International Journal of Industrial Engineering, 30(6), 1616-1628, 2023

DYNAMIC COLLISION DETECTION OF UNMANNED SHIP BASED ON WIRELESS COMMUNICATION

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In order to improve the detection accuracy of the collision detection system for unmanned ships at sea, this paper proposes a dynamic collision detection method based on improved ZigBee network wireless communication technology. The collision parameter detection model of unmanned ships at sea based on the ZigBee network and wireless communication network control is constructed. The communication network model is established by using wireless sensor network communication and radio frequency identification tag recognition technology. The experimental results show that the system can more accurately analyze and detect the collision of unmanned ships at sea and judge the route information of ships when there are obstacles. The collision dynamic detection accuracy of the system is 25% higher than that of traditional methods on average, and the performance is superior.

Keywords: Wireless Communication; Unmanned Ship at Sea; Collision; Dynamic Detection; Zigbee; Sensor Networks.

(Received on April 4, 2023; Accepted on October 3, 2023)

1. INTRODUCTION

With the development of artificial intelligence control technology as an important product of artificial intelligence (Ramezani *et al*., 2018), unmanned marine vessels play an important role in maritime monitoring, maritime rescue and meteorological data collection (Chen *et al*., 2020; Chen *et al*., 2020; Cao *et al*., 2019). During the navigation of unmanned marine vessels, anti-collision designs are needed (Cao *et al*., 2021; Cui *et al*., 2020; Chai *et al*., 2022). Combining wireless sensing technology and autonomous navigation control technology, the anti-collision model of unmanned marine vessels is built. Combining ZigBee wireless communication networking technology, the communication networking design and control design of collision detection of unmanned marine vessels is built to improve the anti-collision ability of unmanned marine vessels (Dou Q *et al*., 2017). ZigBee wireless communication technology is a low-power LAN wireless communication protocol based on the IEEE802.15.4 standard. According to international standards, ZigBee wireless communication technology is a short-distance and low-power wireless communication technology. At present, with the development of ZigBee technology, IPv6/6Lowpan with ZigBee wireless communication as its core has become the core of many other standards, including ZigBee SEP2.0 for smart grid, ISA100.11a for industrial control standards, and active Radio Frequency Identification (RFID)International Organization for Standardization (ISO)1800-7.4. It can be seen that ZigBee is a highly reliable wireless data transmission network, similar to CDMA and GSM networks. The ZigBee wireless communication data transmission module is similar to the mobile network base station. The communication distance of ZigBee ranges from the standard 75 m to several hundred meters and several kilometers, and it supports unlimited expansion. Therefore, ZigBee, as a new wireless network technology with a short distance, low complexity, low power consumption, low data rate and low cost, is widely used in the field of automatic control and remote control and can be embedded in various devices (Fan *et al*., 2020; Leontiadis *et al*., 2011).

With the increasing number of unmanned ships at sea and the increasing number of unmanned ship queues, the risk of collisions between unmanned ships at sea is also increasing. Once a ship collides at sea, it will bring economic losses and may even affect the normal operation of some key maritime channels. The traditional collision detection methods for unmanned ships have slow detection speeds and poor detection accuracy. Therefore, it is necessary to study an effective collision avoidance method for unmanned ships at sea. This study utilized improved ZigBee network technology to achieve communication between unmanned ships at sea, exchanging real-time information such as speed and distance of unmanned ships at sea, enabling the early warning system to timely grasp the navigation information of unmanned ships at sea. A collision detection model was constructed using the uniform beamforming DOA method. These two points are also the novelty and academic innovation of this study. In this paper, ZigBee, an economical, efficient and low data rate (< 250kbps)

DOI:10.23055/ijietap.2023.30.6.9145 ISSN 1943-670X

wireless communication device, is adopted to realize the network communication of unmanned ships on the sea. Based on the self-organizing network of unmanned ships on the sea, the wireless communication frequency band works at 2.4 GHz and 868/915 MHz. Based on the design of the network and system, a dynamic detection system based on ZigBee technology to prevent the collision of unmanned ships on the sea is obtained, which can more accurately warn the collision of unmanned ships on the sea.

On the other hand, in the case of obstacles, the system can also judge the existence and navigation route information of the surrounding unmanned ships at sea. It can also send a traffic warning to the surrounding unmanned ships at the navigation mark point based on wireless communication to remind the unmanned ship navigation control system to pay attention. Huang y *et al*. propose an innovative measurement method of ship collision risk and select multiple scenarios to verify the performance of the method. The test results show that the ship collision avoidance system integrating this innovative method can more accurately calculate the collision probability and measure the collision risk (Jia *et al*., 2020; Liu *et al*., 2021). Chi and Liu designed an intelligent ship collision avoidance system based on computer vision technology and built simulation experiments to compare the working performance of several ship collision detection systems, including the system. The test results show that the system has better stability and stronger early warning ability than the traditional ship collision detection system (Liu *et al*., 2022a). Rong *et al.* (2022) proposed a ship collision detection recognition model based on an improved sliding window algorithm in this study. In this method, the rudder angle is evaluated based on the orientation of the target ship, and a sliding window algorithm is used to identify the corresponding ship maneuvering behavior from the ship trajectory. The test results show that this method can accurately identify the possibility of ship collision based on the trajectory data of the automatic recognition system. Liu *et al.* (2022b) proposed a novel risk assessment model. The model proposes for the first time a self-ship and target ship model based on the Fuzzy Quaternion Ship Domain, which can be used in collision detection tasks for ships at sea. The experimental results using actual operating data show that the model designed in this study has high practical value in ship collision risk assessment.

To sum up, although a lot of research has been carried out to improve the anti-collision ability of ships, there are still few studies on the improvement based on the ZigBee wireless network system. To this end, this paper proposes a collision-collision dynamic detection method for unmanned ships based on wireless communication. In this paper, firstly, a wireless communication network system model based on ZigBee is established, and a collision parameter detection model based on ZigBee network and wireless communication network control is obtained. By using wireless sensor network communication and RFID tag recognition technology, a ship unattended communication network model is established. Secondly, the DOA estimation method of uniform beamforming is innovatively used to establish a uniform rectangular array, and the unmanned ships are distributed in a uniform rectangular grid as array elements to describe the dynamic change process of the unmanned ship queue. Finally, according to the angle change, we can obtain the azimuth and speed information of the unmanned queue of ships, accurately estimate the parameters of the collision dynamic detection system, and complete the collision dynamic detection of unmanned ships at sea. The experimental results show that the contribution of this method is that this method can more accurately analyze and detect the collision of unmanned ships at sea. It is able to judge the existence and route information of unmanned ships at sea when there are obstacles. The system improves the collision dynamic detection accuracy, has superior performance and improves practicability.

2. ZIGBEE-BASED COMMUNICATION NETWORKING SYSTEM MODEL BETWEEN UNMANNED SHIPS AT SEA

2.1 Overall Model Design and Problem Description

The first step of building the communication networking system model between unmanned ships at sea based on ZigBee is to realize the automatic identification of unmanned ships at sea. The identification process mainly includes three stages: ZigBee signal acquisition of dynamic parameters of unmanned ships at sea, classification and identification of dynamic parameters of unmanned ships at sea. In the ZigBee signal acquisition stage of unmanned ship collision dynamic parameters, ZigBee technology is needed to acquire the signal of unmanned ship collision dynamic parameters at sea, and a support vector machine is used to identify the characteristics of unmanned ship collision dynamic parameters at sea, and finally the accurate identification of unmanned ship collision dynamic parameters at sea is completed. The flow chart of identification of collision dynamic parameters of unmanned ships at sea in the communication networking system model between unmanned ships at sea based on ZigBee is described in Figure 1. The dynamic parameters of ZigBee maritime unmanned ship collision are obtained by the recognizer in the ZigBee identification model, and the eigenvalues in the dynamic parameters of ZigBee maritime unmanned ship collision are clustered and analyzed by the K-means clustering algorithm. The eigenvectors are classified by feature extraction and used as the input eigenvectors of the support vector machine algorithm, and the parameters such as azimuth and speed of offshore unmanned ships are estimated and identified by the support vector machine identification algorithm (Chi *et al*., 2019).

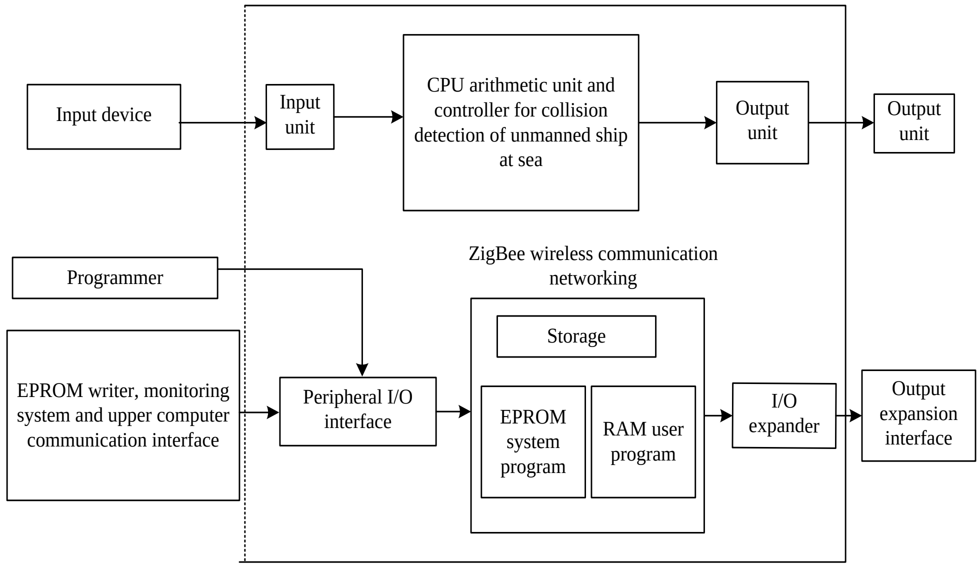


Figure 1. Flow Chart of Identification Process of Collision Dynamic Parameters of Offshore Unmanned Ship Based on Zigbee

Eigenvalues are the basis of identification of dynamic parameters of unmanned ship collision at sea, and the input eigenvectors are mainly ZigBee signals of dynamic parameters of unmanned ship collision at sea, and the result of feature clustering is regarded as the basis of support vector machine identification algorithm (Yan *et al*., 2022). The detailed process is:

(1) The dynamic parameter signal of unmanned ship collision at sea is obtained by RFID technology.

(2) K-means clustering algorithms are used to cluster the different values of each attribute.

(3) Taking the clustering results of different attributes as different values of each attribute in the recognition model of support vector machine, according to the algorithm of support vector machine, the recognition law of dynamic parameters of unmanned ship collision at sea is obtained, and the law is adopted to recognize dynamic parameters of unmanned ship collision at sea in actual operation (Kuang *et al*., 2018; Pu *et al*., 2017). At present, the identification method of dynamic parameters of unmanned marine vessels in congested areas based on induction coil will be interfered by external factors such as light and shadow, vibration, etc., and it can't be accurately identified, mainly because the current technology is based on ZigBee radio frequency signal-to-noise ratio and the idea of filtering is used to remove interference. In this paper, ZigBee technology is used to communicate between unmanned marine vessels to exchange information, such as the speed and distance of unmanned marine vessels in real-time, so as to avoid congestion and collision (Bauza *et al*., 2010; Shen *et al*., 2011). ZigBee is simple, easy to use, reliable and low-cost, so it has certain advantages in the research of collision dynamic detection systems for unmanned ships at sea (Tong *et al*., 2020; Huang *et al*., 2020; Huang *et al*., 2020). Based on this, according to the 802.15.4 standard, thousands of tiny sensors coordinate with each other to realize autonomous communication between unmanned ships at sea and transmit data from one network node to another by radio waves in a relay way, thus improving communication efficiency (Ni *et al*., 2018; Nie *et al*., 2018).

2.2 Collision Warning Method Between Zigbee Networking and Unmanned Ship at Sea

ZigBee technology is used to realize collision dynamic detection of unmanned ships at sea, and its network segmentation is the first step to realize communication and early warning algorithms. On the basis of ZigBee networking, based on intelligent segmentation of different network nodes, different ZigBee collision dynamic detection sub-networks in the network are formed, data transmission and communication are carried out in the sub-networks, and then the data results are reported to the central control unit of the system. There are generally two kinds of segmented data interaction in the ZigBee-based collision dynamic detection network of unmanned ships at sea Xu (2018; Xie *et al*., 2019). One is the peer-to-peer data interaction method, in which a node in networking transmits data with a node in network 2, as shown in Figure 2.

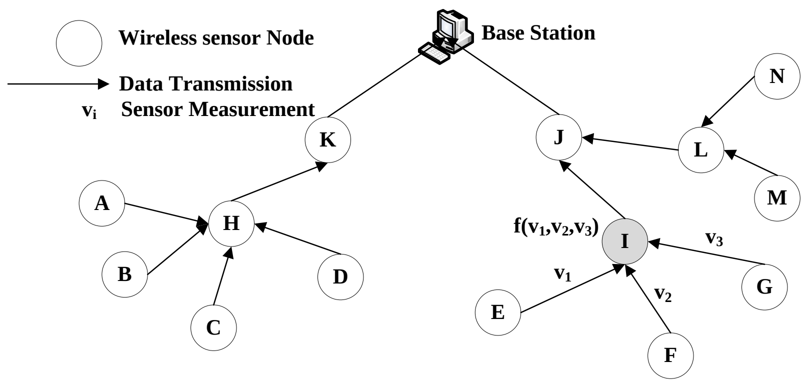


Figure 2. Data Interaction Between Peer Nodes of Zigbee Maritime Unmanned Ship Collision Dynamic Detection

The data interaction of non-peer nodes in the ZigBee-based collision dynamic detection communication system for unmanned marine vessels is shown in Figure 3. In Figure 3, the clustering method is used to mine the congestion information of unmanned ships at sea in wireless sensor networks. In VANETs, similar/close data can be combined by clustering (for example, data with the same characteristics or describing the same phenomenon can be obtained by different sensors) (Yang *et al*., 2019; Yang *et al*., 2022). The current positioning methods of unmanned ships at sea mainly use GPS positioning and wireless network technology to realize automatic collision detection and early warning.

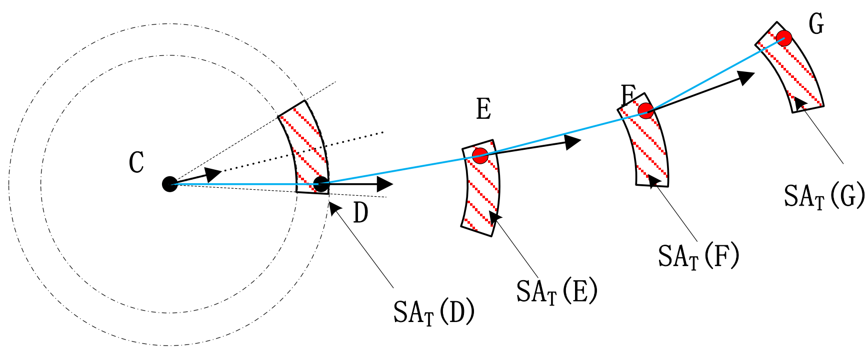


Figure 3. Data Interaction of Collision Dynamic Detection Nodes of Offshore Unmanned Ship Based on Zigbee

As can be seen from Figure 3, under the non-peer model, the nodes in each divided network of ZigBee-based maritime unmanned ship collision dynamic detection communication system can transmit data with any node in other sub-networks (Lai *et al*., 2022).

Based on the above ZigBee networking segmentation, ZigBee under the system networking is segmented into subnets, thus improving the data processing capability of each subnet. In this paper, wireless sensor network communication and RFID tag identification are used to build the ZigBee communication networking system model between unmanned ships at sea. The average value of the weight of the double random probability distribution function represents the weight of the double random probability distribution function, and the weight distribution mark $w(s_i k_j)$is added:

$$w(s_i k_j) = \frac{freq(s_i k_j) + 0.5N_{begin} + 0.5N_{end} + N_{title}}{\sum freq(s_i k_j)} \tag{1}$$

Where: $freq(s_i k_j)$ is the weight distribution characteristic of the double random probability distribution function; N_{title} is the number of eigenvalues distributed in the frequency domain of the double random probability distribution function, N_{begin} and N_{end} are the initial and final features of the dual random probability distribution function in the frequency domain, respectively. Select the feature items with larger weights of the double random probability distribution function to form a set to describe the events to which the double random probability distribution function belongs, namely:

$$e_x = \bigcup S'$$
$$E = \bigcup e_x = \{ek_1, ek_2, \cdots, ek_n\} \tag{2}$$

Wherein, Among them, e_x is the characteristic term of the distribution function, and k_n is the corresponding description coefficient of the distribution function n,$\bigcup S'$ is the event set to which the double random probability distribution function belongs; E is output for the desired result; RFID addressing method is used when the unmanned ship at sea is still sailing along a straight line, considering the topological structure of the route and the relative relationship between the speed of the unmanned ship at sea, the unmanned ship at sea A will become the cluster head and the unmanned ship at sea B-F will become the cluster member. Then, by using GPS positioning and wireless network technology, the information stored in the tag can be read by the unmanned marine vessel equipped with an RFID reader. Then, the unmanned marine vessel positioning system determines the current position of the unmanned marine vessel according to the tag code or the absolute coordinates of the earth combined with GIS and electronic map and realizes the collision dynamic detection of the unmanned marine vessel based on accurate positioning (Zhou *et al*., 2021; Zhou *et al*., 2021).

3. PARAMETER ESTIMATION ALGORITHM AND ZIGBEE-BASED COLLISION DYNAMIC DETECTION SYSTEM FOR OFFSHORE UNMANNED SHIPS ARE KEY TECHNOLOGIES

On the basis of the overall construction of the above system model, ZigBee technology is used to communicate between unmanned ships at sea to exchange the estimation of the speed and distance of unmanned ships at sea in real-time so as to realize the real-time interaction of information, which can more accurately warn the collision of unmanned ships at sea and realize the congestion prediction (Zhang *et al*., 2020).

After the above-mentioned dynamic parameter signals of unmanned ship collision are obtained by RFID technology, the dynamic parameter signals of unmanned ship collision at sea should be clustered and analyzed, and the interference factors among them should be filtered to obtain valuable characteristic information of dynamic parameters of unmanned ship collision at sea, which will provide a reliable basis for subsequent identification of dynamic parameters of unmanned ship collision and dynamic detection system of unmanned ship collision prevention at sea. Collision dynamic detection of unmanned ship queues at sea mostly adopts ZigBee communication design and parameter data estimation and positioning method. The signal transmitter is installed on the unmanned ship at sea. Based on satellite receiving and sending signals, the unmanned ship queue at sea generates differential adjacent interference in the process of dynamic shift. During the monitoring of unmanned ship queue at sea, satellite positioning signals is greatly affected by the dynamic differential update of position data of unmanned ship queue at sea. The uniform rectangular array is established by the DOA estimation method of uniform beam forming, which describes the dynamic change process of unmanned ships at sea. Unmanned ships at sea are distributed in a uniform rectangular grid as array elements, and the boundary of the array is rectangle. The array element spacing d_x in the axial direction is:

$$d_x = d_y = \frac{\lambda}{2} \tag{3}$$

In equation (3), d_y represents the longitudinal spacing of the array elements; λ is an estimated parameter related to the shape of an unmanned vessel. Considering observation vector of unmanned ship queue at sea:

$$z(t) = \sum_{i=1}^{p} \int_{-\pi}^{\pi} a(\theta)\, s_i(\theta, \psi_i; t) d\theta + n(t) \tag{4}$$

Where,ψ_i represents the speed of queue i, t represents the observation time, and $z(t)$ represents the observation vector at the corresponding time,θ is the azimuth angle, the ZigBee positioning signal received during the operation of the unmanned ship at sea, and $n(t)$ is the interference source, $a(\theta)$ represents the popular vector of the queue array of the unmanned ship at sea. Its expression is:

$$a(\theta) = [1, e^{-j\pi \sin\theta}, e^{-j2\pi \sin\theta}, \ldots e^{-j(M-1)\pi \sin\theta}]^T \tag{5}$$

In equation (5), T and $T,$ respectively, represent the total observation time and the total number of queues. For each array element, it contains the target distribution information and expansion angle of the signals transmitted by the ZigBee satellite on the sea unmanned ship. The DOA estimation of the signals received by the ZigBee satellite positioning on the sea unmanned ship realizes the distributed target information modeling of the queue of the unmanned ship on the sea. At this time, the ZigBee satellite signals obtained at the receiving end of the central control platform are the point source echoes, and the frequency spectrum is superimposed at a plurality of spatially close points. At this time, the whole unmanned fleet at sea is a distributed target with uniform rectangular array distribution, and the direction of arrival of the uniform rectangular array popular vector of the unmanned fleet at sea is the azimuth corresponding to the central angle of arrival. According to the angle change, the azimuth and velocity information of the unmanned fleet at sea can be obtained, and the dynamic detection of collision can be realized.

The above-mentioned array signal model includes dynamic differential adjacent interference caused by the dynamic shift of the unmanned ship queue at sea. ZigBee positioning signal is greatly affected by the dynamic differential update of the position data of the unmanned ship queue at sea in the process of monitoring the unmanned ship queue at sea, so it is difficult to estimate the position of the unmanned ship queue at sea. Therefore, some interference suppression methods are needed to improve the performance of parameter estimation. In this paper, the separable outlier weighted interference suppression method is proposed for signal preprocessing, and the minimum variance response invariance algorithm (MVDR) is used to construct the popular vector beamforming map of the ZigBee satellite positioning array of unmanned ship queue at sea. According to separable outlier weighted, the popular vector of ZigBee array signal output corresponding to M linear arrays satisfies:

$$b_i(\theta_i) = \Phi(\theta_i)h_i \tag{6}$$

In equation (6), $\Phi(\theta_i)$ and $b_i(\theta_i)$ are the vectorized mapping functions and popular vector mapping functions for direction angle θ_i, respectively, and h_i is the height of the array. The angular signal distribution function of the ZigBee signal source is a conjugate symmetric function, and the minimum variance of uniform rectangular array of ZigBee information of unmanned ship queue at sea is a non-negative conjugate symmetric matrix of matrix $Q_1(\theta)$. The DOA signal estimation of unmanned ship queue at sea has evolved into solving the minimum variance response function problem. According to the principle of minimum variance response invariance, the spectral peak position of distributed unmanned ship queue at sea$f_1(\theta)$ is obtained as follows:

$$f_1(\theta) = -\log 1\,0(\lambda[Q_1(\theta)]_{min}()) \tag{7}$$

In the above formula, Q_1 represents the direction vector of the direction $\theta_{ik}$of arrival. By calculating the emission echo intensity of the offshore unmanned ship-borne satellite array signal, the minimum variance response$f(\phi)$ invariance algorithm (MVDR) is adopted to obtain the beamforming output of two linear arrays, which is described by the formula:

$$f(\phi) = \frac{1}{b^H(\varphi)\widehat{U}_n\widehat{U}_n^H b(\varphi)} \tag{8}$$

In the above formula, $\widehat{U}_n$ and $\widehat{U}_n^H$ are conjugate symmetric functions of distribution functions, the parameter ϕ_i determines direction and ϕ_i is a vector with multiple parameters. Based on the beamforming algorithm, it provides the target angle information and other basis for the final range-velocity two-dimensional parameter estimation. Based on the above processing, the positioning and identification of the parameter information, such as the speed and azimuth of the unmanned ship at sea, can be realized, and the collision of unmanned ships at sea can be effectively prevented (Zhang *et al*., 2020; Zhang *et al*., 2022; Zong *et al*., 2022). In addition, the system can also judge the existence and navigation route information of unmanned ships around the sea when there are obstacles and send a traffic warning to the unmanned ships sailing around the sea by wireless communication at the navigation mark point to remind the navigation control system of unmanned ships. The specific flow chart of the system implementation is shown in Figure 4. On this basis, simulation experiments are carried out to verify the performance of the system.

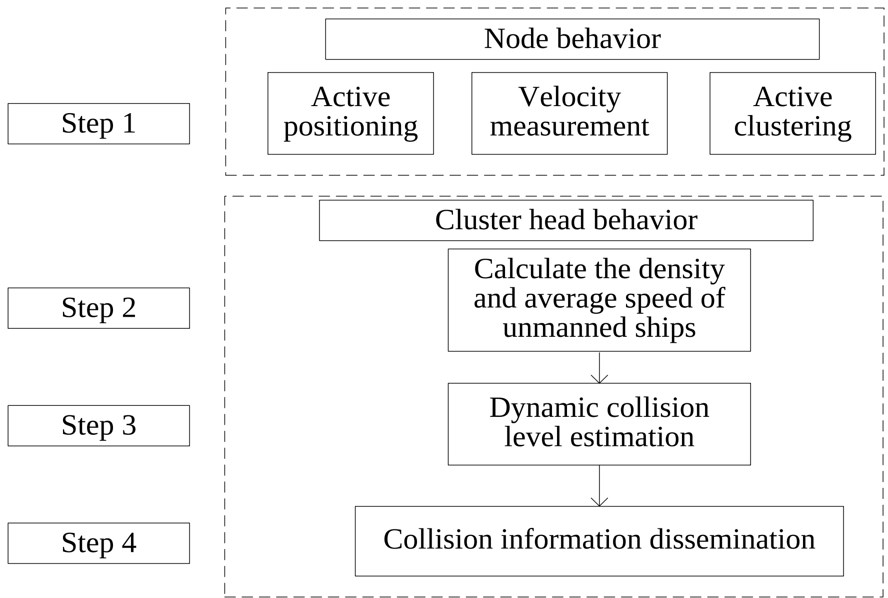


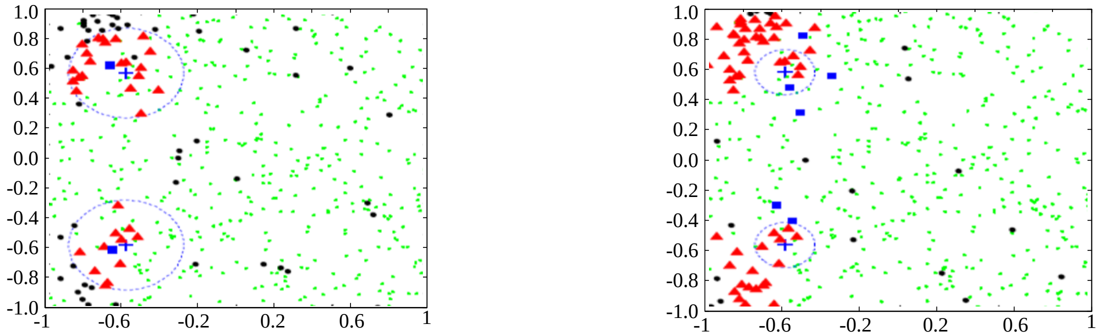
Figure 4. System Implementation Process

4. SYSTEM TESTS AND PERFORMANCE ANALYSIS

4.1 Experimental Design and Dynamic Monitoring Planning Results Analysis

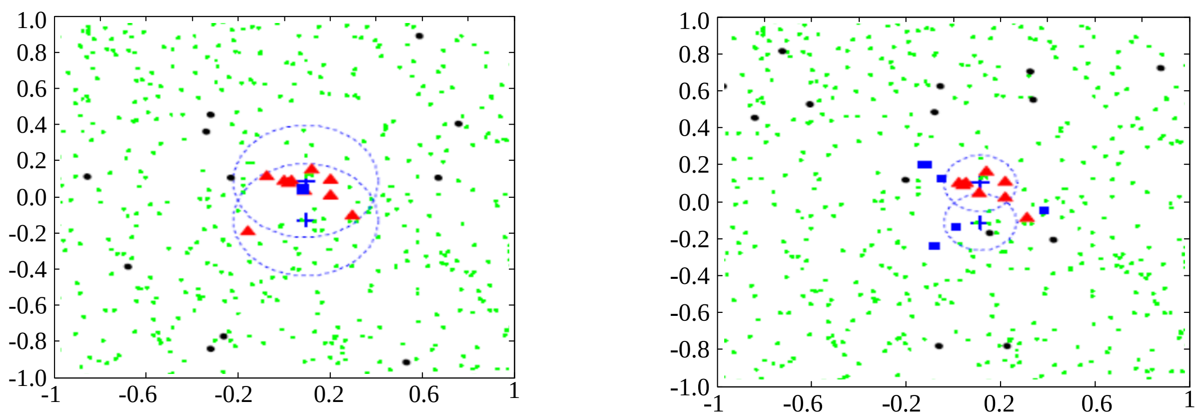
In order to verify the performance of the collision dynamic detection system designed in this paper based on ZigBee technology in realizing the collision dynamic detection and the information exchange of the speed and distance of the unmanned ship at sea, simulation experiments and system tests are carried out. The experimental environment is Intel Core I530, Windows XP system with 1g memory. Based on IEEE 802.15.4, the physical layer and media access control layer are established, and the ZigBee information interactive communication system of IEEE 802.15.4 is established. The number n of uniform rectangular array elements is 20, the azimuth coordinates of the information monitoring center of the offshore unmanned ship are (0,0, 0), and the change range of the azimuth angle is 0 - 90. In the wireless communication network, the wharf of the unmanned ship station on the sea is planned by undirected graph. The impedance of the road section is designed in the form of two-way unmanned ship lanes on the four seas, and the number of navigation mark nodes is divided into 170,265,270 and 320. Firstly, based on the uniform rectangular array, a queue signal model of unmanned ships at sea is constructed. Considering the changing course of unmanned ships at sea, the density of unmanned ships at sea in all unmanned ship lanes is statistically averaged to obtain the density of unmanned ships at sea in the cluster, and the dynamic detection results of unmanned ship distribution scene at sea are shown in Figure 5. In Figures 5 and 6, the blue square represents the detection object, the red triangle represents an unmanned ship that may have a collision risk, the black dot represents a fixed obstacle, the green dot represents other movable obstacles, the blue dashed line delineates the collision detection warning area of the currently selected object, and the blue cross line represents the circle of the collision detection warning area of the currently selected object.

Combined with the model in Figure 5, based on the ZigBee communication protocol of IEEE 802.15.4, the algorithm in this paper is adopted to realize the estimation of parameters such as speed and azimuth of the unmanned ship queue at sea and the square collision detection, and the planning result of unmanned ship at sea based on the collision dynamic detection output designed in this paper is shown in Figure 6.



(a) Scenario 1 (b) Scenario 2

Figure 5. Dynamic Detection Results of Unmanned Ship Distribution Scene at Sea



(a) Scenario 1 (b) Scenario 2

Figure 6. Output of Collision Detection Plan for Unmanned Ship at Sea

4.2 Performance Analysis of The collision Detection Model

According to the results of the analysis of Figure 6, the design of dynamic collision detection model unmanned sailing ship trajectory planning sea effectively improves the ability of maritime unmanned ship route planning, using ZigBee technology exchange of real-time communication between maritime unmanned ship offshore unmanned ship speed, distance and other information, parameter estimation results are obtained as shown in Figure 7.

From the analysis of Figure 7, it is known that the method in this paper can be used for dynamic detection of collision so that the parameter estimation ability of anti-collision of unmanned ships is better, and the navigation information of unmanned ships at sea can be grasped more timely so that the collision of unmanned ships at sea can be warned more accurately. In addition, under the condition of obstruction, the system can also judge the existence and navigation route information of the surrounding unmanned marine vessels and send a traffic warning to the surrounding unmanned marine vessels based on wireless communication at the navigation mark point to remind the navigation control system of the unmanned marine vessels.

To compare the algorithm′ s performance, under the analysis in this paper, the algorithm and the traditional method of collision dynamic testing accurate recognition rate, design two traffic scenes, the sampling time interval between different scenarios, scene one of 4 * 4, scene 2. 8 * 8, verification algorithm of recognition rate, the higher recognition rate, indicates that the better recognition effect of the algorithm, experimental results as shown in Figure 8.

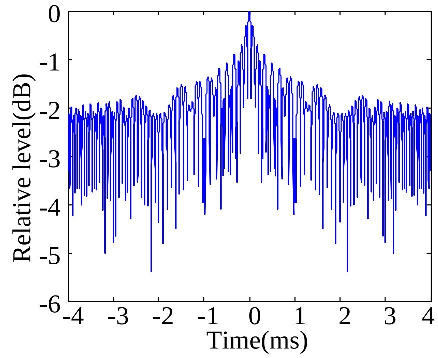
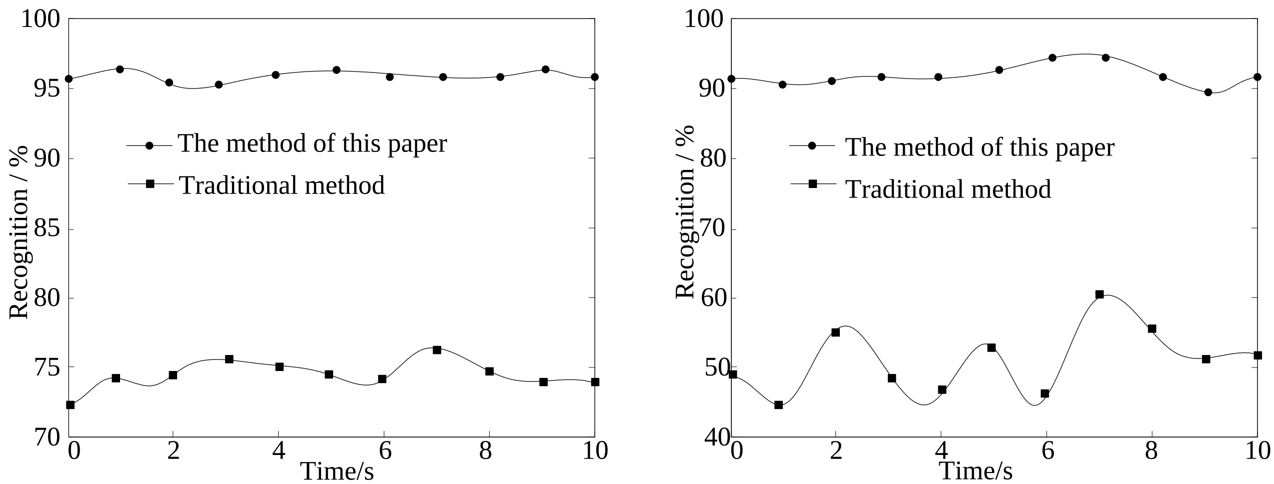


Figure 7. Estimation Results of Anti-Collision Parameters



(a) Scenario 1 (b) Scenario 2

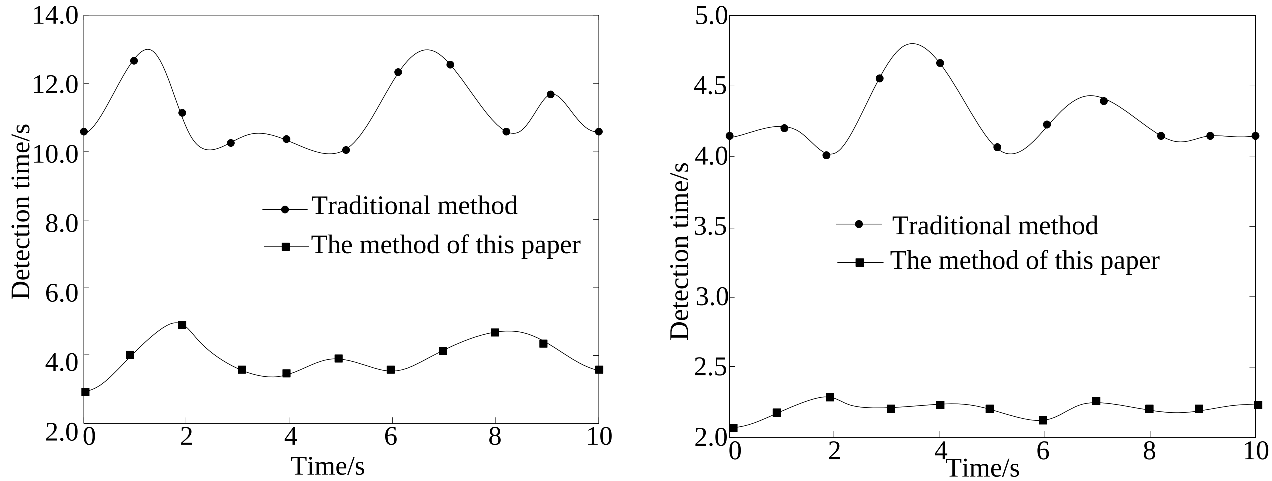
Figure 8. Comparative Analysis of Recognition Rates of Different Algorithms

As shown in Figure 8, it can be seen that in Scenario 1, the average recognition rates of the designed monitoring algorithm and the traditional monitoring algorithm are 95.4% and 74.1%, respectively. The former always has a higher recognition rate than the latter, and the fluctuation amplitude is also significantly lower than the latter. In Scenario 2, there is also a conclusion that is consistent with Scenario 1. That is, the average recognition rate of the monitoring algorithm designed in this design is 92.7%. Always higher than traditional monitoring models, and the fluctuation range of the recognition rate is significantly smaller, with higher stability.

The algorithm of collision dynamic detection for further analysis in this paper, the detection of recognition effect, performance indicators of detection for the experiment, the performance index can effectively reflect the detection method of detection efficiency, index is lower, the detection method of detection efficiency is higher, the unmanned ship provides information more quickly, make the unmanned ship faster to react. The algorithm in this paper and the traditional algorithm are still used for comparative analysis in the experiment, and two experimental scenes are set as the above experiment. The specific experimental results are shown in Figure 9.

As shown in Figure 9, it can be seen that as the experiment began, the detection time of the two monitoring models remained roughly stable around a certain value, but the detection time of the design method in this study was significantly lower than that of traditional methods. Specifically, in Scenario 1, the average detection time of the designed method and the traditional method is 3.8 seconds and 11.3 seconds, respectively. In Scenario 2, the average detection time of the designed method and the traditional method is 2.2s and 4.3s, respectively. In both scenarios, the standard deviation of the detection time for the method designed in this study is significantly lower than that of traditional methods, indicating that the method designed in this study has faster exploration speed and good stability.

Finally, analyze the reader and tag signal receiving sensitivity of the algorithm proposed in this study on two commonly used ship collision detection SOA systems (hereinafter referred to as SOA1 and SOA2) in China. The sensitivity is calculated according to Formula (9).



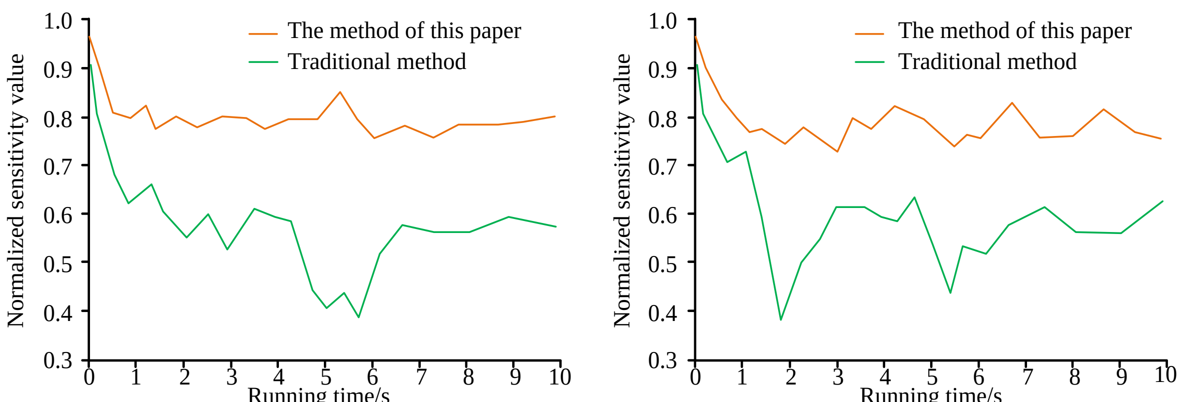
(a) Scenario (b) Scenario

Figure 9. Comparison of Detection Time of Collision Dynamic Detection of Unmanned Ship

$$P_r = \left(\frac{S}{N}\right) \cdot K \cdot T \cdot B_N \cdot F_N \tag{9}$$

From the analysis of Figure 7, it is known that the method in this paper can be used for dynamic detection of collision so that the parameter estimation ability of anti-collision of unmanned ships is better, and the navigation information of unmanned ships at sea can be grasped more timely so that the collision of unmanned ships at sea can be warned more accurately. In addition, under the condition of obstruction, the system can also judge the existence and navigation route information of the surrounding unmanned marine vessels and send a traffic warning to the surrounding unmanned marine vessels based on wireless communication at the navigation mark point to remind the navigation control system of the unmanned marine vessels.

To compare the algorithm′ s performance, under the analysis in this paper, the algorithm and the traditional method of collision dynamic testing accurate recognition rate, design two traffic scenes, the sampling time interval between different scenarios, scene one of 4 * 4, scene 2. 8 * 8, verification algorithm of recognition rate, the higher recognition rate, indicates that the better recognition effect of the algorithm, experimental results as shown in Figure 8.



(a)SOA1 (b)SOA2

Figure 10. Reader Receiving Sensitivity of Collision Detection Algorithms on Two SOA Platforms

According to the analysis in Figure 10, after the system just started to run, the normalized sensitivity value of the reader signal of the algorithm designed in this study and the traditional algorithm on the SOA1 and SOA2 platforms decreased rapidly from a higher position and then stabilized around a certain value. Overall, the reader signal sensitivity of the unmanned ship collision detection detection method designed in this study on the soa1 and soa2 platforms is higher than the traditional collision detection algorithm. The analysis is carried out from the perspective of tag signal reception sensitivity, as shown in Figure 11.

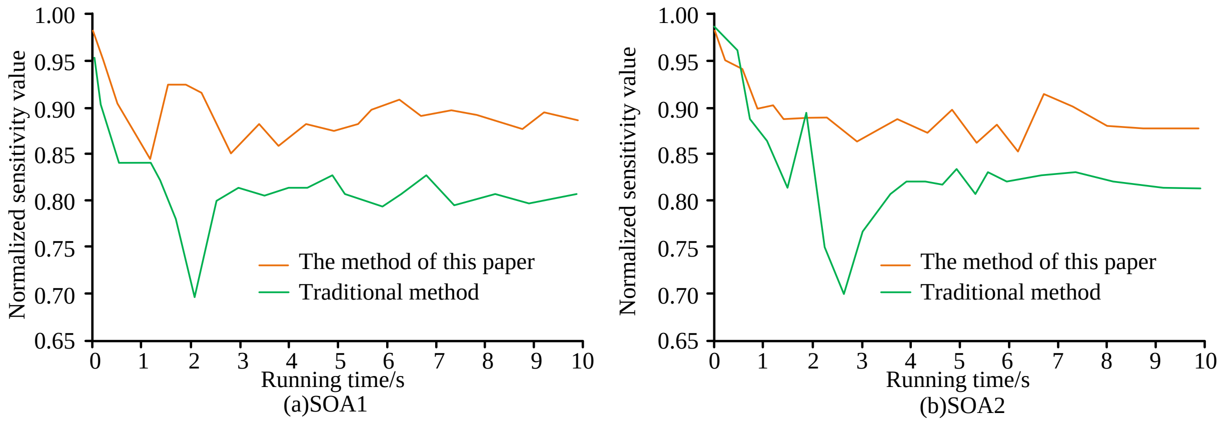


Figure 11. Label Signal Receiving Sensitivity of Collision Detection Algorithms on Two Soa Platforms

It can be seen from Fig. 11 that the tag signal reception sensitivity of the unmanned ship collision detection detection method designed in this study on soa1 and soa2 platforms is higher than the traditional collision detection algorithm as a whole. Only in a few running moments of the SOA2 platform the receiving sensitivity of the tag signal of the traditional algorithm is slightly higher than the collision detection algorithm designed in this study. For example, when the system runs to the 5th second, in the SOA1 and SOA2 platforms, the normalized sensitivity values of the signal labels of the algorithm designed in this study are 0.87 and 0.88, while the corresponding values of the traditional algorithms are 0.81 and 0.83. This is because the collision avoidance algorithm identifier designed in this paper collects the dynamic parameters of the unmanned ship collision, and after the clustering processing of the K-means clustering algorithm, it reduces the negative impact of noise on the subsequent data recognition so that the subsequent data processing system is more sensitive to changes in the input signal.

5. CONCLUSIONS

This article proposes a dynamic collision detection method for unmanned ships based on ZigBee network wireless communication. The simulation experiment results are as follows. In scenario one, the overall recognition rate curve of the collision dynamic monitoring algorithm in this paper is above 95.0%, with the highest collision dynamic monitoring recognition rate reaching 96.7%. The recognition rate curve fluctuates slightly and shows a stable state. The overall recognition rate curve of traditional collision dynamic monitoring algorithms is below 80.0%, with a maximum recognition rate of only 77.5%. In Scenario 2, the recognition rate of the algorithm designed in this study has decreased to a certain extent, but the overall recognition rate curve is still above 90.0%, significantly higher than traditional recognition methods. From the perspective of detection time, in scenarios one and two, the detection time of the method designed in this study is 4.0 seconds and more than 2.5 seconds lower than traditional methods, respectively. From the above data, it can be seen that the ZigBee-based collision dynamic detection method has high practical application value. It can effectively provide reference data for unmanned ships and improve their safety. However, due to the limited energy of the researchers, they did not make physical objects based on the system proposed in this study and installed them on unmanned ships for testing, which is also the future research direction.

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