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Intelligent Vessel Dynamics Video Monitoring System based on AIS Data

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***Abstract*—Vessel dynamics video monitoring system is one of the most significant components in port safety and traffic management. This paper intends to discuss the key points in the design of the system: firstly, the data concerning vessel dynamics position are acquired via AIS; then intelligent video tracking system automatically drives intelligent spherical cameras to monitor vessels in port. Also system components of hardware and software and their working principles are introduced, a stress on the algorism of automatically monitored decision-making control module and its functions in system had been discussed.**

***Keywords*—AIS data, video tracking, dynamics monitoring, intelligent**

I. Introduction

Vessel Dynamics Video Monitoring System is often integrated into Vessel Traffic Services (VTS) for monitoring vessel in port area, and to make up for the deficiencies of radar system like its existence of blind area, susceptibility to electronic jamming[1] , lack of real image, etc. With the development of intelligent spherical monitoring technology, video monitoring system has been updated from hand control to intelligent control. Meanwhile, manless duty vessel dynamic video monitoring system is being vividly portrayed.

Vessel Automatic Identification System (AIS) is an automatic continuous broadcasting system operated on Very High Frequency (VHF) offshore mobile frequency band which supports the exchange of information like International Maritime Organization (IMO) number, position, course, speed, etc. between a vessel and an on-shore broadcasting station. As it is stipulated in Chapter V of International Convention for the Safety of Life at Sea (SOLAS), 1974, that AIS should be compulsorily installed [2], the total number of AIS facilities and its application have been rapidly increasing. It is proved that automatic video tracking of vessels can be achieved by converting vessels' coordinates into the pre-set coordinates of intelligent spherical manipulating consoles, which can drive video cameras to the objects to be monitored.

A. *Significance of video monitoring to port safety management*

Port safety management refers to all the managerial activities which may protect crew and passengers' safety and health, avoid damage to vessel and cargo, and prevent the sea from pollution [3]. Presently, many small- and medium-sized ports tend to become multi-functional, and the vessels loaded with passengers, cargo, aquatic products, etc. pass in and out of ports very frequently, which have brought much trouble to port management. As traditional radar monitoring fails to achieve real-image collection and display, it is unable to track and trace the illegal affairs like vessel pollutant discharge around port area. In addition, radar is inefficient for its existence of blind area and electronic jamming, especially in small ports, whose geographic layout is greatly dependent on its natural terrain, which results in plenty of blind area where radar cannot deploy. On the contrary, video monitoring system is superior for its flexible installation. In particular, the video cameras, which may avoid any blind area for its ability of freely rotating 360° horizontally and 90° vertically, have been quite prevalent as a result of intelligent spherical technology. Meanwhile, IP network video transmission also makes it possible to achieve remote deployment at low cost. Furthermore, the application of active infrared photography and polarized filter photography guarantees the annual available days for video monitoring. In a word, video monitoring has become an important supplement in port safety management.

B. *Significance of video monitoring system based on AIS data*

AIS data includes the information of a vessel's coordinate position. In accordance with the relative regulations of SOLAS Convention, the 300-gross-tonnage-and-over vessels which travel along international routes and 500-gross-tonnage-and-over vessels in Convention countries which travel along domestic routes should be equipped with AIS by stages from July 1st, 2002 to July 1st, 2008. Currently, the number of vessels with AIS facilities has occupied a large proportion to the total number of vessels in and out of ports. Intelligent video monitoring, which is achieved by intelligent spherical automatic positioning driven by AIS data, is going to reduce the manual labor intensity considerably. Moreover, manless duty video monitoring is possible to some extent through a combination with digital video recording system.

II. Implementation of AIS-BASED Port Intelligent Vessel Dynamic Video Monitoring System

An intelligent sphere is actually a combination of photographic manipulating console, digital control facilities and video cameras. It can receive digit-driven signals so as to function in direction and height adjustment, zooming, iris adjustment, active light source control, etc. The most crucial point is that it is generally able to provide a certain number of pre-set points (from 64 to 512 or more) and record parameters of tracking directions and focal lengths so as to achieve continuous fixed-point tracking through digital signals [4].

A. Structure of the system

An AIS-based port intelligent vessel dynamic video monitoring system consists of an AIS receiving system, a vessel dynamics database, an automatic monitoring and decision-making system, the intelligent sphere array, etc., of which the intelligent sphere is able to select active-auxiliary-light-sourced and long-focused infrared cameras according to the actual conditions of a port, as illustrated in figure 1.

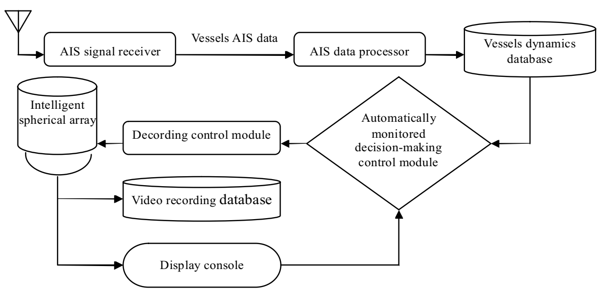

Figure 1. AIS-based port intelligent vessel dynamics video monitoring system

The system works according to the following steps: firstly, the AIS receiving system receives the vessel's AIS signals from the AIS antenna through the signal receiver; then the AIS data processor picks up the data concerning the vessel's dynamics, including the vessel's name, call sign, latitude and longitude coordinates, course, speed, destination port, etc.; finally, the vessel's dynamic data is recorded in the vessels dynamics database.

Automatically monitored decision-making control module is used for picking up objects from the vessels dynamics database, constituting the object queue to be monitored, reckoning the PRI of the object queues, and putting the numbered port area monitoring cameras on the tracking and monitoring of important objects.

B. Main working principles

1) Intelligent spherical positioning

The number of the pre-set points that an intelligent sphere can memorize varies from decades to hundreds. A fixed angle θ is pre-determined between each pre-set point through manual demarcation and the camera at each pre-set point may obtain an angle α, illustrated as in Figure 2.

If the coordinates of the intelligent sphere are known, the coordinates of the monitored vessel can be acquired through AIS; then, the azimuth between the intelligent sphere and the monitored vessel can be worked out; after that, the intelligent sphere is driven to turn to a specific pre-set point. When the azimuth becomes equal to θ with the motion of the vessel, the intelligent sphere turns to the next pre-set point. That is to say, when the angle between vessel position "n" and vessel position "1" is equal to (n-1)•θ, the intelligent sphere turns to the pre-set point n. Since the angle of the camera α is larger than the angle θ, the vessel will be under monitoring all the time.

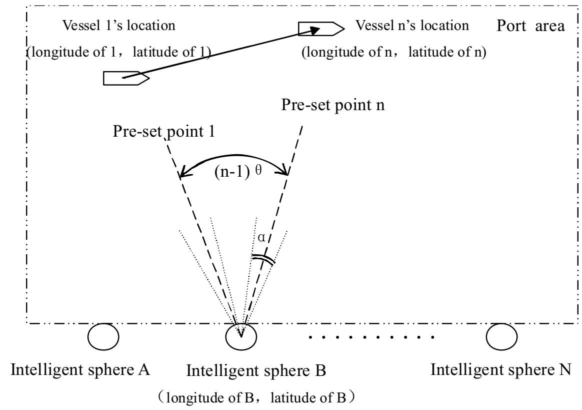

Figure 2. Position relationships between vessels and intelligent spheres

Suppose there is an intelligent sphere with the longitude of X_i and latitude of Y_i. The azimuth of its initial preset point is φ_0. There is an angle θ between every two initial preset points. The largest preset point's azimuth is φ_n, and the total number of the preset points is (n+1).

Based on the above prerequisites, the distance L and the TB of its azimuth between an intelligent sphere and a vessel inside a port area, with longitude of X_s and latitude of Y_s, can be calculated as follows:

$$L = \arccos[\sin(X_s)\sin(X_i) + \cos(X_s)\cos(X_i)\cos(Y_s - Y_i)] \quad (1)$$

$$\rho = \text{arccot}[\tan(X_s)\cos(X_i)\csc(Y_s - Y_i) - \sin(X_i)\cot(Y_s - Y_i)] \quad (2)$$

Titles and symbols for longitudes and latitudes exist for their varied locations in different hemispheres, hence:

Suppose $\Delta Y = Y_s - Y_i$, (3)

on one hand, at a port in the northern hemisphere,

if ΔY≥0：

$$TB = \begin{cases} \rho & \rho > 0 \\ 180° + \rho & \rho < 0 \end{cases} \quad (4)$$

if ΔY<0：

$$TB = \begin{cases} 360° - \rho & \rho > 0 \\ 180° - \rho & \rho < 0 \end{cases} \quad (5)$$

On the other hand, at a port in the southern hemisphere,

if ΔY≥0：

$$TB = \begin{cases} 180° - \rho & \rho > 0 \\ -\rho & \rho < 0 \end{cases} \quad (6)$$

if ΔY<0：

$$TB = \begin{cases} 180° - \rho & \rho > 0 \\ 360° - \rho & \rho < 0 \end{cases} \quad (7)$$

In such case, if $TB \in [\varphi_0, \varphi_n]$ and there is nothing blocking in the way, the vessel is supposed to be under monitoring, finally the serial number of a preset point

$$S_i = INT(\frac{TB - \varphi_0}{\theta}) + 1 \quad (8)$$

Special attention should be paid that a contrast table between real and logical preset points is needed to achieve continuous monitoring because partial internal logical preset points of many intelligent spheres can only be used for specific purposes rather than by real users, i.e., the available logical preset points are discontinuous.

TABLE I. A Contrast between REAL and Logical Preset Points

Serial Number	Real Preset Points	Logical Preset Points
1	S1	L1
2	S2	L2
…	…	…
n	Sn	Ln

2) Automatically monitored decision-making control module

As the number of port vessels is usually greater than that of the monitoring intelligent spheres, it is the major task of automatically monitored decision-making control module to sort out the important monitored objects.

There are some rules in selecting monitored objects. Firstly, for the sake of safety management, the sea-routes in port area with frequent crossing of vessels are the most crucial points to be monitored. Secondly, intelligent spheres in different locations tend to select the nearest vessels as their own objects. Thirdly, it is more necessary to monitor high-speed vessels than low-speed or mooring vessels. Fourthly, the vessels with records of peccancy are superior to be monitored to other vessels. In addition, passenger vessels take priority of being monitored to cargo vessels. Finally, it is not necessary any more to track the vessels bearing off the monitored area. There are too many rules to list.

Automatically monitored decision-making control module functions as follows: firstly, the sorted vessels from vessels dynamics database in the monitored area are put in queue, then each vessel is given specific weight according to its own location, course, speed, historical record, etc.; afterwards, the PRI coefficients , as in (1), of each vessel are worked out; after that, the vessels are sequenced and tracked according to the PRI coefficients so that the intelligent automatic monitoring is achieved.

$$\partial = (k_a \times A + k_v \times v + k_L / L + k_b \times b) \times C \quad \begin{cases} In\ Monitored\ Area, & C = 1 \\ Off\ Monitored\ Area, & C = 0 \end{cases} \quad (9)$$

In (9), ∂ is the PRI coefficient of a vessel to be monitored; k_a is the weight coefficient of the relationship between a vessel's location and its sea-route, the reverse ratio of which to the numerical of the distance from the vessel to the sea-route is adopted; A is the relationship between a vessel's location and its sea-route; k_v is the weight coefficient of the speed of a vessel; v is the speed of a vessel; k_L is the weight coefficient of the distance from a vessel to an intelligent sphere; L is the distance from a vessel to an intelligent sphere; k_b is the weight coefficient of a vessel's historical record of peccancy; b is the exponent of the severity of a vessel's peccancy. Other parameters may also be taken into consideration since ports differ in security management. The higher the numerical of a vessel's PRI coefficient is the higher priority it takes to be monitored.

While deploying multiple intelligent spheres in the automatically monitored decision-making control module, firstly, polling schemes are adopted to each intelligent sphere; then the PRI coefficient of each vessel in the vessel queue to the intelligent sphere is worked out; thirdly, the vessel with the maximum PRI coefficient is sorted out to be monitored and tracked by the intelligent spherical camera; after that, the PRI coefficients of other vessels in the queue excluding the previously monitored vessel to the next intelligent sphere are worked out. In this way, finally every intelligent sphere will find its own object.

C. Components of hardware

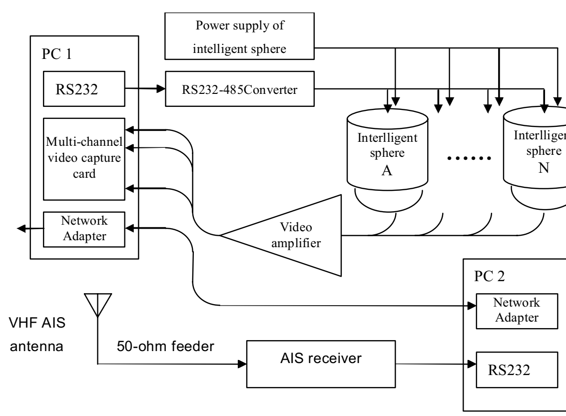

Figure 3. Components of hardware in the system

In figure 3, PC 1 functions as the monitor of an intelligent sphere, the collector of video signals and the transmitter of the server through IP video frequency for remote control; PC 2 implements the tasks of AIS data collection and processing as well as the stocking of vessels' dynamic data. The data in the two PCs can be exchanged through network card and LAN (local area network). If the increase of the number of cameras and intelligent spheres results in the overloading of data in the computers, the tasks of video collection and intelligent spherical control can be distributed to more computers.

D. Introduction to software

The system adopts MYSQL, which is installed in PC 2, to fulfill the database management. The program receives the data from AIS receiver via port RS232, then separates the data concerning vessels and finally updates the records in the database.

PC 1 is equipped with multi-centered video capture card drive and applications so that multiple monitored images can be displayed in a single window or squared figures. Meanwhile, it may function as the video server to transmit the monitored video information to the farther users through the Internet[5].

The program of automatically monitored decision-making control module is installed in PC 1. PC 1 firstly visits the database of PC 2 through the Internet, generates monitored signals via algorism, then passes transmitter RS-232-485 via port RS232 and sends the monitored signals to every intelligent sphere by cable 485. After the signals have been decoded in intelligent sphere-controlled circuits, the remote control over intelligent spheres is achieved.

In order to cope with emergencies and achieve easy monitoring over small-sized ships and other objects in non-vessel dynamics database, monitored control module also offers a manual interface, which is able to drive corresponding intelligent spherical cameras to directional monitoring.

The high-definition video signals captured by intelligent spherical cameras may return to the multi-centered capture card via video cable. If the distance is so large that the video signals are lost en-route, it is advisable to install low-noise video amplifiers to extend effective transmission distance.

E. The Chart for the Software's Working Process

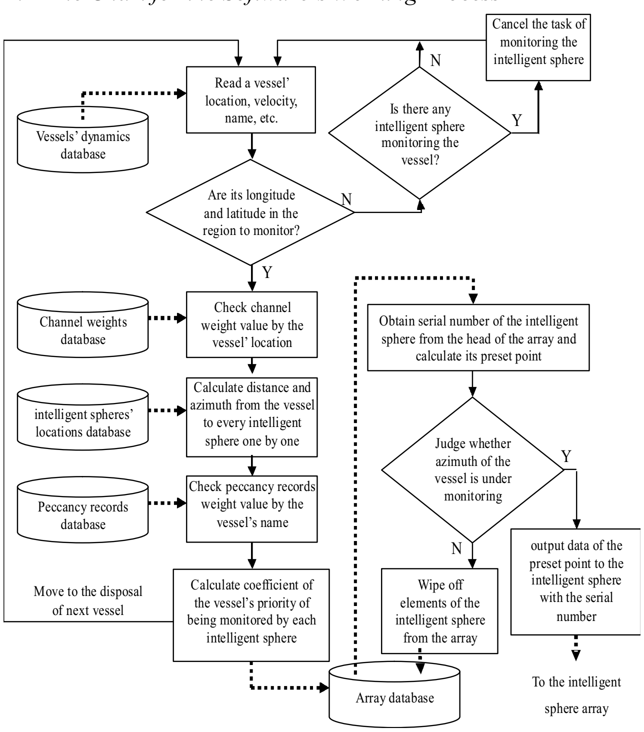

Figure 4. Working Process of the Automatic Monitoring Decision-making Module Software

F. The interface of the software

Figure 5. Working interface of the Software

III. SUMMARY

Since port safeity management is closely related to life safety, traffic and operation safety and ocean environmental protection, it is an important means of guarantee for transportation, production as well as navigation and mooring. As a component of VTS, port vessel dynamics video monitoring system is an indispensable means of port safety management.

Nowadays it has become a trend to achieve the automation and intelligentization of vessel dynamics video monitoring with the aid of computer technology [6]. With the continuous growth of intelligent spherical technology, the all-weather, multi-functional, wireless, networked and intelligentized video monitoring facilities will be generalized endlessly, which are bound to be better applied in shipping industry in future.

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