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MARINE SEARCH AND RESCUE OF UAV IN LONG-DISTANCE SECURITY MODELING SIMULATION

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ABSTRACT

Long-distance safety of Marine search and rescue using drones can improve the searching speed. The current method is based on the long distance security classification of UAV.The degree of accuracy is low. A long-distance security modeling approach based on ArduinoMiniPro's Marine search-and-rescue applying UAV is proposed. The method puts the fault tree analysis and relevant calculation for risk identification into use. The main factors affecting the safety of unmanned aerial vehicle (UAV) are long-distance searching and rescuing. The experimental results show that the proposed method can effectively build modeling for the long-distance safety of the Marine search and rescue UAV.

Keywords: Marine search and rescue, Unmanned aerial vehicle (UAV), Long distance security

INTRODUCTION

As the integration of global economy, maritime transport, communication and tourism are booming, maritime search and rescue and related problems have become the focus of governments and economic entities [1]. Nowadays the rapid development of business, the terrestrial environment deteriorating, and the scarcity of resources are difficult problems. The vast ocean and its rich species have become the key to sustainable economic development. However,the frequent occurrence of marine disasters and a variety of marine disasters caused by inadequate management or training have become an urgent problem [3]. The high-occurrence shipwreck not only brings countless property loss and personal injury, but also causes serious pollution of the marine environment. In recent years, the global shipwrecks are too numerous to mention. In 2000, there was a major shipwreck in Lusi fishery of Jiangsu province.When No. 03127 fishing boat was at berth, it was sunk in a fishing boat form Zhejiang, besides 3 rescuedpeople, 9 people were missing in 12 people [4]. Accidents at sea can cause the immeasurable loss, which highlights the importance of maritime rescue [5]. The efficiency of maritime search and rescue has a very important role. The property and the life security are closely related to the benefits of the broad masses, every action of maritime search and rescue will affect the nerves of masses[6]. At present, what has the relatively high efficiency and accuracy of maritime search and rescue is the unmanned aerial vehicle search and rescue. It has less time-consuming and small deviation in marine search and rescue[7].

As a relatively emerging industry in recent years, the unmanned aerial vehicle has been applied to the fields of investigation, communications and surveillance. Now it has a very wide prospect in the civil fields about the marine applications, the forest fire prevention and the emergency rescue[8-9]. Compared with manned aircraft, the unmanned aerial vehicle has the advantages about the small size, the convenient operation, the low cost and the low requirement for using environment. It has new enlightenment to the development of maritime search and rescue technology [10-11]. The characteristics of rapid take-off and landing of the unmanned aerial vehicle makes it have no special requirements on the takeoff environment, so it can faster provide the surrounding environment of people in distress and geographical location information, thus narrowing the scope of the search and rescue and the scale of rescue, we don't need to spend a lot of time and resources to realize the search and rescue. But the safety of unmanned aerial vehicle in long distance has always been a problem that bothers people .

Reference proposes a long distance security modeling method of maritime search and rescue unmanned aerial vehicle based on visible spectrum. According to the long distance security model of current maritime search and rescue unmanned aerial vehicle, this method analyzes the related factors of long distance security of unmanned aerial vehicle. The Beidou system contains GPS satellite positioning, communication location system of Beidou satellite, Beidou unmanned aerial vehicles Server, Beidou integrated security controller.We research and analyzethe safety of forced landing and the safety of aircraft failure in the process of the long distance search and rescue of unmanned aerial vehicles by using the above hardware. Thus the long distance security modeling of the maritime search and rescue unmanned aerial vehicle has been completed. The modeling method has the detailed hardware, but modeling speed is slow. Reference proposes a method of long distance security modeling method of maritime search and rescue unmanned aerial vehicle based on EKF. The establishment of dynamic networking of the maritime search and rescue unmanned aerial vehicle generates a dynamic multi-level security group management protocol according to the different levels of unmanned aerial vehicle long-distance security. The protocol designs the group key mechanism through the identity of each unmanned aerial vehicle, and divides the distance of unmanned aerial vehicle search and rescue at sea. The results are:the medium and long distance, the long distance and extra-long distance. The security is analyzed according to the grouping of the distance, and the modeling is realized by using the above protocol. The modeling method is simple, but there is a great deviation in the modeling of the long distance safety of unmanned aerial vehicle. Reference proposes a long distance security modeling method of maritime search and rescue unmanned aerial vehicle based on rules. According to the fuzziness of the unmanned aerial vehicle long distance safety index, we establish the fuzzy evaluation model of long distance security of unmanned aerial vehicle through the analytic hierarchy process and fuzzy evaluation method. For the characteristics of long distance search, we research its potential safety hazard and classify it. This is convenient to classify and model the safety of unmanned aerial vehicle.Combined with examples, we carry out the experiments on this model. Experimental results show that the applicability of the modeling method is strong, but the correct rate of classification rate is low.

In view of above problems, this paper proposed a modeling method of the long distance security ofmaritime search and rescue unmanned aerial vehiclebased on ArduinoMiniPro. Experimental results show that the proposed modeling method can efficiently model the long distance security of the marine search and rescue unmanned aerial vehicle,which has high practicability.

LONG DISTANCE SECURITY MODELING OF MARITIME SEARCH AND RESCUE UNMANNED AERIAL VEHICLE BASED ON ARDUINOMINIPRO

In the process of maritime search and rescue, the environment of unmanned aerial vehicle is complex and diverse. Due to long flight, inevitably there will be security risks, so as to cause immeasurable loss [16-17]. Therefore, long distance security modeling of maritime search and rescue unmanned aerial vehicle is the priority among priorities in the development of unmanned aerial vehicle search and rescue. The basicfor researching the long distance security is the identification of the security risk. We need to find the main factors influencing the long distance security of the unmanned aerial vehicle and the relatively weak link during the operation .

This paper uses the fault tree analysis method for the risk identification of the long distance security of the unmanned aerial vehicle, according to the importance of minimum cut sets and structure, we calculate and qualitatively analyze the main factors which are used to identify the long distance search and rescue security of the unmanned aerial vehicle, and build the safety evaluation system of long distance flight of the unmanned aerial vehicle [19-20].

THE SAFETY EVALUATION BASIS OF UAV LONG DISTANCE SEARCH AND RESCUE

The concept of the risk of long-distance search for UAV

There is still no specific definition of risk in the world as so far. But as some researchers deepen their research, a rough definition of risk is appeared: risk is a comprehensive measure of the probability of an accident and the extent of the damage, the formula below is the risk function:

$$R = f\left(P, C\right) \tag{1}$$

In the formula, R is the risk value, P is the probability of an accident, C is the severity of the accident.

The function relationship of formula (1) usually takes the product of P and C as follow:

$$R = P \times C \tag{2}$$

The danger of long-distance search for drones is unavoidable because of objective existence, but the size of the risk is changed largely based on human's behaviors, that is people can adopt certain technical means and the prevention measures, descending failure rate and harm of UAV long distance accident to slow down the risk

The ALARP principle of the risk of long-distance search for UAV

The ALARP principle is the two-flattening principle, The long-range risk of drones appears in all safety systems, and it may only be reduced by human safety measures, but the risk value is not zero, the cost is often reduced by risk while the exponential curve is going up, which need comprehensive analysis of risk and cost [21-23]. The UAV's long distance search and rescue risk ALARP principle is shown in Figure 1.

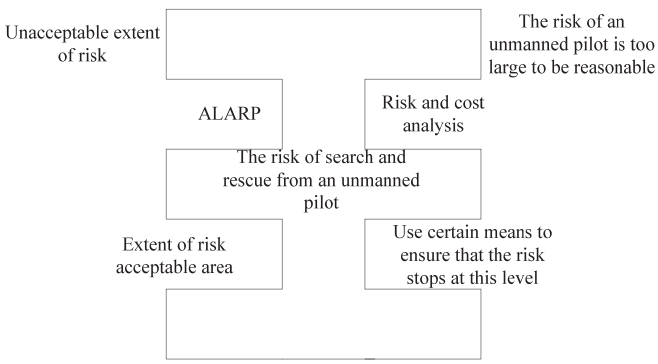
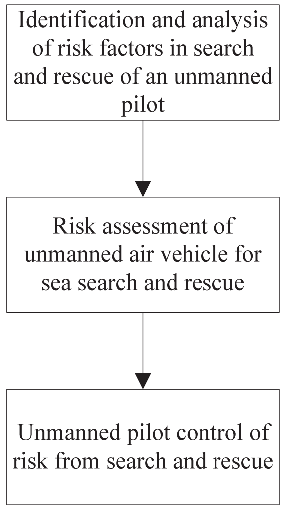


Fig. 1. UAV's long-range risk ALARP principle

Evaluate the safety of long-distance search for UAV, assuming that the risk value of the evaluation is not acceptable and in most cases, this risk is not allowed, it must be forced to reduce it and deal with special circumstances; assuming that the value of the risk is inacceptable area, the risk is allowed to exist, and periodic checks are only required. Assuming that the value of the evaluation is within the acceptable range, the long-range risk of UAV follows the ALARP principle and requires weigh and synthesize costs and risks by certain means: raise the maintenance costs do not significantly reduce risk, so the risk is tolerable and the cost is saved [24-27], on the contrary, investment must be increased to reduce risk. The extent of the UAV's long-distance search and rescue risk is reduced depends on the results of the analysis.

The safety evaluation of UAV long distance search and rescue

The long-range safety evaluation of UAV is aimed at completing the long distance search and rescue, apply the basic theory and method of safety engineering to the marine search and rescue, make recognition and analysis of search and rescue the potential risk factors for long distances, to judge and predict UAV long search and rescue the accident possibility and its serious degree, and then to provide support the emergency response plan and maintenance management. The evaluation process of UAV long-distance marine search and rescue is as follows.



Fig, 2 UAV long distance search and rescue safety evaluation system

UAV ocean long distance search and rescue safety evaluation objectively reflect the extent of the risk of long-distance sea rescue accidents based on the analysis and risk assessment of the failure factors of long-distance search and rescue, guiding the drone search and rescue management to take effective remedial measures by this way and controlling the risk in the ALARP area, reducing the risk of long-distance search for UAV.

UAV long-distance search and rescue risk identification

Long distance search and rescue risk discrimination for UAV, which is risk identification, it is the process of judging and identifying the historical accidents and accidents that have not occurred on the basis of researching and collecting of long distances search and rescue, which is the safety evaluation basis of UAV long distance search and rescue. The main task of UAV long-distance search and rescue risk identification are: finding out the factors of the long-distance search and rescue accident, and making qualitative analysis of the result. The long distance search and rescue risk is deduced by the failure tree which is used to identify and analyze its key factors. The specific steps for UAV long-distance search and rescue risk identification are:

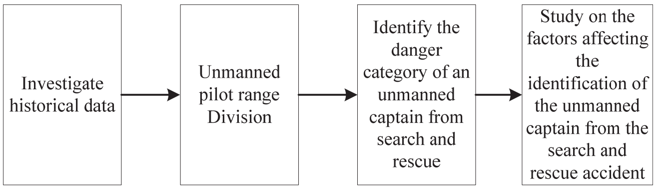


Fig. 3 UAV long distance search and rescue risk identification framework

The risk process changes with the changing conditions of the long distance search and rescue situation, the difference in the size of the entire UAV's long-distance search for different regional risks depends on the complexity of the environment and the changes in its conditions. So the research condition for the safety evaluation of UAV long distance search and rescue is to wait for the division of distance. It can also be used to evaluate the safety of a particular distance, and can consume less manpower, material and financial resources.

The minimum cut set mentioned above is the minimum set of accidents that will be analyzed which will harm to the safety and reliability of UAV. The cut sets can reflect the danger of long distance search and rescue. Every minimum cut set is a way to cause a crash, the more the number of minimum cut sets can reflect the more causes of the long search accident, the more easily lead to accidents, the safety and stability of long-distance search for UAV is poor.

The calculation of structural importance of the accident can help identify and analyze the relative importance of the minimum cut of an accident, which is conducive to long distance search and rescue security stability for UAV. The formula for calculating the importance of the structure based on the minimum cut set is:

$$I_{(i)} = 1 - \prod_{X_i \in K_j} \left(1 - \frac{1}{2^{n_j - 1}}\right) \tag{3}$$

In this formula, X_i represents the i th basic accident, n_j is the total number of the i th accident in K_j , K_j represents the j th minimum cut set in the fault tree, $I_{(i)}$ represents the importance degree of the i th accident structure.

The construction of UAV long distance search and rescue safety failure tree

To construct UAV long distance search and rescue safety failure tree, the minimum cutting set is determined by the operation of long distance search first, for the identification and analysis of long-distance search and rescue accident, the "long distance search and rescue safety" is considered as the minimum cut. The immediate factor that cause the UAV's long distance search and rescue safety declined are: from the failure of the drone's external structure, the failure of the drone's own structure and the overall structure of the drone, take it as an intermediate accident. At last analyze layer upon layer until all accidents are found.

Then calculate the minimum cutting and structural importance of failure tree. For a long distance search and rescue safety failure tree, according to the top-down Boolean algebra, the minimum cut is obtained by the algorithm.

$$\begin{aligned} &A = B1 + B2 + B3 = C1C2 + D1 + C3C4 + D2 + C17C18C19 = \\ &(D1 + D3 + C5 + C6 + C7)(C8 + C9 + C10) + D1 + C2 + (C11 + C12 + C13)(C14 + C15 + C16) + C17C18C19 = \\ &D1 + D2 + (D3 + C5 + C6 + C7)(C8 + C9 + C10) + (C11 + C12 + C13)(C14 + C15 + C16) + C17C18C19 = D1 + D2 + D3C8 + \\ &D3C9 + D3C10 + C5C8 + C5C9 + C5C10 + C6C8 + C6C9 + C6C10 + C7C8 + C7C9 + C7C10 + C11C14 + \\ &C11C15 + C11C16 + C12C14 + C12C15 + C12C16 + C13C14 + C13C15 + C13C16 + C17C18C19 \end{aligned} \tag{4}$$

Formula (4) shows that the fault tree is made up of 2 first order minimum cut set, 21 second order minimum cut set , and 1 third order minimum cut set. It reflects 24 ways of reducing the safety of UAV over long distance search and rescue. It can be seen that the search for long distances is not that security.

To calculate the structural importance of the accident, according to the formula (3), the importance of every accident structure in this fault tree is:

$$I_{C5} = 1 - \left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right) = 0.875 \tag{5}$$

$$I_{C6} = 1 - \left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right) = 0.875 \tag{6}$$

$$I_{C7} = 1 - \left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right) = 0.875 \tag{7}$$

$$I_{C8} = 1 - \left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right) = 0.9375 \tag{8}$$

$$I_{C9} = 1 - \left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right) = 0.9375 \tag{9}$$

$$I_{C10} = 1 - \left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right) = 0.9375 \tag{10}$$

$$I_{C11} = 1 - \left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right) = 0.875 \tag{11}$$

$$I_{C12} = 1 - \left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right) = 0.875 \tag{12}$$

$$I_{C13} = 1 - \left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right) = 0.875 \tag{13}$$

$$I_{C14} = 1 - \left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right) = 0.875 \tag{14}$$

$$I_{C15} = 1 - \left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right) = 0.875 \tag{15}$$

$$I_{C16} = 1 - \left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right) = 0.875 \tag{16}$$

$$I_{C17} = 1 - \left(1 - \frac{1}{2^2}\right) = 0.250 \tag{17}$$

$$I_{C18} = 1 - \left(1 - \frac{1}{2^2}\right) = 0.250 \quad (18)$$

$$I_{C19} = 1 - \left(1 - \frac{1}{2^2}\right) = 0.250 \quad (19)$$

$$I_{D1} = 1; I_{D2} = 1 \quad (20)$$

$$I_{D1} = 1 - \left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right)\left(1 - \frac{1}{2}\right) = 0.875 \quad (21)$$

The result of the formula above shows that the structure importance of basic accident $C5 \sim C19$

$$I_{D1} = I_{D2} > I_{C8} = I_{C9} = I_{C10} > I_{C5} = I_{C6} = I_{C7} = I_{C11} = \cdots = = I_{C16} = I_{D3} > I_{C17} = I_{C18} = I_{C19}$$

and $D1 \sim D3$ are sorted by their size as:

(22)

THE DIVISION OF UAV LONG-RANGE SEARCH SAFETY RATING SCALE

Determine the relative risk value of the long distance search for UAV

Through the risk definition formula $R = P \times C$, combined with these studies, the risk value R for the long distance segment of the UAV are determined. Only in the condition that the failure rate P and the failure result C both represent the objective absolute value, R represents absolute risk value, in the rest of the situation R represents relative risk value. Through the above, and based on the limitation of the actual condition and the complexity of the long distance search and rescue condition, the value of R can only be set within the relative value category recently.

The establishment of the scale model for the safety evaluation of UAV long distance search and rescue

It can be known by the nature of the relative value of UAV long distance search and rescue failure that it doesn't make sense to look at a single relative value, it is necessary to put the value in a real problem, and there is a certain standard that is relevant.

At present, there is no sound standard for the safety evaluation of UAV long distance search and rescues in China, it is needed to improve the support and verification of the failure database. It is very difficult to complete the safety evaluation criteria at the current stage. The rating of the long-range search and rescue safety is shown below:

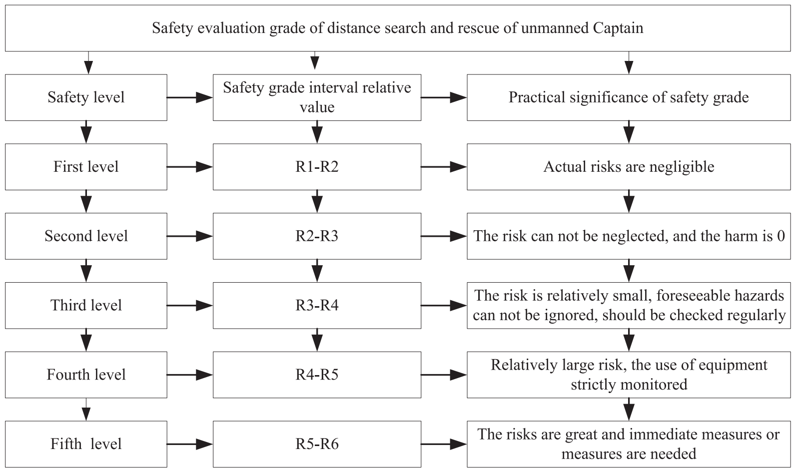


Fig. 4 Rating of the long-range search and rescue safety for UAV.

Assuming that the probability of failure and the range of consequences of failure is known, determine the value of $R1 - R6$ in the figure above by this range. In the actual long-range search and rescue safety evaluation, calculate the relative value R of the risk then contrast with the figure above to determine the risk level of long-range search for UAV, then take appropriate measures to achieve the goal of the long distance safety evaluation and safety alert of the Marine search and rescue for UAV then complete the modeling.

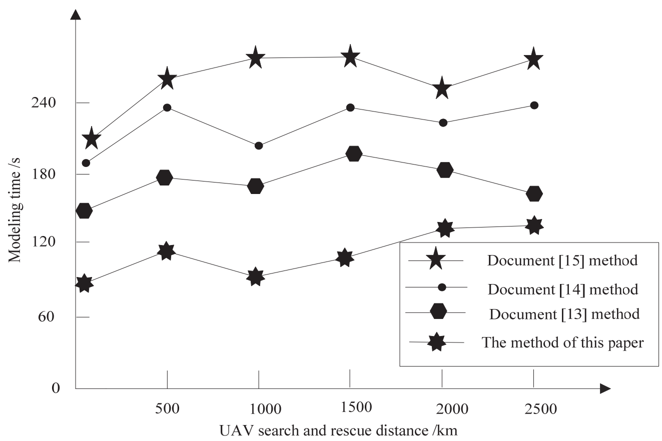


Fig. 5. Modeling time in different ways.

EXPERIMENTAL RESULTS AND ANALYSIS

In order to prove the effectiveness of the long distance security modeling method of maritime search and rescue unmanned aerial vehicle based on ArduinoMiniPro, we need a simulation experiment. In Matlab environment, the long distance security modeling experimental platform of maritime search and rescue unmanned aerial vehicle is constructed. The experimental data are obtained from "eaglet3A" which was successful in flight test Dayi County of Chengdu in July

12, 2012.This unmanned aerial vehicle weighs 15 kg, and the wingspan is 2.6 meters, and the aircraft length is 2.1 meters. The search system of this unmanned aerial vehicle consists of the airborne detector, the ground station, the beacon, the unmanned aerial vehicle, the portable personnel positioning search and rescue device and the high resolution camera. The airborne equipment can activate the beacon in the range of 10 kilometers, so as to read the ID information of the person in distress at sea, and then locate the distress position quickly according to the GPS signal transmitted by the beacon. We use different methods to carry out the same experiment on the experimental subjects, so as to observe the practicality of the modeling method proposed in this paper. Figure 5 is the comparison of the modeling time (s) of different methods. Figure 6 is the comparison of modeling stability (%) of different methods. Figure 7 is the comparison of modeling errors (%) of different methods.

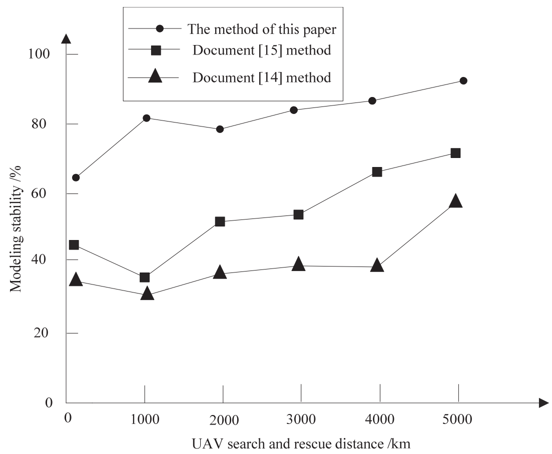


Fig. 6. Modeling stability contrasts in different ways

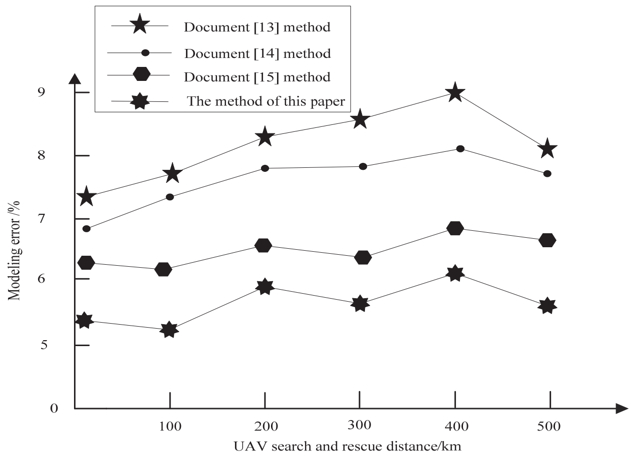


Fig. 7. Comparison of modeling errors of different methods

Analyzing three diagrams, we can see that the proposed modeling method in this paper is relatively good. The modeling method proposed in reference document studies and analyzes the safety of forced landing and the safety of the aircraft failure in the process of long distance search and rescue of unmanned aerial vehicle, but it ignores the factors of external invasion. The method in reference divides the distance of unmanned aerial vehicle maritime search and rescue, and the results are as follows: the medium and long distance, the long distance and the extra-long distance, but there is no description of the risk in each group for the grouping result. The method in reference researches and classifies its security risks aiming at the characteristics of long distance search and rescue,and does not divide the existing accidents or the accident what is happening into the classification [28-30].

In this paper, the method use the fault tree analysis method and correlation calculations to realize the risk identification and the main factors affecting the safe of long distance search and rescueof the unmanned aerial vehicle, and obtains the safety evaluation grade modelof long distance search and rescue of unmanned aerial vehicle,so that the modeling error is smaller, faster, and more stable.

Simulation results show that the proposed modeling method can efficiently model the long distance security of the marine search and rescue unmanned aerial vehicle and reduce the modeling time, and improve the safety of the long distance search and rescue of unmanned aerial vehicle, and provide support for the long distance marine search and rescue of unmanned aerial vehicle [31-33].

CONCLUSION

Using the current method for modeling the long distance safetyof marine search and rescue unmanned aerial vehicle, we can not model accurately and quickly, there is the large deviation problem about the modeling the long distance safetyof marine search and rescue unmanned aerial vehicle. This paper proposed a modeling method of the long distance security ofmaritime search and rescue unmanned aerial vehiclebased on ArduinoMiniPro.Simulation results show that the proposed method can effectivelymodel the long distance security of the marine search and rescue unmanned aerial vehicle.

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