# Description

## Invention Title

**CONTROL METHOD, CONTROL SYSTEM, AND DEVICE FOR UNDERWATER ROBOTS**

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# CONTROL METHOD, CONTROL SYSTEM, AND DEVICE FOR UNDERWATER ROBOTS

## 1. Technical Field

[0001] The invention relates to the technical field of underwater robot attitude control, and specifically to a control method, control system, and device for underwater robots.

## 2. Background Art

[0002] Underwater robots, also known as ROVs, can be widely applied in fields such as marine exploration, environmental monitoring, resource prospecting, and marine engineering. With the complex diversity of underwater environments, the demand for the use of underwater robots is constantly increasing. At this stage, the traditional control technologies for underwater robots face many challenges, such as underwater signal attenuation, the influence of hydrodynamics, and variable environmental conditions, all of which require high control accuracy of underwater robots.

[0003] At present, the control behavior of underwater robots is usually controlled by a PID controller. When using a PID controller to control an underwater robot, the proportional gain in the PID controller is usually preset manually and cannot be adjusted automatically according to external underwater environmental conditions, which increases the operation difficulty of the underwater robot and reduces its control accuracy.

## 3. Summary of the Invention

[0004] The invention provides a control method, control system, and device for underwater robots to solve the existing problem: under normal circumstances, the proportional gain of the PID controller in an underwater robot is usually preset manually and cannot be adjusted automatically according to external underwater environmental conditions.

[0005] The control method for underwater robots of the invention adopts the following technical solution:

[0006] It includes the following steps:

[0007] acquire movement direction progression elements in several directions at multiple moments;

[0008] based on the movement direction progression elements, compare the movement tendencies of the underwater robot in different directions to obtain the movement state degree of the movement direction progression elements in different movement directions; according to the movement state degree, screen out main machine movement directions at different moments from all directions, and construct a main machine movement direction sequence of the underwater robot;

[0009] in the main machine movement direction sequence, analyze the movement degree of the main machine movement direction within a preset local time range to obtain the machine anomaly degree at different moments; according to the machine anomaly degree, compare the abnormal changes of the movement direction progression elements between different main machine movement directions, and classify the movement direction progression elements into core machine to-be-adjusted categories.

[0010] analyze the to-be-adjusted situation of the movement direction progression elements in the same core machine to-be-adjusted category to obtain the correction adjustment component elements; perform attitude control on the underwater robot according to the correction adjustment component elements.

[0011] A method for obtaining the movement state degree is as follows:

[0012] take any direction as a target direction and any moment as a target moment, compare the difference in movement direction progression elements between the target direction and all overall directions at the same moment, and obtain the movement state degree of the target direction at the target moment.

[0013] Preferably, after calculating the movement state degree, the method further includes:

[0014] performing normalization processing on the movement state degree.

[0015] A method for obtaining the main machine movement direction sequence is as follows:

[0016] take any moment as a marked moment; at the marked moment, take the direction to which the movement direction progression element with the largest movement state degree belongs as the main machine movement direction at the marked moment; take the sequence formed by arranging the main machine movement directions at all moments in ascending order of time as the main machine movement direction sequence.

[0017] A method for obtaining the machine anomaly degree is as follows:

[0018] take any moment as a reference moment; obtain the preset local time range of the reference moment; analyze the movement degree of the main machine movement direction within the preset local time range to obtain a range machine attitude stability of the reference moment; according to the range machine attitude stability, combined with the analysis of the extreme situation of the movement tendency of the reference moment in the main machine movement direction sequence, obtain the machine anomaly degree of the reference moment at the reference moment.

[0019] A method for obtaining the range machine attitude stability is as follows:

[0020] analyze the stability of the movement state degree under the overall main machine movement direction within the preset local time range to obtain the range machine attitude stability of the reference moment.

[0021] A method for obtaining the core machine to-be-adjusted categories is as follows: [0022] compare the differences in movement state degrees between the main machine movement directions at different moments, and combine with the machine anomaly degree to obtain the category membership degree between different moments; according to the category membership degree, classify the movement direction progression elements into core machine to-be-adjusted categories.

[0023] A method for obtaining correction adjustment component elements is as follows: [0024] compare the change differences in machine anomaly degrees between different core machine to-be-adjusted categories to obtain the machine anomaly control time range; analyze the coverage length within the machine anomaly control time range to obtain the correction adjustment component elements.

[0025] A control system for an underwater robot, comprising a memory, a processor, and a computer program stored in the memory and running on the processor. The processor executes the computer program to implement the steps of the aforementioned method.

[0026] A control device for an underwater robot, the device comprising:

[0027] a movement direction travel element acquisition module, a machine control command analysis module, and an underwater robot control module; wherein the movement direction travel element acquisition module is used to acquire movement direction travel elements in several directions at a number of moments; the machine control command analysis module implements the steps of the control method for the underwater robot by calling a computer program to obtain correction adjustment component elements; and the underwater robot control module performs attitude control on the underwater robot according to the correction adjustment component elements.

[0027] The beneficial effects of the technical solution of the invention are as follows: based on the movement direction progression elements, the movement tendencies of the underwater robot in different directions are compared to obtain the movement state degree of the movement direction progression elements in different movement directions; the movement state degree is used to reflect the directional tendency of the underwater robot's operation in various directions during underwater operations, making the machine control behaviors of the underwater robot in different directions more obvious. Then, according to the movement state degree, the movement degree of the main machine movement direction within a preset local time range is analyzed to obtain the machine anomaly degree at different moments; the machine anomaly degree is used to reflect the difficulty for the underwater robot to maintain the original predetermined direction for machine operation, making it easier to observe the influence of the buoyancy of the external water body on the underwater robot at different moments. Finally, according to the machine anomaly degree, the to-be-adjusted situation of the movement direction progression elements is analyzed and attitude control is performed on the underwater robot. When the underwater robot is operating underwater, the invention adaptively obtains correction adjustment component elements by analyzing the influence of water flow buoyancy on the robot components in different directions at different moments,

further adjusts the proportional gain, and performs attitude control on the subsequent operations of the underwater robot through the PID controller. This makes the proportional gain of the PID controller more in line with the requirements of the underwater environment and enables more accurate control of the underwater robot during underwater operations.

## 4. Brief Description of Accompany Drawings

[0029] To more clearly illustrate the technical solutions in the embodiments of the invention or the prior art, the accompanying drawings required for describing the embodiments or the prior art will be briefly introduced below. Obviously, the accompanying drawings in the following description are only some embodiments of the invention. For those of ordinary skill in the art, other accompanying drawings can also be obtained based on these drawings without exerting creative labor.

[0030] FIG. 1 is a step flow chart of a control method, control system and device for underwater robots of the invention.

## 5. Specific Embodiment of the invention

[0031] In order to further elaborate on the technical means and effects adopted by the invention to achieve the predetermined invention objectives, the specific implementation modes, structures, features and effects of a control method, control system and device for underwater robots proposed according to the invention will be described in detail below in conjunction with the accompanying drawings and preferred embodiments. In the following description, different "one embodiment" or "another embodiment" do not necessarily refer to the same embodiment. In addition, specific features, structures or characteristics in one or more embodiments can be combined in any appropriate form.

[0032] Unless otherwise defined, all technical and scientific terms used herein have the same meanings as commonly understood by those skilled in the technical field of the invention.

[0033] The following specifically describes the specific solutions of a control method, control system, and device for underwater robots provided by the invention with reference to the accompanying drawings.

[0034] Please refer to FIG. 1, which shows a step flow chart of a control method, control system, and device for underwater robots provided by an embodiment of the invention. a method includes the following steps:

[0035] Step S001: acquire the movement direction progression elements in several directions at multiple moments.

[0036] It should be noted that at present, the control behavior of underwater robots is usually controlled by a PID controller; when using a PID controller to control an underwater robot, the proportional gain in the PID controller is usually preset manually and cannot be adjusted automatically according to external underwater environmental conditions. This increases the difficulty of operating the underwater robot and reduces its control accuracy.

[0037] In a specific implementation of the embodiment of the invention, a method for acquiring the movement direction progression elements is as follows: use a three-axis sensor to obtain acceleration elements in each direction during the underwater operation of the underwater robot in the past day; and use each acceleration element as a movement direction progression element.

[0038] It is particularly noted that the collection interval of acceleration elements is 1 second per time.

[0039] It should be noted that the three-axis sensor can obtain acceleration elements in three directions, and each acceleration element includes a value and a direction.

[0040] So far, the movement direction progression elements in different directions at multiple moments are obtained through the above method.

[0041] Step S002: based on the movement direction progression elements, compare the movement tendencies of the underwater robot in different directions to obtain the movement state degree of the movement direction progression elements in different movement directions; according to the movement state degree, screen out the main machine movement directions at different moments from all directions, and construct a main machine movement direction sequence of the underwater robot.

[0042] It should be noted that when the underwater robot operates underwater, the surrounding water flow will flow to different degrees with the robot's movements. As a result, the buoyancy of water acting on the underwater robot in various directions changes with the flow of the water flow, which generates a certain resistance to the predetermined operation behavior of the underwater robot, interferes with the movement tendency of the underwater robot, and thus interferes with the movement state. Therefore, based on the movement direction progression elements, the movement tendencies of the underwater robot in different directions can be compared to obtain the movement state degree of the movement direction progression elements in different movement directions. Among them, the greater the movement state degree, the more obvious the movement tendency of the underwater robot in the corresponding direction at the corresponding moment, which reflects that the underwater robot performs a larger-scale operation in the corresponding direction.

[0043] Preferably, in some implementations of the embodiment of the invention, a method for obtaining the movement state degree is as follows: take any direction as a target direction and any moment as a target moment, compare the difference in movement direction progression elements between the target direction and all overall directions at the same moment, and obtain the movement state degree of the target direction at the target moment. The specific process is as follows:

[0044] Take a modulus of the movement direction progression element of each direction at the target moment as a reference movement tendency component of each direction at the target moment; take the average value of reference movement tendency components of all directions at the target moment as the total reference movement tendency component at the target moment; take the normalized value of the ratio between the reference movement tendency component of the target direction at the target moment and the total reference movement tendency component as the movement state degree of the target direction at the target moment.

[0045] It is particularly noted that this embodiment uses the norm() function as an example for normalization processing, and the normalization function can be determined according to specific implementation conditions.

[0046] It should be noted that the greater the movement state degree, the more obvious the movement tendency of the underwater robot in the corresponding direction at the corresponding moment, which reflects that the underwater robot performs a larger-scale operation in the corresponding direction.

[0047] It should be noted that the movement state degree to a certain extent represents the movement possibility of the underwater robot's movement at a single moment and in a single direction. For a single moment, the operating state of the underwater robot is mainly represented by the movement tendencies in various directions. If the movement possibility in a certain direction is greater, it means that the movement state of the underwater robot after being represented by the overall direction at the corresponding moment will also approach the corresponding direction. Therefore, according to the movement state degree, the main machine movement directions at different moments can be screened out from all directions, and the main machine movement direction sequence of the underwater robot can be constructed, so as to determine the main movement direction that can best represent the underwater robot at the corresponding moment at different moments.

[0048] Preferably, in some implementations of the embodiment of the invention, a method for obtaining the main machine movement direction sequence is as follows: take any moment as a marked moment; at the marked moment, take the direction to which the movement direction progression element with the largest movement state degree belongs as the main machine movement direction at the marked moment; take the sequence formed by arranging the main machine movement directions at all moments in ascending order of time as the main machine movement direction sequence.

[0049] So far, the main machine movement direction sequence is obtained through the above method.

[0050] Step S003: in the main machine movement direction sequence, analyze the movement degree of the main machine movement direction within a preset local time range to obtain the machine anomaly degree at different moments; according to the machine anomaly degree, compare the abnormal changes of the movement direction progression elements between

different main machine movement directions, and classify the movement direction progression elements into core machine to-be-adjusted categories.

[0051] It should be noted that in the actual underwater environment, due to the presence of other small organisms and microorganisms underwater, the movement of these organisms may also affect the water flow to a certain extent, making the changes of the underwater water flow relatively complex, which leads to sudden changes in the movement state of the underwater robot at a single moment, and these sudden change moments usually have a low degree of matching with the movement states in the surrounding range. Therefore, in the main machine movement direction sequence, the movement degree of the main machine movement direction within the preset local time range can be analyzed to obtain the machine anomaly degree of the reference moment at different moments. Among them, the greater the machine anomaly degree, the more obvious the influence of the buoyancy of the external water body on the underwater robot at the corresponding moment, the greater the difficulty for the underwater robot to maintain the original predetermined direction for machine operation, and it reflects that the underwater robot is more likely to have control anomalies at the corresponding moment.

[0052] Preferably, in some implementations of the embodiment of the invention, a method for obtaining the machine anomaly degree is as follows: take any moment as a reference moment; obtain the preset local time range of the reference moment; analyze the movement degree of the main machine movement direction within the preset local time range to obtain the range machine attitude stability of the reference moment; according to the range machine attitude stability, combined with the analysis of the extreme situation of the movement tendency of the reference moment in the main machine movement direction sequence, obtain the machine anomaly degree of the reference moment at the reference moment. The specific process is as follows:

[0053] Preset a number of moments $T1$, and take the time period formed by $T1$ moments before and after the reference moment as a preset local time range of the reference moment. In this embodiment, $T1=5$ is used as an example for description, and this embodiment does not make specific limitations. $T1$ can be determined according to specific implementation

conditions.

[0054] It is particularly noted that if the actual number of moments before and after the reference moment does not meet *T*1, the preset local time range is obtained based on the actual number of moments before and after the reference moment.

[0055] Preferably, in some implementations of the embodiment of the invention, a method for obtaining the range machine attitude stability is as follows: analyze the stability of the movement state degree under the overall main machine movement direction within the preset local time range to obtain the range machine attitude stability of the reference moment. The specific process is as follows:

[0056] Take the average value of the movement state degrees under all main machine movement directions within the preset local time range as the range machine attitude stability of the reference moment.

[0057] Further, take the main machine movement direction with the smallest movement state degree in the main machine movement direction sequence except for the reference moment as the extreme main machine movement direction; take the absolute value of the difference in movement state degree between the main machine movement direction at the reference moment and the extreme main machine movement direction as the machine anomaly degree of the reference moment.

[0058] It should be noted that the greater the machine anomaly degree, the more obvious the influence of the buoyancy of the external water body on the underwater robot at the corresponding moment, the greater the difficulty for the underwater robot to maintain the original predetermined direction for machine operation, and it reflects that the underwater robot is more likely to have control anomalies at the corresponding moment.

[0059] Preferably, in some implementations of the embodiment of the invention, a method for obtaining the core machine to-be-adjusted categories is as follows: compare the differences in movement state degrees between the main machine movement directions at different moments, and combine with the machine anomaly degree to obtain the category membership degree between different moments; according to the category membership

degree, classify the movement direction progression elements into core machine to-be-adjusted categories. The specific process is as follows:

[0060] Take the main machine movement directions at any two moments as an example, take the absolute value of the difference in movement state degree between these two main machine movement directions as the directional movement difference component of these two moments; take the normalized value of the product of the directional movement difference component of these two moments and the machine anomaly degree as the category membership degree between these two moments.

[0061] Preset two category membership degree thresholds $T2$ and $T3$. Take the moments where the category membership degree is greater than $T2$ and less than $T3$ as robot control anomaly moments; take the category composed of the movement direction progression elements at all robot control anomaly moments as a core machine to-be-adjusted category. Take the moments where the category membership degree is greater than $T3$ as robot control anomaly moments; take the category composed of the movement direction progression elements at all robot control anomaly moments as a core machine to-be-adjusted category. In this embodiment, $T2=0.6$ and $T3=0.76$ are used as examples for description, and this embodiment does not make specific limitations. $T2$ and $T3$ can be determined according to specific implementation conditions.

[0062] Optionally, in another embodiment, the specific process of obtaining the core machine to-be-adjusted categories is as follows:

[0063] Use the category membership degree between different moments as a distance metric, and perform hierarchical clustering on the main machine movement direction sequence according to the distance metric to obtain several clusters; take the category composed of the movement direction progression elements of all main machine movement directions in each cluster as a core machine to-be-adjusted category. The process of hierarchical clustering based on distance metrics is common knowledge in hierarchical clustering algorithms, and will not be repeated in this embodiment. The main machine movement direction sequence includes multiple main machine movement directions, and each main machine movement

direction corresponds to a moment.

[0064] So far, the core machine to-be-adjusted categories are obtained through the above method.

[0065] Step S004: analyze the to-be-adjusted situation of the movement direction progression elements in the same core machine to-be-adjusted category to obtain the correction adjustment component elements; perform attitude control on the underwater robot according to the correction adjustment component elements.

[0066] Preferably, in some implementations of the embodiment of the invention, a method for obtaining the correction adjustment component elements is as follows: compare the change differences in machine anomaly degrees between different core machine to-be-adjusted categories to obtain the machine anomaly control time range; analyze the coverage length within the machine anomaly control time range to obtain the correction adjustment component elements. The specific process is as follows:

[0067] Take the average value of the movement state degrees of all movement direction progression elements in each core machine to-be-adjusted category as the abnormal movement component of each core machine to-be-adjusted category; take the variance of the movement state degrees of all movement direction progression elements in each core machine to-be-adjusted category as the abnormal movement component stability of each core machine to-be-adjusted category. Each core machine to-be-adjusted category contains multiple movement direction progression elements, and each movement direction progression element corresponds to a moment.

[0068] Further, take any core machine to-be-adjusted category as the target adjustment category, take the absolute value of the difference in abnormal movement components between the target adjustment category and each of the other core machine adjustment categories as a category anomaly difference component of the target adjustment category; take the average value of all category anomaly difference components of the target adjustment category as the overall category anomaly difference component of the target adjustment category; take the product of the overall category anomaly difference component,

the abnormal movement component, and the abnormal movement component stability of the target adjustment category as the moment anomaly control degree of the target adjustment category; obtain the moment anomaly control degree of each core machine to-be-adjusted category; within the core machine to-be-adjusted category with the largest moment anomaly control degree, take the maximum time range formed by the moments corresponding to all movement direction progression elements as the machine anomaly control time range.

[0069] Further, take the product of the range of the movement state degrees of the movement direction progression elements within the machine anomaly control time range and the total number of moments included in the machine anomaly control time range as the correction adjustment component elements. Use the correction adjustment component elements as the proportional adjustment coefficient, input them into the PID controller, and perform attitude adjustment and control on the underwater robot through the PID controller.

[0070] It should be noted that the process of controlling the robot through the PID controller according to the proportional adjustment coefficient is a known technology, and will not be repeated in this embodiment.

[0071] So far, this embodiment is completed.

[0072] The above-described embodiments are only used to illustrate the technical solutions of the present application, rather than limiting them; although the present application has been described in detail with reference to the foregoing embodiments, those of ordinary skill in the art should understand that: they can still modify the technical solutions recorded in the foregoing embodiments, or equivalently replace some of the technical features therein; and these modifications or replacements do not make the essence of the corresponding technical solutions deviate from the scope of the technical solutions of the embodiments of the present application, and all should be included within the protection scope of the present application.

## CLAIMS

1. A control method for underwater robots of including the following steps:

acquire movement direction progression elements in several directions at multiple moments;

based on the movement direction progression elements, compare the movement tendencies of the underwater robot in different directions to obtain the movement state degree of the movement direction progression elements in different movement directions; according to the movement state degree, screen out main machine movement directions at different moments from all directions, and construct a main machine movement direction sequence of the underwater robot;

in the main machine movement direction sequence, analyze the movement degree of the main machine movement direction within a preset local time range to obtain the machine anomaly degree at different moments; according to the machine anomaly degree, compare the abnormal changes of the movement direction progression elements between different main machine movement directions, and classify the movement direction progression elements into core machine to-be-adjusted categories;

analyze the to-be-adjusted situation of the movement direction progression elements in the same core machine to-be-adjusted category to obtain the correction adjustment component elements; perform attitude control on the underwater robot according to the correction adjustment component elements;

a method for obtaining the main machine movement direction sequence is as follows:

take any moment as a marked moment; at the marked moment, take the direction to which the movement direction progression element with the largest movement state degree belongs as the main machine movement direction at the marked moment; take the sequence formed by arranging the main machine movement directions at all

moments in ascending order of time as the main machine movement direction sequence;

a method for obtaining the core machine to-be-adjusted categories is as follows:

compare the differences in movement state degrees between the main machine movement directions at different moments, and combine with the machine anomaly degree to obtain the category membership degree between different moments; according to the category membership degree, classify the movement direction progression elements into core machine to-be-adjusted categories;

a method for obtaining correction adjustment component elements is as follows:

compare the change differences in machine anomaly degrees between different core machine to-be-adjusted categories to obtain the machine anomaly control time range; analyze the coverage length within the machine anomaly control time range to obtain the correction adjustment component elements.

2. The control method for underwater robots according to claim 1, wherein a method for obtaining the movement state degree is as follows:

take any direction as a target direction and any moment as a target moment, compare the difference in movement direction progression elements between the target direction and all overall directions at the same moment, and obtain the movement state degree of the target direction at the target moment.

3. The control method for underwater robots according to claim 1, wherein after calculating the movement state degree, the method further includes:

performing normalization processing on the movement state degree.

4. The control method for underwater robots according to claim 1, wherein a method

for obtaining machine anomaly degree is as follows:

take any moment as a reference moment; obtain the preset local time range of the reference moment; analyze the movement degree of the main machine movement direction within the preset local time range to obtain a range machine attitude stability of the reference moment; according to the range machine attitude stability, combined with the analysis of the extreme situation of the movement tendency of the reference moment in the main machine movement direction sequence, obtain the machine anomaly degree of the reference moment at the reference moment.

5. The control method for underwater robots according to claim 4, wherein a method for obtaining the range machine attitude stability is as follows:

analyze the stability of the movement state degree under the overall main machine movement direction within the preset local time range to obtain the range machine attitude stability of the reference moment.

6. A control system for an underwater robot, comprising a memory, a processor, and a computer program stored in the memory and running on the processor, the processor executes the computer program to implement the steps of the aforementioned method.

7. A control device for an underwater robot, the device comprising:

a movement direction travel element acquisition module, a machine control command analysis module, and an underwater robot control module; wherein the movement direction travel element acquisition module is used to acquire movement direction travel elements in several directions at a number of moments; the machine control command analysis module implements the steps of the control method for the underwater robot of any one of claims 1-5 by calling a computer program to obtain correction adjustment component elements; and the underwater robot control module

performs attitude control on the underwater robot according to the correction adjustment component elements.