Research on Development Status and Trend of Underwater Vehicle Technology

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Abstract: Underwater vehicle is underwater application equipment for underwater observation, measurement, maintenance and salvage, including Remote Operated Vehicle (ROV) and Autonomous Underwater Vehicle (AUV). Underwater vehicle plays an important role in military strategy and marine energy exploitation. By consulting the literature, this paper analyses the development status of the global underwater vehicle technology and points out the future development trend of the underwater vehicle.

1. Introduction

With the acceleration of the development of marine resources, underwater vehicles, as pioneers of ocean exploration and extreme environmental survey, have become the focus of attention of various countries. In recent years, after the hotspot of UAV, the underwater vehicle (AUV) has risen slowly not only as professional use, but also in commercial and civil areas. The underwater vehicle has great potential in the field of development, whether in the field of science, education and entertainment or in the field of professional applications are extremely important. This paper will focus on the possibility of the popularization and commercial use of underwater vehicles. Based on the content, this paper will discuss the characteristics, development potential and trend of the underwater vehicle.

2. Development Status of Underwater Vehicles

2.1 Domestic Development Status

2.1.1 AUV

Autonomous Underwater Vehicle (AUV) is a new generation of the underwater vehicle. It adopts a cable-free design and can process the collected data to determine its own action to complete the task. It has the advantages of a wide range of activities, good flexibility and intelligence [1]. Because AUV is not limited by a cable and has high concealment, it has attracted the attention of the military since the 1960s. Around the goals of ocean exploration and Haiti survey, in the mid-1990s, the Institute of Automation of Shenyang Academy of Sciences successfully developed the first 1000-meter "Explorer" submersible in China, and then jointly developed the first 6000-meter "CR-01" and "CR-02" deep-sea AUVs in China with Russia. Among them, "CR-01" reached the advanced international level at that time. Among them, Qianlong series AUV developed in China is mainly used for deep-sea resource exploration, focusing on the deep-sea AUV integrated navigation and positioning technology, deep-sea AUV dynamic positioning technology, which lays a solid technical foundation for the follow-up development of deep-sea AUV. Mainly includes: 6000m class "Qianlong 1", 4500m class "Qianlong 2" and "Qianlong 3"; "Exploration" series AUV is mainly used in marine scientific research, mainly including "Exploration 100", "Exploration 1000" and "Exploration 4500". Among them, "Exploration 4500" is 4500 meters deep-sea AUV, which is mainly used for scientific investigation in cold spring areas. Also, during the 12th Five-Year Plan period, Harbin Engineering University completed the development of 1000-meter intelligent water-IV. Tianjin University completed the development of 2000-meter seabed survey AUV, which is different from shallow-water AUV. For energy saving, deep-sea AUV in China mostly uses non-power submersion to reach the seabed. Because of the complex deep-sea environment and a large amount of noise in the sound, how to filter the noise has become a key problem in AUV deep-sea operation. Qianlong 1 supports two integrated navigation methods based on long baseline and ultra-short baseline. "Qianlong 1" long baseline based integrated navigation method (P-SLAM) is a data fusion method for multi-source measurement data such as attitude angle, velocity and long baseline acoustic positioning. At the same time, this method has the ability of online adaptive recognition of long baseline observation noise. Therefore, the integrated navigation precision of Qianlong 1 is higher, and the absolute positioning accuracy is better than 2.63 m.

2.1.2 ROV Underwater Vehicle with Cable Remote Control

The energy and instructions of ROV (Remotely Operated Vechicle) are provided by the water surface console, which connects the body and the console through the umbilical cord. The advantages of ROV are stronger power, stable signal transmission, convenient recovery and so on. However, the slender cable suspended in the sea has become the most vulnerable part of ROV, which greatly limits the moving range and working efficiency of the submarine underwater. In recent 30 years, China has developed a variety of ROV models, including planktonic, crawling and dragging. In 2002, CISTAR, the first self-propelled cable burying robot developed by Shenyang Institute of Automation Research, China, can realize the laying, inspection and maintenance of optical cables. In 2004, Hailong, the largest sampling robot developed by Shanghai Jiaotong University, successfully dived to 3500 m. "Hailong" is equipped with five cameras with different performance and a variety of robotic arms, which can be used for underwater interventional operations, with a maximum weight of hundreds of kilograms. At present, most commercial underwater vehicles in China are ROV, which are mainly used for underwater photography, underwater operations, and repair and rescue survey.

2.2 Overseas Development Status

In recent years, deep-sea AUV has been the focus of development in the field of AUV. With the continuous progress in the field of AUV, deep-sea AUV is also constantly making breakthroughs. Deep-sea AUV pays more attention to energy consumption, so in structure, fish-shaped, flat-shaped and so on are generally used. The energy of AUV depends entirely on its own supply. Generally, it carries rechargeable batteries. At present, the application of fuel cells is the main direction to improve the AUV's endurance [2]. Typical AUVs include the American Naval Academy's Phoenix and Ares AUVs, which are mainly designed to study intelligent control, planning and navigation functions. Massachusetts Institute of Technology Odyssey II is a robot mainly used for sea ice detection and mapping. The solar autonomous underwater AUV developed jointly by the New Hampshire Institute of Autonomous Underwater Systems and the Russian Far East Academy of Sciences Institute of Underwater Technology is trying to overcome the shortcomings of AUV's long-range endurance [3]. C.S. Dropper Laboratory in the United States has made great breakthroughs in bionic AUV, representing the product of yellow fin tuna robot VCUUV. Canada pioneered the development of Theseus AUV in ice cable laying in 1994. The robot is equipped with a 70kWh aluminum oxide fuel cell with a life of 36 hours. Later, the energy device of the robot was continuously upgraded. By 1997, the second-generation battery test was completed, and the endurance of the robot was significantly improved compared with that of the first generation. Japan's Tokyo Institute of Production Technology is mainly committed to underwater cable detection field and has developed a series of AUVs including Twin-Burger I and II, PTEROA150 and 250.

3. Possibility of Commercial Use of Underwater Vehicles

3.1 Commercial Trends and Prospects

Unlike the task-based underwater vehicle, the universal underwater vehicle has the advantages of simple structure, simplified function and easy operation. It is suitable for a submarine race, speed race and other purposes [4]. At present, there is no perfect underwater vehicle competition project in China. The difficulty lies in the high requirements for the competitors, which need to take into account the material, waterproof and compression resistance, circuit optimization, structure and other factors. But the underwater vehicle competition can be well combined with practical problems, such as marine garbage collection, seabed exploration, rescue missions and so on. With the vigorous development of underwater vehicles, competition mode will inevitably follow, not only to promote the development of underwater vehicles but also to promote underwater robots, so that more people participate in the development and production of underwater vehicles [5].

3.2 Domain Interaction

The underwater vehicle can interact with many fields, including mechanical engineering, ecological environment protection, tourism, material industry and so on. Its development trend will relate to these related industries. For example, in the tourism industry, underwater vehicles can be used as emergency devices or guides for diving or snorkeling, providing additional protection for divers in case of accidents [6].

3.3 Industrial Structure and Planning

Modular production is an indispensable change in the development of underwater vehicles. It is particularly important for the development of AUV, and DIY can produce underwater vehicles suitable for itself. The modular production can be realized by formulating corresponding production standards for robots, which can not only greatly reduce the later maintenance cost of robots, but also facilitate the maintenance of robots in use.

4. Functions of Underwater Vehicles

4.1 Topographic Survey

At present, infrared sensors are mainly used in underwater survey as the main tool of underwater exploration. Its principle is to confirm the surrounding topography and landform by means of the reflection wave. Besides, bionic robots also play an important role in underwater exploration. The main bionic robots are robotic fish submarines. According to the special characteristics of fish swimming, sensitive sensation and processing mechanism, combined with modern advanced technology, an underwater robot with high efficiency, high intelligence and high flexibility is developed [7].

4.2 Underwater Rescue

Rescue underwater vehicles (AUVs) have attracted much attention. They mainly use ROV type AUVs, because they are easy to recover, not easy to lose and have strong endurance. The main principle of the underwater rescue robot is closed-loop control method, which takes the robot as the center of the circle for angle positioning, circulating operation, reducing errors, and accurately locating rescued personnel and rescuing them. Fuzzy control and PID control are the most mature methods for underwater rescue robots, and Bayesian control is the other one. In the future, the underwater rescue robot will develop in the direction of artificial intelligence [8].

4.3 Garbage Collection

Underwater pollution has always been a major problem in China. Due to the different density, shape and cost of marine garbage, it is difficult to recycle it. However, underwater vehicle as a garbage recycling method has great advantages. It can distinguish garbage from underwater garbage by buoyancy measurement and other principles to determine whether it is underwater garbage. Because of its small size and high flexibility, it can reduce the damage to coral and organisms on the seabed.

5. Future Prospects

The future development direction of the underwater vehicle will inevitably be close to artificial intelligence, to simplify its operation and improve its practicability. The commercial use of underwater vehicles will promote the development of the underwater vehicle industry and provide opportunities for solving the real-life problems of underwater vehicles. Through underwater vehicle competition and other modes, the research of underwater vehicle can be popularized to teenagers, which can cause teenagers to think about the environment related to underwater vehicle such as a national ocean. The industrialization of the underwater vehicle module will accelerate the method of underwater vehicle, from the disassembly of the whole machine to the design and development of parts, and promote the performance optimization of the underwater vehicle. In the national aspect, the underwater vehicle will play a more important role in marine protection.

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