# Intelligent Visual Inspection System of Ship Draft Based on UAV

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***Abstract***

Accurately calculating the weight of cargo after shipping is an important issue in ocean transportation. Existing methods mainly indirectly calculate the weight of cargo by obtaining the draft of the ship. To estimate the draft of ships passing through waterways and ports, it is necessary to collect sounding line data. However, the current methods for collecting sounding line data mainly rely on manual measurement, which is inefficient, inaccurate, and has safety hazards. To address these issues, this paper combines artificial intelligence and deep learning technologies to design an unmanned aerial vehicle-based intelligent detection system for ship drafts. Detailed research is conducted on image acquisition, image segmentation, image recognition algorithms, etc., and an intelligent measurement platform for ship drafts is developed.

## 1. Introduction

Transportation by large ships is the most common mode of transportation in the world trade in goods, with the advantages of large cargo mileage and low transportation costs. In ocean transportation, accurate calculation of cargo weight after shipment is crucial. The existing methods of calculating cargo weight are mainly realized by measuring the ship's water gauge. As a scale drawn on the bow, stern and middle of the ship, the ship's water gauge is of great significance for the estimation of the ship's draft. Accurate measurement of the ship's load can be realized through the accurate measurement of the ship's water gauge. As a traditional method of measuring cargo weight, this is not only inefficient and poorly accurate, but also this method requires professional water gauge measurement staff, who must approach the water gauge line by climbing the gangway or taking a small boat, etc., which is a big safety hazard. Therefore, this study aims to develop a intelligent inspection system of ship's water gauge based on Unmanned Aerial Vehicle (UAV) in order to improve the accuracy of the measurement, reduce the human resource investment, and decrease the safety risk. The objective of this study is to design a system that can automatically collect, process and analyze ship's water scale images by combining artificial intelligence and deep learning technologies, so as to realize efficient, accurate and intelligent measurement of ship's draft.

## 1.1 Literature Review

In view of the problems existing in artificial observation, relevant scholars have proposed a variety of ship draught detection methods, the existing research is mainly focused on the following aspects:

(1)Dual Pressure Sensor Ship Draft Detection Method

Although the dual pressure sensor detection accuracy is higher, but there are great limitations, this method exists with the sensor is affected by the environment, and the electronic circuit is not easy to arrange the need for post maintenance and other shortcomings, and secondly, the detection accuracy is related to the density of real-time seawater. The practical application value is not large.

(2)Ultrasonic Water Gauge Detection

This method, although avoiding the shortcomings of the electronic sensor wiring is not easy, but due to the ultrasonic wave by the medium in the air has a greater impact, the measurement accuracy is not high.

(3)Laser Range Finder for Vessel Draft Detection

Laser has the speed of light invariance, successfully solved the ultrasonic sensor because of the medium uneven error, but because the light is easy to scatter on the water surface, easy to be affected by the water surface waves, so its measurement accuracy is very limited. It has been proved through practice that the ranging effect is not ideal, and this method requires the installation of additional equipment on the outside of the hull, which will have an impact on the navigation of the ship.

In view of the above drawbacks of various water gauge measurement methods, therefore, there is a need to develop an efficient, accurate, convenient and intelligent measurement method. In this paper, we introduce an intelligent measurement method for ship's water gauge based on autonomous UAV navigation, AI image recognition and deep learning technology. This method can significantly improve the accuracy of measurement, greatly reduce the investment of human resources, and also reduce the safety risk. By combining modern technologies, we are expected to overcome the problems of the existing dipstick measurement method and realize a more intelligent, efficient, and reliable measurement of the ship's draft, which will bring significant improvements to ship operations and maritime safety.

## 2. Research Methods

In this study, a variety of advanced technological means are comprehensively applied in order to realize the construction and optimization of the intelligent visual inspection system of ship's water scale based on unmanned aerial vehicle.

## 2.1 The Overall Design of Large Ship Draft Intelligent Detection System

The overall design of large ship draft intelligent detection system is shown in Fig.1. In order to solve the problem of automatic weight counting of the ship's water scale in the natural environment, this paper adopts UAV plus machine vision technology, and completes the acquisition of high-definition images of the ship's draft line by building a vision head system so that the UAV realizes autonomous navigation and shoots the draft line of the large-scale ship, and then transmits the high-definition image of the ship's draft line to the UAV remote controller through the image processing technology, which deploys the ship's water scale on the UAV remote controller. Intelligent measurement human-computer interaction platform and ship water gauge detection algorithm are deployed on the UAV controller, and the water gauge intelligent measurement human-computer interaction platform is used to realize the estimation of the ship's draught condition and complete the automatic weight counting of the ship's water gauge.

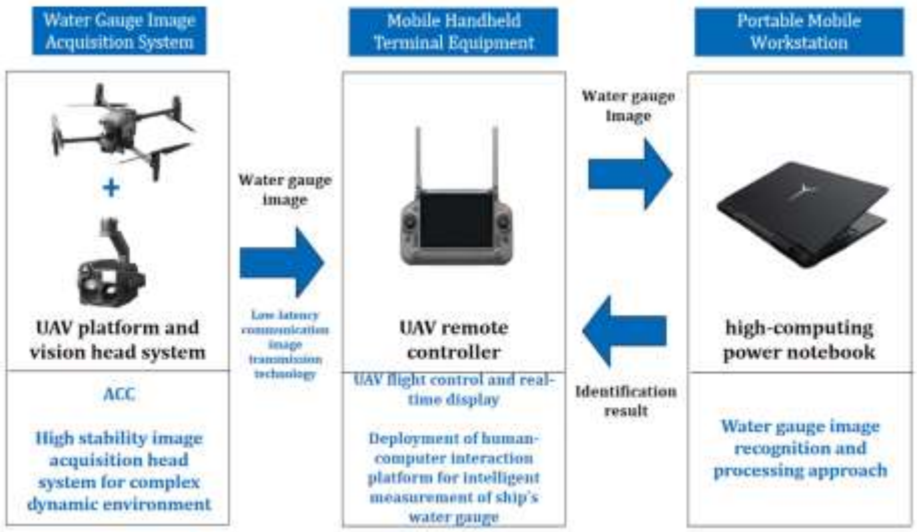


*Fig. 1 The Overall Design of Large Ship Draft Intelligent Detection System*

### 2.1.1 Autonomous UAV Cruise Data Collection

When the UAV platform is used to collect data on the water scale images of large ships, it is necessary for the UAV operator to have a high level of control because of the wind and waves that often occur in the sea-front operation and the need to maintain a certain distance from the ship. In order to improve the system's requirements for operators and make it more popular, the UAV in the system can realize autonomous navigation flight during the whole process of data collection. Only in the application of the new port berth, through the RTK high-precision positioning technology to establish the accurate waypoint map based on the port berth. UAV autonomous cruise data acquisition is completed, the subsequent to the berth of all the water gauge data collection to the post unloading vessel can be according to the waypoint map for autonomous cruise and data acquisition.

The system's image acquisition method for the drone acquisition, using the drone acquisition method is more flexible, not only can be manipulated on the shore, at the same time can be in the anchorage to be measured on the vessel to be manipulated to measure the low-cost, small size, easy to use, mobility, good performance, lower requirements for the environment, and greatly reduce the risk of casualties and other characteristics. The problem of autonomous navigation and flight control of UAVs in unknown and complex environments consists of five main parts: attitude control, fast navigation methods, SLAM algorithms, motion decision and planning, and trajectory tracking.

### 2.1.2 Highly Stable Acquisition Head System for Complex Dynamic Environments

When the UAV shoots the ship's water gauge, its movement speed, movement distance, movement attitude are changing constantly, which will cause the imaging blur, and in order to obtain the ship's water gauge image with high definition, high contrast, and easy to recognize and analyze, it is necessary to carry out real-time autofocus at the ship's water gauge, and automatically expose the white balance, so as to make the imaging clear, and satisfy the processing of the subsequent recognition algorithms. Therefore, the study of real-time, reliable autofocus technology, has important significance and value, and based on image processing autofocus technology is the focus of research and development.

### 2.1.3 Intelligent Measurement Human-Computer Interaction Platform

The ship water scale intelligent measurement human-machine interaction platform is developed based on the hardware equipment of the UAV controller, and is deployed together with the UAV's flight control system. When the UAV automatically acquires the image data of the ship's water scale, it establishes the vessel's voyage through the human-machine interaction platform and loads the corresponding water scale image data, and then the intelligent recognition algorithm of the ship's water scale in the background carries out the pumping of frames on the water scale image data, The intelligent recognition algorithm of the ship's water scale in the background extracts frames, preprocesses, locates the water level line, and recognizes the water scale characters, so as to judge the peak and valley values of the water scale of each section of the ship's image data, and thus calculates the average value of the water scale at that place.

When the ship unloading before and after the unloading of all 12 water gauge image data recognition is completed, you can fill in the pressure warehouse water, fuel load and other common sense of its calculation, through the ship's load calculation system can be calculated by the ship's unloading weight, as shown in Fig.2.


*Fig. 2 Water Gauge Calculation Page*

Establishment of a comprehensive parameter database system for ships in the Group's shipping sector. The database system will integrate comprehensive data such as tank volume table, dimensions and load status parameters of the ships in the Group's shipping sector, and be able to automatically calculate the ship's cargo weight data based on the dipstick readings and the externally inputted tank level and other relevant measurement data. At the same time, the functions of UAV gimbal control, real-time display and storage of water scale image, intelligent reading of water scale, data query of comprehensive parameters of the ship, and calculation of shipboard cargo weight are integrated into the man-machine interactive operation platform for intelligent measurement of shipboard water scale. It analyzes and calculates the ship's draught depth data by synthesizing manual experience and industry norms, establishes a model database, and compares the results with those of manual traditional measurements. The software automatically completes the calculation of the ship's water gauge weighting, and automatically calculates the ship's loaded weight after inputting the ballast water and relevant parameters of the ship.

## 2.2 Research on Ship Intelligent Detection Algorithm

### 2.2.1 UAV Autofocus Algorithm

The traditional hill-climbing search method based on the image processing auto-focusing technology algorithm only judges the search direction by comparing the two images, and the actual focusing evaluation curve is often not as strictly monotonous as the ideal curve, which makes the hill-climbing search method easy to fall into the local extreme point, resulting in focusing failure. For this reason, we improve the traditional hill-climbing search method based on the requirements of this paper, and divide the focus search into two stages : coarse search and fine search. In the fine search stage, three images are used to judge the focus search direction, which reduces the influence of local extremum and improves the anti-interference of the autofocus system. The overall scheme of autofocus is designed as shown in Fig.3.

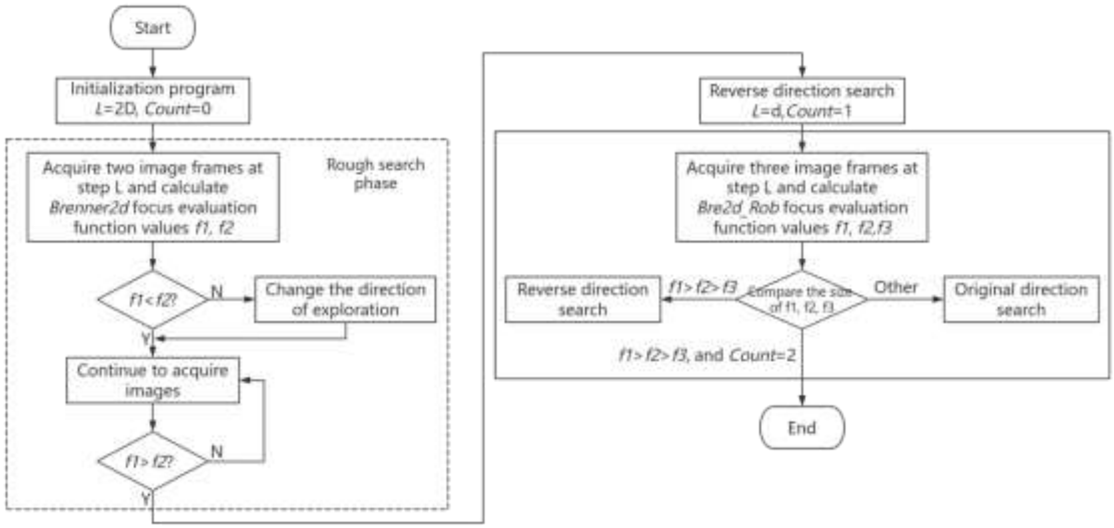


*Fig. 3 Auto Focus Overall Program*

In this paper, an autofocus evaluation function that adapts to multi-directional gray-scale gradient changes is used, and the mathematical formula is shown below. Combining the Brenner2d function with the Roberts function, a new focus evaluation function Brenner2d_Roberts function (referred to as Bre2d_Rob function) is obtained, which combines the advantages of the Brenner2d function and the Roberts function, and can more comprehensively extract the gray gradient information of the different directions of the microscopic image with better stability.

$$F_{\mathrm{Bre2d\_Rob}} = \sum_{x=1}^{M-2}\sum_{y=1}^{N-2}[f(x+2,y)-f(x,y)]\cdot[f(y+2)-f(x,y)]\cdot \left[\left|f(x,y)-f(x+1,y+1)\right|+\left|f(x+1,y)-f(x,y+1)\right|\right]$$

## 2.2.2 Image Preprocessing Algorithm of Ship Draft

The natural environment of the ship terminal is relatively harsh, wind and waves, illumination, fog, seawater reflection, etc. will lead to the acquisition of the image noise is relatively large, will seriously affect the quality of the image, thus increasing the difficulty of the subsequent image processing and identification of the ship's draught line shooting image shown in Fig.4. Therefore, in the pre-processing process of the image, the study of comparative image denoising and enhancement algorithms to filter out the random noise and illumination noise interference, and enhance the characteristics of the water scale become the basis and key of this study. The purpose of image segmentation is to simplify or change the representation of an image, making it easier to understand and analyze. In order to get the ship's draught line, characters and other characteristic areas, the mainstream image segmentation methods, such as comparing the difference shadow method, threshold method, edge method, main color extraction method, etc., have been studied, and the water ruler image segmentation method based on the deep learning image segmentation algorithm is proposed, so as to achieve real-time and accurate segmentation of the water ruler area and the character area, and to reduce the amount of operations of the image processing. The image segmentation and the extraction accuracy of the ship's draft line will directly affect the subsequent image processing and recognition results, the extraction of the ship's draft line is shown in Fig.5.

*Fig. 4 Ship Draught Line Shooting Image*

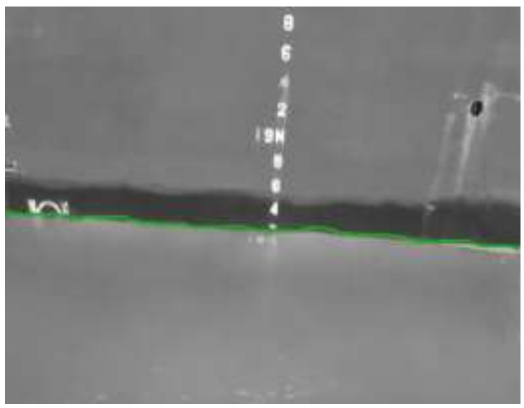

*Fig. 5 Extraction of Ship Draught Line*

### 2.2.3 Algorithms for Water Gauge Image Recognition and Processing

Image feature extraction is an important part of the water ruler character recognition, but also the most complex one, because the different types of ships also cause the water ruler image background is different. Therefore, for different styles of characters, scale lines and other different image patterns, analyze the brightness distribution characteristics and structural features of the image, the study of characters, scale lines and other related feature extraction methods is extremely important, the ship's water ruler markers as shown in Fig.6. In order to quickly and accurately extract the above image features, this paper adopts deep learning OCR algorithm and proposes a new feature extraction and classification method, which further improves the recognition speed and accuracy of the characters, and the digital feature extraction of the ship's water ruler is shown in Fig.7.

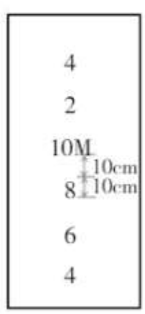


*Fig. 6 Ship Draft Mark*

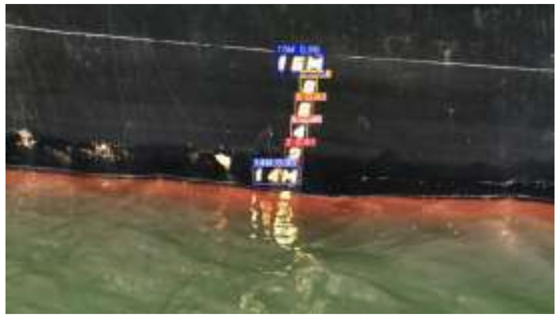

*Fig. 7 Digital Feature Extraction of Ship Draft*

OCR algorithm, that is, text recognition technology, refers to the use of optical technology and computer technology to detect the text in the image, and then identify the text content in the image, which is one of the branches of computer vision research.Traditional OCR text recognition is to view the character recognition of text lines as a multi-label task learning process, and its recognition process is image preprocessing (color image grayscaling, binary processing, image change angle detection, correction processing, etc.), layout division (straight line detection, tilt detection), character positioning cut, character recognition, layout recovery, post-processing, proofreading, etc. Traditional text recognition generally first requires text area localization, correction of the localized skewed text and then segmentation of individual text, and then the use of artificial features HOG or CNN features, combined with the classification model for single character recognition. In complex scenarios, the traditional OCR recognition accuracy is difficult to meet the needs of practical applications, and the performance of deep learning-based OCR is better compared to traditional methods. Deep learning-based text recognition is to use the model algorithm ability to replace the traditional manual methods, automatically detect the text category and location information, according to the corresponding location of the text information to automatically identify the text content. Most existing deep learning recognition algorithms include image correction, feature extraction, sequence prediction, etc. It is mainly divided into four stages:

(1)Image correction module, which turns the tilted and curved text straight, thus reducing the difficulty of feature extraction later, commonly used STN or its variants.

(2)Visual feature extraction module, which computes CNN features, such as VGG, RCNN, ResNet, etc., on the image.

(3) Sequence feature extraction module, extract sequence features containing contextual information from CNN features, usually using BiLSTM, transformer, etc.

(4) Prediction module, which predicts characters from sequence features, generally with CTC and attention.

## 3. Result and Discussion

In this study, the UAV-based intelligent visual inspection system for ship's water scale was used to collect water scale data from different types of large bulk ships in several ports. The acquisition process covers the water scale image data before and after the ship is unloaded, while the manual traditional measurement results are recorded as comparison data. Judging from the water ruler images and videos collected, the data collected by the system under the complex environment are of high quality. The images are clear and recognizable, effectively avoiding the noise interference caused by wind and waves, light, fog, seawater reflection and other factors. Through the preprocessing and segmentation algorithm of the image, the water ruler area and character area can be accurately segmented, which provides a good data basis for subsequent identification. In the analysis of a large number of images collected from different ship types and different water environments, the accuracy of the water ruler character recognition is high, significantly better than the traditional OCR recognition accuracy, which strongly proves the system's excellent performance in data quality assurance. The average observation time of the UAV can be controlled within 20 minutes for the observation of the hydrographic scale of multiple ships. Compared with the traditional manual observation method, the observation time is greatly shortened, which has a significant advantage in time efficiency. Moreover, only one person is needed to operate the UAV, which obviously saves the labor cost and has strong efficiency in the utilization of manpower. Through the above comparative analysis, it is fully proved that the intelligent visual inspection system of ship water scale based on UAV has significant advantages in cost, data quality, safety and environmental protection, and applicability.

## 4. Conclusions

This paper solves the problems of low efficiency, poor accuracy and great safety of the traditional large-scale ship water ruler line inspection method, and introduces the overall design of the intelligent inspection system of ship water ruler line based on UAV, including the UAV auto-focusing algorithm, the image segmentation algorithm based on deep learning, and the image character recognition algorithm. The system has a large application value, which is mainly manifested in the following aspects:

(1) Lower cost, the time of observing the water ruler by UAV for a single ship can be controlled within 20 minutes, which greatly saves the time of water ruler counting and improves the efficiency of ship loading and unloading. The drone only needs 1 person to control, relative to manual observation, can save labor 1-2 people.

(2) Data traceability, water ruler image and video transmission storage is convenient and traceable, can effectively reduce the risk.

(3)Safety and environmental protection, small boat observation has pollution, manual climbing to read the water ruler has personal safety risks, based on the drone and AI vision of the water ruler measurement method, no pollution and safety risks.

(4) Wide applicability, based on the UAV and AI vision of the water ruler measurement method, can be applied to all kinds of waters of large bulk ship water ruler weight counting.

It has important application value and broad promotion prospect in the field of ship operation and maritime safety, and can provide an efficient, accurate, convenient and intelligent solution for large ship water ruler measurement.

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