Intelligent Video Surveillance System Guided by RADAR and AIS Data

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ABSTRACT: In order to solve the problems of traditional video monitoring system that only can monitor a certain fixed area, the matching degree of monitored whole or associated surveillance field is not high, an intelligent video monitoring method which using navigation radar automatic tracking parameters and AIS dynamic data was proposed. The system using tracking parameters output messages of NMEA0183 radar or the output data package of AIS, to obtain the target’s motion elements by analyzing the messages to guide the station and network video station by solving the data allopamy to observe the cloud platform, and open the functions of returning Surveillance video, returning the data of AHRS’s azimuth and elevation, boundary violation alarm et al at the same time. Paper introduced the system’s design process and composition of hardware and software, and the simulation results were given.

KEYWORDS: RADAR tracking; AIS; AHRS; Serials and network; Video surveillance.

1 GENERAL INSTRUCTIONS

A marine radar, consistent with the performance standards in IMO MSC 192.79 resolution (2007 edition), has all kinds of intelligent output functions of basic navigational sensor data acquisition, fusion and target tracking and result calculation. It plays an important role in the aspects of industrial production, maritime management, maritime rights and interests protection etc [1] [2] [3]. Video monitoring system has intuitive, convenient, and informative characteristics, which has become widespread in its applications [4]. In recent years, the advantages of the full digital video monitoring system of water traffic and system networking have become more and more obvious, and with the rapid development of computer image processing technology, network communication technology, the demand for video monitoring system is rapidly growing. But the current video surveillance system monitoring screen exists blind area, and the coverage of monitoring is not high, and the continuous tracking of key monitoring objects cannot be maintained automatically. Thus, it can not play a greater role in monitoring. The intelligent video surveillance system with the guidance of third party control parameters and using MCU and sensor technology as the core featured with its high mutual verification, integration and flexibility make the video frame more controllable, which is the development trend of video monitoring system [5].

The existing wired or wireless control can realize remote azimuth and elevation control, focusing and aperture control [5], high-quality video return and other functions. It provides great study opportunities for achieving the peripheral equipment guidance and the realization of three-dimensional intelligent monitoring. Focusing on this problem, design a kind of combination control system, using the ship navigation radar TT (automatic tracking) results or AIS (Automatic Identification System) target parameters to guide the camera, so that the screen can be switched in real time according to the target bearing, meanwhile initiating surveillance video return, visual recognition, alarm and a series of actions [6].

2 MARINE RADAR TT (TARGET TRACKING) AND OUTPUT AIS

2.1 Marine radar TT (Target Tracking)

Target tracking by navigational radar is based on radar digital video quantization, digitalized compass course, digitalized speed, followed by window capturing, simplified Calman filter tracking, target motion parameters calculation, collision risk analysis and alarm, ship’s trial etc to realize
corresponding functions. First of all, the whole radar video is stored in the mass memory composed of distance (S), range (B) and signal intensity (intensity) these three parameters’ quantized image data. In a circle of antenna scanning, the most simple access scheme is expressed as: whether each quantization unit (pixel) has signal or not, with signal outputting "1", no signal outputting "0". Certainly, the result of such quantization is $\alpha \theta$ type. For the purpose of realizing flat square display $x - y$, mathematical coordinate conversion of the video matrix is needed.

According to the 8th marine radar interface requirements of version 2007 of performance standards EPFS, electronic positioning system interface shall be provided. i.e., assuming the ship’s position is known, and according to the navigational phase conversion method:

$$D\phi = S \cos TB; \quad D\lambda = S \sin TB \sec \phi_x;$$

$$\phi_r = \phi_x + D\phi; \quad \lambda_r = \lambda_x + D\lambda;$$

(1)

The target location can be calculated, on the basis of that continuous tracking is being conducted at certain time-step intervals, target relative motion parameters of the vessel can be calculated and collision risk analysis can be concluded. In combination with the data of ship’s course and speed, the target’s true motion data can also be calculated.

2.2 AIS target tracking

AIS is a typical marine information system. Under the IEC61162-1 standard, the UART (multi serial asynchronous communication) is used for basic information collection such as those from the compass, log, EPFS course, speed and position. A message is generated by such information in combination with consolidated or input static information of the ownship (ship name, call sign, the position of the antenna, identification code, etc.) and safety navigation information. The message is further exchanged by VHF channel 87 and 88 to realize wireless data exchange in SOTDMA mode. And then, the dynamic and static information of the ownship and the target ship are mainly output by the AIS ship IEC61162 statement. Title, author and affiliation frame.

2.3 Radar tracking or AIS tracking information output

As an intelligent navigation instrument, navigation radar has a standardized serial input and output interface. The input interface receives information from the compass, log, electronic positioning system, while the output interface broadcasts the data information and target tracking information to other equipment’s radar system. There are kinds of statements which comply with the IEC61162-1 standard for radar digital broadcasting, among which the radar system information statement format is:

```
"$RARS, x.x,x.x,x.x,x.x, x.x,x.x,x.x, x.x,x.x,x.x,a,a*hh<CR><LF>"
```

(2)

Word block contains 2 sets of radar electronic bearing line (EBL), the Variable Range Marker (VRM) parameters and radar operating lever (CURSOR) position of the cursor.

The target tracking statement format is:

```
"$RATLL, xx, lll, lll, a, yyyy, yy, a, c-c, hhmmsss.ssa,a,a*hh<CR><LF>"
```

(3)

```
"$RATTM, xx, x.x, x.x, a, x.x, x.x, a, x.x, x.x, a, c-c, a, a, hhmmsss.ssa,a,a*hh<CR><LF>"
```

(4)

The first word "$RATLL" in sentence (3) means direct output of target’s latitude and longitude. Information content is separated by ".". The first word "$RATTM" in sentence (4) indicates the tracking result of the target. The information content is equally separated by ",". Taking sentence (4) as an example, the "$" indicates start sentences, and sentence blocks in turn are: target number, target distance, target bearing, true / relative target speed, target course, true / relative CPA and TCPA, speed unit, target name, target status, reference target and UTC.

Similarly, AIS serial output of the target ship data also satisfy the IEC61162 protocol, for example, a ship AIS output of the other ship’s static and dynamic data using statement "!AIVDM, l, 1,, A, 15Cga00008LOnt>ICf', S6NTOOSU, O*3D", the ship dynamic and static information can be obtained according to ITU-RM.1371-1 protocol analysis [6]. The data cover information types, repeated instructions, target ship identification code MMSI, navigational status, rate of turn, speed over the ground, position accuracy, longitude, latitude, course over ground, true course etc.

3 LAYOUT OF TEXT

3.1 System layout design

The system is supported by the provision of navigation radar and AIS parameters. Its main body includes: marine navigation radar and AIS, local master control computer, subordinate control machine, pan-and-tilt camera and AHRS (superposition of angular shift sensor is supplemental), remote control computer, remote control subordinate machine, remote control pan-and-tilt camera and AHRS navigation status reference system.
The function of all parts:

Marine Navigation Radar: through the TRACK CONTROL interface to provide parameter data, the position and motion parameters of radar tracking target, ownship position and motion parameters;

Marine AIS: through the pilot interface to provide the position and motion of ownship, position and motion parameters of targets;

Guide Station Master Control Computer: to realize passage of control instructions to control the lower position machine through guide data receiving module, parameters and control path selection module, guide parameter of rotor azimuth and pitching angle module, sequence control algorithm module calculation.

Control Lower Position Machine and Control 2-axis Servo Motor: to realize motion control of pan-and-tilt azimuth angle and pitching angle;

Pan-and-tilt Camera and AHRS: used for visual axis alignment under lower position control machine and providing visual axis azimuth angle and pitching angle feedback signal by AHRS;

Remote Control Computer: through local master control computers of the network and guidance station to realize video and parameters exchange, adding remote guiding algorithm in the guide parameters turn azimuth and pitching angle module, the others similar to local control.

3.2 The core system control programming design

3.2.1 Radar and AIS boot parameters acquisition and decoding under the agreement of IEC61162

Radar and AIS radar boot parameters are provided by "TRACK CTRL" and "AIS" port. Radar system parameters and target tracking parameters communication conforms to the IEC61162-1 standard. The plain code sentence starts with "$". AIS communication conforms to the IEC61162-2 standard, the secret sentence code (AIS) starts with"!". The target ship’s operations and dynamic and static data are mainly acquired from (! AIVDM, AIVDO!) statements. The received data is further analyzed and eventually the ship’s dynamic and static information can be calculated according to the relevant protocol [10]. Communication method RS-422, low bit rate 4800 BPS, 34800 BPS high rate, under C# development environment, the serial port was used to realize total control host computer to acquire radar or AIS guide data. The decoding process is shown in Figure 2.
3.2.2 **Boot parameters calculation and design of the remote communication based on UDP protocol**

Remote monitoring visual axis azimuth, elevation angle calculation and realization based on the network: radar guidance station computer measures target bearing, distance, course, speed etc. and movement parameters as well as guidance station geographical location data. Through UDP network protocol, network environment re-organization and broadcasting are achieved. Monitoring station terminal uses UDP network protocol to realize the terminal identity registration. After the IP endpoint and the port number match the main control system, the message data packet is obtained, and the network data is received. Through communication statement analysis, the target data is obtained. Then according to the monitoring station position, target bearing and distance are calculated by formula (5) in relation to monitoring station.

\[
S = \sqrt{D\phi^2 + D\lambda^2 \cos^2 \phi_M}
\]

\[
TB = \arctan \frac{D\lambda \cos \phi_M}{D\phi}
\]

\[\phi_M = (\phi_r + \phi_{Camera}) / 2, \quad \phi_N : + \lambda_E : +\]

Eventually, a command control angle is calculated. See Figure 3 for flow chart of remote mode based on UDP protocol.

\[
\text{TEXTBOX load network order msg}
\]

\[
\text{IPendPoint (_Broadcast _8888)}
\]

\[
\text{Assignment text to string parameters}
\]

\[
\text{Convert string to bytes}
\]

\[
\text{Uoc=new UdpClient()}
\]

\[
\text{Ucsend}
\]

Figure 2. Flow chart of radar of AIS parameters algorithm.

Figure 3. Flow chart of remote mode based on UDP protocol

3.2.3 **The design of lower end computer instruction system and control algorithm**

Locate tables close to the first reference to them in the text and number them consecutively. Avoid abbreviations in column headings. Indicate units in the line immediately below the heading. Explanations show the gesture of pan-and-tilt is constrained by \(\psi\) (bearing), \(\theta\) (height) and \(\gamma\) (roll), among which \(\gamma\) is controlled by damping gravity pendulum. Approximately deem \(\gamma \approx 0\). \(\psi'\) (bearing), \(\theta'\) (height) angular velocity is realized by a DC speed regulating motor which is controlled by PWM. PWM signal is output by pan-and-tilt controller centered by single chip machine. Through the motor drive module to control the azimuth and pitching motion of the pan-and-tilt motor, single chip pan-
and-tilt machine accepts control instruction from upper computer in a form of serial communication mode. The communication protocol is Pelco-D/Pelco-P pan-and-tilt control protocol. Taking PELCO-D protocol as an example, its data format is:

\[
\Delta = -u_k -u_{k-1} - u_{k-2} \]

\[
\beta = \sum_{j=0}^{k} e(j)T + k_d (e(k) - e(k-1))/T
\]

The system output is given below by using of incremental control method:

\[
\Delta u(k) = k_p [e(k) - e(k-1)] + K_d [e(k) - 2e(k-1) + e(k-2)]
\]

\[
u(k) = \Delta u(k) + u(k-1)
\]

Table 2-1. PELCO-D Protocol Format.

<table>
<thead>
<tr>
<th>Bit</th>
<th>Word1</th>
<th>Word2</th>
<th>Word3</th>
<th>Word4</th>
<th>Word5</th>
<th>Word6</th>
<th>Word7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use Synch</td>
<td>Byte Address</td>
<td>Command1</td>
<td>Command2</td>
<td>Switch</td>
<td>Focal Dis</td>
<td>Data1</td>
<td>Data2</td>
</tr>
<tr>
<td>Synch Word</td>
<td>Add.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bearing</td>
<td>Pitching</td>
</tr>
</tbody>
</table>

The advantages of incremental control algorithm are small error action and convenient to realize switch without disturbance. When a computer is malfunctional, the original value can be kept, and a good control result can be achieved by weighting. System angle position tracking is achieved by using incremental PID control. Considering the general pan-and-tilt such as PTS-303Q with maximum speed 10°/s; maximum pitching speed 1°/s; horizontal azimuth deviation up to 180°; pitching deviation up to 40°, thus in a larger deviations range, the pan-and-tilt azimuth and pitching speed command is given a maximum value. After debugging, the system design is within the range deviation of 30°, pitch angle deviation is less than 3°, run the PID control. Taking azimuth as an example, setting at time of t, the K sampling gives radar boot parameters \(\psi\); sampling AHRS feedback is \(\psi\); deviation input is \(e(k) = (\psi - \psi)/30\); PID output control is \(u(k)\), then pan-and-tilt control instruction decimal data is \(u(k) \times 64\); pan-and-tilt bearing speed command is the conversion of decimal to hex system [7].

3.2.4 Design of video acquisition

Design of video capture is based on cypress 68013 and NXP SAA7115 independent scheme which are designed for streaming USB video capture card. This card offers 2 AV and 1 S-VIDEO input, plugging and playing, supporting hot swap, easy to use and especially suitable for notebook computer. Its S-VEDIO port is connected to automatic zoom camera through BNC. The built-in filter can eliminate the noise and make the image clearer and more vivid, and it also support YUV2, RGB and other video streaming format. The system uses special SDK development kit and the VC# programming language to realize the development of video capture function and radar-guided, pan-tilt controlled comprehensive development through serial communication under PELCO-D protocol. Meanwhile, after the captured video was compressed using MPEG-4 compression standards, the bit streams are transmitted to a remote host via Ethernet interface remote host. The remote host calls for decoding program to decode the bit streams and interface remote host. The remote host calls for decoding program to decode the bit streams and have them displayed in the display terminal [8].
4 RADAR-GUIDED MONITORING OBJECT STRUCTURING AND PID CONTROL SIMULATION TEST RESULTS

The system uses MDC-1820 photoelectric marine navigation radar. Communication format is RS485. Radar data and target tracking data use the standard NMEA0183 navigation instrument. Serial input and output interface TRACK CONTROL and AIS transit serial output interface is shown in Figure 6. Use azimuth and pitch velocity adjustable control 0~64 level under the PTS-303Q numerical control pan-tilt PELCO-D protocol. The corresponding hexadecimal instruction is 00~3F. Led by radar or AIS boot parameters, it uses the PID control module control. The artificial zoom adjustment is realized in software operation interface. The range of azimuth deviation is more than 30°; range pitching deviation more than 3°. The azimuth and pitching velocity output is the maximum value 3F. The range of azimuth deviation is less than 30°; range pitching deviation less than 3°. Using critical point saturation method or the trial and error method, which the sampling period is 0.1s, PID control parameter tuning KP, KI, KD took 0.6, 0.02 and 1.7 respectively. The simulation results is shown in Figure 5. The system achieves stability within 3~4s, and the overshoot is less than 1.5% which is in the maximum deviation value. The system is almost no concussion after initial overshoot recover.

5 CONCLUSION

This paper introduced a dynamic video monitoring system based on the guidance of radar data, tracking data and AIS parameters. The system realizes bearing and distance positioning on the target by radar or AIS boot parameters. It uses radar station parameters to calculate remote boot parameters and drive the local and remote camera rotation to the target location for monitoring and alarm. The experimental results show that, in low noise and unobvious sensor feedback burr, the system can
accurately track and monitor the target. The three-dimensional monitoring means such a radar plane situation combined with video monitoring can more effectively assist the safety personnel to deal with the crisis, to maximize access to a full range of monitoring and chain of evidence.

6 AUTHOR INTRODUCTION

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