Enhancing Maritime Navigation Safety through AIS-Based Visual Augmentation: A Deep Learning Approach to Integrating Real and Virtual Views

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Abstract:

Modern ship navigation systems predominantly utilize Electronic Chart Display and Information Systems (ECDIS) integrated with Global Navigation Satellite System (GNSS) equipment, radar, Automatic Identification System (AIS), and compass equipment to generate computer graphics. However, these computer-generated graphics are entirely virtual and do not fully replicate the real-world view seen through the ship's windshield. Consequently, users must manually interpret and convert this virtual information into actionable navigation data. This dual focus on the navigation screen and real-world traffic hazards contributes significantly to human error in ship navigation, often leading to accidents.To enhance the safety and usability of navigation systems, this design introduces an AIS-based visual enhancement simulation system for ship navigation. This system aims to transform the current navigation methods by superimposing computer-generated navigation information onto the real-world scene in real-time, thereby providing a more realistic and intuitive interface for the user.

Keywords:

AIS analysis, Visual enhancement, Deep learning, human-computer interaction**.**

1. Introduction

Feasibility analysis: The technical or implementation feasibility of the project. The first step is to analyze and extract the required AIS and radar fusion data; the second step is to identify and track the nearby ships and various navigation aids in the real-time video; the third step is to identify the navigation aids in ECDIS; The AIS and radar fusion data are displayed in combination with nearby ships in the captured peripheral camera shooting video, and the identified ECDIS navigation aids are displayed in combination with various navigation aids in the real-time video of the camera.

2. AIS-based ship driving visual enhancement simulation system technical solution

2.1 The characteristics and innovations of this project

The first part identifies the farthest distance based on the image of the compass deck peripheral camera, delineating the AIS and the range of data processed by the radar.

Data analysis of AIS and radar data is performed separately through the IEC61162-1-2000 document and the NEMA0183 protocol. By matching the position data of the AIS and radar data (using the rectangular range to filter the AIS position A (λA, φA), the radar position B (λB, φB)). Screening: A list of target ships within ±15' (0.25°) nautical mile of rectangular data, forming a SHIPS LIST.

Function: Select the target ship that meets the following conditions and enter the rectangular filter list.

Longitude screening: $\lambda A-0.25° \leq \lambda B \leq \lambda A+0.25°$

Latitude screening: φA-0.25°≤φB≤φA+0.25°)

The radar data is matched with AIS data based on the ARPA-related ship list. If there are multiple matching radar targets in the matching area, the distance data distance is the shortest comparison. In the short distance case, the AIS and the multiple matching target Euclidean distances are calculated according to the plane rectangular coordinate system, and the minimum distance radar target is matched. When the location match is successful, it is determined that the target match is successful. If the AIS does not have a matching radar target, the AIS target data is output. Through the matching of the radar target and the AIS target position, it effectively compensates for the radar detection blind zone and false echo, as well as the blind zone and deviation of the AIS equipment signal and improves the accuracy and reliability of the target position information.

2.2 Design ship image recognition and motion tracking

2.2.1 Target Recognition

The improved inception target recognition module is combined with artificial intelligence image analysis technology based on deep learning. Through extensive image training, features are extracted from the bottom layer to achieve recognition and automatic optimization of diverse image representations. Applying Google's tesorflow framework, using neural network algorithm, the ship and various navigation aid pictures are put into Inception V3 for training, so that the model can be classified according to the characteristics of various diseases.

In order to quickly identify and classify, the Inception V3 model was improved. One is to change the mean sampling of the model in Inception V3 to the maximum value of the mean, ie:

$$Ti = (Pmean(Xi-1)+Pmax (Xi-1))/2$$

$$\text{where } Xi = f(WiTi +Bi)$$

By the mixed sampling image to avoid the shortcomings of single sampling layer feature extraction, the image features are fully extracted and merged to improve the image recognition rate.

Second, the SVM classification layer is better for processing images of high-dimensional features than the Softmax classification layer. The traditional Softmax layer is used for classification. When the feature type is greater than 0.9, the classification is correct, but the loss function will continue to be calculated and increased. The system runs time, and by changing the traditional Softmax classification layer, the Softmax classification layer is improved to use a linear kernel function

$$K(x_1, x_2) = (x_1 \cdot x_2)$$

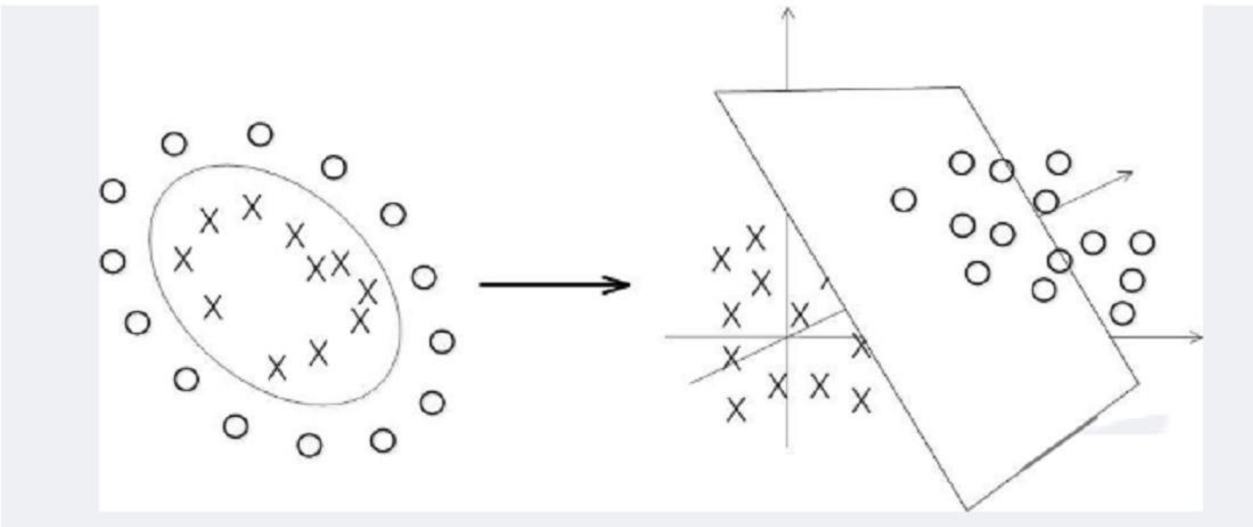

Figure. 1 The kernel function maps the input space to the high-dimensional feature space

with few parameters, fast speed and high precision. As the classification layer of SVM kernel function, SVM classifier pays more attention to the classification error sample, and will not process the sample that has been classified correctly, which can greatly improve the training speed and recognition rate, and provide better prevention of over-fitting. Theoretical guarantee. Through technological improvements, the extraction speed and accuracy of ships and various navigation marks and lighthouses are greatly improved. And for the identified target, the true orientation is assigned according to a fixed camera (on the ship axis), and is sorted and labeled in ascending order in the order of the true azimuth rays starting from the camera.

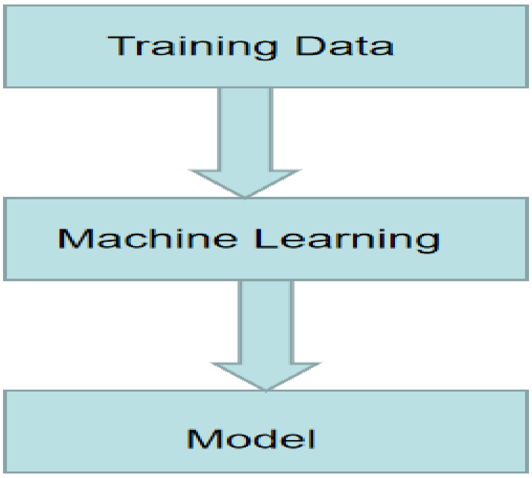

Figure. 2 Target recognition module

The processed image undergoes: image graying by pre-processing weighted average method; image enhancement uses spatial domain template processing method, which is suitable for aquatic environment and the result is relatively intuitive; the filtering process adopts Gaussian filtering, It introduces the concept of weights to ensure smooth processing.

2.2.2 Target Tracking

As the ship gradually enters the video surveillance area, the tracking target size changes, and the tracking window changes accordingly. In order to solve this problem, this paper adopts the Camshift tracking algorithm. The Camshift algorithm is not very demanding on computer hardware, and the execution efficiency is fast. It can have good effects in the case of not many interferences. However, when there is interference in the surrounding environment (such as light and occlusion), tracking can still be achieved if a small amount of occlusion occurs, but when the occlusion is severe, the target loss occurs. If the position of the next detection of the target can be predicted in advance, even if there is a serious occlusion, the tracking can be performed according to the predicted position, and even if there is an error in the position, the target is not lost. Therefore, tracking based on Kalman filter algorithm is adopted. The Kalman filter is a recursive estimator, which is an algorithm for linear minimum variance error estimation of the state sequence of a dynamic system. It is computationally intensive and it can use any point in the image as a starting point to estimate and observe the trajectory of the target. Generally, using the Camshift algorithm, after the target tracking occlusion loss is lost, the Kalman algorithm is used for target tracking, and the obtained target tracking map continues to be tracked using the Camshift algorithm.

2.2.3 Identify the navigation aids in ECDIS

Using the second chapter target recognition method, the electronic chart display standard ECDISIHO S-57IHO S-52 is used to identify various navigation aids required (lighthouse, lamp post, buoy, bright focus, reef, shipwreck, fish and fish) , mooring area, pilot station, pilot position, etc.) and data collection (identification of the location, location and target of the target contains ECDIS basic information)

The fourth part combines the AIS and radar fusion data with the nearby ships in the captured peripheral camera video (using the second part to sort the target sequence in ascending order of the camera as the starting point of the true azimuth ray, screening AIS and radar fusion The true azimuth target in the data matching the video recognition, calculate the distance from the ship, and arrange the matching video recognition target according to the distance and the ascending order, and combine the identified navigation aids in the ECDIS with the various navigation aids in the real-time video of the camera. (Identify the target position and true azimuth of the navigation aid in ECDIS, calculate the distance by position, and match the video recognition target in the same true orientation according to the distance and ascending order).

POI (Point of Interest, including all identified objects) Display Module Design This module includes POI label display, POI search screening, radar chart display and electronic chart display. The core of this module is the POI tag display, which is to display the POI data near the location, such as distance, bearing, height and target-specific information. If the ship information displays the AIS information drop-down menu, only the basic information (ship name, distance to the ship and heading 2D model) is displayed when not clicked, and all the AIS information is displayed after clicking. Lighthouse (basic display name, distance to own ship and ECDIS icon, display details after clicking).

System function:

(1) POI display function (real scene display, main screen, radar map upper right corner position, ECDIS reduction window, radar chart below, floating label);

(2) object identification function (position tracking, position positioning, image recognition, Prompt information);

(3) Navigation function (search box, live view display, route highlighting, prompt information).

2.3 implementation plan

Including relevant methods, technical routes, experimental means, key technologies, and implementation forms of the program

Implementation:

During the voyage, the ship mainly relies on Global Positioning System (GPS), Automatic Ship Identification System (AIS), chart, radar, navigation aids and other equipment and driver experience to achieve navigation. During the navigation of the ship, the collected AIS information can be processed to accurately obtain the navigation information of the ship and identify the target ship. The driver needs to comprehensively apply navigation aids such as AIS and navigation aids such as navigation aids to assist the maneuver. Due to the relatively independent facilities and equipment, the navigation aids of this traditional navigation mode are not good when the route conditions are complicated or the visibility is poor. As an emerging hot technology, Augmented Reality (AR) technology has many advantages and broad application prospects. Therefore, it proposes a solution to solve the problems that are difficult to solve in the practice of traditional ship navigation aids by using AR technology.

The design consists of four parts: video image acquisition system, recognition and analysis system, virtual and real combination system, and image display system. The video image acquisition system is a camera for acquiring video or photos, which can be a normal high-definition camera or an HD camera with night vision function. The function of the recognition analysis system is to identify the effective information (such as the navigation mark, the environment, its ship, etc.) in the extracted video image, analyze the information required for navigation, and correspond to the three-dimensional model in the database. The function of the virtual and real combination system is to accurately combine various virtual 3D models with video images. The image display system is a video image that enhances the display and combines the virtual three-dimensional model and is finally presented on the display terminal.

AR technology has three notable features:

(1) The real environment information can be stored more completely on the display device;

(2) It can realize the processing of specific information in near real time,

Enhancement and control;

(3) Realize dynamic and intuitive information based on real environment

Interaction.

Technical route:
Using AR technology in the navigation aid of the ship, a large amount of information originally analyzed and processed by the ship's pilot can be processed by the AR analysis and synthesis system, and then combined with the basic parameters of the background, and the processed result is enhanced and displayed on the driving. On the screen in front of the staff, to achieve a variety of information simultaneously and intuitively enhanced display.

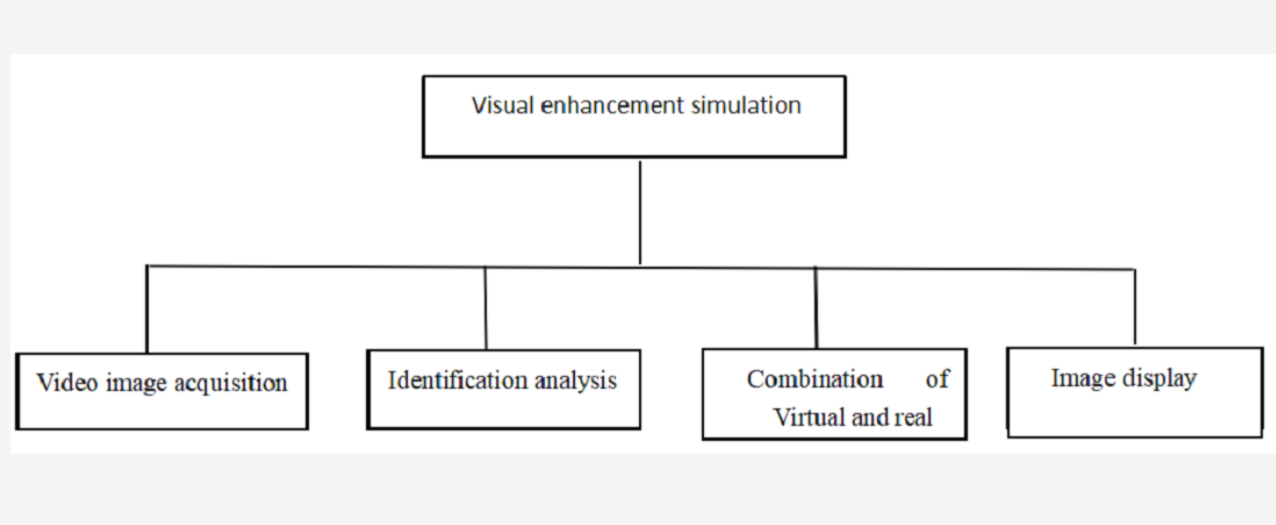

Figure. 3 Visual enhancement simulation system

3. Plan realization form

In the future, the ship will be "intelligent", enabling the ship's pilot to easily and efficiently and safely complete the ship's navigational order, and the integration, intelligence and real-life of the ship's navigation and navigation system will become inevitable. Using AR technology in the navigation aid of the ship, a large amount of information originally analyzed and processed by the ship's pilot can be processed by the AR analysis and synthesis system, and then combined with the basic parameters of the background, and the processed result is enhanced and displayed on the driving. On the screen in front of the staff, to achieve a variety of information simultaneously and intuitively enhanced display.

While the ship is sailing, although there are many modern technologies such as GPS, AIS, radar, ARPA, and compass to provide safe and reliable navigation guarantee services for navigation, most of these information application systems are independent of each other, providing convenience for the voyagers. Accuracy also increases the workload. The application of augmented reality technology will integrate all ship navigation information, and can be selected by human-computer interaction gestures, all or part of the enhanced display on the screen. The information displayed on the screen includes: static information and dynamic information when the ship is sailing, surrounding navigation mark , the navigation mark, the vessels in the adjacent sea area, and the geographical environment and meteorological environment of the surrounding sea. These are visually presented on the screen in a visual way, which is convenient for the ship's driver to view and ensure that the ship is driving normally in a traffic-intensive port area.

4. Conclusion

Modern ship navigation systems predominantly rely on Electronic Chart Display and Information Systems (ECDIS) integrated with Global Navigation Satellite System (GNSS) equipment, radar, Automatic Identification System (AIS), and compass equipment to create computer-generated graphics. However, these virtual graphics do not fully replicate the real-world view seen through a ship's windshield. As a result, users must manually interpret and convert this virtual information into actionable navigation data, leading to a divided focus between the navigation screen and real-world traffic hazards. This split attention significantly contributes to human error in ship navigation, often resulting in accidents.

To enhance the safety and usability of navigation systems, this design introduces an AIS-based visual enhancement simulation system for ship navigation. This system aims to transform current navigation methods by superimposing computer-generated navigation information onto the real-world scene in real-time, thereby offering a more realistic and intuitive interface for users.

Advancements in virtual reality (VR) and augmented reality (AR) technologies have facilitated remote development in port operations within the port industry. The emergence of centralized remote control and dispatch centers in the port and shipping sectors will be accelerated, along with the standardization of front-end production systems.

This paper proposes an AIS-based visual augmentation simulation system for ship navigation to address the persistent challenges in traditional navigation practices. By providing drivers with more direct visual information, this system enables faster and more intuitive understanding of the surrounding navigation environment, reduces the burden on seafarers, and enhances navigation safety. The AIS-based visual enhancement simulation technology is interdisciplinary, combining elements from multiple fields and exhibiting innovative and forward-looking characteristics. With the advent of big data and the rapid rise of data science, this technology has evolved into an emerging model for ship navigation, driven by data analysis and research, transforming ship driving visual simulation from a simple processing task into a sophisticated, data-driven process.

References

[1] Lu Ping. Research and Application of Key Technologies in Image Processing in Mobile Augmented Reality [D]. Southeast University(China), 2015,p.41-50.

[2] Cai Wei. Simulation of Video Image Fuzzy Feature Extraction for Mobile Terminals[J]. Computer Simulation,2017,34(11):154-157,p.3-7.

[3] Zhai Rong, Jin Yongxing, Hu Qinyou, Shi Chaojian, Wang Shengzheng. Prediction of Ship Navigation Behavior Based on AIS Information and BP Neural Network[J]. China Navigation, 2017, 40(02): 6-10,p,1-10.

[4] Zeng Yuting. Research on object detection and tracking method based on deep learning [D]. Donghua University of Technology(China), 2018. p.19-31.

[5] Yang Gaoxing. Research on Ship Tracking and Type Recognition Based on Computer Vision [D]. Dalian Maritime University(China), 2017. p.8-63.

[6] Jiang Cong. Design and Application of AIS and Navigation Radar Information Fusion Simulation Platform [D]. Harbin Engineering University(China), 2011. p.5-29.

[7] Liu Xizuo, Song Yuan, Li Caixia, Zou Wenmeng. Real-time enhanced simulation system for ship driving based on AIS[J]. Journal of System Simulation, 2013, 25(08): 1851-1855. p.4-7.

[8] Paul D. Hutchison,Ronald J. Daigle,Benjamin George. Application of Latent Semantic Analysis in AIS Academic Research[J]. International Journal of Accounting Information Systems,2018. p.2-6.

[9] Paul D. Hutchison,Ronald J. Daigle,Benjamin George. Application of latent semantic analysis in AIS academic research[J]. International Journal of Accounting Information Systems,2018. p.4-13.

[10] MIYAKE Rina,HASEGAWA Kazuhiko,FUKUTO Junji. Collision Risk Assessment Based on Behaviour Analysis of Collision Avoidance Manoeuvre Using AIS Data[J]. The Journal of Japan Institute of Navigation,2016,135(0). p. 16-19.