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Three-Dimensional Reconstruction of Live Fish through the Moiré Technique

Ariovaldo José da Silva, Juliana Aparecida Fracarolli, Fernanda Fernandes Adimari Pavarin, Kátia Cristina Suzigan, Thais Queiroz Zorzeto Cesar and Inácio Maria Dal Fabbro

School of Agricultural Engineering, University of Campinas (UNICAMP), Av. Cândido Rondon, 501, Campinas 13083-875, SP, Brazil

Abstract: Currently, in fish farms, the controls of the physical characteristics of the fishes, for example, size and mass are made by means of the operation of fish removal, in which the tanks are emptied to capture the animals and perform the biometry. This operation demands large volumes of water and generates effluent containing high concentrations of organic matter and nutrients that can contribute to the deterioration of water quality in the recipient bodies. Therefore, the development of technologies that use digital image processing, such as the moiré technique and image analysis, can be important allies for the preservation of environmental quality by avoiding the fish removal and the discharge of effluents, increasing productivity due to optimization of the time and still the saving of water. To obtain the images a 9-liter glass aquarium, a support for notebook and light projector, a digital camera brand Samsung Galaxy Camera 2 were used. The objective of this work was to obtain the three-dimensional reconstruction of live fish in aquariums. In the future, the technique can be developed to obtain the mass and the volume of the fish in fish tanks, replacing the fish removal, allowing the preservation of water resources.

Key words: *Oreochromis niloticus*, fish removal, water saving, image analysis, biometrics.

1. Introduction

Among the agricultural activities, fresh water fish farming has been highlighted, the Nile tilapia being one of the species with the highest farming potential [1], due to its production qualities, its excellent texture and the taste of its meat, besides not presenting micro-bones and enabling the filleting and industrialization of its carcass [2, 3].

Presently, in fish farming, the control of the physical characteristics of fish, for example, size and mass, is made through the harvest operation, in which the ponds are emptied in order to capture the animals and to do the biometrics. That operation demands great volumes of water and generates effluent containing high concentrations of organic matter in the receiving bodies.

Therefore, the development of technologies which employ the processing of digital images, such as, for example, the moiré technique and image analysis, may be important allies for the preservation of the environmental quality since they avoid effluent discharge, increase of productivity due to the time optimization, and also water saving.

Moiré corresponds to silk texture in which at the reloading and smooth shifting layer to layer dark and light fringes appear. The coincidence of two periodical structures-gratings named rasters forms the moiré fringes. This optical method is suitable for measurement of length, angle of rotation and also contactless surface shape deviation evaluation. It was firstly described in 1874 by Lord Rayleigh and contemporary is used as the impulse dial gauges for linear measurement of length or for digital measurement of rotation movement and moiré inspection systems of surface, for example, optical contour mapping of surfaces in topography [4].

McKenzie *et al.* [5] used moiré method to assess

Corresponding author: Juliana Aparecida Fracarolli, assistant professor, research fields: biospeckle and post-harvest technology.

the imprint created by the tread pattern of a tyre during a single passage of a tractor and to determine the depth of imprint created after multiple passes of the same tractor. The authors concluded that moiré method is enable to evaluate soil surfaces in agricultural. Zhao *et al.* [6] developed a fast shadow moiré method in combination to principal component analysis (PCA) technique to determine the topography of a surface.

Silva *et al.* [7] applied shadow moiré method to generate spatial dimensions of solid figures. In the research fruits were used to obtain volume. The method of water volume displacement was used for data comparison in which the change of liquid volume is equal to the object volume. The results allowed stating that moiré techniques can be used for volumetric determination of irregular objects as fruits and others vegetable organs.

In aquiculture, the images can be taken *in situ* or *ex situ*. In the first case, traps are assembled into the tank in order for the animals to pass slowly in front of the camera. Alternatively, we can take a statistic representative sample of the population and transfer the animals carefully to a glass tank, kept in the same environmental conditions of the fish tank.

In this experiment, images of the one fish were obtained from a glass tank and later treated by moiré technique in order to create a three-dimensional reconstruction of the fish. In future works, it is intended to develop a methodology to obtain the mass of the fish without the need for harvesting, knowing the volume and specific mass of the fish. This research may result in better technology for the biometric control of fish, minimizing the need for harvesting and, consequently, the excessive water demand and the discharge of effluents rich in organic matter.

2. Materials and Methods

For the development of this research, a system of intensive farming of tilapia fries was installed in the Environmental Control Laboratory in the School of Agricultural Engineering of the University of Campinas (FEAGRI/UNICAMP) where an image acquisition system was also installed.

2.1 Fish Farming Installations and Image Acquisition System

The fish farming installations were based on the procedure used by Sánchez and Matsumoto [8]. Nile tilapia fries (*Oreochromis niloticus*) were farmed in a glass reservoir. The fish received three daily meals of balanced feed containing 30% of protein. The daily food quantity corresponded to 2% of the average weight of the fish in the aquarium. The appropriate dissolved oxygen concentration for the cultivation of tilapia, that is, 1.2 mg/L was kept by air insufflation in the farming container [9].

Outside the aquarium, the set up to capture the images of the fish was installed using the moiré fringes and two-dimensional image analysis techniques in order to obtain the three-dimensional reconstruction of the animals. The fish's images with moiré fringes were acquired using a digital camera Samsung GC200ZWAZ 16M BCA and a projector Benq MS504.

2.2 Methodology for Image Processing

In order to create the contrast between the moiré fringes and the object, the object is usually painted with white mat paint. In the case of living and in-the-water fish, that fact is not viable, constituting a challenge. It was obtained four images of sinusoidal grids projected on a background with phase shifts of 0, $\pi/2$, π and $3\pi/2$ of periods from each other. The grid projected on the fish was also obtained (object) (Fig. 1).

The difference between each plane image (I1, I2, I3, I4) in relation to the object image (U1) was done. The result of the procedure can be observed in Fig. 2.

The use of moiré technique may carry some errors and interference that can be compensated by the software techniques according to Idesawa *et al.* [10]. These errors can occur due to curved contours level

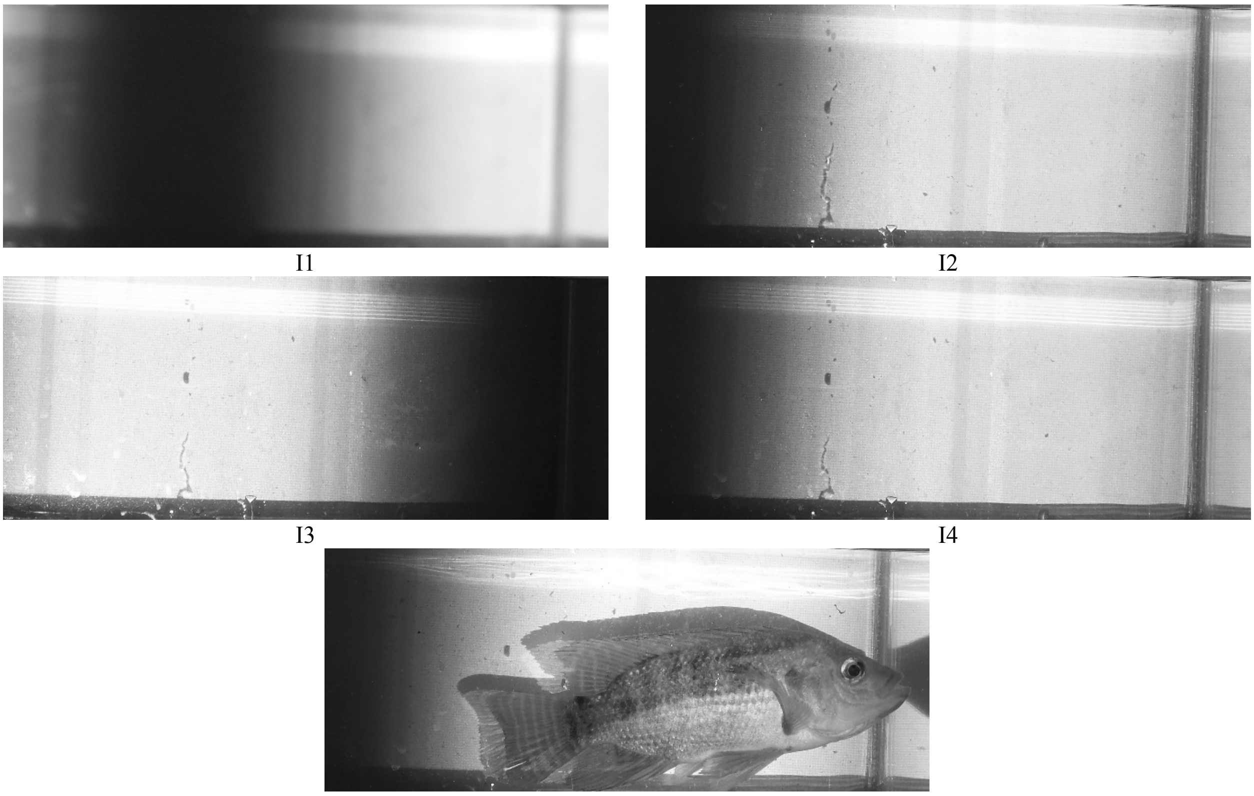

Fig. 1 Images of the sinusoidal fringe in the offset plane of (I1) 0, (I2) π/2, (I3) π and (I4) 3π/2 and (U1) image of the fish.

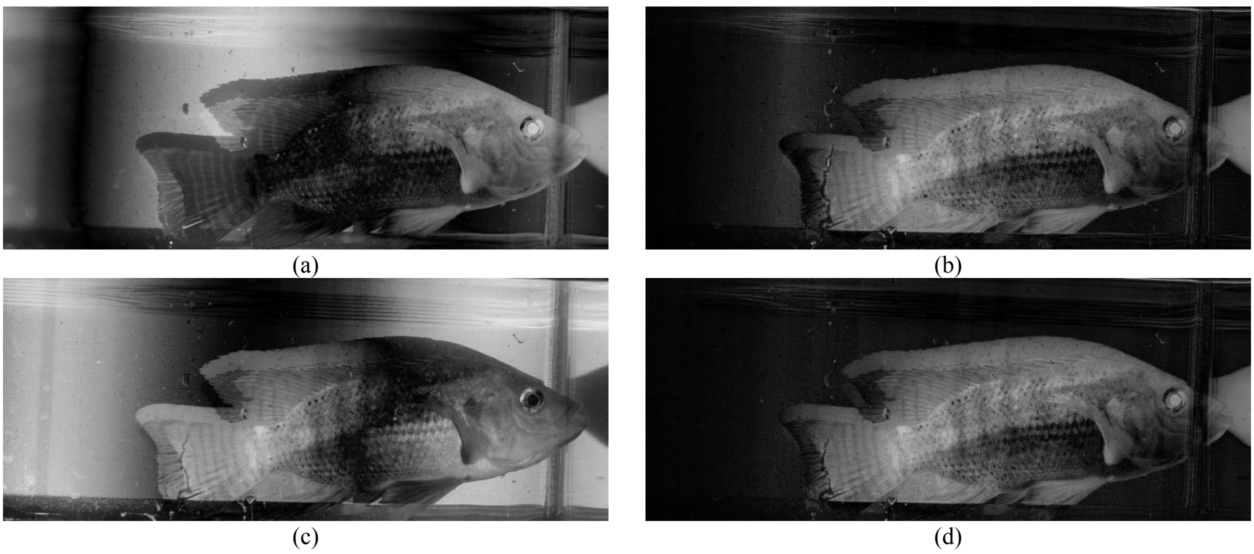

Fig. 2 Images with phase shift of (a) 0, (b) π/2, (c) π and (d) 3π/2.

and projection-observation system.

In the image processing, the software ImageJ v1.51k [11] and Rising Sun Moiré version 0.87 [12] were used. The ImageJ software was used to create a mask of the object (Fig. 1), to convert the color scale to 8 bits, to do arithmetic operations (subtraction, Fig. 2), and to visualize the treated image in three dimensions.

The Rising Sun Moiré software was used for the juxtaposition of the four images (Fig. 2) of the shifted phases with the Phase Processing and Calculate Displacement from Phase tools and the result can be observed in Fig. 3.

3. Results and Discussion

The three-dimensional reconstruction of the fish was obtained through software techniques as visualized in Fig. 4. The 3D image obtained corresponds to size of the fish and proves that this technique can be used with success.

Surface contours can be observed in distinct colors on the generated image at a specific point in the timeline, and give information about the topographic map of the fish, allowing estimating its volume. In a second moment, a new estimated volume can be compared with previous measurements as needed.

The color near the green hue represents points of more portions in Z axis and the color near the purple hue represents the points of minor portion in the Z axis.

This work presents an innovation by generating the three-dimensional reconstruction of living, submerged-in-water fish, saving time and resources.

Costa *et al.* [13] applied the moiré technique to quantify the volume of a kind of nut known in Brazil as macauba fruit. The authors compared the moiré technique to the Archimedes method in order to obtain the volume of the fruit. Lino and Fabbro [14] obtained the topography of artificial fruit through the moiré technique. They compared the three-dimensional model acquired by a laser scanner to the model obtained through the moiré technique. In both works, the authors found a good correlation between the three-dimensional model obtained through the moiré technique and the comparison methods which were volume shift of a fluid and the 3D model acquired by a laser scanner.

Fig. 3 Phase map.

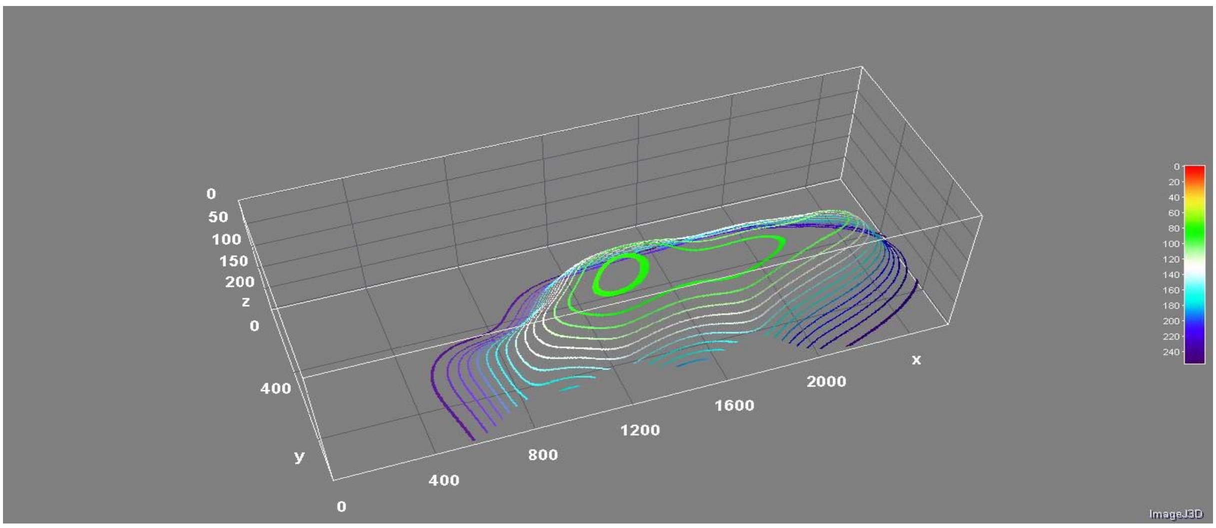

Fig. 4 Three-dimensional reconstruction of the fish.

4. Conclusions

A simple and low-cost procedure for the acquisition and treatment of the images was developed, which made it possible to obtain the three-dimensional reconstruction of the fish. Improving this study will allow the fish farmer to monitor the growth of the fish with no need for draining the ponds. In that way the hydric resources are preserved, since the nutrient and organic matter discharges which become polluting when discharged into bodies of water will be reduced.

In future works, knowing the anatomy of the studied species of fish, it will be possible to develop a mathematical model in which, from an image of the sagittal section of the fish, it is possible to know the dimensions of its lateral plane of symmetry and thus to determine its volume.

Based on that information, it will be possible to develop a software linked to an image acquisition system in a fish farming pond in actual scale in order to help the fish farmer to monitor the growth rate of the fish and to guide them on the administration of feeds in order to optimize the amount of protein offered to the fish and to avoid excesses of nitrogen in the fish farming pond water.

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