Estimation of Mass Characteristics for a Rainbow Trout Based on Individual Linear Sizes in Underwater Video Surveillance System

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***Abstract*—Accurate estimation of mass characteristics is crucial for understanding the growth and health of fish populations. This study focuses on the estimation of mass characteristics for rainbow trout using individual linear sizes measurements obtained from an underwater video surveillance system. The proposed methodology leverages computer vision techniques to extract fish length, height and other linear sizes between fins from video footage. Subsequently, a mass estimation model is developed based on the relationship between fish linear sizes and mass derived from a representative sample of fish weighed individually. We constructed a dataset for 356 individual fish with approximately 50 thousand samples. The system's performance is evaluated through experiments conducted in a controlled underwater environment, and the results demonstrate a high degree of accuracy (approximately 91%) in estimating the mass characteristics of rainbow trout based on their linear size. Used model is Histogram-based Gradient Boosting Regression Tree. The results are good, but there are still a number of improvements to be made.**

I. Introduction

Accurate measurement of fish mass is of utmost importance for various applications, including fisheries management, aquaculture, and ecological studies. The mass of a fish provides valuable insights into its growth rate, nutritional status, feed efficiency, life conditions, and overall health. Traditionally, obtaining accurate mass measurements has been a labor-intensive process, requiring the capture and weighing of individual fish. However, recent advancements in computer technology have opened up new possibilities for non-invasive and efficient mass estimation techniques.

In this context, the FishGrow Platform has emerged as a comprehensive system for monitoring and managing fish populations in aquaculture settings. The platform integrates various technologies, including underwater video surveillance systems, computer vision, and advanced data analytics, to provide a holistic approach to fish growth analysis. A crucial component of this platform is the accurate estimation of fish mass based on their individual linear size measurements, obtained from the underwater video surveillance system.

The implementation of a reliable mass estimation method within the FishGrow Platform offers significant advantages for fish farmers and researchers. It allows for continuous monitoring of fish populations without the need for manual handling and weighing, thereby reducing stress and potential harm to the fish. Moreover, the system can provide real-time data on fish growth rates, enabling timely adjustments to feeding regimes, disease prevention strategies, and overall management practices.

This paper presents the details of the developed method for estimating the mass characteristics of rainbow trout based on their individual linear size measurements captured by the underwater video surveillance system integrated into the FishGrow Platform. By leveraging computer vision techniques, the system automatically extracts length, height and other linear sizes information from video footage and establishes a relationship between fish linear sizes and mass. The accuracy of the method is evaluated through experiments conducted in a controlled underwater environment, comparing the estimated mass with the actual measured values of a representative sample of rainbow trout.

The rest of this paper is organized as follows. In section II, we will talk about various characteristics of fish, their application in solving practical problems, and also mention the conditions for our task. In section III, we will talk about the sequence of application of various methods to obtain individual characteristics of fish used to estimate the mass. in section IV, we will talk about our method of obtaining individual characteristics of fish and mass estimation: the methods used from section III are selected with the calculation of meeting the conditions of our task specified in section II. In section V, we will talk about early experiments to estimate the mass of individual rainbow trout and the metrics used to assess accuracy. In section VI we will tell you about the accuracy obtained on the test dataset and about further plans to improve the result.

II. Videoanalytics of Individual Fish Characteristics

Video analytics in the field of fish analysis encompasses a wide range of practical tasks that can be accomplished using computer vision techniques. These tasks include the measurement of linear dimensions, such as length and height, the calculation of fish velocity through multiple video frames, and the identification of various behavioral characteristics,

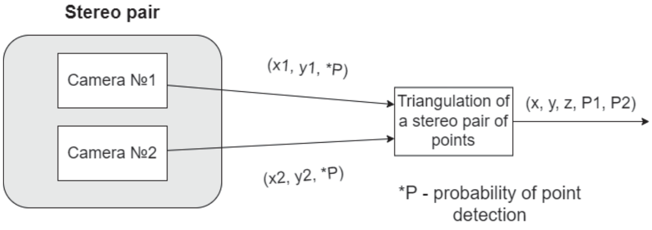

Fig. 1. Stereo pair and getting 3D-coordinates scheme

such as signs of fish diseases (e.g., fish swimming upside down)

In addition to the specific tasks mentioned above, video analytics can offer further insights into individual fish characteristics. For example, it can be used to determine swimming patterns, activity levels, feeding behavior, and interactions among fish within a population. By analyzing video data, researchers and fish farmers can gain a comprehensive understanding of fish behavior, health, and overall population dynamics.

In the context of the FishGrow Platform, the my specific task at hand is the estimation of fish mass in underwater video surveillance system. It includes the next conditions:

1) Model for mass estimation should work fast;
2) Using stereo pair that is included in underwater video surveillance system;
3) Fish key points (Fig.1) detection in two synchronous images(Fig.2) from stereo pair;
4) Calculation three-dimensional key points using relevant detected key points from two synchronous images and the algorithm of triangulation of a stereo pair of points (Fig.1);
5) And as a result using linear sizes between each three-dimensional key points for individual fish mass estimation.

III. Methods for Fish Mass Estimation Based on Computer Vision Algorithms

To obtain images in order to estimate the mass of fish, researchers usually use two approaches:

1) using a monocular camera;
2) using a binocular camera.

The first approach requires the use of various algorithms to obtain the correct individual sizes of fish. This is due to the fact that the fish can be both close-up in the image and located in the distance. The second approach makes it possible to obtain correct individual fish sizes using stereo vision algorithms.

Next, the researchers determine methods for extracting fish features:

1) Segmentation of the fish in the image;
2) Getting the key points of the fish.

And then the researchers determine the extractable characteristics to estimate the mass:

1) Perimeter

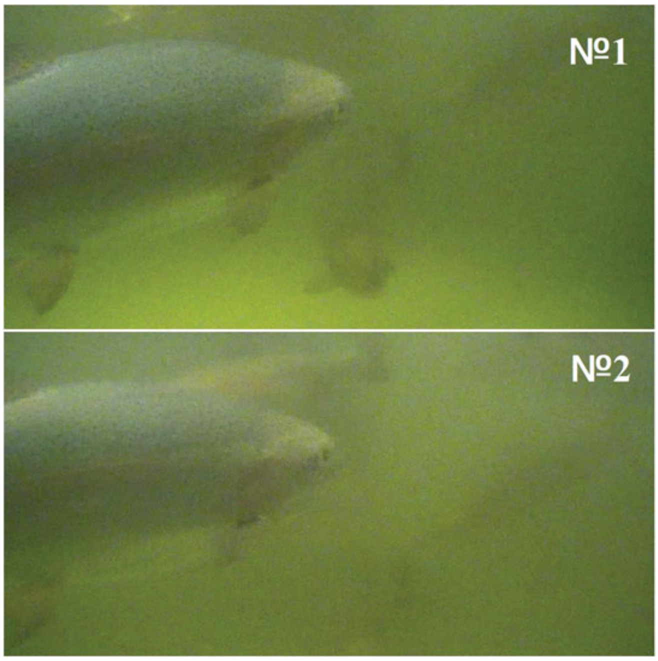

Fig. 2. Two synchronous images of fish form stereo pair

2) Area
3) Length

IV. Estimation of Mass Characteristics for a Rainbow Trout

A binocular camera (stereo pair) is used as the approach used to obtain it due to condition No. 1 described in Section II. Also, the use of key points instead of segmented fish is dictated by condition No. 2 from the same Section.

As the extracted individual characteristic of the fish, we used an alternative one: the set of linear sizes of the fish, calculated as the Euclidean distance between the three-dimensional coordinates of the key points. This decision is caused by conditions No.3 and No.4 of Section II.

We use the following solution:

1) Obtaining three-dimensional coordinates of eight key points of the fish (Fig.3) and the confidence probabilities of the point detection model in two images (Fig.2). As a result, each key point will have the following form: (x, y, z, P_1, P_2).
2) Calculation of the linear dimensions of the fish: The Euclidean distance between each pair of three-dimensional key points with the addition of four probabilities: $(x_i, y_i, z_i, P_{1i}, P_{2i}), (x_j, y_j, z_j, P_{1j}, P_{2j}); i, j \in [1, 8], i \neq j$. Distance has the following formula: $d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}$. The resulting linear size will have the following form: $(d_{ij}, P_{1i}, P_{2i}, P_{1j}, P_{2j})$. In total, such non-repeating combinations of pairs of key points are obtained: $C_8^2 = 28$. Each combination contains 5 values: $(d_{ij}, P_{1i}, P_{2i}, P_{1j}, P_{2j})$, so the resulting number of ex-

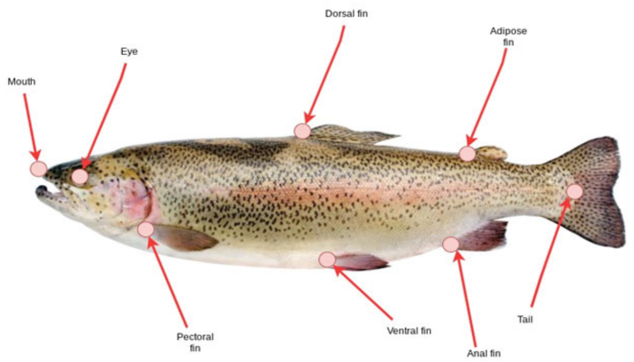

Fig. 3. 8 Rainbow Trout's key points: mouth, eye, dorsal fin, adipose fin, tail, anal fin, ventral fin, pectoral fin

tracted fish characteristics for mass estimation is $28*5 = 140$

3) The application of filtering using interquartile range (IQR) on the relationship between linear sizes: Fig.4 shows an intuitive diagram of the distribution of the ratio of the calculated lengths of fish to their heights in the images. From this diagram it can be seen that, on average, the length of the fish is about 3.5 times the height of the fish. However, there are clearly abnormal values that cannot be used for training and testing the model. If ratio of length to height is in range $[q_{10}, q_{90}]$, then sample is used in train or test datasets, otherwise not. Here q_{10} and q_{90} are called percentiles. But it is possible to filter not only in ratios of lengths to heights. As mentioned earlier, a fish with 8 key points has 28 linear sizes in total. The number of filtering ratios between all pairs of linear sizes will be: $C_{28}^2 = 378$. If at least one of the 378 ratios does not in the interquartile range, then sample will not be used for training and testing.
4) Application of automatic machine learning methods, presented in the form of the AutoSklearn library from Scikit-learn: as a result of fitting, a Histogram-based Gradient Boosting Regression Tree model was obtained.
5) Model accuracy assessment: 3 metrics were used to assess the accuracy of the model: one numerical and two visual
   - Average relative error over the entire sample;
   - Scatter plot for mass estimates;
   - Mass distribution histograms for one of the individual fish.

V. Early Experiments

For training and testing, a dataset consisting of 50,000 examples obtained using video recording of individual fish was used. A total of 356 fish were recorded, for each of the videos, approximately 140 frames with fully detected fish were obtained. Dataset collection was implemented using FishGrow Platform equipment. You can see the result of the

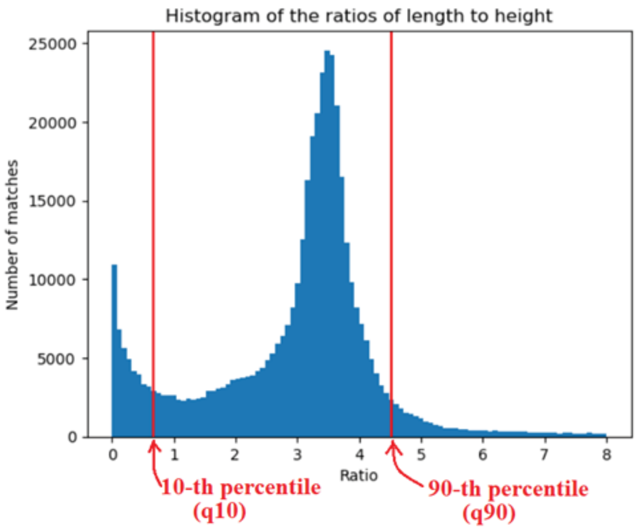

Fig. 4. Histogram of the ratios of lengths to heights for all 356 fish in dataset. If $ratio \in [q_{10}, q_{90}]$ then sample is used in train or test datasets

mass estimation in these images (Fig.5, Fig.6, Fig.7). Shall we analyze each of them:

1) The average relative error over the entire test dataset (the average along the orange line in Fig.5) it was 9.06%, so the total accuracy of the model is about 91%. However, this error is strongly influenced by small fish (¡300 grams). Due to the fact that the smaller the fish, the more each extra gram predicted by the model will affect the error.
2) On Fig.6 a scatter plot is depicted, where each point has the following form: $(expected\_weight, predicted\_weight)$. On the OY axis, for any x, you can observe a spread of values. We added a blue line to show how the points should ideally lie (i.e. when the predicted mass is equal to the expected one, it will lie on the blue line). You can just notice that for small fish, the predicted mass is quite close to the blue line, which indicates the accuracy of the prediction. However, for large fish, the spread of predictions is increased, which may be due to the fact that there are not enough large fish in the dataset ($>$ 1300 grams).
3) On Fig.7 a histogram of the distribution of mass predictions for a individual fish is shown. This histogram is useful for tracking anomalies in predictions for specific fish.

VI. Conclusion

In this study, we developed a method for estimating the mass characteristics of rainbow trout based on their individual linear size measurements obtained from an underwater video surveillance system. The proposed methodology leverages computer vision techniques, including key point detection and three-dimensional coordinate calculation, to extract fish linear

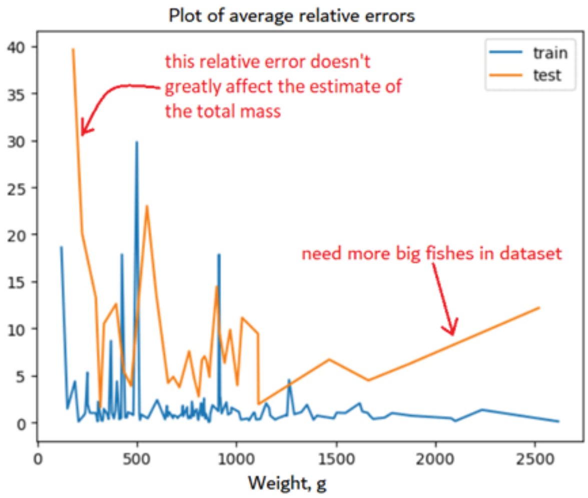

Fig. 5. Plot of average relative errors for each mass category

sizes from video footage. A representative sample of rainbow trout was weighed individually to establish the relationship between linear sizes and mass. The developed mass estimation model demonstrated a high degree of accuracy in estimating the mass characteristics of rainbow trout based on their linear size.

The experimental results showed that the developed method achieved an average relative error of 9.06% on the test dataset, indicating an overall accuracy of approximately 91%. The scatter plot analysis revealed a close correlation between predicted and expected fish mass, particularly for small fish, while larger fish exhibited slightly higher prediction variations. The mass distribution histogram provided insights into prediction anomalies for specific individual fish.

In the near future it is planned:

1) Evaluate a new experimental version of the model capable of estimating the mass for data with gaps (when not all key points are detected in the images);
2) Implement other assessments (MAE, RMSE and R2);
3) Increase the dataset by adding new video recordings of large fish ($>$ 1500 grams)

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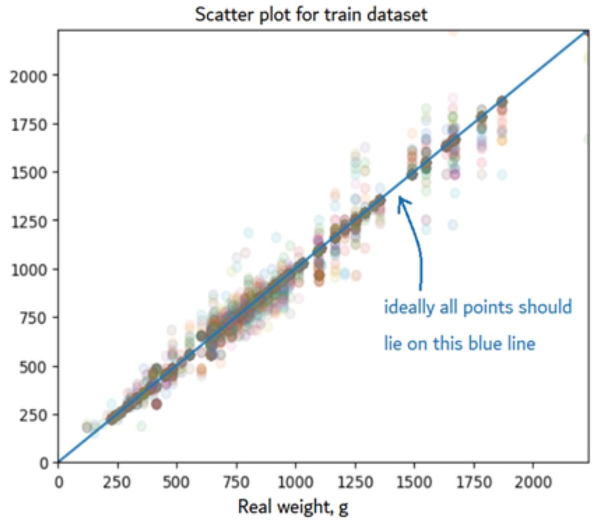

Fig. 6. Scatter plot for visual evaluation model accuracy on train dataset

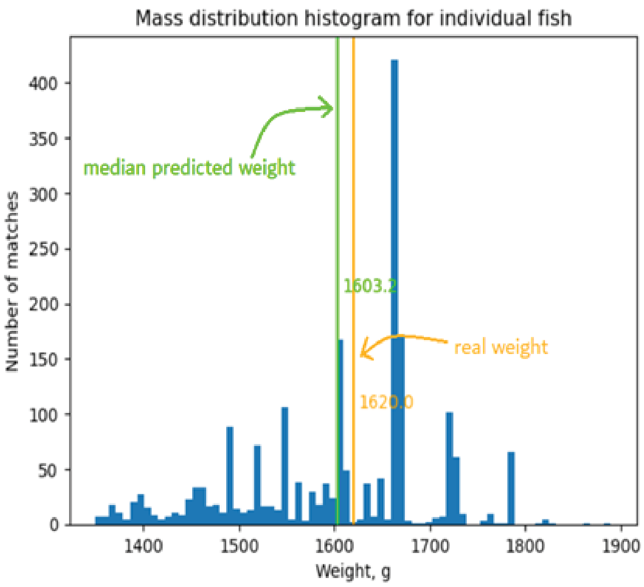

Fig. 7. Mass distribution histogram for one of the individual fish