AUV Cruise Path Planning Based on Energy Priority and Current Model

Guangcong Liu[1], Hainan Chen[1,2], Xiaoling Wu[2,*], Dong Li[3,2], Tingting Huang[1,], Huawei Fu[1,2]

[1]Guangdong University of Technology, Guangzhou 510006
[2]Guangzhou Institute of Advanced Technology, Chinese Academy of Sciences
[3]Jinan University, Guangzhou
liugc@gdut.edu.cn,{hn.chen,xl.wu}@giat.ac.cn
*Corresponding author

Abstract. In this paper, we study the influence of the current on selection of the cruise path of AUV (Autonomous Underwater Vehicle). We extended the current model into 3D space. According to this extended current model, we analyze AUV's energy consumption under the affects of the water flow and compare it under different cruise paths. This study mainly focuses on the path optimization based on the current model and energy priority. To some extent, it provides a theoretical basis for the optimization of the AUV cruise path.

Keywords: AUV, path planning, current model, energy optimization.

1 Introduction

AUV (Autonomous Underwater Vehicle) is a kind of underwater robot that controls and manages the tasks with their own autonomous control processing center. It is different from remote operated vehicle with wire. Path planning is an important link of the key technologies of mobile robot. According to some optimization criteria (e.g. the shortest route, the shortest travel time and the minimum work load, etc.) the autonomous mobile robot can find an optimal path to avoid obstacles from the initial state to goal state in its movement space [1].

Global path planning for mobile robot mainly includes two parts: one is the environment modeling; the other is the valid path searching. Environment model is an abstract description of the robot's activity space. To build an environment model, commonly the first step is to abstract the environmental factors and then use these factors to describe the reality of the environment before the path planning algorithm execution. In other words, building an environment model is to use appropriate approaches to represent the impact factors of the environment. Common environment model include raster map, topology diagram, visual map and free space method, etc.

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2 . State of Arts

In the past, AUV was mainly used in deep submergence assignments, such as submarine topography exploration, submarine cable accident repair, etc. In addition, due to its inherent ability to adjust its own position quickly and its good underwater maneuvering performance, AUV has been widely used in the underwater sensor network. AUV utilizes its maneuvering characteristics to avoid network deployment hole, or participates in the relay to enhance signal transmission and data collection. AUV can greatly improve the application ability of underwater sensor networks. According to different emphasis of path planning, the researchers have carried out related researches. With the rapid development of science and technology, some intelligent techniques are applied to mobile robot path planning, such as neural network, genetic algorithm and fuzzy control, etc, and good results are achieved.

The current research of the AUV's path planning is mainly focused on the real-time job environment. With this in mind, the most important factor in the AUV's path planning is that AUV must finish its mission as soon as possible. Since the AUV is more and more valuable in the underwater sensor network applications, we gradually discovered that the cruising ability is another point. In the UWSN (Underwater Wireless Sensor Networks) application, the AUV should continuously cruise under the water to maintain the network topology. So in the study of the AUV's path planning, the minimization of energy consumption is also very important. This paper just focuses on this issue and studies the current's effect on AUV's energy consumption.

3 Path Optimization Based on the Current Model

The AUV must have enough energy to improve its cruise ability. On one hand, we can study the efficient energy storage technology to extend the AUV's cruise time. Some researchers presented the energy harvesting technology to harvest the environment energy for AUV's cruise [2] which also improves the cruise time of the AUV. On the other hand, we can analyze the AUV's cruise process to find out the optimal job scheme and reduce the energy consumption. The goal of this paper is to optimize the cruise project and reduce the energy consumption through the analysis of the AUV's task processing during the AUV's cruise course, and finally to improve the cruise ability.

3.1 Current Model

For the current model, there has been some valuable research in the early stage of the Physical Oceanography and the Pure Kinematics. In these studies, velocity field was used to describe the water flow. According to the scholar's research, they found the oceans are a stratified rotating fluid, hence vertical movements are, almost everywhere, negligible with respect to the horizontal ones [3].

This paper mainly studies the influence of the current on the selection of the AUV's cruise path. Since the cruise path of the AUV is always in the three-dimensional space, we must build a current model in three-dimensional space to plan the AUV's cruise path, and then we can get a real simulative environment. Up to now, the recent researches mainly analyze the current model in the two-dimensional space with plane analysis. To address this problem, we adopt the random offset vector to set the offset of the vertical direction based on the existing current model. With this offset vector we can simulate the current in the 3D space.

Fig. 1 demonstrates a simulation water flow in the 3D space by the random offset vector and the stratified feature based on the existing current model. To study the energy consumption, we set three different paths for the AUV to reach the same destination. The point A is the current position of the AUV, and B is the destination. Among the three paths, the AB is the direct route. In the ACB route, AUV first go to C point and then goes to the destination B. In the ADB route, it first goes to D, and then goes to B point.

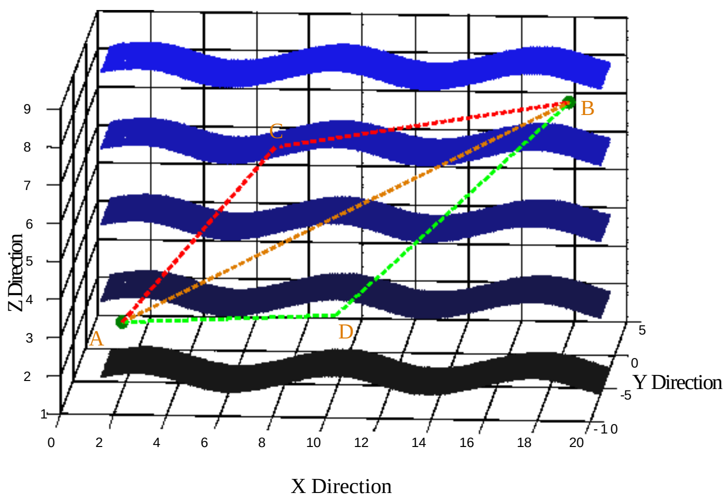

Fig.1. The current graded model and cruise path in 3D space.

3.2 The Effect of the Current on Energy Consumption

The effect of the current is the most important factor to optimize the cruise path. When AUV is in the reverse flow, it must overcome the resistance of the current. Compared with the down-flow, it would consume more energy to go forward. So without considering the barrier and time priority, we should include the down-flow area in the path as much as possible, and use the current's flow to reduce the AUV's energy consumption, furthermore it can shorten the AUV's cruise time.

To make it clear, we suppose the AUV can get the present current model and accurately get its logical position and the destination position. Once the cruise area model is established, the problem of the cruise path optimization would be converted to the problem of minimizing the angle between the tangent vector of the cruise path and the velocity field's tangent vector. When this angle is too large, then the water flow does negative work to AUV. At this stage the energy consumption is obvious. On the contrary, if this angle is small, water flow can do positive work. Water flow drives the AUV go ahead, so this can reduce the energy consumption. When AUV is in the ocean environment, it can even use the ocean current and vortex to cruise without power, which would effectively improve the AUV's cruise ability.

3.3 Performance Analysis

In this paper, we adopt the MCM (Meandering Current Mobility model) model [4] to study the effect of the current to AUV's cruise. Firstly we decompose the instantaneous velocity field to get the current direction vector. And then calculate the angle between the direction vector and the tangent vector of cruise path to measure the energy consumption. Finally we can evaluate the pros and cons of different cruise path by energy consumption. During the simulation, as the angle is the effect factor of the current cruise path, we can only consider the current's effect, which shows that the effect factor is proportional to energy consumption. The greater the angle, the stronger the resistance of the current and the more the energy consumption. Fig. 2 illustrated the energy consumption of three different paths. Obviously, different cruise path has different energy consumption.

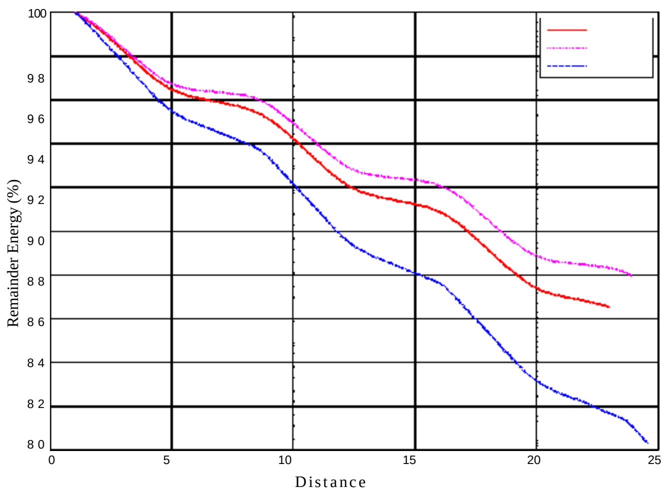

Fig. 2. The three cruise paths' energy consumption.

As shown in Fig.2, path AB's energy descent velocity is between path ACB and path ADB. As a kind of conservative and compromising solution the direct path from the origin to the destination is not a bad choice. Of course this is not the best scheme. In Fig. 2, we can see that path ACB's energy consumption has been reduced 2%

compared with path AB's while path ADB's energy consumption is obviously higher than the others. In conclusion, the selection of the break point in the cruise path influences the AUV's energy consumption.

4 Conclusion

This paper investigated three different AUV cruise path's energy consumption under the current model. Our numerical and analytical results clearly show that it can reduce the energy consumption when we plan the AUV's cruise path. The research of the effect to AUV is important. In the future we will continuously study the AUV's path planning based on the current model to improve the AUV's cruise ability and performance.

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