A Research on Control Strategy for Autonomous Sailboats

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ABSTRACT

To guide autonomous obstacle avoidance navigation of an unmanned sailboat, the customized A* collision avoidance path planning algorithm and the PID track following control algorithm based on the linear LOS (Line of Sight) guidance law are presented in this paper. Simulation results show that the proposed method achieves successfully autonomous obstacle avoidance under multiple obstacles, and the effectiveness of the proposed method is validated.

KEY WORDS: unmanned sailboat; autonomous obstacle avoidance; A* algorithm; LOS; PID

INTRODUCTION

With the increasing consumption of global energy, more and more researchers pay attention to the green ships powered by intelligent sail. However, traditional sailboats are controlled by manual operation, thus not only great labor intensity of ship operators is needed, but also the sail angle cannot be quickly adjusted according to the change of the wind angle. The operation has a certain hysteresis, and wind energy cannot be effectively utilized. At present, only a few autonomous sailboats over the world can achieve turning and changing sails under unmanned operation. Therefore, it is of profound significance to study the control strategy for autonomous sailboats.

In general, the control strategy adopted by autonomous sailboats can be divided into three modules: navigation, guidance, and control (Xu et al., 2018). The guidance module realizes the collision avoidance path planning, while the control module realizes the track following. The collision avoidance path planning means that after knowing about the starting point and the target point, autonomous sailboats can plan a reasonable and shortest collision avoidance path according to the ocean geographic information of the navigating zone. Then, after obtaining the path information, the track following ensures the autonomous sailboats travel along the planned route by controlling the sail, rudder, and other actuators.

Researchers on collision avoidance path planning for unmanned sailboats have been carried out. Pêtrès et al. (2012) proposed an artificial potential field method, which sets the un navigable angle of autonomous sailboats as a virtual obstacle. Moreover, they presented the simulation results under the steady and unsteady wind field and carried out some actual sailing tests. However, this method could not avoid the risk of falling into the local minimum value. Stelzer et al. (2010) proposed the local path with the velocity made good algorithm, and the speed polar diagram of the sailboats is modified according to the location and distance of the obstacle. Meanwhile, they provided some good simulation results. Du and Xu (2018) proposed a multi-dimensional dynamic programming method. In this algorithm, the sailed voyage length and the current position are adopted as a state variable, and the short-term route planning between the neighboring way points is defined as a control variable. They presented a group of optimal routes with the minimum voyage time, corresponding to different voyage length.

In terms of the track following of autonomous sailboats, the way point is usually set in advance, and the linear track following control is carried out between the two waypoints. At present, some researchers have realized the autonomous control of unmanned sailboats through fuzzy control, PID control, and some intelligent control combined with PID. For example, Yeh and Bin (1992) designed a controller based on the fuzzy logic theory, so that the unmanned sailboats could obtain the maximum speed on the predetermined trajectory. Cruz and Alves (2010) used the P/PID controller to realize the function of changing sails along the downwind; Wang (2015) designed the independent sail and rudder controllers to achieve the track following of the unmanned sailboats.

In this paper, the customized A* collision avoidance path planning algorithm and the PID track following control algorithm based on the linear LOS (Line of Sight) guidance law are used to guide autonomous obstacle avoidance navigation of an unmanned sailboat. The paper is organized as follows. Firstly, the control model for the motion of three degrees of freedom (3-DOF) of the autonomous sailboat is described. Secondly, the customized A* collision avoidance path planning algorithm is presented. Thirdly, the track following strategy consisting of the linear LOS (Line of Sight) guidance laws and the design of the rudder and sail controllers is introduced. Fourthly, some simulation