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Automated within tank fish mass estimation using infrared reflection system

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A B S T R A C T

Fish size and mass information during different growth stages is important for precise feeding regime management, oxygen consumption calculations, antibiotic prescription and improving fish welfare, but also to facilitate decisions on grading, harvesting and time to harvest. The main purpose of this study was to develop an automatic system to estimate fish mass using fish dorsal geometrical features and machine learning algorithms such as random forest (RF) and support vector machine (SVM). To develop the model, Kinect as a RGB-D camera was used to acquire depth map and top view images of 295 farmed seabass (*Dicentrarchus labrax, L.*) of different sizes. Eight dorsal geometric features were extracted and used for model development. Ten-fold cross validation was used to optimize and validate the models. Comparison of models was made in term of the coefficient of determination (R_{cv}^2) and Root Mean Square Error of prediction (RMSEP) of cross validation. Both models exhibited significant prediction, however, SVM algorithm with R_{cv}^2 of 0.872 ($p < 0.01$) and RMSE of 0.13 gave a slightly better prediction of weight compared to RF with R_{cv}^2 of 0.868 ($p < 0.01$) and RMSE of 0.13 was the highest R^2. Subsequently, Infrared reflection system (IREF) which is composed of a NIR range camera with an external illuminator, was also used in this study to acquire 20 fish dorsal images inside the tank. Like validation results, both algorithms had the significant prediction, however, despite the validation results, RF with $R^2 = 0.84 (p < 0.01)$and$RMSE = 0.12$ was better in comparison to SVM with $R^2 = 0.72 (p < 0.01) and RMSE = 0.16$. The study demonstrated that seabass geometrical dorsal features together with machine learning algorithms could be used for mass predictions. Furthermore, the IREF system can be used as a reliable, inexpensive, stress-free and accurate sensor for monitoring and estimating fish mass during cultivation within the tank.

1. Introduction

Measurement of fish mass is important for stock assessment in aquaculture management. Fish mass information has a critical role in managing feeding regimes (Kubitza and Lovshin, 1999), oxygen consumption calculation, antibiotic dose prescription, grading time and the optimum time of harvest (Lines et al., 2001). Accurate size estimation during the rearing cycle can be used to maintain homogenous size batches which is advantageous for welfare by reducing aggression and feeding competition (Ashley, 2007) and increasing the growth rate. For instance, separating males, which are 20–30% smaller (Saillant et al., 2001), from females for selective breeding in the seabass (*Dicentrarchus labrax, L.*) optimizes breeding schemes and maximizing efficiency from 5 to 25 percent per generation (Vandeputte et al., 2009).

Fish mass estimation is important in recirculating aquaculture system (RAS). RAS is being considered by fish farmers because it is possible to maintain good rearing conditions such as controlled temperature, water quality, and feed utilization, during the whole year. However, over feeding or under feeding events in RAS, as a major problem, is still influencing growth and survival of the animal. Furthermore, overfeeding affects the water quality which may increase the potential for diseases as well as increasing production costs due to extra load on the mechanical filters, bio-filters and oxygenation equipment (Chang et al., 2005). Therefore, monitoring fish growth for optimizing feeding is one of the primary consideration in RAS system (Gutierrez-Wing and Malone, 2006) and better nutrient recycling and waste management. Besides, it would help to have uniformity which is an essential requirement for more efficient automated processing after harvesting (Costa et al., 2013). In other words, monitoring of fish for stock assessment in aquaculture and commercial fisheries is essential for the economic and environmental management and ultimately for more sustainable fish production.

The conventional approach to obtain information on fish mass is by sampling and weighing. To be accurate, a representative portion of the population must be examined (Lines et al., 2001), this approach is labor-intensive and stressful for fish. If fish could be measured without

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handling is of great interest for the aquaculture community.

Machine vision system (MVS) is a non-invasive technique for estimating fish mass and size which has been attracting interest of researchers and agriculturists during the past three decades; in-tank measurement avoids stress and injury (Saberioon et al., 2017). The stereo-vision system has become one of the more popular systems for measuring the fish length and mass (Shortis et al., 2016). Dios et al., (2003) used a stereo-vision system to estimate fish weight in a nursery; the estimated measures were within 4% of the mean weight from the direct measurement. Costa et al. (2006) estimated fish length using a submersible dual camera module with an error of only 2% of the fish true length. Torisawa et al. (2011) used a stereo-vision system to estimate the fish length with an error ratio (standard error/mean) of 5% of the fish true length. Williams et al. (2016) showed the capability of stereovision system for measuring fish length within a trawl manually and automatically. Al-Jubouri et al. (2017) developed a system based on dual synchronized orthogonal webcams to estimate the length of individual free-swimming zebrafish in an aquarium. Although all of the above-mentioned studies have proven effective and non-invasive, generally, a stereo-vision system requires multiple hardware and complicated software for synchronizing cameras. More handling and complicated manual procedures such as calibration is also required which stress the fish and does not provide information in real time because of intensive post-processing of stereo vision images (Shortis et al., 2016). Furthermore, image spatial resolution dramatically decreases as objects move away from the sensors (Gokturk et al., 2004). Other researchers have tested other approaches such as laser scanner (Almansa et al., 2015) or a CCD camera (Hufschmied et al., 2011; Miranda and Romero, 2017; Trobbiani and Venerus, 2015), however, these only applied to low densities of flatfishes at the same depth or only one fish pass through a tube. Indoor tanks with poor lighting is another issue compromising high-quality images (Saberioon et al., 2017). Near infrared based computer vision can provide good quality images in an environment with relatively dim light; some recent studies have been used in aquaculture. For example, Pautsina et al. (2015) developed Infrared reflection system (IREF) for 3D fish movement tracking. Hung et al. (2016) developed an underwater video system for monitoring shrimps during the night using the infrared-based system. Zhou et al. (2017) showed the application of IREF system for quantifying the variations in fish feeding behavior.

Different image features have also been investigated for measuring mass in fish. For instance, Zion et al. (1999) used fish area to estimate the fish mass of grey mullet (*Mugil cephalus*), Carp (*Cyprinus carpio*) and St. Peter (*Oreochromis*) with 95, 99 and 99 percent accuracy, respectively. Balaban et al. (2010a, 2010b) estimated body weight of four different Alaskan Salmon species and Alaskan Pollock (*Theragra chalcogramma*) from area obtained by image analysis and a mathematical correlation (between weight and area) with an R-square value of 0.99. Gümüş and Balaban (2010) also predicted the weight of rainbow trout based on the area which was measured from the side-view. Costa et al. (2013) used a combination of partial least square (PLS) and Elliptic Fourier analysis (EFA) for predicting weight based on estimated body length from the lateral image. de Verdal et al. (2014) exhibited reliable correlation (98%) between weight and body features (area, perimeter, length, height, and volume) extracted from area of side images of European seabass larvae. Viazzi et al. (2015) showed the mass estimation of Jede perch (*S. barcoo*) by using area and length of fish from a side view image captured outside of water. All above-mentioned features measured from fish lateral images which require fish catching from a tank or submerging image equipment to acquire lateral images. Although features extracted from lateral images are accurate, however, only limited number of fish can be sampled because of occlusion when several fish overlap simultaneously. Moreover, acquiring suitable fish orientation could be more complicated (Miranda and Romero, 2017; Shortis et al., 2016). Therefore, it would be difficult to adopt these methods for a high intensity rearing system like RAS. Some researchers have also tried using top-view images for predicting weight. For example, Odone et al. (2001) found a relationship between shape and weight using support vector machine and thirteen features extracted from both dorsal and lateral images of fish. They reported an accuracy of weight prediction with only 3% error rate. Hufschmied et al. (2011) predicted strugeon (*Acipenser baerii*) mass with 94% accuracy using top view images. Although they acquired significant accuracy of weight prediction, the fish had to be forced into a specific oriented position or kept at a known distance from imaging system. Therefore, developing an automated fish sampling system in indoor facility tanks (i.e. size and mass information) which would be non-invasive, fast and inexpensive is needed.

The main purpose of this study was to develop a non-invasive and remote, automatic fish sampling method to estimate size and mass farmed Seabass (*Dicentrarchus labrax, L.*) while swimming freely using IREF system for real-time monitoring. The introduced methodology is based on image analysis and utilizes the fish dorsal geometrical features and machine learning algorithms such as Support Vector Machine (SVM) and Random Forest (RF) for predicting weight of individual fish in a tank. To the best of our knowledge, no studies have been done on weight and mass estimation using IREF system in tanks. The specific objectives of this study were to (1) evaluate the feasibility of geometrical dorsal features for estimating seabass's mass in tank (2) investigate the potential of IREF system for estimating mass and (3) assess and compare two machine learning algorithms (SVM and RF) for mass prediction using seabass geometrical dorsal features. It was envisaged that this rapid, non-invasive and inexpensive method for obtaining accurate information of size and mass during rearing cycle would be valuable in fish farming.

2. Material and methods

2.1. Model development

Fig. 1 illustrates the overview scheme of the introduced system for seabass weight prediction. The experiment was conducted at IFREMER experimental facility of Palavas, France. A total 295 farmed Seabass (*Dicentrarchus labrax, L.*) with different lengths (mean = 26.32 cm and sd = 11.48 cm) and weight (mean = 0.33 kg and sd = 0.34 kg) were randomly selected and sampled for model development.

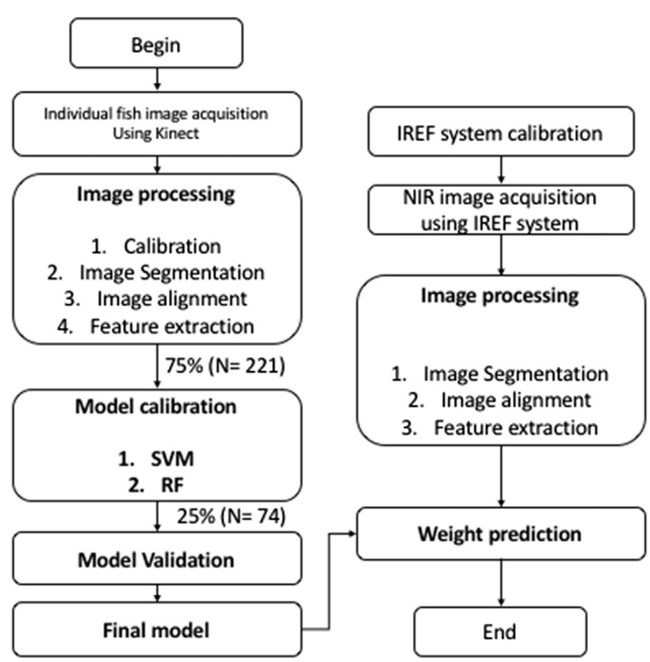

Fig. 1. Schematic of methodology.