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Identification method of suspicious targets in submarine cable boundary based on multi-source data fusion

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Identification method of suspicious targets in submarine cable boundary based on multi-source data fusion

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Abstract. This paper studies a new all-round visualized cable zone monitoring system and target identification method. Specifically,a mobile robot vision system based on distributed control was designed for improving the efficiency of video processing. Secondly,the saliency measure based on background priors was used for image preprocessing and excluded the background regions which were less important. Finally,the recognition accuracy of the target was improved accord- ing to the dynamic template matching to images which had been processed. The experimental results show that the method can meet the requirements of real-time and veracity in the process of mobile robot's target recognition,the method show good effectiveness.

1. Introduction

The research of this project is mainly aimed at realizing the comprehensive monitoring of the submarine cable in the submarine cable laying area of the South Japan Line. The submarine cable channel area of the South-Japan line serves as an important navigation channel. Ship anchoring and towing anchors are frequent, and there are high-quality sand mines in the sea area, which leads to serious illegal sand mining. All of the above will cause serious damage to the safe and stable.

In view of the current status of submarine cable operation and maintenance, the construction goal of this project is to establish a set of control and control platform for effective monitoring and early warning of ships in the submarine cable protection area, to realize the application of advanced technical means to monitor the navigation of passing ships, to identify suspicious ships in time and to report the drive away as well as to protect the safety of the submarine cable.

The project system is mainly divided into monitoring subsystem, information processing subsystem and user application subsystem. The monitoring subsystem consists of AIS receiver, maritime radar and monitoring software. Data acquisition of ship information is mainly carried out through AIS information receiver and maritime radar [1].

The information processing subsystem needs to process the information. First, it is determined by the zone detection algorithm whether the ship is in the forbidden anchorage zone. The second is to predict the movement trend of the ship through a certain algorithm. Once the ship enters the forbidden area and has a tendency to break down, the system can issue a warning to the corresponding ship by automatically triggering the alarm module function. The user application subsystem is the user interface of the system. Through this subsystem, the user is provided with a visual and convenient

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2. Overall design of the monitoring system

The monitoring system obtains the navigation information of the ship in a specific sea area by means of radar, AIS, etc., and judges whether the ship has a tendency to break down through the background software analysis and algorithm, and automatically issues a warning through the VHF station to drive away the relevant ship. A multi-layer design approach is adopted in the architecture.

2.1 Communication layer

Responsible for the underlying communication, including radar, AIS data parsing and packaging, and dynamic data storage. This layer contains the core content of radar and AIS communications, including the implementation of communication protocols[2-3].

2.2 Data layer

The data layer provides non-dynamic data for the system, mainly database data and chart data. The database stores the received and transmitted communication data, including radar target echoes, AIS ship information, and so on. This information can be used for subsequent track playback as well as historical data query services[4].

2.3 Business logic layer

Mainly provide various functional support for the application layer, including GIS engine module, communication module, algorithm analysis and data access module.

2.4 Application layer

Provide users with specific business functions. This system includes the following functions:

Electronic chart: Provide electronic chart service.

Track playback: Show historical tracks on charts.

Radar AIS: Displays ship information acquired by radar and AIS, as well as programmatic control of radar and AIS.

VHF: Use VHF to communicate with ships.

Basic data management: Manage basic data.

System Management: Manage system parameters.

3. Data fusion of AIS and radar

3.1 Radar and AIS

A radar is an electronic device that uses electromagnetic waves to detect a target. Radar tracking technology uses the radar to emit electromagnetic waves to illuminate the target and receive its echoes, thereby obtaining information such as the distance, velocity, azimuth and altitude of the target radar position[4-5].As a new type of ship navigation aid system, Automatic Identification System (AIS) has the basic ability to automatically exchange ship information and ship identification between ships. The field of device installation is shown in Figure 1:

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Figure 1. The field of device installation

3.2 Radar and AIS data characteristics

In terms of the way information is acquired, radar is an active sensor that acquires the target position and its motion parameters by emitting electromagnetic energy and receiving secondary scattered echoes. Therefore, the radar can obtain a panoramic traffic image of the water, in addition to all moving targets, there are still and fixed targets, as well as other environmental information [6-7]. In addition, the radar target echo can reflect the size and shape of the target to some extent. The AIS detection of the target is involuntary, it can only receive ship information with the AIS system. AIS information includes the ship's ship name, call sign, MMSI, length, GPS position, loaded cargo and other static information, location, heading, speed, destination port, distance from the main channel and other dynamic information as well as ports, weather, ocean currents, etc. Navigation information.

3.3 Radar and AIS data fusion basic steps

Radar and AIS data fusion requires two major steps: track correlation and data fusion [8]. Track correlation can be divided into two parts: data calibration and data correlation.

3.3.1 Data calibration. Radar is related to AIS track

The processing object is the target location data provided by the two sensors. From the theory of data fusion, data fusion must consider temporality and spatiality. When the radar and AIS acquire the target position data, the sampling moments are not necessarily the same; and the description of the target position is different; the radar is expressed as distance and inclination, and AIS is expressed as longitude and latitude[9-10]. Therefore, the data should be calibrated before the target track correlation between the two is performed. The purpose of data calibration is to unify the time and space reference points of the radar and AIS, and to perform time shifting and coordinate transformation to form a uniform reference point for time and space.

3.3.2 Data association

The role of the association is to determine whether the radar and AIS target data are from the same target. In view of the ambiguity of the data target association between radar and AIS, a clustering method can be used.

The fusion of radar and AIS target data is mainly to fuse the track-related data according to an appropriate algorithm, and to fuse the information from different sensors to represent the same target, and obtain more accurate track data.

The fusion architecture of AIS and radar data is shown in Figure 2.

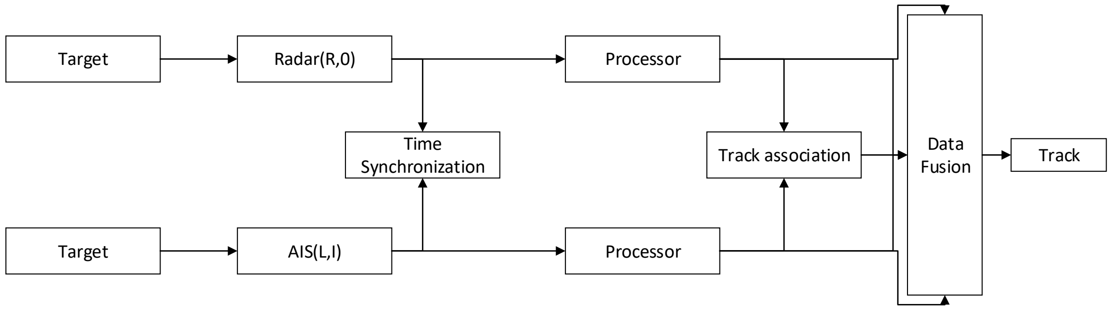

Figure 2. Data fusion architecture diagram

4. Radar and AIS target track related processing method

In this paper, the target track obtained by one radar and one AIS is merged, mainly to process the position data of the target. Among the acquired target data, multi-target radar data and multi-target AIS data are usually included. The target of each AIS data is determined by itself, because the target information transmitted by the AIS contains the static and dynamic information of the ship. The relevant processing to be done is to find one of the many radar targets corresponding to the determined AIS target track. To determine the track correlation, it is necessary to coordinate the information of two sensors, time synchronization (time calibration), and then make track correlation judgment [11].

4.1 coordinate transformation

The target location data provided by the AIS is actually obtained by the GPS receiver. The WGS-84 coordinate system is the coordinate system currently used by GPS. There are two methods for converting it to Cartesian coordinates [12].

4.1.1 Gauss-Krüger projection

It is a horizontal axis isometric cut elliptical cylinder projection. It cuts an elliptical cylinder on the ellipsoid of the earth. The tangential line of the elliptical cylinder and the surface of the ellipsoid is a warp, and then projects the points in the specified range on both sides of the central meridian to the elliptical cylinder according to certain constraints. Up, thereby getting a Gaussian projection of the point.

4.1.2 Approximate calculation

The calculation formula is as follows:

$$x_a = (L_a - L_0)cosB_a \tag{1-1}$$

$$y_a = B_a - B_0 \tag{1-2}$$

Among them, the first point represents the geographic coordinates of the ship, and the second point represents the geographic coordinates of the AIS target position data.

4.1.3 Coordinate transformation of radar target position data

The radar target position is expressed in polar coordinates, expressed as the spacing R and the azimuth θ. The calculation formula for transforming it into a Cartesian coordinate system is:

$$x_r = Rsin\theta \tag{2-1}$$

$$y_r = Rcos\theta \tag{2-2}$$

4.2 Time alignment

The scanning period of the radar is 15r/min-30r/min, which is relatively fixed. In the automatic mode, the dynamic information interval of the AIS broadcast is different in different states of the ship, so it is necessary to time align the target information of the radar and the AIS.

Here we use the nearest neighbor rule heuristics:

Assume that the sampling moments of AIS and radar in a time period are as follows:

AIS sampling time sequence:

$$T_A = t_{A1}, t_{A2} \dots \dots , t_{Af} \tag{3}$$

Radar sampling time sequence:

$$T_R = t_{R1}, t_{R2}, \dots \dots , t_{Rt} \tag{4}$$

During this time period, the sequence of sampling moments of the AIS and the radar are grouped into one set. According to this set, the nearest neighbor rule heuristic is used for time alignment, that is, a uniform sampling time sequence is determined.

4.3 Track related

Track correlation refers to the similarity of the two tracks obtained by the sensor system. The system uses the normal membership function method in fuzzy mathematics to perform fusion calculation. When the two tracks are far apart, the Euclidean distance is larger and the membership function value is smaller [13-14].

The steps of the fusion algorithm are as follows:

Establish a fuzzy factor set. The factors affecting the track are the ship position, speed and heading, so the set of fuzzy factors is a three-factor set.

Determine the weight of the fuzzy factor set.

Calculate the Euclidean distance of the fuzzy factor.

Calculate the membership function value of each fuzzy factor.

Calculate the comprehensive similarity.

Establish a fuzzy correlation matrix for the track from the node of the AIS and the track from the radar node.

Finally, the target location data fusion is performed.

5. Kalman filter prediction trajectory

Each figure should have a brief caption describing it and, if necessary, a key to interpret the various lines and symbols on the figure.

5.1 Kalman filter algorithm system state equation

$$X(k) = \emptyset(k, k-1)X(k-1) + T(k, k-1)U(k-1) + W(k-1) \tag{5}$$

Where: $X(k)$ is an n-dimensional state vector, reflecting the state of the system at time $\emptyset(k, k-1)$ is the n × n-dimensional state transition matrix of the system, describing the state transition from the $(k-1)$ state The parameter matrix to the state at time k; $(k, k-1)$ is the n × m-dimensional input control term matrix; $U(k-1)$ is the control input vector at time $(k-1)$; $W(k-1)$ is the n-dimensional mean A zero-system process white noise sequence that describes the noise or error that shifts from one state to another [14].

5.2 Dynamic system measurement equation of Kalman filter algorithm

Dynamic system measurement equation:

$$Z(k) = H(k)X(k) + V(k) \tag{6}$$

Where: $Z(k)$ is the m-dimensional observation vector, which represents the state that the dynamic system is measured at time k ; $X(k)$ is the n-dimensional state vector, which reflects the state of the system at time k; $V(k)$ is The m-dimensional observed noise sequence is used to describe the noise or error of the dynamic system moving from one state to another; $H(k)$ is the m × n-dimensional observation matrix, and the observed noise $V(k)$ is the zero-mean white noise sequence.

5.3 Constructing Dynamic Equations for AIS Trajectory Modeling

Set in the geographic coordinate system, the ship's position latitude and longitude coordinates$(\varphi(k), \lambda(k))$; T is the time interval, $\omega_\varphi(k)$, $\omega_\lambda(k)$ is the mean value is zero.The two orthogonal components of the noise $W(k)$ are independent of each other, $\omega_\varphi(k)$ and $\omega_\lambda(k)$ are

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independent of each other, and $\theta(k)$ is the heading. According to the constant-direction navigation method, the coordinate equation of the positioning node k is as follows:

$$\varphi(k) = \varphi(k-1) + v(k-1)Tcos\big(\theta(k-1)\big) + \omega_{\varphi}(k-1) \tag{7}$$

Get the system state equation:

$$X(k) = \emptyset(k, k-1)X(k-1) + T(k, k-1)U(k-1) + W(k-1) \tag{8}$$

Obtain the system measurement equation as：

$$Z(k) = H(k)X(k) + V(k) \tag{9}$$

5.4 ship trajectory estimation recursion process

Due to the characteristics of the dynamic equation of the ship, when calculating the dimension of the ship $(k-1)$ time, the latitude of the ship $(k-1)$ and k is required[15].

Therefore, according to the Kalman basic formula, the recursive process based on Kalman filter ship trajectory estimation is shown in Figure. 3.

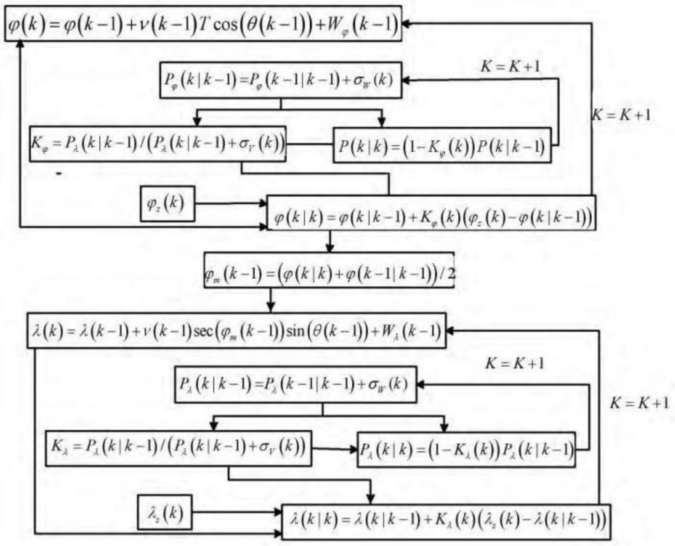

Figure 3. Schematic diagram of the trajectory estimation recursive process

6. Summary and expectations

The main function of the monitoring system studied in this paper is to identify, monitor and alert the ship entering the protection zone.

After testing, the system can monitor the ships entering the sea in a certain sea area, and can detect a part of suspicious warnings and drive to achieve the purpose of protecting the submarine cable.

The current shortcoming of the system is that it is impossible to detect all suspicious vessels. On the one hand, the real-time nature of detection needs to be improved. In the future work, I hope to improve the corresponding algorithm.

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