Research on Stable Motion Control Method of Underwater Robot Based on Collaborative Filtering Technology

Cheng Peng*
Chongqing Vocational College of Transportation, School of Intelligent Manufacturing and Automobile Chongqing, China, 402247
* Corresponding author: chengpeng_93@163.com; hchk12@zjpedi.com

Abstract. As countries in the world continue to deepen marine research and development and the need for national defense construction, unmanned underwater robots are playing an increasingly important role in scientific experiments, seabed oil and gas exploration and testing, and military affairs. The motion stability of underwater robots is the key to ensure the safe and reliable operation of underwater robots, and it is the main content of stability control research to make underwater robots return to the initial state of motion after being disturbed. Therefore, it becomes very important to study stability control methods. It's necessary. This thesis first analyzes the motion characteristics of collaborative filtering technology in water, and establishes a dynamic model of an underwater robot system composed of main thrusters, double vertical thrusters and double-sided thrusters, and performs basic fluid flow for underwater robots.

1. Introduction

With the continuous progress of the big data and Internet era, people have gradually entered the era of information flooding from the era of poor information. It is undeniable that although the continuous development of the information age has brought us many opportunities, but at the same time it has also encountered great challenges for us: information is continuously supplied in massive amounts and users need to find the information they need in the massive information. It is a more difficult thing. The recommendation system is an important tool to solve this challenge, and the recommendation system has a corresponding application before machine learning has become popular. In recent years, in order to be more flexible in different scenarios, many recommendation technologies have emerged. Among them, collaborative filtering occupies a pivotal role in the recommendation field[1-3]. This technology has not only been widely studied in scientific research, but also has good applications in life, and is a relatively influential recommendation technology in the recommendation field[4-6].

Collaborative filtering technology can also be combined with the movement of underwater robots to recommend the optimal path. There are many types of underwater robots developed in the United States and have a wide range of uses, including manned submersibles, cabled remote-controlled underwater robots, and underwater autonomy[7-8]. The U.S. Naval Graduate School and many well-known universities have made great contributions to the research of underwater robots, especially with the encouragement and support of the U.S. Navy. REMUS600, currently developed by the Marine Systems Laboratory of the Woods Hole Oceanographic Institute, a new autonomous underwater robot with a diameter of 12.75 inches will be used to carry mine countermeasures for the US Naval Research (ONR). This series of underwater Robots have already been put into production and commercialization[9-10]. The U.S. Navy is currently studying how to build a network for underwater robots to obtain global
ocean data and spatial information, thereby enabling it to obtain solutions that far exceed the capabilities of current underwater robots[11]. The UK has also accelerated research on unmanned underwater robots in recent years. The UK is preparing to start designing an unmanned autonomous underwater robot that can guarantee endurance and remote monitoring at the same time, and carry minesweeping equipment specifically to perform anti-mine tasks[12-15]. In 2009, the British arms company BAE Systems successfully developed an unmanned underwater robot named "Talisman L", weighing only 50 kilograms, and has a unique sonar search system that can accurately locate mines and is mainly used for underwater applications. For mine clearance operations, Norway has carried out research on unmanned underwater robots as early as the 1990s, and designed and produced many types of underwater robots. The more successful one is the "Fox Whale" series. The Norwegian Navy passed a three-year plan in April 2002[16-17]. The goal is to develop an unmanned underwater vehicle model with mine reconnaissance capabilities to test and evaluate the mine countermeasure capability of the unmanned underwater vehicle. The design is relatively complete. The more advanced technology is the "Mine Sniper".

2. Ease of Use

Suppose A robot has stable items P and M; robot chooses preference B’s favorite item is Q; robot prefers C likes items P, M and N; if the robot prefers A at this time, it needs to be recommended, then it first needs to be based on similarity The calculation finds its similar users. After finding similar robots, based on collaborative filtering, the robot C with better controllability will be recommended to the target robot A from the item N that the robot prefers and the robot prefers A that it has not paid attention to it. The recommendation technology based on collaborative filtering was first applied in the field of information retrieval, and the recommendation process relied on natural language processing, artificial intelligence machine learning and other technologies. The recommendation method is generally achieved through the following steps: first, extract the characteristics of the item; second, according to the expression of the control behavior of the item, such as accepting or not accepting, obtain the preference characteristics of the robot through these specific expressions; third, Generate a recommended set.

According to the preference of the robot and the preference of motion control, it is matched, and the one with a higher degree of matching is recommended to the user. The prevalence of Toutiao like today is inseparable from the control of content-based text recommendation technology. It uses user behavior to describe user preferences, calculates the similarity between project topics and user preferences, and selects the top ones in descending order of similarity. Items are used as recommended results and the results are returned to the recommended list. For example: "Data Mining: Concepts and Techniques" is a book in the field of data mining. Suppose a user, based on his behavior, finds that he prefers to read books related to data mining. After collecting his preferences, the system will eventually recommend books similar to the "Basics of Statistical Learning" series to the user. The core idea of recommendation based on association rules is that it is necessary to find a rule with a certain connection from historical data, and then make recommendations based on this rule. The form is like: Event D has a certain probability after event B occurs, and this probability is calculated based on the previous data. The purpose of association rules is to find the relationship between items in the data set. Among them, there are two indicators to measure the rule, one is support and the other is confidence. The degree of support refers to the probability that there are both B and D in all transaction orders. For example, the total number of transaction orders today is 10, and there are 3 orders that purchase both the introduction to data mining and the basis of statistical learning. The support of the rule (Support) is 33.33%. At the same time, the collaborative filtering method can be applied to the research of the stability motion control preference of underwater robots.

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\text{support } (B \rightarrow D) = \frac{P(BD)}{P(B)} = \text{support } (B \cup D)
\]  

Confidence refers to the reliability of robot D in all control methods that include robot B. To put it simply, the control method of robot B is recommended to robot D.
Confidence \( (B \rightarrow D) = P(\langle D | B \rangle) = \frac{P(\langle BD \rangle)}{P(\langle B \rangle)} \) 
(2)

It is not an easy task to find items with strong associations in the massive information, because the premise of meeting the requirements of strong association rules must meet the minimum support and minimum confidence. A strong association rule can be generated only when the itemsets that meet the minimum support, that is, frequent itemsets, and the confidence is greater than or equal to the minimum confidence.

The stability of an underwater robot can be defined as the ability to return to a balanced state after being disturbed without corrective behavior, such as the power of the thruster or the use of control surfaces. Therefore, maneuverability can be defined as the ability of an underwater robot to perform specific maneuvers. Excessive stability means that when a robot is marginally stable and easy to control, the control effect used is excessive. In this way, a compromise between stability and maneuverability must be sought. For spacecraft or underwater robots, static stability and dynamic stability are commonly used to distinguish. Static stability refers to the evaluation of the stability of the robot when the control surface is fixed and the thrust of all thrusters are constant. Dynamic stability refers to the evaluation of the stability of the robot when both the control surface and the propulsion power are allowed to change. This shows that the dynamic characteristics of the control system must also be considered in the stability analysis.

Control research can also be achieved for the trajectory of the robot. Given that the PID tracking controller requires the desired input vector of position, velocity and acceleration, in order to continuously update the velocity and acceleration vector, some form of trajectory must be generated for the underwater robot. We can avoid the generation of this trajectory by setting a constant acceleration and a desired speed. However, when the desired position is reached, a large negative acceleration is required in order to stop the movement of the underwater robot. Because the underwater robot may not produce such a large negative acceleration, the underwater robot will overshoot. This will cause the underwater robot to take more time to reach the desired position. A simple trapezoidal trajectory can be used to increase the underwater robot's speed from 0 to a desired constant value, and then reduce it to 0. Figure 1 shows a schematic diagram of this trajectory.

3. **Recommended experiments for stability**

In this experiment, based on the research of collaborative filtering recommended control method, and on the basis of ensuring the straight-line stability of the underwater robot's horizontal navigation, the steering stability of the horizontal navigation can also be tested. In the experiment, the underwater robot is deflected to the preset yaw angle, and then the dynamic stability of the underwater robot's direction is tested. Through the test system software platform, the lateral dual thrusters are controlled to perform
differential output, so that the underwater robot is adjusted from the current heading of $8^\circ$ to $-53^\circ$ in the pool, and then the dynamic stability of the underwater robot's movement direction is tested. The test results show that on the basis of ensuring the directional stability of the underwater robot when navigating on the horizontal plane, the directional maneuverability and flexibility are also satisfied.

![Figure 2 Motion trajectory experiment](image)

In the experiment, the underwater robot is set up in advance through the software platform of the test system. The positions of the eight coordinate points are shown in Figure 4. The starting coordinate point is $(0, 0, 0)$, and the ending coordinate point is $(0, 6, 4)$. When the underwater robot starts to move, the test system software platform starts to record the position information of the underwater robot during the test. The position information, its movement track is shown in Figure 2. The test shows that the comprehensive motion performance of the underwater robot basically conforms to the set route, and achieves the expected effect. This article mainly studies the motion stability control of the underwater robot. According to the overall structure of the underwater robot, the dynamic equation of the underwater robot is deduced. Based on the analysis of the basic fluid dynamics of the underwater robot, the water is obtained. The kinematics equations of the lower robot lay the foundation for stability analysis and control methods; several methods for judging the motion stability of underwater robots have been established, including the stability of straight line, direction and position, longitudinal stability and lateral stability. Corresponding theoretical proof is provided; a passive adaptive controller is designed, the global stability of the motion controller is theoretically proved, and the adaptive compensation for the influence of ocean currents is proposed, which is verified by the experiment of underwater robots.

4. In conclusion
Through the analysis of collaborative filtering technology, the article applies collaborative filtering technology to robot control, and analyzes the promotion effect of control methods on collaborative filtering technology. The stability theory of the robot is mainly described, and the forward and inverse kinematics modeling and analysis of the robot in the rod coordinate system are carried out, and then the gait planning and optimization are carried out. The gait planning is verified by simulation in theory. It is feasible and can be applied to the walking motion of robots. The article carries out specific gait experiments on the existing robots in the laboratory according to the two gait planning before and after optimization, and verifies that the optimized gait planning is more stable and reasonable, and that the optimized gait planning is more stable and reasonable. It can play a certain guiding role in related research on similar human-like biped robots.

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