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Biometrical Optimization System for Red Tilapia (Oreochromis sp.) through Image Processing in Growing Environments

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Abstract

The costs of an aquaculture production process are affected by about 70% by the technical food management, in that sense, it is absolutely necessary to accurately establish the food rations throughout the cultivation cycle, making adjustments weekly, so the determination of biometric variables is required with the same periodicity. The objective of this research was to make possible an alternative for obtaining biometric information in an aquaculture production process, obviating harmful aspects, which occur in the development of traditional biometrics, where it is required to perform invasive procedures (partial fishing) that generate negative impacts on cultured organisms. In this sense, in the development of the present study, magnitudes of the specimens of red tilapia (Oreochromis sp) were determined, through the analysis of images obtained in culture environments at high densities, all this, using a software specially designed to measure the length of the specimens, managing to generate a lower impact on the fish. For the development of the software it became necessary to determine the events and sequences, thanks to unified modeling language diagrams - UML, in this specific case the use cases, sequence and entity relationship were used. Subsequently, each of the events and sequences determined in the UML were embodied in code, using the C# programming language and the Visual Studio (IDE) in its community version. On the other hand, the calibration of the system was carried out in three clearly defined phases: 1. selecting the image capture device, 2. support structure adjustment of the image capture equipment, and 3. calibration of the measurement software.

Keywords: *Red Tilapia, Biometrics, UML Diagrams, Use Cases, Entity Relationship.*

1. INTRODUCTION

In the exercise of the activity of fish it is imperative to keep a constant monitoring, logging and control of the various operations of the production process, all of this, in order to make decisions that ensure a sustainable practice with the use of the resources in the appropriate amount and by taking decisions in a In recent years, aquaculture in Colombia has shown significant timely manner, which enables the production of a product of optimum quality.

Growth, comparable to the global dynamics, and is mainly represented by fish production (Tilapia, Cachama and Trout) and farmed shrimp; which has had an important

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development in recent years, with an estimated production close to 179,351 tons for the year 2020 [1].

However, despite this growth, aquaculture in Colombia has faced multiple situations that have further limited its development, for example, low levels of technology could be cited. Especially those processes that require maintaining a necessary and constant monitoring, and registration of the various operations of the production process, all this, in order to make decisions that guarantee a sustainable practice, with the use of resources in the appropriate amount and by making decisions in a timely manner, which makes it possible to obtain an optimal quality product [2].

Within these activities that should be followed with strict regularity and systematicity is the measurement of parameters of physical-chemical [water quality] and determination permanent the degree of development of the fish farming [biometrics] , the latter becomes essential information for the adjustment and implementation of effective activities, as it is the technical handling food, in that sense, the obtaining of such biometric information in a reliable manner, it allows to establish the degree of effectiveness of the feed supplied depending on the weight gained and the growth speed of the animals, all this resulting information is of vital importance since it allows to have a clear vision regarding the production costs and the profitability of the crop, since they are highly influenced by the feeding process [3].

It is clear to indicate that the collection and processing of biometric information is an aspect that has hindered the development of the activity easier, all time today to collect such information in a fish farming should be to go on a fishing partially consistent (between 10% and 20%) of all the animals that are immersed in the production process, which generates a negative impact on animals, the product of the abuse that takes place by the manipulation, resulting in the best of cases stress, understanding this as physiological reactions that favor pathological events and / or death [4], another negative aspect is associated with the fact of the need to employ extra labor, given the representativeness of the sample to be treated. For all the above, it is necessary to explore the development of alternative techniques such as the one proposed in this article, which is supported by a technological development that would contribute to the reduction of the negative impacts generated with the implementation of traditional biometrics.

2. MATERIALS AND METHODS

The research was experimental with a quantitative approach, the data obtained from the response variables were analyzed using statistical tools for the subsequent interpretation of the data. The experiment was conducted according to what was proposed by several authors [5] [6]. In addition, the study was carried out using the CDIO (Conceive, Design, Implement and Operate) methodology [7].

The experimental development of the research was carried out in a fish farming company specialized in the cultivation of red Tilapia (Oreochromis sp) located in the town of Mandinguilla, Chimichagua municipality, Cesar department, Colombia. An important number of entrepreneurs are in operation in this sub-region, which makes it an ideal area to carry out contrast tasks between traditional biometrics and biometrics performed through the treatment and processing of images, with the support of the software developed in the present research work.

2.1 General growing conditions

In order to achieve one of the main objectives of the research, which is to carry out a comparative analysis between the data obtained in traditional biometric processes and those from the treatment of images obtained in real crop environments, by applying a software that replaces this practice, a fish production system with a seeding density of 45 fish / m3, carried out in HDPE geomembrane tanks, and based on a feeding scheme discriminated by stages, was established as a population, where, the frequency of feeding was stratified by stages as follows: precría, 6 times/day; lift, 4 times/day; and fattening, 3 times/day, as well as fish are classified by height and weight in the following way: precría animals of 1 to 5 grams, lift specimens between 5.1 and 80 grams and fattening fish over 150,1 grams, it is important to note that for the processing and analysis of the information we used the data of total length (LT) of the animals when presented with the weights mentioned above.

On the other hand, during the sampling ensured that the growing environments present conditions of water quality parameters the same or similar, for this we conducted a monitoring diary of some of them: concentration of dissolved oxygen, oxygen saturation, temperature, pH, nitrite, alkalinity and suspended solids; to which are employed a meter multi-parameter portable YSI-6050000.

2.2 Sampling

The information was gathered by performing 4 biometrics monthly specimens at different stages of cultivation, thus obtaining a certain number of samples and data to contrast then with biometry performed by the image processing supported by the software developed, treating a total of 900 images, for the biometrics was taken to the information relating to the total length (LT), a measure of the fish from the mouth to the earlobe most extensive of the caudal fin; standard length (LS), where we measured the fish from the mouth to the last vertebrae excluding the caudal fin; and dorsal length (LD), for which a 50 cm aluminum ichthyo-meter with graduation in mm and a digital caliper were used, with an accuracy of 0.1 mm [8].

2.3 Methodological development

The study was experimental, addressed with a quantitative approach, which had as main objective the calibration and optimization of the software developed for obtaining the size by using the image processing, the registration of the images was used (1) a camera GoPro HERO 7 Black water-resistant to 10 m, touch screen, 4K video HD, pictures 12MP, live streaming and stabilizer; (2) a metal frame with a frame referenced;(3) and a system of additional lighting. The lighting system consists of a GoPro Sjcam Waterproof Diving Submersible Led Light 30 mts 300 Lux, which are arranged parallel to the camera at a distance of 6 cm. The camera was configured for manual image acquisition with these settings, a total of 510 images were taken with a resolution of 1040 x 780 pixels. The camera was at a distance of about 60 cm from the fish.

2.4 Conventional sampling and quantification of red tilapia

The conventional measurement of red tilapia was carried out by means of the implementation of a net, in order to confine the fish to facilitate their extraction. Once the fish is out of water, we proceeded to perform the measurement with a vernier caliper and the caliper digital, for this we conducted two types of measurement, standard length, where we measured the fish from the mouth to the last vertebrae excluding the caudal fin and the total length, which was measured the fish from the mouth to the earlobe most extensive of the caudal fin [8].

2.5 Measuring red tilapia digitally

For the digital measurement it was necessary to create a system made up of three components: Image capture device (digital camera), physical support structure and measurement software.

Selection of the capture equipment

In the study carried out, it was determined that in order to obtain optimal images for processing, basic requirements must be met, such as [11]:

1. color profile: RGB or Adobe RGB (never sRGB);

2. image size: minimum of 2832 x 4256 px. or, failing that, the largest that the camera allows;

3. sensitivity: 100 ISO or failing that the lowest allowed by the camera and

4. capture format: RAW.

Consequently, three market products were studied theoretically, which according to underwater optics research [12] [13] [14]. Present the best results in capturing images in aquatic environments with high disturbance and we proceeded to choose that camera that theoretically presented a better value for money, these are GoPro® HERO 7, Mako G-125, GoPro® HERO 6

The selection of equipment for capturing pictures that will provide maayores prestacioness tests were performed with different cameras generic, with which we obtained satisfactory results (distorted images, low-quality, and objects are out of focus), in order to improve these results was tested with type cameras GoPro®, choosing the version HERO 7 Black water-resistant to 10 m, touch screen, 4K video HD, pictures 12MP, live streaming and stabilizer, achieving images with the quality needed to perform measurement tests.

Additionally, it required a lighting system annex, constituted by a GoPro Light Led Submersible Diving Waterproof Sjcam 30 mts 300 Lux, which were placed in parallel to the chamber, at a distance of 6 cm, the resolution chosen for the images was of 1040 x 780 pixels, establishing a distance between the lens and the fish of approximately 60 cm.

To make the selection of the lighting devices it was necessary to take into account that the work environment in which would be the system was an aquatic environment with turbiedades significant between 30 and 60 cm profondidad Secchi, therefore, this should be adjusted to the requirements of the international standard IEC 60529 Degrees of Protection ip68 [15]. In addition, the purchased equipment had to meet the main objectives regarding lighting, which are:

1. keep the luminous intensity constant;

2. keeping the direction of the lighting and

3. optimize contrast to differentiate objects

Construction of the support structure

For the construction of the support structure of the figure 1, capture equipment, 3 proposals were made, a cubic structure with 2 cameras, located on the front face and on the top, a cylinder-shaped structure, with two cameras located one above the other and a conical-shaped structure with a single camera located at the smallest end of the cone, finally it was determined that the structure that fit the need for the system was the conical shape, since this allows to have a frame of reference to make the measurement, which avoids the need of using two cameras, substantially reducing the processing required to define the length of the fish.

In addition, this structure has a support for the camera, with the aim of improving the mobility and prevent failures approach at the time of the capture of the image, this structure has the quality of being easy to immersion, thanks to the tubular structure is filled with water when immersed in the culture environment, and little invasive, which allows you to meet better the main objective, which is to mitigate the negative effect presented by the measurement of fish in a conventional way [16].

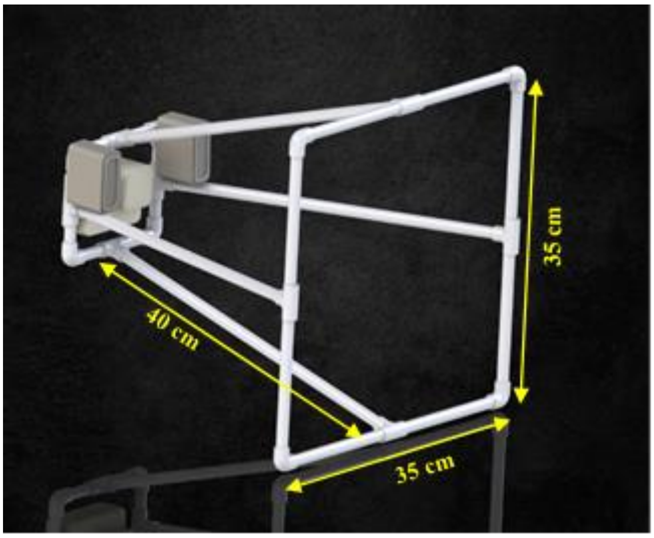

Figure 1: Support structure.

On the other hand, this structure provided the ability to capture a significant number of fish for each shot taken, even if it is desired to increase the range of sampled fish, the camera can be adjusted to make bursts of photographs, allowing a few movements in the production environment to capture a significant sample in a short period of time.

Now, at the time of establishing the measures of the structure had as a criterion, the open end of the cone was defined by the visual field of the camera, under this slogan it was necessary to adjust the measures of the frame according to the type of camera to use, it is for this reason that at the time of implementing the prototype, with the final chamber (GoPro Hero 7 Black) it was necessary to reset all of the initial steps of the framework being finally with 40 cm long, 35 cm wide and 35 cm high (Figure 1).

It is valid to emphasize that to define these measurements the turbidity and the density of fish were taken into account, since it was possible to determine in the tests carried out that with the initial measurements of the frame the quality of the images was substantially reduced, that is, due to the opacity of the environment the specimens were not perceived clearly, because the distance between the fish and the camera lens made the sharpness of the images lose; for this reason, a distance of 40 cm was defined between the lens and the final frame of the structure, a distance in which the image quality is totally improved (the frame allows capturing a large number of individuals in a single shot).

2.6 Measurement algorithm

The development of the algorithm started with the design of diagrams-use case, where it was possible to clearly identify how the interaction that the user performs with the system, the system operator has two options, configure or measure, in both options you can load your images, make measurements, step back in points placed for measurement and refresh or restart the taking of a measure, the substantial difference of these two options is that in the configuration, you can generate a fixed reference in regard to the relationship pixel-cm for further measurements, while in the measurement option it is allowed to use the pixel-centimeter reference previously made in the configuration, or to take into account a new pixel-centimeter reference, starting from the uploaded image when using the structure option.

2.7 Calibration

To carry out the calibration tests, measurement tests were started on different objects with a previously established magnitude, for this purpose rulers, squares, rectangles, plastic animal figures were used, among others, later measurements were carried out on fish in a conventional way, where the total and standard length was recorded, necessary information to make the contrast with the data from the treatment of the images previously obtained by the team.

Figure 2: Conventional biometrics

2.8 Software (algorithm)

For the digital measurement, it was necessary to develop an algorithm consisting of four stages: acquisition, processing, measurement and visualization. During the acquisition process, the user selects the folder containing the previously captured and previously saved images of the fish, then the user selects the image he wants to measure, at that moment the processing begins, where the system applies smoothing filters to improve the image with which the user is given an improved form that allows to identify in a simple way the regions of interest; at the stage of measurement, the user identifies those regions and proceeds to locate the horizontal and vertical points at the ends of the frame of reference and subsequently in the fish [17].

In this stage the software is in charge of identifying if the image has the desired dimensions in the framework of reference (must be fully-square), in the case of non-compliance, the software will take care of resizing the image to the appropriate measures, this process is carried out with the intention of not to lose the relationship that exists between the height and width of the final image, after verifying the dimensions of the image, the software performs the conversion from pixel to centimeter, taking into account the existing relationship in the frame of reference, which is already known previously measured in centimeters, the final part of this stage consists in relating the measure in pixels, of the fish with the relationship pixel-centimeter previously found, so finally getting to the part of display, where the user is shown a window with the length in centimeters of the fish in question [18].

On the other hand, this system has an interface composed by different windows where you can configure the variables used by the system or failing to opt for to perform direct measurements, the process starts by registering the magnitudes of the structure for the establishment of a frame of reference at the time of the measurement of the fish, in figure 3a, we can see the configuration window.

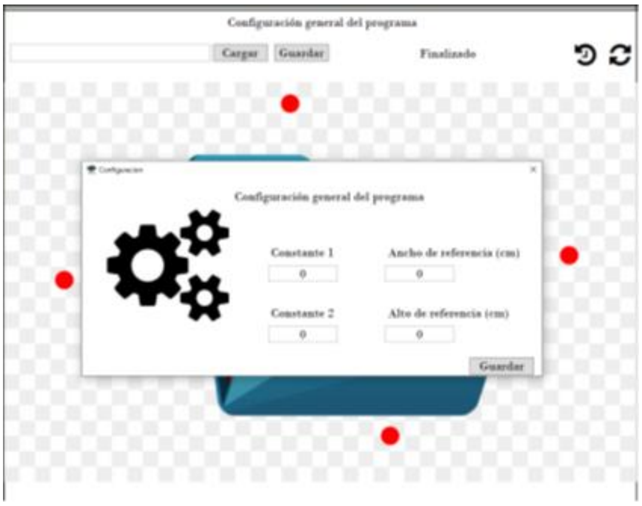

Figure 3a: Configuration window

On the other hand, in Figure 3b, the functionalities of the selection window are observed. In this module, the image that meets the measurement criteria is loaded.

Figure 3b: Selection window

Finally, in Figure 3c, the measurement window is illustrated, which provides the following functionalities:

1. Upload image button: allows you to select a folder where the images of the specimens to be measured are stored.

2. Uploaded images display space: Displays the images that are in the selected folder.

3. Selected image display space: Displays the selected image, in this space the loaded fish is measured, vectoring the ends of the fish (horizontal and vertical).

4. Zoom in and zoom out buttons: buttons that allow you to zoom in or out of the selected image if necessary.

5. Reload buttons previous state: in case of having made a mistake when locating the fish points, the system allows to return to a previous state or reset to an initial state.

6. Next button: allows you to move to the next uploaded image to perform a new measurement process.

7. Save Button: allows to convert the data taken in pixels to centimeters or millimeters, depending on the selected configuration and presents in the form of a pop-up message the length of the fish.

Figure 3c: Measurement window

2.9 Statistical processing of information

The statistical parameters of the data obtained were calculated and an analysis of variance (ANOVA) was performed in each of the stages (pre-breeding, lifting and fattening), where the significance between the data from traditional biometric processes and through image processing was established. All the statistical calculations and analyses described were established with the help of the statistical softwares IBM® SPSS® Statistics in its version 25 and STATGRAPHICS® Centurion, version 18.

3. RESULTS AND DISCUSSION

Preliminarily, it is important to describe the behavior of the main physico-chemical parameters during the sampling within the framework of the experimental design:

The water temperature in the months of cultivation presented an average value of 29.56 °C ± 1.32; this parameter remained within the optimal range for the growth of the species which is from 28 to 32°C [9].

In terms of the dissolved oxygen this presented an average value throughout the cycle 5,57 mg/l ± 0,41, presenting higher values in the months of September-October, coinciding with the rainy season; this parameter was found within the ranges established for the optimal development of the fish which is 5.0 to 9.0 mg/l [10].

For its part, the pH had an average value of 7.77 ± 0.34, showing a solid tendency to neutrality, the alkalinity had an average of 81 ppm ± 0.51 and the ammonium and nitrite values ranged between 0.63 ppm ± 0.36 and 0.44 ppm ± 0.14 respectively. In general terms, the monitored parameters fluctuated within the desirable ranges for the cultivation of red tilapia (Oreochromis sp), as described by (Su Hsien-Tsang, 2008), even when the managed densities are relatively high (20 kg/m3 of biomass), this due to the strict control that is maintained over the culture environments, mainly associated with the mechanical oxygenation support 7/24.

3.1 Evaluation of the System

In the evaluation process of the system, 1572 samples (fish) were analyzed with measurements ranging from 4.5 cm to 23.6 cm, magnitudes taken both conventionally and with the use of the developed software, obtaining differences ranging from 0 cm to 1.7 cm, which translated in percentage range between 0% and 7.2% error, values relatively consistent with those obtained by (Martinez, 2014), who assessed the growth of sea Bream and sea Bass using biometrics common and implementing a trading system of monitoring by cameras called VICASS (Video Image Capture And Size system) is based on the principle of the measurement for photogrammetry and stereo vision, where you need an even number of images, acquired in a synchronized way, where there is a common area between the two pictures to predict the weight; in this way determined the average weight of the fish (with an error of 21 g for golden and 15 for the bass) and the condition factor of these. This research despite the fact that it shows an acceptable experimental error value (9 – 19% for Bream and 8 - 9% for Sea Bass).

It is of the utmost importance to note that the statistical treatment adopted in the present investigation was applied only on the total length (LT) of the 1572 data segmented into three groups, according to criteria related to the degree of development of the specimens, see Table 1.

Table 1. Stratification of data for processing and analysis

Stage of development of specimens	**Total Length (range cm)**	**Number of samples**
Precria	4.5-11.5	524
Levante	11-17.5	524
Fattening	18.9-23.6	524

Table 2 shows the summary of the data obtained, to which a statistical analysis was applied, in this specific case the analysis of variance (ANOVA) was chosen because this technique or statistical test is used to compare means of two or more groups.

Table 2. Summary of the data obtained (Precria)

Group	**Count**	**Sum**	**Average**	**Variance**
Traditional biometrics	524	4129.2	7.88	3.74
Software	524	4145	7.91	3.74

For the analysis of such information, there were two hypothesis, null hypothesis: it consists in the fact that the measure of average length of the samples taken with the conventional method is equal to the measure of average length of the samples taken with the software, and the alternative hypothesis.

Table 3. ANOVA for Precria

	Sum of Squares	**Df**	**Mean Square**	**F**	**P.**
Between Groups	0.2382	1	0.238	0.06361	0.800
Within Groups	3916.797	1046	3.744		
Total	3917.036	1047			

Table 3 show the measure of average length of the samples taken with the conventional method is different to the measure of the average length of the samples taken with the software, to perform this process is determined to be an alpha of 0.05, thanks to this analysis it was possible to define that there is a statistically significant difference in the precariousness between the treatments, because the calculated F is lower than the tabulated F.

Table 4 shows the summary of the data obtained for the lifting phase, statistical analysis, ANOVA groups.

Table 4. Summary of the data obtained (levante)

Group	**Count**	**Sum**	**Average**	**Variance**
Traditional biometrics	524	7590	14.484	3.616
Software	524	7602.2	14.508	3.522

Was applied, this technique or statistical test is used to compare means of two or more.

Table 5. ANOVA for Levante

	Sum of Squares	Df	Mean Square	F	P.
Between Groups	0.1420	1	0.1420	0.0397	0.841
Within Groups	3733.684	1046	3.569		
Total	3733.826	1047			

Table 5 show the analysis in the phase of the levante is observed a value of F= 0 0,0397, less than the F tabulated, indicating the non-existence of statistically significant differences, between the data obtained by processes biometric traditional and the measurements made with support of the developed system.

Table 6. Summary of the data obtained (fattening)

Group	Count	Sum	Average	Variance
Traditional biometrics	524	11164.4	21.306	1.499
Software	524	11171.3	21.319	1.472

Table 6 shows the summary of the data obtained for the fattening phase, statistical analysis, ANOVA was applied, this technique or statistical test is used to compare means of two or more groups.

Table 7. ANOVA for Fattening

	Sum of Squares	Df	Mean Square	F	P.
Between Groups	0,0454	1	0,0454	0,0305	0,8612
Within Groups	1554,395	1046	1,4860		
Total	1554,441	1047			

Finally, when doing the analysis of variance of the data for the fattening phase using the two techniques for obtaining the information, a value of F= 0.0305 is noticed, lower than the tabulated F, reflecting, as in the previous one, the absence of statistically significant differences. Table 7, therefore we accept the null hypothesis, with which we suggest continuing to venture into the development of a solution of this type, which makes possible the replacement of traditional biometrics.

4. CONCLUSION

For the registration of the images (the input to the present research) is selected, then multiple tests, the camera GoPro® with the achieved optimal photographs, consistent with the results obtained in other investigations [12] [13], where it is shown the use of this type of cameras under the water, and even in environments that are turbid, these tests allowed us to obtain images with a pilot uniform and without distortion.

Thanks to the results of the present research work, where a comparison is made between the results obtained by the measurement process versus conventional the measurement is performed with the proposed software, and supported under a statistical analysis that concluded that there is no significant difference between the two forms of measurement, it is valid to suggest the staging and consolidation of the software proposed as an alternative for the determination of biometric information of the red tilapia in controlled environments.

It is important to highlight that from the scientific information supported in this study it is possible to obtain relatively reliable qualitative and quantitative data, which facilitate decision-making in production processes, obviating the negative impact generated with traditional biometrics.

Product of the multiple tests it was able to determine that the relationship between the pixels of the image, the measure, in centimeters, of an object and the distance to which this camera, it can be replaced with the use of a frame of reference, which should be located at a close distance of the object to be measured, to get results that are framed within the range of error described above.

The implementation of a non-invasive biometric system (such as the one proposed in this study) could eventually lead to more efficient production processes from the economic point of view, because it allows to improve the feeding adjustment procedures, which would be reflected in a greater food conversion, additionally it would reduce stress levels due to the manipulation of individuals (potentially decreasing the mortality rate).

It is recommended to deepen the application of artificial intelligence for automatic identification and measurement of the specimens present in each image [19]. It is also suggested to apply stereo vision to avoid the use of reference frames and detect the distance of each specimen present in the images taken. Additionally, it is recommended to explore mechanisms to determine biometric factors such as weight, relating the length of the specimen to the condition factor, and finally investigate the relationship of fish color with pathological events and well-being [20].

Finally, it is recommended to explore mechanisms to determine additional biometric information related to pathologies and general condition of the fish by means of the color ratio of the specimens.

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