



Research Review of Ship Draft Observation Methods

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Abstract: In order to systematically analyze and summarize the research status and development trend of draft observation, co-work cluster analysis base on draft observation was carried out by using knowledge VOS viewer software. Two research hotspots of draft observation were obtained, human visual observation combined with auxiliary equipment and artificial intelligence observation. The object and method of ship draft observation are summarized, and the main research direction is analyzed. The analysis focuses on improving observation accuracy, reducing labor costs, and being able to apply in complex environments. Future research directions of draft observation mainly include how to combine the traditional ship draft observation with artificial intelligence in the future, reduce error of draft observation to millimeters, identify obstacles, explore neural network autonomous learning optimization models, reduce the observation time and labor cost and meet the requirements of diversified application scenarios. At the same time correct the attitude that the accuracy of the current human observation is not high enough or even a negative in the artificial intelligence research area, finally promote the ship, insurance assessment, maritime and other aspects, in order to make the technology which combined artificial observation with intelligent assistance can be applied in practice to solve relevant lawsuits and provide an authoritative legal basis, and be used as the legal basis in the declaration of the ship and subsequent legal disputes.

Keywords: Ship Draft Observation, Ship Draft Survey, Ship Draft, Draft Observation Accurate, Bulk Carrier, Artificial Intelligence

1. Introduction

As a trend of ship maximization, ships play an extremely important role in international trade in global integration [1]. At present, the annual transport volume of dry bulk carrier in the world exceeds 120 million tons per year, and the cargo weight measurement method of bulk cargo is based on ship's draft survey. This paper discuss the importance roles draft survey and find out the core factors which affect the draft survey is based on draft observation by experienced water observers, and then make corrections to calculate the displacement of the ship [2], therefore, the precision of draft observation is the core factor which affects the ship draft survey. It can be clearly seen from Figure 1 that the observed error per centimeter of the three main ship types in the bulk market corresponds to the quantity of goods under the summer load. For example, the error per centimeter of the cape size ship is 120 tons, and the value of the cargo error per centimeter is 24,000 dollars with the common coal of 200 dollars per ton.

Therefore, improving the error of ship draft observation can reduce the error of delivery of goods and ensure the interests of shippers and consignee.

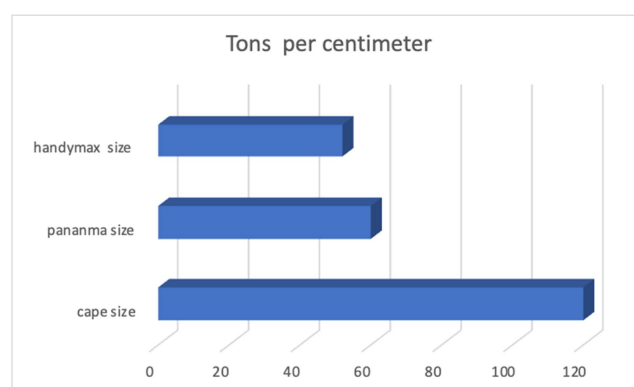


Figure 1. The tons per centimeter due of observation error.

In the research process of improving the precision of draft observation, this paper found that there was a lack of review

articles by authors with professional navigation background. In the field of draft observation technology, selected Web of science (WOS) and China National Knowledge Network Infrastructure (CNKI) databases to analyze articles related to ship draft observation [3]. Using co-work cluster analysis VOSviewer [4] Figure 2, the technological development in the field of draft observation in recent 20 years is summarized as follows: Visual observation combined with auxiliary means, neural network image recognition technology, radar sensor technology, pressure sensor, optical

fiber detection technology, sonar technology, IR technology [5], the following is to introduce various technologies and compare their advantages and disadvantages in the end of each introduction, the purpose is to improve the observation accuracy of the ship draft survey, so that research in related fields can quickly distinguish the practical direction; accelerate the feasibility of technology in related fields and reduce labor costs; reduce penalties caused by errors in cargo gauge inspection, ensure sufficient reserve buoyancy and reduce navigation risks of the ship. [6]

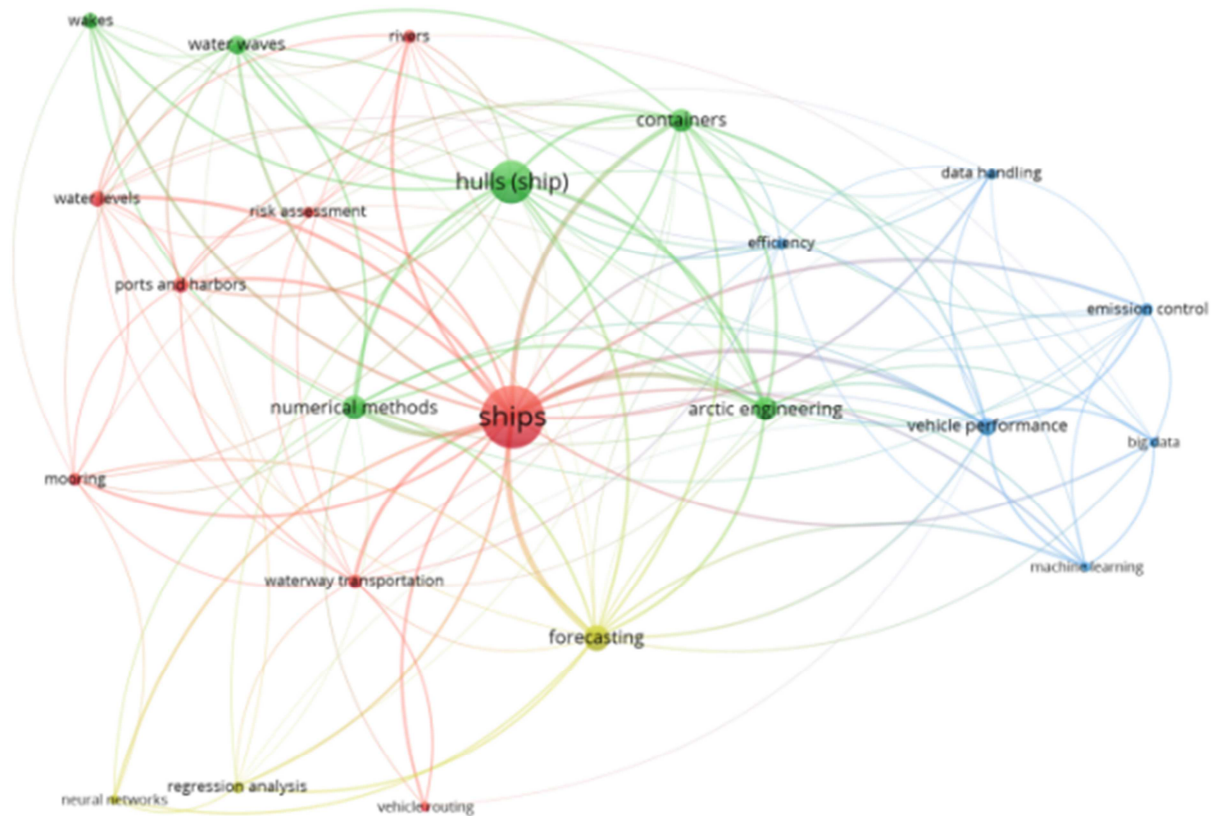


Figure 2. The technological development in the field of draft observation in recent 20 years.

2. Introduction: Current Research Progress of Water Scale Observation

2.1. Traditional Visual Observation

The traditional visual observation method is the visual observation method or the combination of the yacht, bracket, climbing ladder to read the six sides of the ship, which requires that angle of observation should be as parallel to the water surface as possible. This is also the current legal inspection standard of most countries including the People's Republic of China import and export commodity weight appraisal procedures [7].

In the process of observation, the method of visual observation for bulk carriers Figure 3 [8] is the legal requirement and the method is generally accepted in the cargo deliver. In the state of calm water, the visual observation can

complete in high accurate level. According to the author's practical experience of many years of observation, when the wave height exceeds 50cm, the auxiliary device of the "regulator" can reduce the amplitude of wave fluctuation in the regulator, reduce the difficulty of reading by low field personnel, and improve the accuracy of the final reading [9].

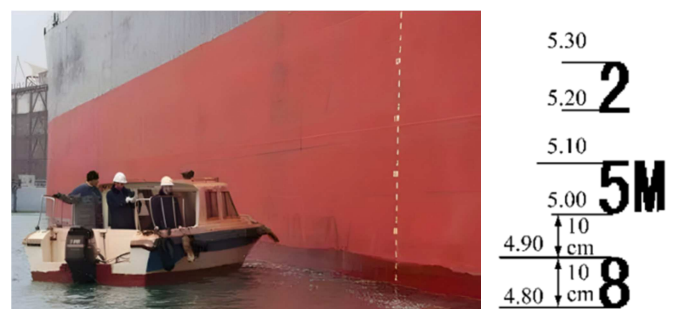


Figure 3. Visual draft observation draft mark. Illustration.

2.2. Image Recognition Technology

The ultimate purpose of the overall working method of image recognition is to obtain the value of water mark at the junction of waterline mark and horizontal plane by using image processing technology based on the dynamic recognition of water mark. First, cut the collected images, extract the target region to be determined and eliminate interference. At the beginning of the image capture, the characters in the segmented image are recognized by neural network, then the position of the boundary line between the ship and the water surface is determined to obtain the distance between the horizontal plane and the bottom edge of the nearest character, and the draft data of the ship is obtained. The follow-up research of Figure 4 realized the machine vision object inspection and calculation method based on deep learning. The pre-marked and processed image data of the water gauge were input and trained. After several iterations of training, the draft observation object detection model meeting the expected accuracy was obtained. Research on Application of Draft Survey.

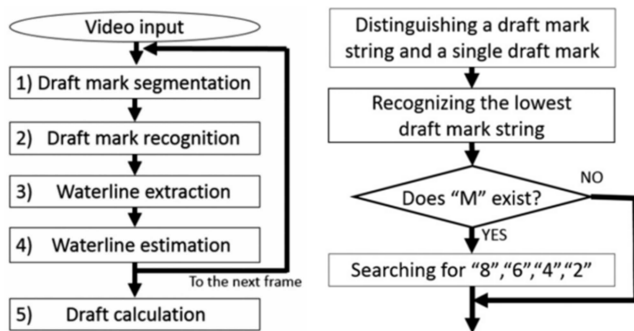


Figure 4. The Bulk Carrier Shipping Overweight Measuring System Based On Image Processing [10].

2.2.1. Target Detection Algorithm of Improved YOLOv3

Water measure object detection algorithm adopts YOLOv3 105-layer version model. The network of this model is the feature extraction network of darknet-53. Excluding the final full connection layer, there are 52 convolutional layers in total, which is composed of many residual modules, indicating that the YOLOv3 model is widely applied [8].

In order to obtain enough images of ship draught readings, the acquired images are first pre-processed; then the images are processed using a deep learning target detection algorithm with improved YOLOv3 model to predict the approximate location of the waterline and identify draught features; finally, the prediction results are analyzed and processed to obtain the final reading results.



Figure 5. YOLOv3 Image recognition theories [8].

Video type	Manual reading (m)	Method 1a (m)	Method 2b (m)	Method3c (m)	Reading error (m)
Calm water	7.36	7.356	7.355	7.356	0.004/0.005/0.004
Large waves	11.38	11.353	11.357	11.368	0.027/0.023/0.012
Water with obstacles	7.19	7.184	7.183	7.193	0.006/0.007/-0.003
Water trace	7.03	7.041	7.034	7.035	0.011/-0.004/-0.005
Tilted draft characters	11.37	11.382	11.378	11.375	-0.012/-0.008/-0.005
Rusted draft character	7.57	7.563	7.565	7.567	0.007/0.005/0.003

Figure 6. Compare different methods accuracy of observation [8, 11, 12].

Based on the YOLOv3 model, in the condition of static water observation, accuracy is high, away from the traditional image segmentation algorithm, but no test data be collected under wave amplitude more than 50 cm situation.

2.2.2. Application of U2-NetP Network with YOLOv3 to Observe the Draft Mark

The method proposes an idea that combines image processing and deep learning, able to adapt to different complex situations, especially in the presence of relatively large waves, recognition and obstacles where wind avoidance

signs are obscured. The method proposes a small U2-Net neural network combined with coordinate attention for semantic segmentation, using the YOLOv5n network structure for ship draft observation. [13]

At the same time, the method uses morphological operations to identify water lines and performs Canny edge detection and robust estimation for each frame of water lines. In the experimental setting, the method is fitted with an accuracy of up to 1 cm, which demonstrates the superiority of the method. [14]

The advantage of image processing is that it is an image of a

ship's draft is recognized at a certain time. The boundary between the ship and the water surface in the image is fixed and will not change, which provides a static basis for subsequent image processing and relevant feature extraction and avoids the observation illusion caused by sea waves or ship floating state during manual observation. On the other hand, the images taken can be saved as records, which is conducive to the follow-up query and review, and solves the results obtained by the traditional measurement method. [15]. At present, image recognition technology mainly combines UVA and unmanned yacht for image recognition. However, in the process of UVA shooting close to the water, the risk of

equipment damage is increased in the case of high waves, it is also difficult to recover and released for the unmanned boat to obtain image. Moreover, the unmanned yacht also cannot solve the problem that the lens fluctuates with surging waves in the case of the wind and waves, thus increasing the difficulty of reading. The author believes that image recognition combined with UVA is relatively simple to operate, the cost is controllable, and with the increasing accuracy of measurement, it will be the main development direction of draft observation means in the future and may even replace the traditional manual observation.



Figure 7. Ship draft observation in obstacle situation [13].

2.3. RADAR Detection

The measuring instrument uses a movable radar searching the unit to rotate out of the ship's bulwark and point straight out to sea. Turn on the radar liquid level measuring instrument, firstly continuously measure for no more than 2 min, including at least 2 complete wave periods, to obtain the average vertical distance D from the radar probe to the sea surface more accurately. Deduct the known distance from the fixed bracket to the r searching unit (i.e., the height of the tripod) E , then the distance B from the deck to the waterline can be obtained. The distance A from the deck line to the ship's water line is obtained from the ship's own parameters; the distance $B + E$ is measured by radar. Then the actual draft C of the ship is $C = D - E - B$ [16].

At present, the radar level meter for tanker level measurement is basically similar to the principle introduced, but the tanker level measurement is less affected by rolling, so it has been well applied in tanker level measurement. [17] The Research of Method of Automatic Level Gauge in Oil Tank, compared with the radar level meter in oil tank, due to the large fluctuation amplitude of the outboard swell of the bulk carrier, it takes a long time to collect data in large wind and waves, and the accuracy decreases, more observation points need to be arranged, and the time of equipment installation and commissioning is long. At the same time, the radar signal is affected by density and temperature in the process of air and seawater transmission, and the actual measured data is need calculated the correction of ship's list. It takes too many

measurements step, resulting in increased random error. [18] Analysis of Draft Survey Errors on Error Propagation Principle, in the end the radar detection and other similar equipment requires regular third-party inspection and calibration, otherwise the equipment measurement data errors will increase.

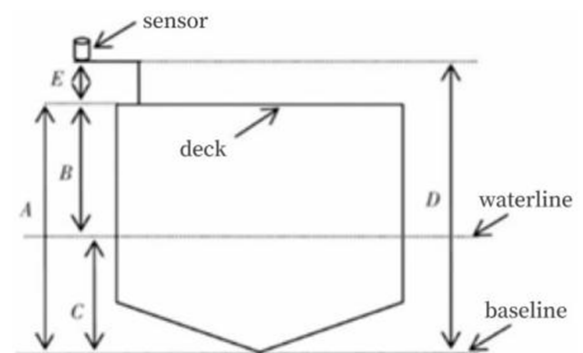


Figure 8. Radar detection working principal. [16].

2.4. Optical Fiber Technology

Optical fiber technology has been suggested as a new design for draft observation, this design propose a liquid level optical sensor for measuring the sea level in the sounding pipe. Draft readings obtained by optical sensors will be entered into ships' navigational system and load master. The working principal like the sensor of the oil tank in the car.

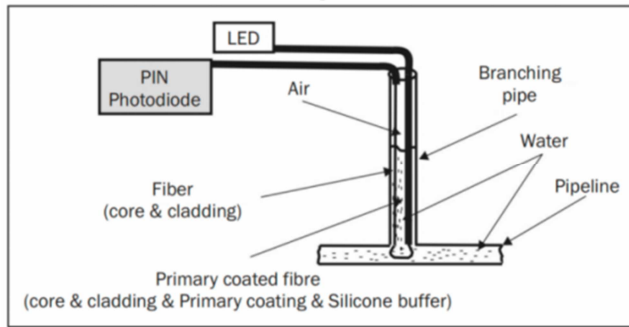


Figure 9. Working principle of Optical fiber technology [19].

The light from a LED is directed into an optical fiber appointed in each vertical branching of the pipeline, which conditioned by positions of draft marks.

Light propagates through the optical fiber. The portion of the fiber immersed in water up to the draft height is a double-clad fiber (water is the second cladding layer) with a refractive index of approximately. Since total internal reflection occurs at the core-cladding interface, light propagates as cladding mode rays. The light reaches the PIN photodiode as a detector, but it needs to be considered that absorption causes light loss. In the part of the fiber in the duct branch that is exposed to air (refractive index of about 1), less total internal reflection occurs because the fiber has internal reflection. Only the cladding, and more leakage rays. [19]

The advantage of this design is that seawater enters the measurement tube, which can reduce the range of seawater fluctuation in the case of large wind and waves. The design lack of actual observation accuracy of the data and requires a certain installation and maintenance cost.

2.5. IR

Laser distance measurement method to measure the distance from the deck surface to the water surface simultaneously at multiple points (up to 10 points) along the ship's side on the port and starboard sides. After the numerical regression analysis, the influence of water waves and other factors are almost eliminated, and the influence of hull deformation is also considered, so that the distribution curve of hull draft along the length of the ship is obtained more accurately. Combined with the ship's loading manual, the ship's displacement can be obtained more accurately. If the ship's displacement in the empty state has been accurately measured, the ship's load can also be obtained. The measurement system is characterized by large range, relative high measurement accuracy, easy operation and reliability. [20]

The working principle of IR is like the radar's design principle. The design needs to take consideration the bulk carrier outboard swell fluctuation amplitude is relatively large, in the big wind and wave collection data need a long time, the accuracy of the test would be reduced. The design also needs to arrange more observation points, equipment installation cost long time, at the same time, the radar signal is affected by density and temperature in the process of air

and seawater transmission, and the actual measured data needed to correct for the ship's list, and too many steps of measurements data lead to increased random error.

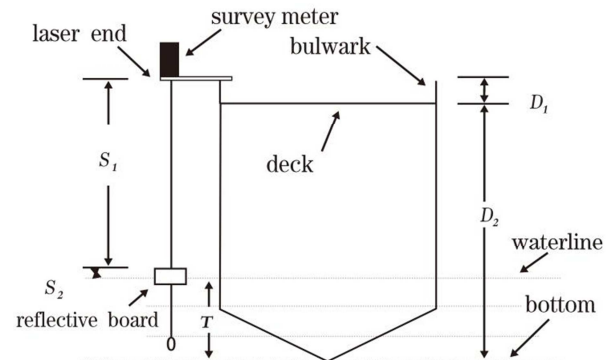


Figure 10. Working principle of IR technology [20].

2.6. Ship Hull Climbing Robot

The control system of the wall climbing robot can climb the hull of the ship. For the water line image recognition problem, an improved edge water line detection algorithm based on the canny operator is proposed. In the tests of the developed prototype, the adsorption performance, motion and overrunning characteristics of the wall-climbing robot and the collection and recognition functions of the draught table were tested respectively. During the test, the prototype has relatively good stability, and the error of the sketch test result was less than 3cm.

The advantage of climbing robot is the angle of observation can be close to parallel to the water surface, the technology is not too mature to complete observation in complex operation, right now the climbing robot state in a development and testing stage, high cost of equipment, maintenance costs are also high, if the hull is not vertical shape, it is the high requirement for robot's adsorption performance.

2.7. Design of a Ship Draft Measuring Ruler

Turn the power switch off on the control panel to energize the equipment, the power indicator light is on behalf of the normal energization, if the measurement at night, then at the same time close the lighting switch. Turn the tape measure crank to release the water ruler, so that the head end of the vertical immersion in water, when the indicator light is on, the buzzer sounds to prove that the end has been immersed in the water, at this time the observer can learn the approximate height of the water surface to the measurement point by observing the scale of the measuring tape D. At this time reverse slowly turn the crank to lift the measuring head, especially when the scale reading close to D should slowly turn the crank, if the alarm stops, at this time the end has left the water surface, quickly D is the measuring height. D1 minus D2 and D3 from the distance measuring point to the deck line and from the deck line to the height of the load marker line, the height D4 from the load marker line to the draught position can be deduced from the actual draught value of the ship. The relationship of measurement dimensions is shown in Figures 12.

For personnel operation, accuracy of the measurement is not satisfactory, the error of instantaneous reaction to water is not well controlled. At the same time, in the case of the wind and waves, the lead cone requires a large weight to be applied,

which leads to the operation is not very convenient. Other point needs to be considered is that during the process of measurement, the hull appears to list, which will also affect the accuracy of measurement.

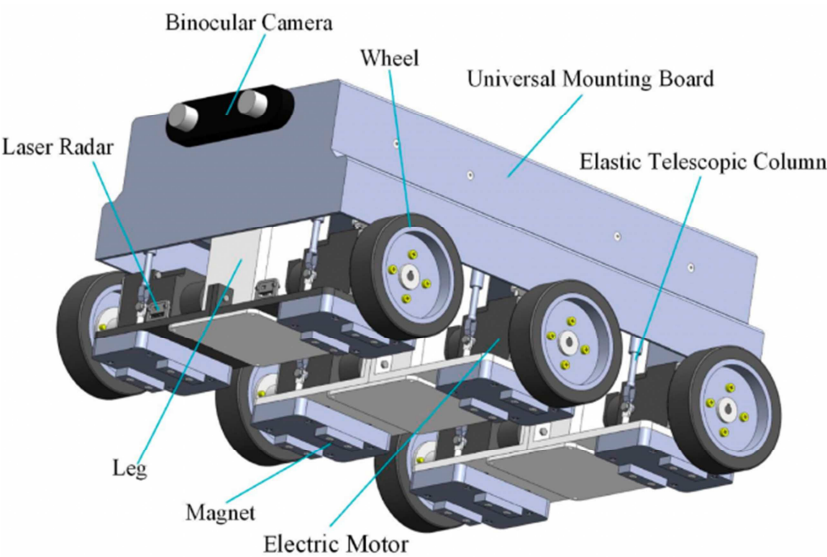


Figure 11. The working photos of climbing robot. [21].

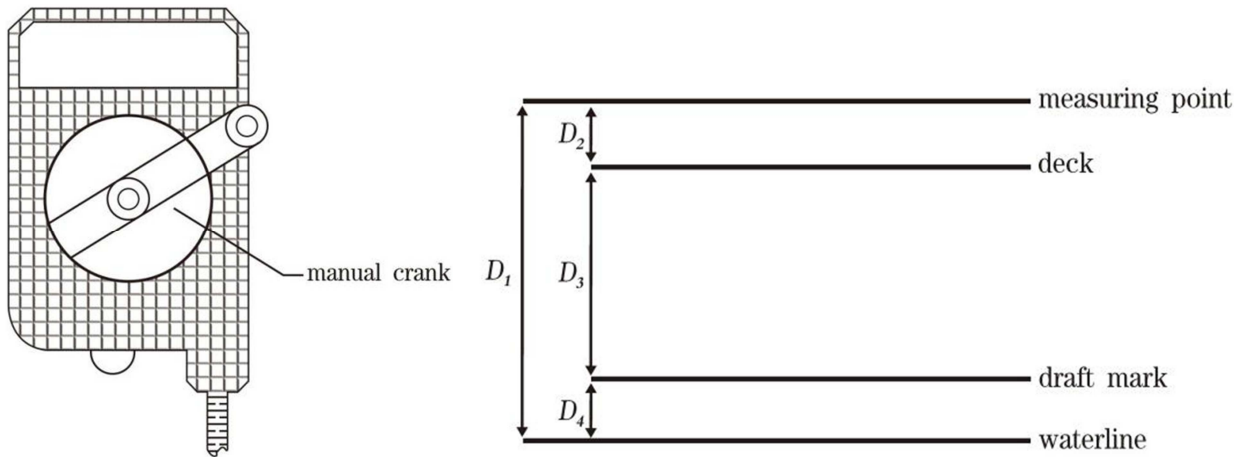
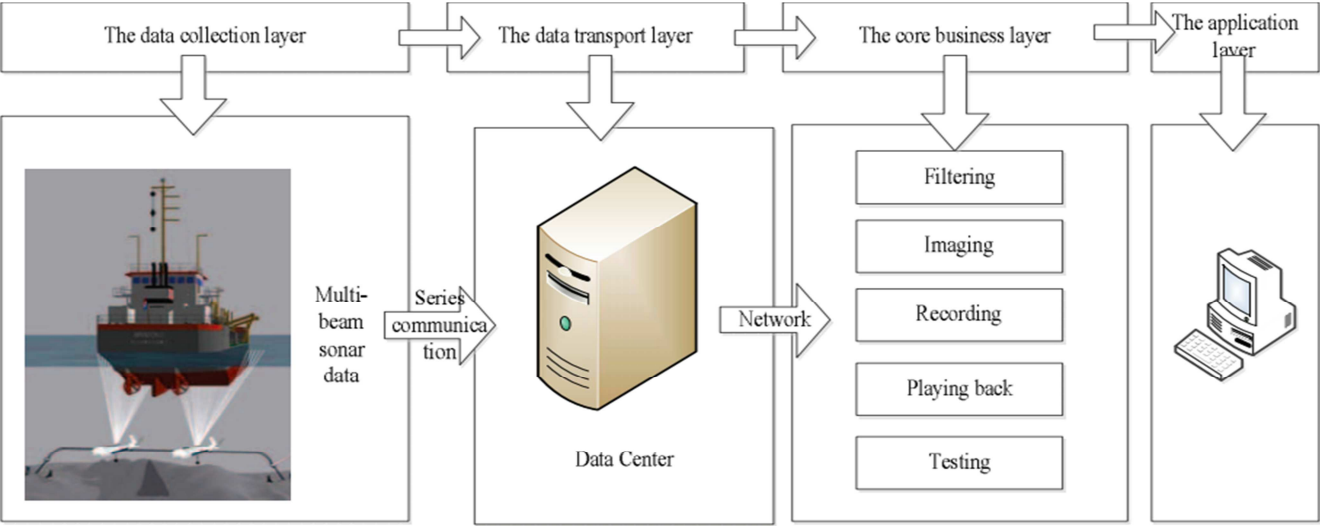


Figure 12. The design of ship draft observation [22].



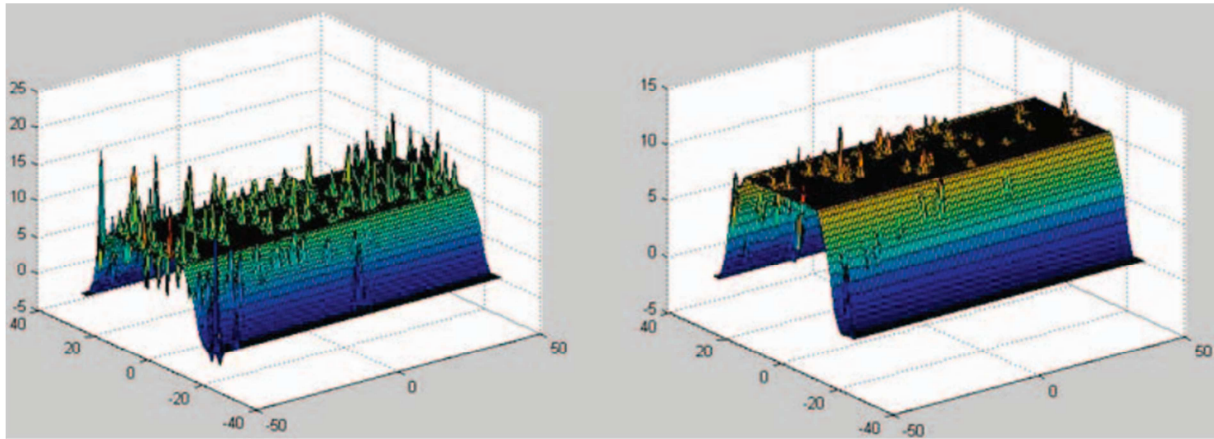


Figure 13. The design of sonar draft observation and the scanning model. [23].

2.8. Sonar Technology

The design based on sonar ultrasonic distance measurement, achieve the collection and real-time display of the ship underwater information, and achieve the relatively precise calculation and display of the underwater ship target distance information and draft value, the ship draft monitoring has a certain degree of feasibility, can reduce the number of ship stranding or aground incidents. [23]

Sonar technology is currently applied to detect the error of the basic in about 3-5 centimeters, for the accuracy of draft observation is not enough, while the ultrasonic pre-set in the channel is easy to be covered by river sand, the maintenance costs are high, ultrasonic is more suitable for active warning before passing the shallow point of the channel, to prevent the stranding accident happen.

2.9. Pressure Sensor Detection

This design adopted a novel dual-sensor detection method based on the traditional pressure sensor method to measure the ship's draft, in which two pressure sensors are distributed vertically up and down at a certain distance near the draft line on the side of the ship. This method mainly eliminates the errors caused by gravitational acceleration and water density

to ensure that the nonlinear error is 0.07%~0.08% and the accuracy of draught detection is optimized to 2 cm, but the pressure sensors need to be installed on the hull and exposed to the external environment, which inevitably causes damage to the equipment and high maintenance cost. Every ship needs to install such equipment, which causes excessive cost.

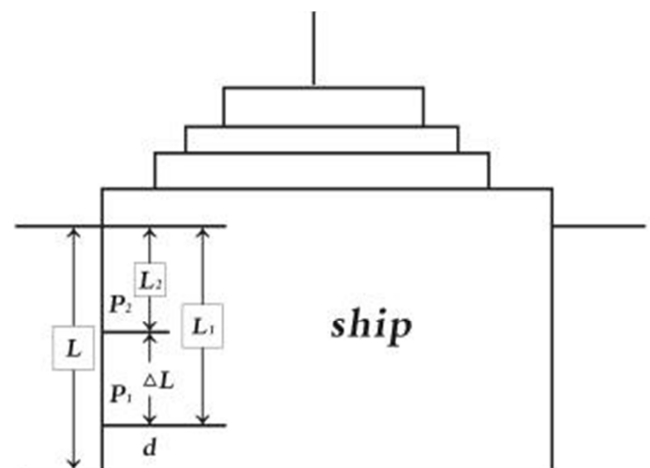


Figure 14. The design of sonar draft observation and the scanning model [24].

3. Design Performance Reviews

Research scope	Different methods	Visual observation	Image	RADAR	Pressure sensor	Robot	Ultrasonic	E-ruler
Draft observation	calm water detection accurate	good	good	medium	medium	good	medium	poor
	big wave and swell detection accurate	good	N/A	medium	N/A	medium	poor	poor
	ice water detection ability	good	N/A	N/A	N/A	N/A	N/A	poor
	night vision	medium	medium	medium	medium	medium	fair	poor
	human resource	medium	good	medium	good	good	good	medium
	maintenance cost	good	medium	poor	medium	poor	poor	medium

Figure 15. Design Performance Reviews.



Figure 16. Ship draft observation the different situation (night, calm water; icing water; big wave and swell).

Through the systematically analysis at present in the bulk carrier's draft observation, professional human visual inspection is still the relatively preferred solution, because its core value can complete the draft in the complex situation (night, sea ice, big swell and obstacles obscured) [25]. Human visual observation can accurately complete the draft observation in still water scenario. At the present the human visual can complete the observation at the seaside of the ship with the help of auxiliary equipment such as brackets which can reduce the intensity of personnel operations [26].

Neural network image recognition is currently the most likely future technology which can replace the traditional human visual inspection, especially image recognition combined with UVA artificial intelligence observation method may totally replace human visual inspection in the future. A set of UVA artificial intelligence observation equipment can finish multiple ships to detect, rather than fixed in the ship to increase the installation cost of equipment and the maintenance cost. While image recognition can automatically record the observed environment, data, reduce the human resource. [27, 28].

In the future, after the development of image recognition technology, will gradually replace the traditional human visual inspection technology. The advantage of fiber optical is that seawater enters the measurement tube, which can reduce the range of seawater fluctuation in the case of large wind and waves. The disadvantage is that it requires a

certain installation and maintenance cost. Sonar technology can play an important role for the safe navigation in the ship channel without requiring precise measurement accuracy, such as early warning of ships passing through shallow points.

Other technologies under the comprehensive consideration of accurate, maintenance cost, and complex environment are not suitable to complete the draft observation.

4. Summary and Prospect

Systematically review the draft observation research, the current research direction only focus on calm winds and waves test result, the accuracy can reach the human eye, but research direction lack of the ability to complete in the complex situation. The reason is the researchers lack the practical working experience such as stimulate the ship berths at an open quay, the actual height of the swell sometimes may exceed 50cm, and high latitude areas in winter sea surface with icing; the ship's draft would be blocked by the obstacle, so that the application of artificial intelligence cannot fully complete the observation in the different situation at the present.

Although many articles point out various problems of human visual observation, but most articles in the observations error data comparison are based on human visual observation, indicating the measurement basis is based on

artificial observation, the subsequent test should be in the water flow laboratory simulation of natural waves for data testing will be more accurate. At the same time, it is needed to remain that artificial intelligence-aided testing has the possibility of being tampered, it is a potential risk for the ship, the subsequent application of the process should consider being under the supervision of the administrative authorities. Shore figure calculation can be more accuracy than visual observation, but it cannot solve how the ship party supervises the real weight situation of the goods and cannot calculate the loss in the process of transportation, as well as the weighing time is too long, time-consuming.

The draft observation needs to complete reading in the complex environment (night, icing, big wave, obstacle) and ensure the observation accuracy, this paper draft observation systematically review all the popular methods, aims to solve the problem of accurate observation of the bulk carrier [29], explore more accurate draft observation method, in order to meet the trend of the ship maximization and global economic integration, solve the disputes in the area of maritime insurance and inspection.

From the current international common implementation standards and application compatibility in the complex situation, traditional visual inspection method is irreplaceable near soon, the traditional visual inspection combined with image recognition to solve the complex problems of various scenarios is the direction near soon, and the future manual visual inspection will be totally replaced by the UVA with image recognition.

References

- [1] Ni, Xy (2020). Energy conservation A review of the accuracy of ship draft observation for international dry bulk carriers via vessel speed reduction, *Ocean engineering*. 59. 710-715. DOI 10.1016/j.enpol.2013.04.025.
- [2] Jiang Li. (2016). Research on Application of Draft Survey. *China Port Science and Technology*.
- [3] BAOTia n-tian. 2020. Research view of shipping management. *Journal of Traffic and Transportation Engineering*. 2020 (20). 1671-1637(2020)04-0055-1.
- [4] Sun tuna, 2011, Advances in draft survey factor and it's optimization methods in China, *journal of inspection and quarantine*. 2011 (21) Van Eck, NJ. (2017). Citation-based clustering of publications using CitNet Explorer and VOSviewer. *SCIENTOMETRICS*. 11 (2). 1053-1070 DOI. 10.1007/s11192-017-2300-7.
- [5] GUO Guang zheng. 2011. Accurate Measurement Techniques and Discussion about Draft. *Journal of Qingdao Ocean Shipping Mariners College*. 2011 (32).
- [6] The International Convention on Load Lines, 1966; LL1966, IMO.
- [7] Rules for the Weight Survey of Import and Export Commodities-Weight by Draft (SN/T 0187-93).
- [8] Wei Zhan. 2021. The System Research and Implementation for Autorecognition of the Ship Draft via the UAV. *International Journal of Antennas and Propagation Volume* 2021, Article ID 4617242, 11 pages doi. org/10.1155/2021/4617242.
- [9] Hongxiang. He. 2021. Design of Simple Auxiliary Equipment for Ship Draft Observation. *Ship Standardization and Quality*. 2021 (1). 24-25.
- [10] Takahiro Tsujii. 2022. "Automatic draft reading based on image processing," *Opt. Eng.* 55 (10), 104104 (2016), doi: 10.1117/1.OE.55.10.104104.
- [11] Zhang, G., & Li, J. (2020). Search on recognition method of ship water gauge reading based on improved unet network. *Journal of Optoelectronics Laser*, 31 (11), 1182-1196.
- [12] Wang, B. P., Liu, Z. M., & Wang, H. R. (2021). Computer vision with deep learning for ship draft reading [Article]. *Optical Engineering*, 60 (2), 10, Article 024105. https://doi.org/10.1117/1
- [13] Weihao Li. 2022. Research and Application of U2-NetP Network Incorporating Coordinate Attention for Ship Draft Reading in Complex Situations. *Journal of Signal Processing Systems*. doi.org/10.1007/s11265-022-01816-w.
- [14] Wang lei. 2020. Research on water level recognition method based on deep learning algorithms. *Water resource information*. 2020 (3) DOI: 10.19364/j.1674-9405.2020.03.009.
- [15] Xin Ran. 2011. Draft Line Detection Based on Image Processing for Ship Draft Survey. *Proc. of the 2011 2nd International Congress CACS, AISC 145*, pp. 39-44.
- [16] SHEN Yijun. 2017. Application of ranging technique of radar level meter for draft survey. *Chinese journal of ship research*. 2017 (6). DOI: 10.3969/j.issn.1673-3185.2017.06.020.
- [17] Sivaraman, S. 1990. Field tests prove radar tank gauge accuracy. *Oil and Gas Journal*, Volume 88, Issue 17, Pages 89-90, Apr 23 1990.
- [18] ZHU Jing-lin. 2018. Analysis of Draft Survey Errors on Error Propagation Principle. *JOURNAL OF GUANGZHOU MARITIME UNIVERSITY*. 2018 (26).
- [19] RENATO IVČE, Ph.D. 2011. Determining Weight of Cargo Onboard Ship by Means of Optical Fiber Technology Draft Reading Promat – Traffic Transportation, Vol. 23, 2011.
- [20] CHEN Wenwei. 2013. A New Measurement System of Ship Draft. *SHIPBUILDING OF CHINA*. 2013 (54).
- [21] Cui, S.; Pei, X.; Song, H.; Dai, P. Design and Motion Analysis of a Magnetic Climbing Robot Applied to Ship Shell Plate. *Machines* 2022, 10, 632. doi.10.3390/machines10080632.
- [22] Ma Xiaobo. 2016 Design of a Ship Draft Measuring ruler. *Ship ocean engineering*. 2026. vol45-3.
- [23] Li Xinli. 2015 Research on Data Processing Method of Detection for Dynamic Ship Draft Based on Multi-beam Sonar System. *The 3rd International Conference on Transportation Information and Safety*. June 25 – June 28, 2015, Wuhan, P. R. China.
- [24] SUN Guo-yuan. 2002. Study on Automatic Determining Ship's Draft and Stability Parameters. 2002 (2). *NAVIGATION OF CHINA*. 1000-4653(2002)02-0028-03.

- [25] D. A. ROTHROCK. 2007. The Accuracy of Sea Ice Drafts Measured from U.S. Navy Submarines. JOURNAL OF ATMOSPHERIC AND OCEANIC TECHNOLOGY. VOLUME 24. DOI: 10.1175/JTECH2097.1.
- [26] Zhong Wang. 2020. A Ship Draft Line Detection Method Based on Image Processing and Deep Learning. Journal of Physics: Conference Series. 1575. (2020) 012230 doi: 10.1088/1742-6596/1575/1/012230.
- [27] Xing Wang. 2020. On Research of Video Stream Detection Algorithm for Ship Waterline. 2020 International Conference on Big Data, Artificial Intelligence and Internet of Things Engineering (ICBAIE). DOI 10.1109/ICBAIE49996.2020.00050.
- [28] LV Yongxiang, 2017. Status and Analysis of Ship Ultra-draft Detection Technology. Transportation Science & Technology. 2017. (5). DOI 10.3963/j.issn.1671-7570.2017.05.039.
- [29] China ship owner mutual insurance association 2022. NO525. lost prevention information.