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Real-Time Obstacle Avoidance Motion Planning for UUV Based on Minimum Jerk Algorithm

Du Du[1], Siming Yuan[1], Tianchen Li[1], Zesheng Jin[2,*], Ruichi Sun[2] and Wei Zhang[2]

[1]Naval Research Institute, Beijing 100161, P. R. China
[2]College of Intelligent Systems Science and Engineering, Harbin Engineering University, Harbin 150001, P. R. China
*Corresponding author: 360773764@qq.com

Introduction

The Unmanned Underwater Vehicle (UUV) is a kind of equipment that can work underwater for a long time and is commonly used in the underwater environment to perform tasks such as ocean terrain exploration, military reconnaissance, and cooperative anti-submarine operations. Motion planning, as one of the critical technologies of the intelligent body, should ensure that the UUV finds a path from the starting point to the target point in the operating space with the obstacle environment.

Research Questions

Many research results in motion planning have been based on planning paths from the starting point of a known obstacle environment. However, the UUV is limited by the sensing range in the actual working environment and needs to obtain all the global obstacle information. The UUV needs to plan a global path first and continuously perform real-time obstacle avoidance planning during the motion based on the sensed obstacle information.

Methodologies

This paper improves the A* algorithm to reduce the number of visited nodes and improve the efficiency of path planning. Moreover, combined with the minimum jerk to fit between path points, obtain a feasible motion trajectory to achieve the motion planning of UUV real-time obstacle avoidance.

Table

TABLE 1. Heuristic effect

Heuristic	*Time cost*	*Path cost*	*Visited nodes size*
Diagnol distance	*0.369906ms*	*1.511930m*	*50*
Diagnol + tie-breaker	*0.320465ms*	*1.461212m*	*26*
Euclidean	*1.232567ms*	*1.421212m*	*241*
Euclidean + tie-breaker	*1.236871ms*	*1.468075m*	*271*
Manhattan	*0.470320ms*	*1.484644m*	*47*
Manhattan + tie-breaker	*0.375530ms*	*1.444644m*	*36*

Mathematical Formulas

$$minimum\ \text{jerk} = \int_0^T (p^{(3)}(t))^2 dt \qquad (4)$$

$$f(t) = \sum_{i=0}^{5} p_i t^i = p_0 + p_1 t + p_2 t^2 + p_3 t^3 + p_4 t^4 + p_5 t^5 \qquad (5)$$

$$Mc = b$$

$$M = \begin{bmatrix} A_0 & 0 & 0 & \cdots & 0 \\ B_1 & A_1 & 0 & \cdots & 0 \\ 0 & B_2 & A_2 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & A_{M-1} \\ 0 & 0 & 0 & \cdots & B_M \end{bmatrix}, b = \begin{bmatrix} D_0^T & D_1^T & 0_{m\times \bar{d}_1} & \cdots & D_{M-1}^T & 0_{m\times \bar{d}_{M-1}} & D_M^T \end{bmatrix}^T \qquad (6)$$

Figure

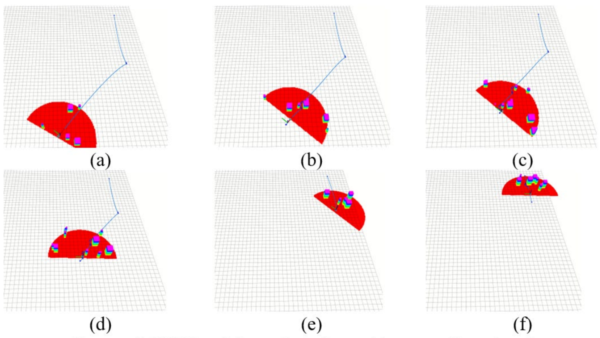

FIGURE 5. UUV real-time obstacle avoidance motion planning

Conclusion

We design a motion planning framework based on the improved A* algorithm applied to UUV in an obstacle environment for UUV online for motion planning. By adding the A* algorithm to the tie-breaker to solve the same cost problem and adding the path point simplification, the optimality of path finding of the A* algorithm is exploited, and the problem of too many path points is also solved. In addition, compared with a single A*, the minimum jerk makes the trajectory between path points more consistent with the dynamics of UUV, more energy-efficient, and closer to reality.