

A Study on Simulation of Single Sailing Training System

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Abstract—The single sailing simulation system is introduced in this paper based on a large amount of data from the experiment. Combining traditional method with the fuzzy control, a new method of routes planning is put forward. Relying on simulating the system using MATLAB tool, we can find the optimist degree and routes of the sailing using the shortest time reach the finish line in theory. The planning routes can be used to direct the sailing through coordinate conversion. Modelling the single sailing and marine environment based on Virtual Reality Technology, simulate the sailing. The Simulation results prove that the proposed method in this paper is helpful for the sailing training

Keywords—single sailing; optimization path; simulation; virtual reality.

I. INTRODUCTION

Modern sailing originates from Netherlands. The sailing is a sport combined by entertainment, ornamental, exploration and athletics. It is motivated by natural wind and sails on the ocean. China is a nation that has long history of sailing cultural. Even if the single sailing has short history, our country has made a great progress along with more attention paid on it. It is really significant to do more research on single sailing training, such as path optimization and weather forecasting.

The sailing needs wide space to compete on the ocean, which is 1-2 km away from the coast. The Olympic sailing competition usually adopts trapezoid traces, as shown in Figure.1. The competition field is an equilateral triangle constructed with three buoys. Each edge is no less than 2-2.5 sea miles. The starting and finishing line are both virtual line which is 100-200 meters wide, and the width decreases as the amount of the sailings cut down. Another way to calculate is using the amount of the boat multiple the length of the boat firstly, and then using the number multiple 1.25 meters. The starting and finishing lines are parallels. The first buoy and the wind direction form 90-degree angle.

Because of the environment condition and the competition field is always varied, the field is settled based on the real-time environment. The preparation work should be finished in 5 minutes before the competition started. The sailing trace should be combined by against wind, horizontal wind, tailed wind. It will test the athletics overall abilities, not just fortune.

Sailing is restricted by the field, the equipment and so on. It is a complicated game which is affected by many

aspects. To improve the quality of the training system, we use MATLAB tool to simulate all the influence factors in the sailing process. We use the traditional algorithm combined with artificial programming methods to calculate the optimized sailing trace. Based on the simulation and ocean experiment, the result can guide the athletics in an effective way.

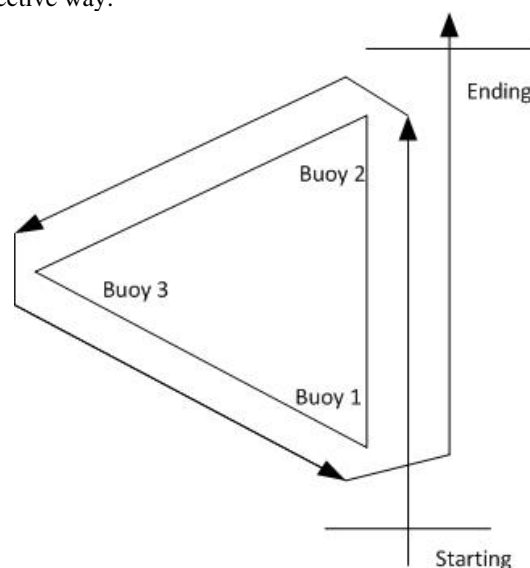


Figure 1. Sailing route of sailboat

II. FORCE ANALYSIS AND BEST SAILING ANGLE

The sailing is composed by five sections, hull, masts, sails, the rudder and the central board. As shown in Figure. 2a, the hull is the main portion. The hull's size is different in the kinds of the sailings. The mast is used to stick sails. The sails received wind from the ocean which is the power source of the sailing. The rudder is like the steering wheel in car. The central board is used to balance sailings.

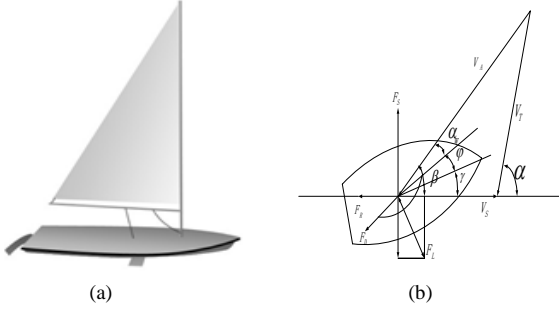


Figure 2. (a) The sailboat structure, (b) Principle diagram of force

The power of the sailing is collected from wind. When the wind blows across the sails, two sides of the sail receive different force based on Bernoulli Effect. We can classify the wind into three kinds, the real wind, the sailing wind and the relative wind. The real wind is the wind speed tested on the mainland. The sailing wind is the opposite direction wind which is equal to sailing speed. The relative speed is the vectorial resultant of the real wind and the sailing wind. We assume that the sailing sails along right direction as shown in Fig. 2b. The real wind V_T and the direction form an angle α . The speed of the sailing is V_S . The direction and the sails form an angle γ . The relative wind speed V_A and the sailing direction form an angle β . When wind blow across the sailing, based on Bernoulli Effect, the pressure on the slow speed side is larger than the other side. The pressure forms a force F_L , which is vertical to the sails. The stream forms a force F_D , the aerodynamic lift and aerodynamic drag form the motivation power [1]:

$$F = F_L \sin \beta - F_D \cos \beta \quad (1)$$

The aerodynamic lift and aerodynamic drag form the horizontal force, the force is:

$$F_t = F_L \cos \beta + F_D \sin \beta \quad (2)$$

The aerodynamic lift coefficient CY and aerodynamic drag coefficient CX are lift and drag force. The sails lift force and the drag forces are as below:

$$Y = \frac{1}{2} \cdot \rho \cdot c_y \cdot A \cdot V_A^2 \quad (3)$$

In the formula, Y is the lift force, X is the sails' drag force, the ρ is air density, A is the area of the sails, V is the relatively wind speed.

The relatively wind blow the sails in speed V_A with angle α . The relatively wind and the direction force an angle β . The sails get the force

$$F_t = \rho_{air} \cdot A \cdot V_a^2 \cdot \sin \alpha \quad (4)$$

F_t can be separate into forward force F_f and vertical force F_h [2]. When the sails get the balance force, the sailing will get uniform motion. The acceleration of the

sailing is really fast which can be ignored. So the wind force is equal to the drag force, as below:

$$V_b^2 = F_t \cdot \sin(\beta - \alpha) = \rho_{air} \cdot A \cdot V_a^2 \cdot \sin \alpha \cdot \sin(\beta - \alpha) \quad (5)$$

The speed of the sailing can be defined as [3].

$$V_b = \sqrt{\frac{\rho_{air} \cdot A \cdot \sin \alpha \cdot \sin(\beta - \alpha)}{C}} \quad (6)$$

Where C is the drag force coefficient. The ship speed in L direction is

$$V_{BM} = V_b \cdot \cos \omega \quad (7)$$

The sailing time is

$$t = \frac{L}{V_{BM}} = \frac{L \cdot \sqrt{C}}{\sqrt{\rho_{air} \cdot A \cdot V_A^2}} \cdot \frac{1}{\sqrt{\sin \alpha \cdot \sin(\beta - \alpha) \cdot \cos \omega}} \quad (8)$$

In order to minimize the time, we could use the fmincon function to do that [4]. We separate the sailing period into each parts and optimize it [5].

TABLE I. RELATIONSHIP BETWEEN THE ANGLE OF WIND, HEADING AND ROLLING

Wind angle θ (degree)	Rolling angle α (degree)	Angel between sail and heading β (degree)	Heading angle ω (degree)	Minf (α , β)
0	24	24	48.0	3.6742
15	28.7	28.7	42.4	2.8199
30	33.5	33.5	37.0	2.2686
45	38.6	38.6	32.2	1.8942
60	43.8	43.8	27.6	1.6303
75	49.2	49.2	23.4	1.4394
90	54.7	54.7	19.4	1.2990
105	60.4	60.4	15.8	1.1953
120	66.2	66.2	12.4	1.1190
135	72.1	72.1	9.2	1.0646
150	78.0	78.0	6	1.0280
165	84.0	84.0	3	1.0069
180	90	90	0	1

III. SAILING PATH PLANNING BASED ON FUZZY CONTROL

The traditional control is an accurate control. This method needs to analyze the data and description accurately and it uses unified formula to control [6]. The force analysis of sailing is very complex and always changeful. We should use GPS to control the sailing paths [7].

The path-planning question can be divided into two kinds based on the environment. The first is the path-planning based on model. All the information can be accessed in this kind. The other is the path-planning based on the sensors. The information of the environment can be access partly or nearly unknown [8].

Based on the fuzzy control planning, we can utilize the formula shown above as the knowledge storage. We can

make out that, when the wind angle larger than 90° , the function changes a little. So, in this condition, the sailing sails straight forward without caring other information. The function changes a lot when the wind angle is less than 90° . Then, the optimized sailing angle has to be considered [9].

Based on force analysis, when the relatively wind angle not equal to 180° , the sailings could always move straight

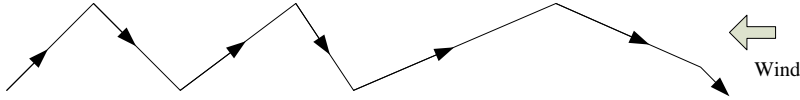


Figure 3. Sketch map of the sailing trace which is like the Chinese character of 'Zhi' when sailing against wind.

Based on the optimized angle, we can design our fuzzy control algorithm. We use the member function [10].

$$Z(x, y) = \begin{cases} 0, & \sqrt{(x-x_t)^2 + (y-y_t)^2} \geq R \times g(\vec{V}, \vec{D}) \\ 1 - \frac{\sqrt{(x-x_t)^2 + (y-y_t)^2}}{R \times g(\vec{V}, \vec{D})}, & \text{else} \end{cases} \quad (9)$$

Where (x_t, y_t) is the target, R is larger than 0. We select $R = L$, L is sailing distance, \vec{V} is the speed, \vec{D} is the vertical distance (x, y) away from the target (x_t, y_t) , g is direction coefficient, we can select $g > 0$ based on different situations, g is \vec{V} and \vec{D} angle's reduce function.

$$g(\vec{V}, \vec{D}) = 1 + \lambda \cos \varepsilon \quad (10)$$

Here $0 < \varepsilon < 90^\circ$, It is the angle formed by \vec{V} and \vec{D} . We select EV , T is the sailing's finishing time across the k area [11].

$$EV = \tau_1 T + \tau_2 Z(x, y) \quad (11)$$

$$T = L / (n \cdot V) \quad (12)$$

V is the separate speed on the shortest path.

$$V = V_y = V_B \cos \psi \quad (13)$$

$Z(x, y)$ is the member function, τ_1, τ_2 are weighting coefficients. During competition, we are looking forward the shortest time, so $\tau_1 > 0$, $\tau_2 < 0$. Through knowledge we can set the parameters as $\tau_1 = 0.9$, $\tau_2 = -1.08$, $\lambda = 0.7$ [12]

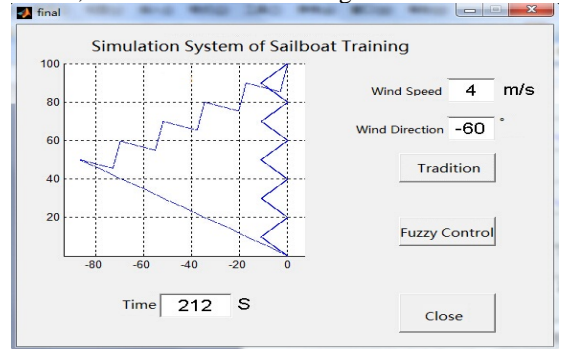
IV. SIMULATION RESULTS

The sailing competition changes a lot, including so many parameters, so the artificial path planning can fit all the conditions. The fuzzy path planning algorithm is a kind of artificial path planning algorithm. It doesn't need the accurate math function. We can use the fuzzy control method instead of it. It can fit the changing environment. Fuzzy control uses control method to describe the

relationship between the parameters. That is to say that the fuzzy control function doesn't need the accurate math functions. The artificial path planning method is more efficient than the traditional ways. The result of our method is more useful in daily training. However, this is only the theory result. It is hard for ordinary athletics to understand. For any conditions, the result is shown in Figure.4a.

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(a)



(b)

Figure 4. (a) The simulation of single sail training system
(b) 3D visualization of single sailing

Based on our results above, we firstly use traditional method to calculate the experiment result as the knowledge storage. And then, use the divided thinking to optimize the shortest paths. In our paper, while using fuzzy control, we consider the sailing effective speed on the effective sailing directions and the distance away from the target. We take consider of these two factors to make the final decisions.

V. CONCLUSIONS

In this paper we make a study on the simulation research of the single sailing, combining the traditional path planning algorithm with the intelligent path planning of the fuzzy control algorithm. According to the force analysis of sailing, the best sailing angle for the given environment is selected and the optimal path of the sailing during the sailing competition is planned out. Our research can provide the theoretical basis for scientific sailing training, as well as provide guidance and reference for improving the sailing competition results.

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