Design of Autonomous Obstacle Avoidance Unmanned Boat System for Wetland Monitoring

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Abstract. In view of the drastic reduction of wetland area, serious pollution, low efficiency of prior art and many factors, this paper proposes an autonomous obstacle avoidance unmanned boat system design for wetland monitoring. The system adopts D* algorithm and improved LOS guidance law to realize unmanned ship track control and global path planning, and combines Yolov3 algorithm for target recognition and partial data acquisition during navigation to achieve autonomous obstacle avoidance navigation. The sensor is used to collect the wetland environment information and upload it to the shore monitoring centre to complete the automatic data collection and monitoring of the wetland. The system can improve the efficiency and quality of wetland monitoring, reduce labor costs, and can be widely used in wetland monitoring automation, marine environment monitoring, and cloud service platforms.

1. Introduction
In recent years, with the environmental pollution, land development and climate change and other factors, the wetland area has decreased sharply [1]. As wetland is home to many animals and plants, the pollution and area of wetlands are reduced, which will inevitably lead to the reduction or even extinction of many animals. The wetland area is vast and the environment is complex. It is difficult to monitor traditional manpower alone, the process is cumbersome and inefficient, and in the process of wetland monitoring, the monitoring cost and efficiency between different monitoring methods vary greatly, and should be based on actual monitoring indicators. Choose a different monitoring method. Remote sensing technologies that are currently used more often are susceptible to weather and can result in inaccurate or completely obscured images. With the informatization, the arrival of the intelligent era, and the development of unmanned boats [2] are also at the peak of development. In this paper, an unmanned boat system that can achieve autonomous obstacle avoidance is used for wetland detection.

In this paper, the D*[3] algorithm is used to globally plan the wetland monitoring area, and the improved LOS (Line-of-Sight) guidance law [4] is used for track control, so that the unmanned boat can sample the wetland area according to the specified route. Monitoring, real-time monitoring of regional environmental information, combined with the advanced YOLO (You Only Look Once) v3 algorithm [5] for short-term obstacle recognition of the current unmanned boat patrol area, assisting unmanned boats for accurate path planning and autonomy Obstacle avoidance [6-7]. During the voyage, the UWB (Ultra-Wideband) positioning system can be used to monitor the unmanned boat path in real time and track
tracking. At the same time, during the whole voyage of the wetland waters, the unmanned boat will pass the temperature and humidity carried. Wetland environment monitoring sensors such as cameras constantly adjust the real-time trajectory and collect the wetland environment information, and upload it to the shore-based system in real time through the communication system [8] for information integration and processing, and finally complete the monitoring of the wetland environment. This paper can be used to help wetland monitoring improve monitoring efficiency and quality, and reduce labor intensity and labour costs.

2. Design of autonomous obstacle avoidance unmanned boat system for wetland monitoring

The system described in this paper is mainly divided into path planning navigation module, wetland information collection monitoring module and shore monitoring centre. The system combines the known environmental information and the location and topography of the wetland, uses the D* algorithm to plan the initial global path of the unmanned boat, and then uses the LOS guidance law to control the unmanned ship’s track to ensure that the unmanned boat deviates from the original track. After that, they can quickly return to the right track. At the same time, in the face of obstacles that may be faced during the voyage, such as birds, aquatic animals, aquatic plants, etc., real-time monitoring is carried out using the monitoring equipment carried on the bow, and the target is identified and classified by the YOLOV3 algorithm. Guide the unmanned boat to take obstacle avoidance measures for different kinds of obstacles. During the voyage, the unmanned boat will use its temperature, humidity, camera, pH and other sensors for wetland monitoring and water body collection, and use ARM (Advanced RISC Machine) embedded system and unlimited communication system to transmit it. Displayed to the shore monitoring centre, so that the staff can carry out the next monitoring process. In addition, while monitoring the wetland environment, the shore monitoring centre can also monitor the operation of the unmanned boat and remotely control if necessary, to facilitate the normal operation of the unmanned boat and accurate data collection. The specific flow chart is shown in figure 1 below.

Figure 1. System solution flow chart
3. System specific module design

3.1 Path planning navigation module

The path planning navigation module described in this paper adopts the D* algorithm to improve the LOS guidance law and the YOLOv3 algorithm for the autonomous navigation avoidance of unmanned boats. Firstly, the ARM embedded system equipped with the hardware of the unmanned boat system is used to obtain the geographical environment information of the wetland area to be detected captured by the satellite, including the global environment information of the location, shape, connectivity and obstacles in the wetland. After processing, the D* algorithm is used for global path planning to plan an optimized wetland monitoring path for the unmanned boat, and the unmanned boat can sail along the shortest path as much as possible, thereby independently and safely and energy-saving performing the wetland monitoring function. By comparing the deviation between the actual navigation trajectory and the planned path, the background uses the improved LOS guidance law algorithm to perform the corresponding path adjustment in real time and delivers the adjustment command to the unmanned boat. The unmanned boat is mounted on the camera during the navigation process. The YOLOv3 algorithm monitors and identifies obstacles on the water surface in real time, transmits relevant data to the background calculation, and performs path planning modification according to the type of obstacles to compensate for the deviation of the unmanned boat from the planned path. The autonomous navigation of the unmanned boat can be realized, and the wetland information can be collected in a timely and accurate manner according to the planned route.

In this paper, two maps are used for unmanned boat path planning, which are stable map and temporary map respectively. The specific implementation steps are as follows:

i. Grid encryption of known obstacle areas according to a stable map to accurately determine the position information of the obstacle.

ii. Establish a node matrix and an adjacent node connectivity matrix of the cryptographic grid, and update the connectivity between the nodes according to the more accurate obstacle information.

iii. Find the starting and ending points of the original path at the edge of this obstacle area.

iv. Using the Dijkstra algorithm for this obstacle region, the target node G is searched for the starting node, and the shortest path from the target point to each node in the road network and the actual value h of the position to the target point are stored.

v. The unmanned boat starts to move along the shortest path. When there is no change in the next node of the movement, no calculation is needed. The shortest path information calculated by the Dijkstra algorithm in the previous step can be traced back from the starting point.

vi. When the current position node Y detects that the state of the next node X has changed, that is, when a new obstacle is detected, the YOLOv3 algorithm is used to identify new obstacles and then classify them, which can be classified into fixed obstacles and movement obstacles. Things and short-term obstacles.

vii. According to the type of obstacle, the unmanned boat corrects its actual value h at the current position to the target node G and stores the affected points in the corresponding map. Traversing the child nodes of Y, continuously calculating the optimal path to the target node G until the minimum value k before and after the h change is greater than or equal to h, at which time the new path is constructed.

Among them, fixed obstacles mainly refer to wetland plants and all non-moving and long-term obstacles that may occur in specific environments; moving obstacles mainly refer to man-made garbage and other obstacles that can move with water flow; short-term obstacles mainly refer to wetland animals. Wait for a short stay, but not a negligible obstacle. When the identified obstacle belongs to a short-term obstacle and a moving obstacle, the related information is only updated in the temporary map, and the information of the fixed obstacle needs to be updated to both maps at the same time.

3.2 Wetland information collection and monitoring module

When the unmanned boat is sailing in the wetland waters, the unmanned boat will continuously collect environmental information such as the temperature, humidity, sulphur dioxide content, water quality
and pH value of the wetland through the wet environment monitoring sensors such as the temperature and humidity and pH detection modules mounted thereon, and the video information and water conditions captured by the camera are transmitted to the shore monitoring centre in real time through the wireless communication module. After receiving the information on the wetland environment returned by the unmanned boat, the shore monitoring centre will integrate the information and store the information. After the unmanned boat completes the entire wetland environment testing process, the shore monitoring centre can obtain the overall environmental information of the wetland. In the later stage, the researchers will conduct research and analysis on the data.

3.3 Shore monitoring center
The shore monitoring centre is mainly used to receive the navigation information from the unmanned boat subsystem in real time, and displays the position of the unmanned boat on the monitoring interface. The shore monitoring centre is mainly composed of two parts: the wetland environment information monitoring display and the unmanned boat track monitoring. Wetland environmental information monitoring displays the wetland environment information of the sample points in real time and saves them in the background for post processing. At the same time, the unmanned boat track monitoring interface displays the unmanned ship track in real time, and uses the UWB wireless positioning device on the unmanned boat to monitor the position information and the heading information of the unmanned boat in real time, and send the position information and the direction information. To the ARM embedded system. By feeding back to the shore monitoring centre through the wireless communication system, the unmanned boat monitoring interface can clearly see the position information of the unmanned boat and the actual navigation trajectory. At the same time, it can also be displayed on the UWB positioning system's own interface, which is convenient for taking measures in case of accidents or manual operations of unmanned boats. As shown in figure 2 below.

Figure 2. Schematic diagram of rectangular path monitoring of UWB positioning system

4. System experiment analysis

4.1 Experimental environment configuration
The traditional wetland field observation is the artificial sampling observation of fixed-point timing, but with the development of science and technology, the traditional ground monitoring method cannot meet the requirements of modernization in terms of data accuracy and timeliness. Therefore, real-time moving unmanned boats can collect more sample points in a larger density and range, which is very efficient in space and time compared to traditional observation methods. The experimental environment configuration of this paper is shown in figure 3. The network parameters are configured as follows: the momentum is 0.9, the weight attenuation is 0.0005, the number of iterations is 50 000, the learning rate uses a step-by-step strategy, the initial value is set to 0.001, the number of changes is 30 000 and 40 000, and the ratios are 0.1 and 0.1.
Figure 3. Experimental configuration diagram

4.2 Quantitative evaluation index analysis
In order to verify the validity and accuracy of the detection, this paper selects the accuracy rate $P_r$ (Precision), recall rate $R_e$ (Recall) and harmonic mean $F_1$ (F-measure) and the detection time to quantitatively evaluate the recognition results of obstacles in the face of water. And the average accuracy mean $mAP$ (mean Average Precision), and the number of frames per second $FPS$ (frames per second) are selected as the evaluation indicators of the moving target detection model.

Its calculation formula is as follows:

$$P_r = \frac{TP}{TP + FP} \quad (1)$$

$$R_e = \frac{TP}{TP + TN}$$

$$F_1 = \frac{2TP}{2TP + FP + TN}$$

Take the temporary obstacles of wetlands studied in this paper as an example, where $TP$ refers to the number of obstacles detected correctly, $FP$ refers to the number of obstacles that identify errors, and $TN$ refers to the number of obstacles detected by omissions. With the recall rate of the target obstacle as the abscissa and the accuracy of the target obstacle as the ordinate, a P-R curve is finally drawn. The area under the curve is $AP$ (Average Precision). For each obstacle, the final average value of the $AP$ is obtained as $mAP$.

In addition, for global path planning, this paper uses mobotsim (Mobile Robot Simulator) simulation model platform to carry out simulation experiments to verify the effectiveness of the applied algorithm. A number of experiments have been carried out, and the results show that the proposed algorithm can successfully escape the obstacle area and reach the end point with the shortest path. The result is shown in figure 4 below.

Figure 4. Simulation experiment result chart

4.3 Qualitative evaluation index analysis
In order to verify the robustness and accuracy of the global planning and autonomous obstacle avoidance algorithms in this paper, through the sensors and global planning algorithms carried on the ship, temporary obstacles such as birds are thrown in the pools where the established navigation area has been set. Class model, small trunk, etc., ship inspection experiments on the ship's autonomous obstacle avoidance in the ship pool. The ship conducts autonomous navigation under the established route. During the process, due to the obstruction of temporary obstacles, it accurately identifies and bypasses
the obstacles, returns to the established line, and collects information about the water body. The experimental results are in line with the expected effect. The result of the implementation is shown in figure 5 below.

Figure 5. Experimental result chart

5. Conclusion
This paper proposes a design scheme for autonomous obstacle avoidance unmanned boat system that can be used for wetland monitoring. It completes the system global path planning, local path adjustment, wetland monitoring information collection and target identification scheme design, and carries out simulation experiments in the ship pool, achieved good experimental results.

Due to the time, the number of monitoring sensors and the limitations of the target identification samples, this paper only carried out partial experiments in the ship pool. In the follow-up study, the field monitoring experiments in the wetlands will be completed and the monitoring indicators will be improved.

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References
[1] Barbro Ulén, Pia Geranmayeh, Maria Blomberg, Magdalena Bieroza. Seasonal variation in nutrient retention in a free water surface constructed wetland monitored with flow-proportional sampling and optical sensors [J]. Ecological Engineering, 2019, 139.
[2] Liu Qunming, Lan Yufei, Shi Yinggang. Design of water control unmanned boat control system [J]. Wireless Internet Technology, 2019, 16 (15): 65-66.
[3] Philani Biyela, Randhir Rawatlal. Development of an optimal state transition graph for trajectory optimisation of dynamic systems by application of Dijkstra's algorithm [J]. Computers and Chemical Engineering, 2019, 125.018, 59 (01): 207-215.
[4] Chen Jun, Feng Hui, Xu Haixiang, Yu Wenzhao. Variable speed tracking control based on LOS for dynamic positioning of ships[J]. Journal of Wuhan University of Technology (Transportation Science and Engineering), 2018, 42(04): 642-646.
[5] Peng Linyi. Design of obstacle recognition system based on convolutional neural network [D]. Guizhou University, 2019.
[6] Luo Wei. Research and implementation of autonomous cruise on unmanned surface water surface [D], Jiangsu University of Science and Technology, 2018.
[7] FAN Yunsheng, SUN Xiaojie, WANG Guofeng, GUO Chen. An Autonomous Dynamic Collision Avoidance Tracking Control Method for Unmanned Surface Boats[J]. Journal of System Simulation, 2018, 30(10): 3781-3788.
[8] Zhong Weibo, Luo Wei, Lu Daohua, Feng Youbing, Huang Xianghong, Chen Chao. Design and implementation of unmanned boat communication navigation control system [J]. China Shipbuilding, 2018, 59 (01): 207-215.