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Research on Tracking and Positioning of Chemical Plumes by Underwater Robot Based on Turbulent Environment

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With the advancement of science and the further acceleration of marine development projects, research on chemical plumes based on bionic olfactory robots has gradually become an international research hotspot. Bionic olfactory technology is used to track and locate chemical plumes, and to guide underwater robot to search and track continuously, so as to realize accurate positioning of the undersea hydrothermal vents. However, due to a number of factors, turbulence gradually occurs in the water, which hinders the tracking and positioning of the underwater robot. In view of this, this paper first analyzes the related theoretical overview of the tracking and positioning of chemical plumes by underwater robots, and then basing on the turbulent environment, this paper further analyzes the tracking and positioning process of chemical plumes by underwater robots, in the hopes of providing theoretical guidance for marine hydrothermal exploration.

1. Introduction

1.1 Literature review

Currently, for the problem of tracking and positioning of chemical plumes by underwater robots in the real water flow environment, we can refer to the principle of biological olfactory positioning, from the perspective of source distribution of underwater chemical plumes, two strategies of drawing algorithm and path planning are proposed, which largely increases the efficiency of active positioning of chemical plumes (Deng et al., 2016). Combined with specific conditions under the sea, a hydrothermal plume flow model is established, which is an effective way for the tracking and detection of underwater robot. At present, in the study of tracking and positioning of underwater robots, the application of the model by relevant scholars is relatively simple, which cannot accurately monitor the specificity of the target. To solve this problem, a discrete hydrothermal plume flow simulation model is proposed, which provides strong technical support for underwater robot operations (Jiu et al., 2015). The underwater mobile robot is applied to multiple chemical plume flow sources, by establishing a dynamic plume flow model and using independent assumptions and calculation methods, the possible position of the plume flow can be accurately obtained (Shi et al., 2008). By using multiple robot system strategies, we can achieve tracking of chemical plumes by gas-positioning source, and then introduce an ant colony algorithm to track turbulent smoke plumes from the direction of motion of the robot (Meng et al., 2008). Based on the bionic behavior, it is proposed that, the underwater robot automatically tracks and locates the hydrothermal plumes in the sea, which can accurately locate the vents of the deep-sea hydrothermal plume flows in the shortest time, and the designing of its bionic behavior can form a brand-new computer bionic environment based on the original bionic environment (Tian et al., 2012).

1.2 Research purposes

With the accelerating pace of marine development projects, in the process of human exploration of the ocean mysteries, underwater robots have received a high degree of attention and been well developed (Xu and Li, 2011). During the installation and commissioning of the deep-sea Christmas tree, the underwater robots can track and monitor the tree under the sea through visual inspection, assist relevant staff to complete the docking of the tree with the recycling tool (Wang, 2017). In recent years, due to the large uncertainties in underwater

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robot systems, whether underwater robots can work accurately and efficiently has always been a problem that has troubled related scientific researchers. The general methods of controlling underwater robots mainly include neural network controller, PID control system and fuzzy logic control method. However, in actual operation, all three methods have problems with parameters that cannot be determined, which is not conducive to the operation of underwater robots in the sea (Liu and Xu, 2001). In a turbulent environment, not only will it interfere with radar signals, but it will also cause atmospheric propagation energy leakage, making the signals in the sea gradually decline, which is not conducive to the smooth implementation of all operations in the sea (Sun et al., 2015). At the same time, in the turbulent environment, the robot's ability to perceive in a certain area is severely degraded, and the search and detection of a specific object cannot be balanced, which affects the judgment of the results and further hinders relevant scholars from tracking, positioning and researching the target object (Zhang and Xu, 2015). Basing on this, this paper's research of tracking and positioning of chemical plumes by underwater robots based on turbulent environment is of great significance.

2. Overview of relevant theories of underwater robot's tracking and positioning of chemical plumes

At present, with the country's emphasis on marine resources and the increasing need for military exploration, underwater robots have achieved rapid development. Underwater robots are a brand-new product in the field of intelligence (Feng, 2000). They are mainly based on intelligent technologies, with computer processors as the main driver, and combined with the advanced underwater propulsion systems, communication systems, navigation systems, energy systems, execution systems, and security systems (Li et al., 2007). When tracking down chemical plumes underwater, underwater intelligent robots can identify and memorize complex underwater environments with their own advanced technology (Yan et al., 2002). They can intelligently automate human-made tasks. At the same time, in the whole process, underwater robots can adapt to the underwater environment in the shortest possible time and can search for and track the target in the shortest time, as shown in Figure 1.

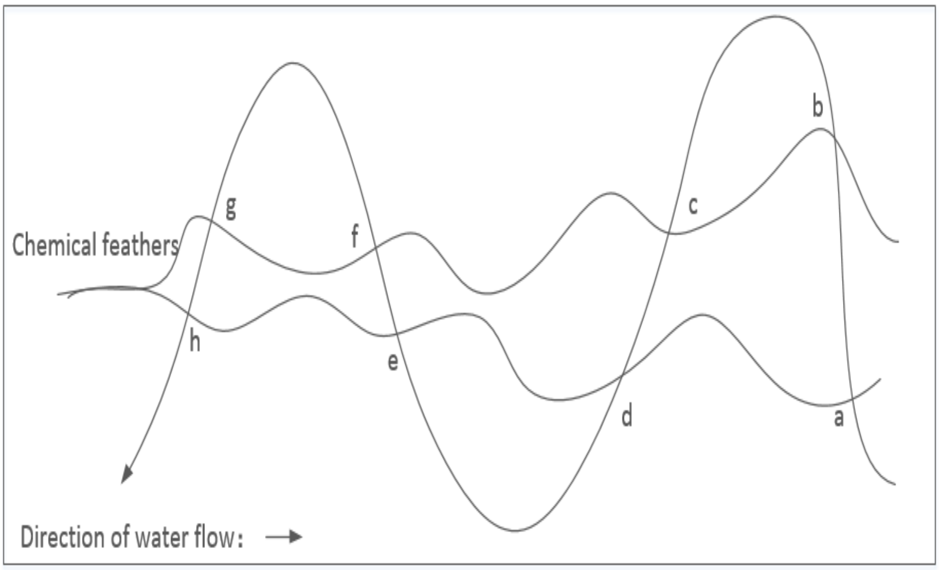

Figure 1: Tracking and positioning trajectory of chemical plumes by underwater robots

According to Figure 1, we can see that the tracking and positioning of chemical plumes by the underwater robots in the sea presents certain trajectories, as the trajectory grows, the chemical plumes gradually spread, the underwater robot tracks along the direction, and the tracking nodes will gradually decrease (Ren and Zhang., 2000). In recent years, with the advancement of science, humans have conducted in-depth analysis of different devices based on propulsion systems, communication systems, navigation systems, energy systems, execution systems, and support systems for underwater intelligent robots, and combined with current advanced technologies to continuously improve the function of underwater robots (Liu et al., 2002). Therefore, underwater robots are gradually well-known in the marine field. With the progress of time, the tracking and positioning of chemical plumes by underwater robots has gradually progressed to the following directions;

First, the direction of remoteness. With the complicating of marine creatures, underwater robots are bound to expand their monitoring range (Yu et al., 2002). It is expected that the scope of their activities in the future will remain within a radius of 250-5000 km, and they can work continuously under water for more than 100 hours. If you want to achieve above ideal results, you need the support of a great power source (Gan et al., 2002). The power source of underwater robots mainly comes from the electric power. When it is working, it will carry its own battery pack (Song et al., 2014). The current research on electric power mainly focuses on solar cells, fuel cells and nuclear energy cells. However, when tracking chemical plumes under water, fuel cells and nuclear energy batteries are generally not used (Sun et al., 2014). Solar cells are generally the main source of electric power for underwater robots. It is mainly because when the robot is tracking down the chemical plumes underwater, when the shortage of electric energy is detected, it can float to the surface and supply energy by itself, the solar energy is infinite, so the supply of electric power to an underwater robot can also be used indefinitely in an unlimited amount of time, which will not affect the battery charging efficiency, and won't influence the service efficiency of underwater robots(Yin and Liu et al., 2014).

Second, the direction of collaboration. In terms of oceanographic surveys, underwater robots play a significant role, which is a major focus of current research (Huang et al., 2014). However, with the increasing workload of underwater tracking chemical plumes and the complication of work, underwater robots will require multiple robots to work together. Therefore, a number of underwater robots working collaboratively will soon become the development direction of future underwater robots. Compared with a single underwater robot, multiple underwater robots have the features of high work efficiency and wide monitoring range. In the underwater area, multiple underwater robots use their own communication facilities to perform operations on a large scale and use each robot's own characteristics to coordinate and complete the work tasks (Yu et al., 2014).

Third, the direction of deep-sea operations. According to statistics, on the earth, there are more than 97% of the ocean has a depth less than 6,000 meters, deep-sea operations and studies of deep-sea phenomena under 6,000 meters is the research goal for all countries. At present, China, United States, Russia, and France have already owned smart robots that operate in oceans that exceed 6,000 meters (Liang et al., 2014). Although underwater robots can reach a depth of more than 6,000 meters, during actual operation, their working efficiency is far lower than that within 6000 meters, and the operation of robots by related personnel is also inconvenient. It can be seen that with the development of science, deep-sea operations have gradually become the development direction of underwater robots (Fu et al., 2014).

3. Tracking and positioning process of chemical plumes by underwater robots based on turbulent environment

Table 1: Specific classification and related content of underwater robot

Classification of underwater robots		
Standard	Content	Type
Intelligence and demand	Towed underwater vehicle, remote controlled underwater vehicle, and intelligent underwater vehicle.	Unmanned underwater robot
Whether or not to carry people	Manned submersible, unmanned submersible (mooring underwater vehicle and unmanned underwater vehicle)	Unmanned underwater robot
Specific content of underwater robot		
Target	Autonomous decision-making and control to accomplish scheduled tasks in complex marine environment.	
Use characteristics	Technologies such as artificial intelligence, detection and recognition, information fusion, intelligent control, system integration and so on are applied to the same downloading body.	
Features	Flexibility and wider application	
Result	Autonomous decision-making and control to accomplish scheduled tasks in complex marine environment.	

In the turbulent environment, for the study of the tracking and positioning of chemical plumes by underwater robots, we need to search for the source of the chemical plumes. In detail, it is necessary to proceed from underwater mobile robots, smoke sensors, wind speed sensors, and information collection devices. Through the collation of academic theory, we find that there are more specific classifications of underwater robots, and the characteristics and specific targets of their implementation are shown in Table 1. One is according to the actual needs of users to divide, can be divided into cable underwater robot, referred to as ROV; the other is based on the actual operation needs to be divided into, called autonomous underwater vehicle, referred to as AUV. In addition, according to the purpose of using underwater robot, it can be divided into investigation robot and operation robot, which can be used for observation, test material collection, underwater welding, underwater and heel action, and can be divided into seabed robots and water machines according to the different functions of the use of active sites. Intelligent underwater vehicle (intelligent underwater robot), which uses artificial intelligence, detection recognition, intelligent control and system integration, is used in the same water download body. It is the machine person who decides and controls the scheduled tasks in the complex marine environment without artificial real-time control. Because this robot does not need to be constrained by cables, it will be more flexible in underwater operations and operations, and its application will be more extensive.

For the mobile robot, according to the underwater tracking and positioning conditions, it is necessary to combine the various types of robots and select the best mobile robot in actual operation (Detweiler et al., 2014). The robot needs to configure sensors that can perceive the basic underwater environment, such as laser scanners, optical encoders, battery packs, integrated sensors, buzzers and other accessories. These accessories, together with the mobile robots, are coordinated and controlled by computer software. According to the tracking and positioning tasks, we can set a task list. Each time the mobile robot performs a task, the system will intelligently initiate the next task according to the task list. Each task is performed in order of priority. When the chemical plumes are tracked in a turbulent environment, new tasks are loaded by computer software. Underwater robots can be programmed and sequenced according to the task list.

Table 2: Parameters of two types of sensors

Monitoring environment	Sensor types	Range underwater
Gas	D6F-W01A1	0-1m/sec
Gas	D6F-W04A1	0-4m/sec

Next, we need to determine the relationship between the two types of sensors with different parameters and the wind speed sensor, the specific determined values are shown in Table 3.

Table 3: Relationship between sensor voltage value and wind speed sensor

Type: D6F-W01A1					
Wind speed	0m/s	0.25m/s	0.5m/s	0.75m/s	1.00m/s
Output voltage	1.00v	1.40v	2.00v	3.30v	5.00v
Type: D6F-W04A1					
Wind speed	0m/s	1.00m/s	2.00m/s	3.00m/s	4.00m/s
Output voltage	1.00v	1.60v	2.90v	4.10v	5.00v

For the smoke sensor, in a turbulent environment, smoke sensor has a relatively high sensitivity to the volatile gases. When the gas concentration in the water area is high, the conductivity of the sensor gradually increases. Therefore, in the turbulent environment, when tracking and positioning the chemical plumes, the concentration of gas in the environment can be known from the voltage value of the smoke sensor.

For the wind speed sensor, in the turbulent environment, tracking and positioning of chemical plumes mainly needs to determine the parameters of the sensor. Here, two types of D6F-W01A1 and D6F-W04A1 are selected to determine the parameters of the wind speed sensor, as shown in Table 2.

According to the wind speed and output voltage values shown in Table 3, using Excel software to fit all the data in Table 3, and then using the multi-selection mode, we can get the approximated formula for the wind speed and output voltage. During the fitting process, all values can be determined using coordinates. Among them, the abscissa can be set as the wind speed of the wind speed sensor, and the ordinate can be set as the voltage

value of the sensor. Finally, the function is plotted according to different values, and the relationship between the voltage value of different sensor types and the wind speed sensor can be intuitively observed.
For the information collection device, in the turbulent environment, the correlation value detected by the smoke sensor and the wind speed sensor cannot directly enter the relevant program of the robot. Therefore, when tracking and positioning the chemical plumes, an information acquisition, collection, and processing device is required to process the information and transfer it into the programs of the robot. A good information collection device has a USB interface and an interface board, and we also need to develop a serial communication program. In actual use, the serial communication program needs to be debugged. The debugger needs to understand the operating mechanism of the serial communication program when tracking and positioning the chemical plumes, and then set the relevant parameters according to the corresponding operation mechanism. This debug method is relatively flexible. After the serial port is initiated, the relevant data can be read. If the data read by the serial port is used as a task to be performed by the robot, the tasks of the robot will be correspondingly increased.
So far, based on the turbulent environment, the underwater robot tracking and positioning the chemical plumes has completed the overall assembly. In all the assembly processes, the concentration information of the chemical plumes can be discriminated, the wind speed around the water areas can be perceived, and the communication problem is solved, which improves the accuracy of tracking and positioning of chemical plumes by underwater robots.

4. Conclusion

In summary, based on the turbulent environment, the studies of the tracking and positioning of chemical plumes by underwater robots have a high application value in the field of marine exploration, which effectively solves the disadvantages of underwater robots in the tracking and positioning process, greatly improves the tracking efficiency and positioning accuracy. This also makes this method of using underwater robot to track and locate the chemical plumes to have good application prospects, we believe in the future, in the turbulent environment, the method of using underwater robot to track and locate the chemical plumes will be fully utilized in marine engineering.

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References

Deng W., Han D.F., Jiu H.F., 2016, A Method for Tracking and locating chemical Feathers of Underwater Robots Based on Olfaction, Journal of Motor and Control, 20(1), 110-118.
Detweiler C., Banerjee S., Doniec M., 2014, Adaptive Decentralized Control of Mobile Underwater Sensor Networks and Robots for Modeling Underwater Phenomena, Journal of Sensor & Actuator Networks, 3(2), 253-266.
Feng X.S., 2000, From cable remote underwater vehicle to autonomous underwater vehicle, Engineering Science in China, 2(12), 29-33.
Fu B., Zhang F., Ito M., 2009, Development of a new positioning system for underwater robot based on sensor network, Artificial Life & Robotics, 14(1), 43-47.
Gan Y., Wang L.R., Liu J.C., 2004, Embedded basic motion control system for underwater vehicle, Robot, 26(3), 246-249.
Huang D.D., Ji S.M., Chen G.D., 2017, Influence of bubble breakup on SiC particles in gas liquid solid three phase turbulent environment, Mechanical and electrical engineering, 34(9), 965-970.
Jiu H.F., Pang S., Han B., 2015, Establishment and Simulation of a Hydrothermal Pinnate Flow Model, Computer Simulation, 32(9), 404-408.
Li Y., Chang W.T., Sun Y.S., 2007, Research and development status and Prospect of autonomous underwater vehicle, Robot technology and Application, 17(1), 25-31.
Liang Q., Zhang D., Song Q., 2010, A Potential 4-D Fingertip Force Sensor for an Underwater Robot Manipulator, IEEE Journal of Oceanic Engineering, 35(3), 574-583.
Liu J.C., Yu H.N., Xu Y.R., 2002, Improved S surface control method for underwater vehicle, Journal of Harbin Engineering University, 23(1), 33-36.
Liu X.M., Xu Y.R., 2001, S Surface Control Method for Underwater Robot Motion, Oceanographic Engineering, 19(3), 81-84.

Meng Q.H., Li F., Zhang M.L., 2008, Research on the Active Olfactory Realization of Multi robot in the Turbulent Plume Environment, Journal of Automation, 34(10),1281-1290.
Ren F.J., Zhang L., 2000, Development status of underwater robot, Journal of Jiamusi University (NATURAL SCIENCE EDITION), 18(4), 317-320.
Shi K., Tian Y., Yu J.C., 2008, Multi Chemical Plume Source Location Based on Grid Map, Journal of instruments and Instruments, 29(S), 390-394.
Song H.F., Che Y., Zhao X., 2014, Enhancement of optical fiber coupling efficiency in turbulent environment, Optical precision engineering, 22(12), 3205-3211.
Sun F., Kang S.F., Zhang Y.S., 2015, Study on Channel Fading Characteristics of Atmospheric Waveguide in Turbulent Environment, Modern Radar, 37(3), 71-74.
Sun L.Y., Xia M., Han J.F., 2016, Modulation transfer function of underwater imaging system in turbulent environment, Journal of Optics, 27(8), 10-17.
Tian Y., Li W., Zhang A.Q., 2012, Simulation Environment of Deep-sea Hydrothermal Plume Tracing for Autonomous underwater Vehicle.Robot, 34(2), 159-169, DOI: 10.3724/SP.J.1218.2012.00159
Wang L., 2017, The Application of Underwater Remote Control Robot in the Installation of Underwater Oil Recovery Tree, Chemical Engineering and Equipment, 42(4), 66-67.
Xu Y.R., Li P.C., 2011, Development Trend of Underwater Robot, Journal of Nature, 33(3), 125-132.
Yan K.C., Li Y.P., Yuan X.q., 2002, Research on remote autonomous underwater vehicle, Robot, 24(4), 299-303.
Yin H., Liu Z., 2015, Performance analysis of atmospheric laser communication system based on OFDM in weak turbulence environment, Journal of Changchun University of Science and Technology (NATURAL SCIENCE EDITION), 16(3), 133-135.
Yu J.C., Li Q., Zhang A.Q., 2008, Adaptive neural network control for underwater vehicle, Control theory and Application, 25(1), 9-13.
Yu T., Wei L., Zhang A., 2012, A Simulation Environment for Deep-Sea Hydrothermal Plume Tracing with Autonomous Underwater Vehicles, Jiqiren/robot, 34(2), 159, DOI: 10.3724/SP.J.1218.2012.00159
Zhang S.Q., Xu D.M., 2015, A Search Algorithm for Multi Weak Perceptive Machine Human Flavor Source in Turbulent Environment, Control and decision, 30(8), 1429-1433.