

# Research on the development and path exploration of autonomous underwater robots

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**Abstract.** With the increasing development of marine science and technology, autonomous underwater robots have become a hot spot in the field of underwater research and applications, and have been widely used in deep-sea scientific research, marine resources research, and deep-sea security. This paper focuses on analyzing the current research and development status and application prospects of autonomous underwater robots and predicts their future development trend. Aiming at the difficulties in engineering practice of path search in underwater unknown space, the traditional space path exploration method is analyzed, and a hybrid search algorithm is proposed to plan a reasonable and efficient dynamic path for target search in unknown underwater space.

**Keywords:** Autonomous underwater robot, Path search, Development trend.

## 1 Introduction

In recent years, all countries in the world have paid increasing attention to the development of underwater robot technology, which has been applied in the fields of deep-sea scientific research, marine engineering operations, and national military affairs. Generally speaking, underwater robots can be divided into the following three categories: autonomous underwater vehicles (AUV), cabled remotely controlled underwater vehicles (ROV), and active/remotely controlled underwater vehicles (ARV). Among them, the autonomous underwater robot is mainly an intelligent operation robot that utilizes a large number of cutting-edge technologies such as artificial intelligence, pattern recognition technology, and system integration technology<sup>[1]</sup>. It can carry sonar, optical cameras, ultra-short baseline positioning systems, and other equipment for use in Underwater detection and navigation<sup>[2]</sup>, the operator can control the movement of the underwater robot in real-time.

Autonomous underwater vehicles have their energy and the ability to navigate independently. They can carry out large-scale reconnaissance missions. In engineering practices such as underwater emergency search and rescue and underwater resource exploration, they can accurately and efficiently grasp the external and internal space of

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underwater targets. feature. Therefore, the development of autonomous underwater robots has important military and civilian value [3]. Path planning is one of the important contents of autonomous underwater robot technology research. In narrow underwater spaces, excellent path planning is helpful for the shore personnel to have a more comprehensive understanding of the underwater situation and effectively improve the success of underwater rescue by rescuers. Rate. In the 2018 incident where the Thai youth football team was trapped in a cave, the rescuers used underwater robots to explore the path because the path blocked by water in the cave was tortuous and narrow, and it took several days to find the trapped person. Therefore, there is still a lot of room for improvement in the field of underwater unknown space detection and path planning, which can be combined with intelligent algorithms for in-depth research.

## **2 Application prospect and development trend**

### **2.1 Application prospect**

In the process of research and development of marine resources, the ocean, which occupies 71% of the earth's area, is a huge treasure house of important resources that is far from being developed. At the beginning of the 21st century, people are facing the triple challenges of population growth, shortage of land resources, and changes in human economic and social development. To maintain human survival, reproduction, and economic development, we have to make use of marine resources, which is an unavoidable choice for human beings. For regions with limited resources per capita, research in the maritime field is more unique. It can be seen that underwater robots will play a significant role in deep-sea environmental monitoring, marine resource exploration, and deep-sea scientific research.

In addition, in future wars, zero casualties will become the key to the war. Therefore, the strategic position of the unmanned weapon system will be highly valued, and its potential combat effectiveness will also become more prominent. As its main part, the underwater robot system can use water ships or submarines as the main base to carry out tasks such as environmental reconnaissance, intelligence collection, and data communication in the gaps of the deep seabed, thereby enriching the combat survival space of water ships or submarines.

Among them, autonomous underwater robots can go deeper into dangerous areas controlled by the enemy more safely, and can also stay for a long period of time in an active way, which is a military weapon with outstanding economic benefits. At present, the applications that countries are focusing on research and development include mine warfare, anti-submarine warfare, intelligence acquisition, monitoring and reconnaissance, target detection, and environmental data acquisition.

### **2.2 Development towards specialization and modularization**

Traditional AUVs can carry out various reconnaissance tasks such as acoustic reconnaissance, optical detection, and hydrological monitoring at the same time. Offshore R&D personnel has been expecting that in the future, AUVs will have faster speeds, longer routes, longer working hours, lower power consumption, lighter weight, and lower production costs. However, due to the influence of many factors such as energy consumption, volume, load, and production cost, it has been unable to meet the needs of various offshore engineering tasks. Therefore, future autonomous underwater robots will mainly develop in the direction of specialized and modularized detection and loading

AUVs, such as acoustic detection AUVs for far-space lines, area optical detection AUVs, and modular loading AUVs.

Among them, the main feature of the modular load AUV is that it can be designed as a modular load detection load for mission requirements. It is lighter in weight, cheaper in cost, and more flexible in function. At the same time, its adaptability and endurance in specific environments are more balanced.

### **2.3 Towards the development of independent operation**

In the future, the AUV system will develop from an information-based AUV to an autonomous AUV system. It will have two core functions of large-scale long-term autonomous monitoring and refined operation, and establish a long-term comprehensive three-dimensional unmanned monitoring and operating system based on the AUV system. And realized the transformation from the human-centered scientific expedition management mode to the future scientific expedition and expedition association cooperative management model with the AUV system as the core. In addition, to develop an autonomous underwater robot with an independent operating model, it must have key capabilities such as independent environmental teaching and reliability analysis.

The reliability analysis capability refers to the real-time data obtained through the AUV to analyze the working status of each component and its impact on the quality of each task. Immediately evaluate whether it can complete the current task, and actively suspend tasks that cannot be achieved due to its work reliability. Due to the rapid development of deep-sea technical equipment such as AUVs, future deep-sea research and scientific expeditions will enter an unmanned era. Intelligent AUVs with completely independent production and operational capabilities will also become the main method for human research in the deep sea.

### **2.4 Develop towards clusters and collaborative operations**

The operational efficiency of individual AUVs is limited, and there are also certain differences in the operational capabilities of various types of individual AUVs. According to this, in the future, it will develop from a single individual AUV operation to a group computer operation, and make full use of the operational advantages of various AUVs to improve the observation effect of AUVs. The future ocean observation will be long-term, all-around three-dimensional ocean observation. This requires the establishment of a multi-platform coordinated operation system such as AUV, ROV, and ARV, so that the entire sea area can be observed and explored from the perspective of various water depths, various sizes, and various sea surface parameters.

## **3 Path-finding algorithm**

### **3.1 Route plan**

Path planning is also a key work link for autonomous underwater robots to perform autonomous operations. According to the characteristics of autonomous operation, route planning can be divided into two categories, one is the traditional route planning from the starting position to the ending position, and the other is the complete traversal route planning. Line real-time path planning relies on the AUV's understanding of the surrounding environment and uses the detection system and sensors to collect surrounding environmental information so that the AUV can plan the best route based on this

information content. The complete traversal route planning is to use the designed evaluation function to find an unobstructed continuous route from the starting point to the target location within the planning range, to optimize the evaluation function. Many scholars have done a lot of research on underwater path planning. Emili generates topology information by considering the constraints of the workspace during the construction of the topology environment and then uses this method to calculate the topology path to guide the path search in the workspace [4]. Sun introduced a heuristic search method for the unknown underwater environment [5]. Most of the current research is based on sufficient underwater spatial structure information. Therefore, a hybrid search algorithm can be studied to detect the unknown water space.

### 3.2 RRT search algorithm

Rapidly expanding random tree algorithm (RRT) can quickly navigate empty areas and find the next traversable route in unfamiliar, high-dimensional environments. The path mode of the RRT algorithm is similar to the exploration process and the growth and expansion process of branches [6]. When exploring the unknown space structure, an initial node in the state space structure can be regarded as the root node, and the method of randomly collecting and increasing the number of leaf nodes can be used to obtain a high-speed expanding random tree. The expansion steps of the RRT algorithm are shown in Figure 1.

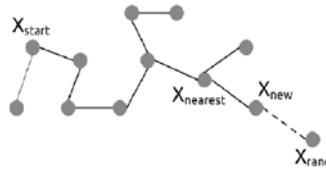


Fig. 1. Process of RRT Algorithm.

### 3.3 RRT\* search algorithm

The RRT\* algorithm is improved on the basic RRT algorithm. Compared with the basic RRT algorithm, the RRT\* algorithm improves the original node selection function based on RRT and adds the process of parent node optimization [7]. The RRT\* algorithm is shown in Figure 2. The algorithm is asymptotically optimized. When the number of iterations increases, the result of the path planning can converge to the optimal solution under the current random tree to a certain extent.

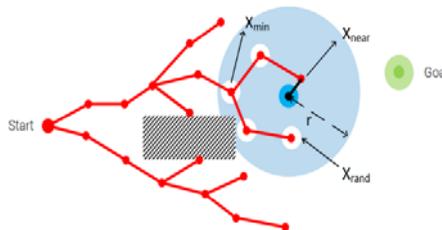


Fig. 2. Schematic diagram of RRT\* algorithm.

### 3.4 Hybrid RRT search algorithm

To improve the efficiency of route search, the understanding of the overall environment of the underwater robot should be improved; the repeated search of the area by the underwater

robot should be reduced; the reverse search of the underwater robot should be reduced. Based on the above reasons, an improved hybrid search algorithm based on RRT path planning and calculation can be proposed. The basic RRT algorithm has a strong tendency for unknown areas, while in the hybrid RRT search algorithm, the underwater spatial perception information is obtained through 3D sonar, and the environmental boundary area is obtained. At the global path calculation level, the RRT algorithm is used to make coarse-grained path branch decisions, and the edge signals of the selected branches are fed back to the local path calculation, and then the micro-local path search is performed according to the RRT\* algorithm and the underwater space perception information is updated. Realize underwater space path search. The structure of the hybrid RRT search algorithm is shown in Figure 3. The specific idea is to divide the exploration path planning problem into two stages, that is, the local search stage, which is responsible for efficient exploration in the space around the current robot pose, and the local search stage, which relocates the robot back to the global space after the local exploration of the robot is completed. Global search phase.

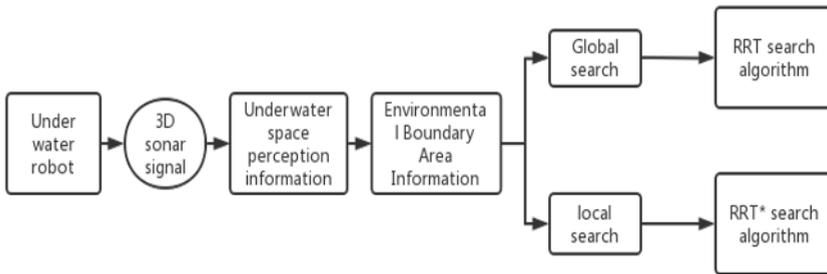


Fig. 3. Hybrid RRT algorithm structure diagram.

## 4 Conclusion

At present, with the increasing progress of science and technology, the research of autonomous underwater robots has made great progress. It is undeniable that autonomous underwater robots, as advanced underwater research equipment full of potential, will play a crucial role in ocean development, exploration, and future warfare, and have broad development prospects. Aiming at the path search in the underwater unknown space, a hybrid RRT search algorithm proposed in this paper uses the characteristics of the rapidity of the RRT algorithm and its tendency to extend the unknown space and combines the local search stage with the global search stage, which can the excellent performance of the algorithm is applied to the underwater unknown space. However, there is still room for further optimization in this field. In the future, with the development of artificial intelligence, autonomous underwater robots will be more intelligent and have more extensive applications.

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