Self Introduction

Software Engineering Lab

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1. Introduction

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Irrigation Ponds in Japan:

- Irrigation ponds are known as “tameike”, which are artificially created bodies of water designed to store and supply water for agricultural purposes.
- Many of these ponds were constructed in Japan when rice cultivation began, to ensure a reliable water source. [1].
- They also serve as measures for disaster prevention and provide habitats for various animals and plants.

Distribution of Irrigation Pond in Japan

The issues of the irrigation ponds in Japan:

- Due to labor shortages, maintenance of many irrigation ponds has become insufficient, leading to increased aging and abandonment.
- Aging ponds raise disaster risks, such as flooding and sediment outflow due to structural failure.

→ It is important to regularly monitor changes in storage capacity of ponds over time for decision-making regarding large-scale interventions.

[1] 兵庫県ホームページ. “ため池講座”. Jun 1, 2020. https://web.pref.hyogo.lg.jp/nk11/af08_000000031.html

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2. Previous research:

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Kaizu at all [2] developed a method for measuring the depth of irrigation ponds using an autonomously operated small boat.

Method:

1. Preparing a radio-controlled boat equipped with sonar
2. Setting up a route in Google Map and let it navigate automatically
3. Performing depth measurement while navigating automatically along the route
4. Creating a bottom map using 3D spline interpolation


radio-controlled boat


Route in Google Map

Image when navigating

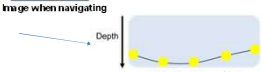

Image of spline interpolation

[2]Kaizu,Y .et al. (2020). Development and Verification of Simple Depth-Sounding Methods for Agricultural Reservoirs by Using Small Sonar and Boat Controlled by Autopilot System. IDRE Journal No. 311 (88-2), pp. Ⅳ_17-Ⅳ_19 .

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Problems in previous research

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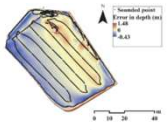
Problems:

Because the boat route is planed with Google Maps, but the location of the shoreline varies. This causes the following two problems.

Case 1: Actual shore location closer than expected.
⇒ The boat may run aground.

Case 2: Actual shore location is farther than expected.
⇒ Insufficient data collection leads to non-negligible errors in estimating water storage.


Blue : Shallower than actual
Red : Deeper than actual

Solution

Automatic correction of boat path by determining shoreline and measuring distance to reduce depth error

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3. Our research approach and objective

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To solve problems in the previous research:

- We proposes and evaluates a system that dynamically adjusts the route of an autonomous boat for depth measurement.
- The system determines the boundary between the shoreline and the water surface and measures the distance to this boundary using sensor data while the boat is in motion.
- The objective is to establish a safe and efficient depth measurement route for automated boats.

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4. Proposed system: Structure of the Prototype Boat

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Boat of previous studies:

Boat developed this time:

Changes or additions:

1. Propulsion system changed from thrusters to ducted fans
2. Hull changed from hull kit to body board.
3. Waterproof case used for placement of electronic equipment.
4. Camera installed in the front of the boat.

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4. Proposed system: Functional Configuration

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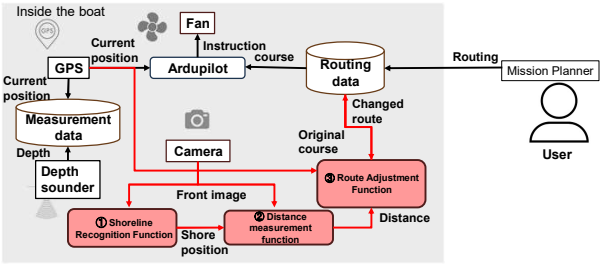

Three functions were incorporated to realize shore recognition and modification of the navigation route.

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Shoreline Recognition Function

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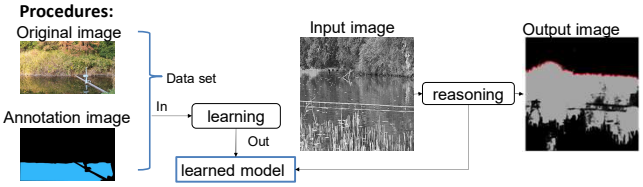
Method:

To determine the image position of the shoreline, a machine learning technique known as semantic segmentation [3] is utilized. This method has the advantage of being applicable even with low-resolution images from inexpensive camera modules.

Procedures:



[3] Mukai,K., Hara,N., and Konishi,K. (2021). "A Study on Obstacle Detection from Monocular Camera Images by Semantic Segmentation in a Small Unmanned Vessel. Transactions of the Institute of Systems, Control and Information Engineers", Vol. 34, No. 12, pp. 319-321.

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Distance measurement function

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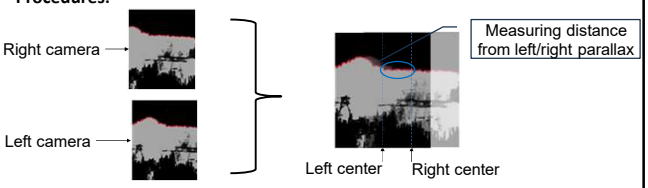
Method:

The distance to the shoreline is measured using the stereo matching method [4], which can be calculated with the same camera.

Procedures:



[4] Takase,R., Nishi,T., Yoshimi,Y., and Kawai,Y., (2015). "Stereo matching based on pixel-wise global tree". IPSJ Research Report. Vol. 2015-CVIM-197.

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Route Adjustment Function

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Method:

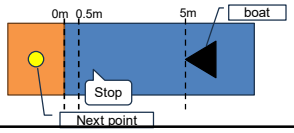
The timing for route modification is determined based on the operational constraints of the boat.

Operational constrains on boat:

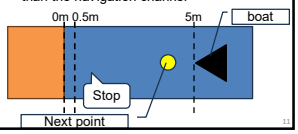
- Boat will auto-navigate at up to 0.5 m/s
- The distance from the boat's maximum speed to a safe stop is 5 m
- Safety margin shall be 0.5m

Determination of timing of route changes:

If the actual shore position is closer than the navigation channel



If the actual shore position is farther than the navigation channel



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5. Experiments

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The three functions were evaluated individually. This is because:

- To understand the accuracy of each function and identify issues when combined and operated
- To identify technical issues and modifications within each function

Points for verification of individual function experiments:

- Shore Recognition Function:
  Can the shape of the shore be recognized?
- Distance measurement function:
  Can the distance be measured accurately from a distance sufficient to change the course?
- Route adjustment function:
  Can the vessel navigate safely even if there is a problem with the set route?

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Experimental results of shore recognition function

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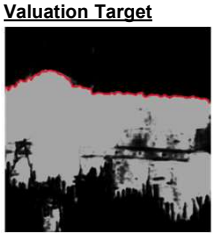
Assessment Results

result \ correct	Water surface	Not water surface
Water surface	12787607	1094730
Not water surface	1212901	35236408

Number of pixels

Accuracy	0.95415149
Precision	0.92114224
Recall	0.91336736
Specificity	0.969868
F1score	0.91723832

Valuation Target



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Experimental results of distance measurement function

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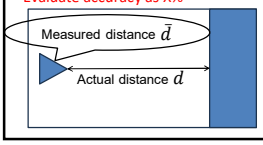
Evaluation Method

Divide the error between the measured distance and the correct distance by the correct distance

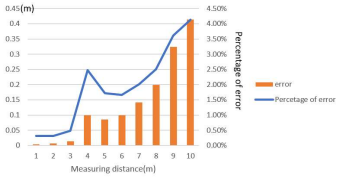
Calculation Formula: $\mathrm{E} = |d - \bar{d}|$

$$X = \frac{E}{d}$$

Evaluate accuracy as X%



Assessment Results



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Experimental results of route adjustment function

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Figure 1 Planned and navigated routes

What worked well ：

25 close approaches to shore and 22 reroutes.

issue ：

・Caught in an underwater obstacle (Figure 2)

・Misrecognition of shoreline position by the shoreline recognition function

Figure 2 Underwater obstacles

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6. Conclusion

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- We proposed and evaluated an inexpensive and accurate system for determining the boundary between the shore and the water surface, measuring the distance to this boundary, and dynamically adjusting the navigation route.
- We developed:
  - An experimental boat.
  - Implementation of three functions: shore recognition, distance measurement, and rout adjustment.

➢ The results of the experiments, the accuracy of each function was verified and found to work well enough to change the route to ensure safety and accuracy.

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