a non-operation image of the wave captured from a position corresponding to the imaging position when the operator does not perform the manual operation, and

wherein the determination unit determines whether the additional operation is necessary for the target wave image, based on a necessary determination model learned with the learning data including the non-operation image.

4. The hydrofoil height control device according to any one of claims 1 to 3, further comprising a model correction unit configured to correct the additional-manipulated-variable derivation model based on a comparison result between the additional manipulated variable obtained by inputting the target wave image to the additional-manipulated-variable derivation model and the manual manipulated variable of the operator for the target wave image input to the additional-manipulated-variable derivation model.

5. The hydrofoil height control device according to any one of claims 1 to 4, wherein the target wave image acquisition unit is configured to acquire a plurality of the target wave images captured at a plurality of the imaging positions, and

wherein the additional-manipulated-variable acquisition unit is configured to acquire the additional manipulated variable, based on one or more target wave images having no halation among the plurality of target wave images.

6. The hydrofoil height control device according to any one of claims 1 to 5, wherein the additional-manipulated-variable derivation model outputs one of a plurality of previously classified additional-manipulated-variable candidates as the additional manipulated variable.

7. The hydrofoil height control device according to any one of claims 1 to 6, further comprising an output unit configured to output a manipulated variable that preferentially

controls the flap, instead of or in addition to the actual manipulated variable of the flap output from the operation unit.

8. A hydrofoil craft comprising:

- 5 the hydrofoil height control device according to any one of claims 1 to 7;
 at least one imaging device for acquiring a target wave image of a wave captured from at least one imaging position on the hydrofoil craft; and
 one or more flaps controlled by the hydrofoil height control device for adjusting a height of the hydrofoil craft from a water surface.

10

9. A hydrofoil height control method for controlling a flap for adjusting a height of a hydrofoil craft from a water surface, comprising:

- a normal-manipulated-variable acquisition step of acquiring a normal manipulated variable of the flap used in a normal operation of the hydrofoil craft, the normal manipulated
 15 variable being determined based on a deviation between an actual height of the hydrofoil craft from the water surface and a target height of the hydrofoil craft from the water surface;

a target wave image acquisition step of acquiring a target wave image of a wave captured from at least one imaging position on the hydrofoil craft;

- a determination step of determining whether an additional operation is necessary for the
 20 flap in addition to the normal operation, based on the determined normal manipulated variable and the target wave image;

- an additional-manipulated-variable acquisition step of, if it is determined that the additional operation is necessary, acquiring an additional manipulated variable of the flap according to the target wave image, based on an additional-manipulated-variable derivation
 25 model learned with learning data including a relationship between a manual operation image of the wave captured from a position corresponding to the imaging position when an operator performs a manual operation and a manual manipulated variable in the manual operation; and

an operation step of outputting an actual manipulated variable of the flap, based on the

normal manipulated variable and the additional manipulated variable.

10. A program configured to cause a computer to function as:

a normal-manipulated-variable acquisition unit configured to acquire a normal manipulated variable of the flap used in a normal operation of the hydrofoil craft, the normal manipulated variable being determined based on a deviation between an actual height of the hydrofoil craft from the water surface and a target height of the hydrofoil craft from the water surface;

a target wave image acquisition unit configured to acquire a target wave image of a wave captured from at least one imaging position on the hydrofoil craft;

a determination unit configured to determine whether an additional operation is necessary for the flap in addition to the normal operation, based on the determined normal manipulated variable and the target wave image;

an additional-manipulated-variable acquisition unit configured to, if it is determined that the additional operation is necessary, acquire an additional manipulated variable of the flap according to the target wave image, based on an additional-manipulated-variable derivation model learned with learning data including a relationship between a manual operation image of the wave captured from a position corresponding to the imaging position when an operator performs a manual operation and a manual manipulated variable in the manual operation; and

an operation unit configured to output an actual manipulated variable of the flap, based on the normal manipulated variable and the additional manipulated variable.

11. A model construction device configured to construct an additional-manipulated-variable derivation model used for acquiring an additional manipulated variable of a flap for adjusting a height of a hydrofoil craft from a water surface, comprising:

a manual operation image acquisition unit configured to acquire a manual operation image of a wave captured from one or more positions on the hydrofoil craft;

an analysis unit configured to analyze a relationship between the manual operation

image of the wave captured on the hydrofoil craft when at least one operator performs a manual operation and a manual manipulated variable in the manual operation; and

a model construction unit configured to construct the additional-manipulated-variable derivation model for acquiring the additional manipulated variable of the flap according to the

5 target wave image, based on an analysis result of the analysis unit.