UNDERWATER ROBOT WITH ADAPTIVE SURFACE CAPABILITY AND A REMOTE CONTROL INTERVENTION METHOD

Technical Field

[0001] The invention relates to the technical field of data transmission, and specifically to an underwater robot with adaptive surface capability and a remote control intervention method.

Background Art

[0002] An underwater robot is a high-efficiency cleaning tool that integrates functions such as diving, autonomous scanning cruise, and cleaning. It can realize efficient cleaning of underwater fixed objects such as ships and underwater inclined pipelines without stopping the water supply. It has extremely wide applications in fields such as marine engineering, underwater equipment maintenance, and port and wharf maintenance. The underwater robot with adaptive surface capability is equipped with adjustable mechanical arms, brushes, or a deformable shell. During the cleaning process, the robot can receive and process data from sensors (e.g., tactile sensors, distance sensors, etc.) in real time, and adjust its behaviors (e.g., equipment expansion/contraction, rotation, etc.) through a built-in control system to adapt to complex underwater environments and surface changes. During the underwater cleaning process, the automatic mode also has various limitations. For example, when there are changes in task content, equipment damage, poor cleaning effect, environmental changes, or other situations, manual intervention is required in a timely manner to ensure equipment safety and the smooth progress of the task.

[0003] However, when the operator transmits data and information to and from the underwater robot, the existing information transmission methods are limited by factors such as the underwater environment and transmission distance. As a result, the transmitted data is split into multiple data packets for transmission, which prevents the accurate and timely transmission of data information and makes it difficult for the operator's instructions to be transmitted to the underwater robot in a timely manner.

Summary of the Invention

[0004] The invention provides an underwater robot with adaptive surface capability and a remote control intervention method to solve the existing problem: the existing information transmission methods are limited by factors such as the underwater environment and transmission distance, which causes the transmitted data to be split into multiple data packets for transmission. This leads to the failure of accurate and timely transmission of data information, and makes it difficult for the operator's instructions to be transmitted to the underwater robot in a timely manner.

[0005] The remote control intervention method for an underwater robot with adaptive surface capability of the invention adopts the following technical solution:

[0006] It includes the following steps:

[0007] acquire different machine remote control data of the underwater robot, different terrain degree data, different surface degree data, and several underwater environment data under different underwater machine dimensions;

[008] analyze the delay and loss of underwater environment data during underwater transmission under the same underwater machine dimension to obtain a underwater transmission data loss degree of each underwater machine dimension; analyze the complexity of the terrain distribution of the water body based on the terrain degree data and surface degree data to obtain the underwater terrain signal interference degree of the underwater robot; comprehensively consider the underwater environment data under different underwater machine dimensions, the underwater transmission data loss degree, and the underwater terrain signal interference degree to obtain wireless communication interference degree of the underwater robot underwater;

[0009] analyze the control difficulty of the remote control signal on the underwater robot based on the wireless communication interference degree and the content volume of the machine remote control data to obtain the complete transmission difficulty of each piece of machine remote control data.

[0010] perform adaptive packetized transmission on the machine remote control data based on the complete transmission difficulty.

[0011] Preferably, a method for obtaining the underwater transmission data loss degree is as follows:

[0012] for any underwater machine dimension, analyze the difference in the time data volume of the underwater robot receiving the same underwater environment data in that dimension to obtain the underwater transmission delay and loss degree of the underwater environment data; integrate the underwater transmission delay and loss degrees of all underwater environment data in the underwater machine dimension to obtain the underwater transmission data loss degree of the underwater machine dimension.

[0013] Preferably, a method for obtaining the underwater transmission delay and loss degree is as follows:

[0014] compare the start and end times of the same underwater environment data between sending and system receiving to obtain the delay time amount of the underwater environment data; compare the data content of the same underwater environment data between sending and system receiving to obtain the delayed data loss degree of the underwater environment data; obtain the underwater transmission delay and loss degree of the underwater environment data based on the delay time amount and the delayed data loss degree.

[0015] Preferably, after calculating the underwater transmission data loss degree, the method further includes:

[0016] Performing normalization processing on the underwater transmission data loss degree.

[0017] Preferably, a method for obtaining the underwater terrain signal interference degree is as follows:

[0018] compare the extreme differences between the terrain degree data and the surface degree data to obtain the underwater terrain complexity of the underwater robot; analyze the distribution consistency of the surface degree data to obtain the surface influence degree of the underwater robot; obtain the underwater terrain signal interference degree of the underwater robot based on the underwater terrain complexity and the surface influence degree.

[0019] Preferably, a method for obtaining the underwater terrain complexity is as follows:
[0020] among all terrain degree data, take the maximum value of the terrain degree data as the maximum terrain degree data, and the minimum value of the terrain degree data as the minimum terrain degree data; among all surface degree data, take the maximum value of the surface degree data as the maximum surface degree data, and the minimum value of the surface degree data as the minimum surface degree data;

[0021] take the absolute value of the difference between the maximum terrain degree data and the maximum surface degree data as the upper limit degree difference value; take the absolute value of the difference between the minimum terrain degree data and the minimum surface degree data as the lower limit degree difference value; take the sum of the upper limit degree difference value and the lower limit degree difference value as the underwater terrain complexity of the underwater robot.

[0022] Preferably, a method for obtaining the wireless communication interference degree is as follows:

[0023] obtain the data feedback stability of the underwater robot based on the underwater terrain signal interference degree and the fluctuation of the content volume contained in the underwater environment data; obtain the wireless communication interference degree of the underwater robot underwater based on the data feedback stability and the underwater transmission data loss degree.

[0024] Preferably, a method for obtaining the data feedback stability is as follows:

[0025] acquire the dimension standard deviation of all underwater environment data under each underwater machine dimension; take the average of all dimension standard deviations as the comprehensive dimension stability; take the inverse normalized value of the underwater terrain signal interference degree and the comprehensive dimension stability as the data feedback stability of the underwater robot.

[0026] Preferably, a method for obtaining the complete transmission difficulty is as follows:
[0027] analyze the content distribution of each piece of machine remote control data to obtain the remote control content repetition degree of each piece of machine remote control data;

obtain the complete transmission difficulty of each piece of machine remote control data based on the remote control content repetition degree and the wireless communication interference degree.

[0028] Preferably, a method for obtaining the remote control content repetition degree is as follows:

[0029] for any piece of machine remote control data, acquire the length and the number of types of the machine remote control data; take the product of the length and the number of types of the machine remote control data as the remote control content repetition degree of the machine remote control data.

[0030] The beneficial effects of the technical solution of the invention are as follows: by analyzing the delay and loss of underwater environment data during underwater transmission under the same underwater machine dimension, the underwater transmission data loss degree is obtained; based on the terrain degree data and surface degree data, the complexity of the terrain distribution of the water body is analyzed to obtain the underwater terrain signal interference degree; the wireless communication interference degree is obtained by comprehensively considering the underwater environment data under different underwater machine dimensions, the underwater transmission data loss degree, and the underwater terrain signal interference degree; based on the wireless communication interference degree and the content volume of the machine remote control data, the control difficulty of the remote control signal on the underwater robot is analyzed to obtain the complete transmission difficulty; further, adaptive packetized transmission is performed on the machine remote control data. The invention reduces the underwater interference on remote control, decreases the loss degree of remote control data, and improves the ability of the underwater robot to adapt to underwater surfaces.

Brief Description of Accompany Drawings

[0031] 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 accompanying drawings without exerting creative labor.

[0032] FIG. 1 is a flow chart of the steps of a remote control intervention method for an underwater robot with adaptive surface capability according to the invention.

Specific Embodiment of the invention

[0033] To further elaborate on the technical means and effects adopted by the invention to achieve the intended invention objectives, the following detailed description is provided regarding the specific implementation methods, structure, characteristics, and effects of the underwater robot with adaptive surface capability and remote control intervention method proposed in accordance with the invention, 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. Furthermore, specific features, structures, or characteristics in one or more embodiments may be combined in any suitable form.

[0034] Unless otherwise defined, all technical and scientific terms used herein have the same meanings as commonly understood by those skilled in the art to which the invention pertains.

[0035] The following specifically describes the specific scheme of the underwater robot with adaptive surface capability and remote control intervention method provided by the invention, in conjunction with the accompanying drawings.

[0036] Please refer to FIG. 1, which shows a flow chart of the steps of a remote control intervention method for an underwater robot with adaptive surface capability provided by an embodiment of the invention. The method includes the following steps:

[0037] Step S001: acquire different machine remote control data of the underwater robot, different terrain degree data, different surface degree data, and several underwater environment data under different underwater machine dimensions.

[0038] It should be noted that when the operator transmits data and information to and from the underwater robot, existing information transmission methods are limited by factors such as the underwater environment and transmission distance. As a result, the transmitted data is

split into multiple data packets for transmission, which prevents the accurate and timely transmission of data information and makes it difficult for the operator's instructions to be transmitted to the underwater robot in a timely manner.

[0039] In a specific implementation of the embodiment of the invention, a method for acquiring machine remote control data, terrain degree data, surface degree data, and underwater environment data is as follows: install five types of sensors—sonar sensors, pressure sensors, temperature sensors, flow rate sensors, and optical sensors—on the underwater robot. Each sensor sends data to a remote control platform at a frequency of 1 time per second, and the remote control platform records the underwater environment data transmitted from the underwater robot's sensors at a frequency of 1 time per second. Record the sending time when each piece of underwater environment data is sent from the underwater robot and the receiving time when it is received by the remote control platform; the data sending lasts for 1 hour. After receiving the data transmitted by the sonar sensor, the remote control platform constructs a 3D model to acquire several pieces of terrain degree data and several pieces of surface degree data. Treat the four types of sensors—pressure sensors, temperature sensors, flow rate sensors, and optical sensors—as one underwater machine dimension each, and take the data transmitted by these four types of sensors to the remote control platform as underwater environment data. Each piece of underwater environment data corresponds to one sending time and one receiving time, and the values of the same piece of underwater environment data at the sending time and receiving time may not be the same.

[0040] It is particularly noted that during the process of the remote control platform recording the underwater environment data transmitted from the underwater robot's sensors, if no underwater environment data transmitted from the underwater robot's sensors is detected, the underwater environment data recorded by the remote control platform at the corresponding time is defaulted to 0. In this embodiment, the remote control platform stores by default machine remote control data for remotely controlling four machine items of the underwater robot: working speed, cleaning precision, diving depth, and cleaning target area range. The frequency of data sending, the frequency of data recording, and the machine items of the underwater robot that can be controlled by the remote control platform can all be determined

according to actual conditions.

[0041] It should be noted that the surface degree data refers to the degree of the surface on the object that the underwater robot is to come into contact with. The process of converting sonar sensor data into terrain and object surface degree data through a 3D model is a well-known technology, and will not be repeated in this embodiment.

[0042] So far, through the above method, different machine remote control data of the underwater robot, different terrain degree data, different surface degree data, and several underwater environment data under different underwater machine dimensions are obtained.

[0043] Step S002: analyze the delay and loss of underwater environment data during underwater transmission under the same underwater machine dimension to obtain a underwater transmission data loss degree of each underwater machine dimension; analyze the complexity of the terrain distribution of the water body based on the terrain degree data and surface degree data to obtain the underwater terrain signal interference degree of the underwater robot; comprehensively consider the underwater environment data under different underwater machine dimensions, the underwater transmission data loss degree, and the underwater terrain signal interference degree to obtain wireless communication interference degree of the underwater robot underwater.

[0044] It should be noted that when the underwater robot feeds back the underwater environment data of its location to the console, the underwater environment data received by the console may be lost due to the influence of underwater noise interference. By combining the loss of underwater environment data, the environmental interference intensity during communication between the console and the underwater robot can be obtained. At the same time, the specific situation of its current location can be roughly obtained by combining the underwater environment data, thereby obtaining the wireless communication interference degree of the underwater robot underwater.

[0045] Preferably, in some implementations of the embodiment of the invention, a method for obtaining the underwater transmission data loss degree is as follows: for any underwater machine dimension, analyze the difference in the time data volume of the underwater robot

receiving the same underwater environment data in that dimension to obtain the underwater transmission delay and loss degree of the underwater environment data; integrate the underwater transmission delay and loss degrees of all underwater environment data in the underwater machine dimension to obtain the underwater transmission data loss degree of the underwater machine dimension. The specific process is as follows:

[0046] Preferably, in some implementations of the embodiment of the invention, a method for obtaining the underwater transmission delay and loss degree is as follows: compare the start and end times of the same underwater environment data between sending and system receiving to obtain the delay time amount of the underwater environment data; compare the data content of the same underwater environment data between sending and system receiving to obtain the delayed data loss degree of the underwater environment data; obtain the underwater transmission delay and loss degree of the underwater environment data based on the delay time amount and the delayed data loss degree. The specific process is as follows:

[0047] Taking any piece of underwater environment data in any underwater machine dimension as an example, the absolute value of the difference between the sending time and the receiving time of the underwater environment data is taken as the delay time amount of the underwater environment data; the absolute value of the difference between the values of the underwater environment data at the sending time and the receiving time is taken as the delayed data loss degree of the underwater environment data; the product of the delay time amount and the delayed data loss degree is taken as the underwater transmission delay and loss degree of the underwater environment data.

[0048] Further, the normalized value of the average of the underwater transmission delay and loss degrees of all underwater environment data in the underwater machine dimension is taken as the underwater transmission data loss degree of the underwater machine dimension. In this embodiment, the norm() function is used as an example for normalization processing, and the normalization function can be determined according to specific implementations.

[0049] Preferably, in some implementations of the embodiment of the invention, a method for obtaining the underwater terrain signal interference degree is as follows: compare the extreme

differences between the terrain degree data and the surface degree data to obtain the underwater terrain complexity of the underwater robot; analyze the distribution consistency of the surface degree data to obtain the surface influence degree of the underwater robot; obtain the underwater terrain signal interference degree of the underwater robot based on the underwater terrain complexity and the surface influence degree. The specific process is as follows:

[0050] Preferably, in some implementations of the embodiment of the invention, a method for obtaining the underwater terrain complexity is as follows: among all terrain degree data, take the maximum value of the terrain degree data as the maximum terrain degree data, and the minimum value of the terrain degree data as the minimum terrain degree data; among all surface degree data, take the maximum value of the surface degree data as the maximum surface degree data, and the minimum value of the surface degree data as the minimum surface degree data; take the absolute value of the difference between the maximum terrain degree data and the maximum surface degree data as the upper limit degree difference value; take the absolute value of the difference between the minimum terrain degree data and the minimum surface degree data as the lower limit degree difference value; take the sum of the upper limit degree difference value and the lower limit degree difference value as the underwater terrain complexity of the underwater robot.

[0051] Further, the standard deviation of all surface degree data is taken as the surface influence degree of the underwater robot. The average of the underwater terrain complexity and the surface influence degree is taken as the underwater terrain signal interference degree of the underwater robot.

[0052] It should be noted that the greater the underwater terrain signal interference degree, the weaker the adaptability of the underwater robot to the underwater environment surface and the higher the complexity of the underwater environment, which reflects the worse stability of the underwater environment.

[0053] Preferably, in some implementations of the embodiment of the invention, a method for obtaining the wireless communication interference degree is as follows: obtain the data

feedback stability of the underwater robot based on the underwater terrain signal interference degree and the fluctuation of the content volume contained in the underwater environment data; obtain the wireless communication interference degree of the underwater robot underwater based on the data feedback stability and the underwater transmission data loss degree. The specific process is as follows:

[0054] Preferably, in some implementations of the embodiment of the invention, a method for obtaining the data feedback stability is as follows: acquire the dimension standard deviation of all underwater environment data under each underwater machine dimension; take the average of all dimension standard deviations as the comprehensive dimension stability; take the inverse normalized value of the underwater terrain signal interference degree and the comprehensive dimension stability as the data feedback stability of the underwater robot. In this embodiment, the $exp(-x)$ model is used to present the inverse relationship and normalization processing, wherein x is the input of the model. Implementers can select the inverse function and normalization function according to actual conditions.

[0055] Further, the product of the data feedback stability and the underwater transmission data loss degree is taken as the wireless communication interference degree of the underwater robot underwater.

[0056] So far, through the above method, the delay and loss of underwater environment data during underwater transmission under the same underwater machine dimension are analyzed to obtain the underwater transmission data loss degree of each underwater machine dimension; the complexity of the terrain distribution of the water body is analyzed based on the terrain degree data and surface degree data to obtain the underwater terrain signal interference degree of the underwater robot; and the wireless communication interference degree of the underwater robot underwater is obtained by comprehensively considering the underwater environment data under different underwater machine dimensions, the underwater transmission data loss degree, and the underwater terrain signal interference degree.

[0057] Step S003: analyze the control difficulty of the remote control signal on the underwater robot based on the wireless communication interference degree and the content

volume of the machine remote control data to obtain the complete transmission difficulty of each piece of machine remote control data.

[0058] It should be noted that machine remote control data is usually divided into basic control parameters, configurations, setting formulations, etc. The transmission difficulty of different types of machine remote control data varies under different conditions. When the transmission difficulty of machine remote control data is low, it indicates that good communication can be ensured; when the transmission difficulty is high, good communication effects cannot be guaranteed.

[0059] Preferably, in some implementations of the embodiment of the invention, a method for obtaining the complete transmission difficulty is as follows: analyze the content distribution of each piece of machine remote control data to obtain the remote control content repetition degree of each piece of machine remote control data; obtain the complete transmission difficulty of each piece of machine remote control data based on the remote control content repetition degree and the wireless communication interference degree. The specific process is as follows:

[0060] Preferably, in some implementations of the embodiment of the invention, a method for obtaining the remote control content repetition degree is as follows: for any piece of machine remote control data, acquire the length and the number of types of the machine remote control data; take the product of the length and the number of types of the machine remote control data as the remote control content repetition degree of the machine remote control data.

[0061] Further, the normalized value of the product of the remote control content repetition degree and the wireless communication interference degree is taken as the complete transmission difficulty of the machine remote control data.

[0062] So far, through the above method, the control difficulty of the remote control signal on the underwater robot is analyzed based on the wireless communication interference degree and the content volume of the machine remote control data, and the complete transmission difficulty of each piece of machine remote control data is obtained.

[0063] Step S004: perform adaptive packetized transmission on the machine remote control data based on the complete transmission difficulty.

[0064] It should be noted that since packetized transmission processing divides a single remote control data instruction into multiple remote control data instructions, the probability of data loss during transmission is higher. Moreover, if the order of different segments of the instruction is incorrect, the remote control data may fail to be executed correctly.

[0065] Preset a complete transmission difficulty threshold $T1$. Machine remote control data with a complete transmission difficulty greater than $T1$ is transmitted as a single data packet in its entirety without packetization processing; machine remote control data with a complete transmission difficulty less than or equal to $T1$ is subjected to packetization processing, and the packetized data is transmitted. In this embodiment, $T1 = 0.5$ is used as an example for description, and this embodiment does not impose specific limitations; $T1$ can be determined according to specific implementation conditions.

[0066] It is particularly noted that the process of packetizing and transmitting data is a well-known technology, and will not be repeated in this embodiment.

[0067] Further, the underwater robot receives the data packets and reconstructs the machine remote control data; after receiving the data packets and verifying that they are correct, the underwater robot sends a confirmation message to the console. Preset a time interval $T2$. After receiving the confirmation message, the console stops sending the machine remote control data; otherwise, the console repeatedly sends the machine remote control data at intervals of $T2$ until a confirmation message is received. In this embodiment, $T2 = 1$s is used as an example for description, and this embodiment does not impose specific limitations; $T2$ can be determined according to specific implementation conditions.

[0068] It is particularly noted that if the underwater robot receives machine remote control data and then receives another piece of machine remote control data with the same code, it will not execute the latter and will send a confirmation message to the console.

[0069] So far, this embodiment is completed.

[0070] The above descriptions are only preferred embodiments of the invention and are not intended to limit the invention. Any modification, equivalent replacement, improvement, etc. made within the principles of the invention shall be included in the protection scope of the invention.

CLAIMS

1. A remote control intervention method for an underwater robot with adaptive surface capability, including the following steps:

acquire different machine remote control data of the underwater robot, different terrain degree data, different surface degree data, and several underwater environment data under different underwater machine dimensions; the machine remote control data is used to instruct the remote control of the underwater robot's working speed, cleaning precision, diving depth, and cleaning target area range;

analyze the delay and loss of underwater environment data during underwater transmission under the same underwater machine dimension to obtain a underwater transmission data loss degree of each underwater machine dimension; the underwater transmission data loss degree refers to the normalized value of the average of the underwater transmission delay and loss degrees of all underwater environment data in the underwater machine dimension, the underwater transmission delay and loss degree is the product of delay time amount of the underwater environment data and the delayed data loss degree of the underwater environment data; the delay time amount is the absolute value of the difference between the sending time and the receiving time of the underwater environment data, and the delayed data loss degree is the absolute value of the difference between the values of the underwater environment data at the sending time and the receiving time; analyze the complexity of the terrain distribution of the water body based on the terrain degree data and surface degree data to obtain the underwater terrain signal interference degree of the underwater robot; the underwater terrain signal interference degree is the average of the underwater terrain complexity of the underwater robot and the surface influence degree of the underwater robot; the underwater terrain complexity is the sum of the upper limit degree difference value and the lower limit degree difference value; the upper limit degree difference value is the absolute value of the difference between the maximum terrain degree data and the maximum surface degree data, the lower limit degree

difference value is the absolute value of the difference between the minimum terrain degree data and the minimum surface degree data; the maximum terrain degree data is the maximum value among all terrain degree data, the maximum surface degree data is the maximum value among all surface degree data, the minimum terrain degree data is the minimum value among all terrain degree data, and the minimum surface degree data is the minimum value among all surface degree data; the surface influence degree is the standard deviation of all surface degree data; comprehensively consider the underwater environment data under different underwater machine dimensions, the underwater transmission data loss degree, and the underwater terrain signal interference degree to obtain wireless communication interference degree of the underwater robot underwater;

analyze the control difficulty of the remote control signal on the underwater robot based on the wireless communication interference degree and the content volume of the machine remote control data to obtain the complete transmission difficulty of each piece of machine remote control data;

perform adaptive packetized transmission on the machine remote control data based on the complete transmission difficulty.

2. The remote control intervention method for an underwater robot with adaptive surface capability according to claim 1, wherein a method for obtaining the wireless communication interference degree is as follows:

obtain the data feedback stability of the underwater robot based on the underwater terrain signal interference degree and the fluctuation of the content volume contained in the underwater environment data; obtain the wireless communication interference degree of the underwater robot underwater based on the data feedback stability and the underwater transmission data loss degree.

3. The remote control intervention method for an underwater robot with adaptive surface capability according to claim 2, wherein a method for obtaining the data feedback stability is as follows:

acquire the dimension standard deviation of all underwater environment data under each underwater machine dimension; take the average of all dimension standard deviations as the comprehensive dimension stability; take the inverse normalized value of the underwater terrain signal interference degree and the comprehensive dimension stability as the data feedback stability of the underwater robot.

4. The remote control intervention method for an underwater robot with adaptive surface capability according to claim 1, wherein a method for obtaining the complete transmission difficulty is as follows:

analyze the content distribution of each piece of machine remote control data to obtain the remote control content repetition degree of each piece of machine remote control data; obtain the complete transmission difficulty of each piece of machine remote control data based on the remote control content repetition degree and the wireless communication interference degree.

5. The remote control intervention method for an underwater robot with adaptive surface capability according to claim 4, wherein a method for obtaining the remote control content repetition degree is as follows:

for any piece of machine remote control data, acquire the length and the number of types of the machine remote control data; take the product of the length and the number of types of the machine remote control data as the remote control content repetition degree of the machine remote control data.