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ESTIMATING THE SURVIVAL OF AQUA FAUNA BY IMAGE ANALYSIS TECHNIQUES FROM THE VIDEO SEQUENCES OF POND AQUACULTURE

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Abstract

Survival status of aqua fauna is estimated by studying the dynamic behaviour (motion) in underwater environment. Survival status of aqua fauna particularly, shrimp is estimated to prevent huge economic losses to the aqua farmers. A novel approach has been proposed in this research work to address this issue through segmentation, extraction of features, motion analysis and classification of aqua fauna from the pond aquaculture video sequences. First, the content-based video is translated into frames, and the image content is segmented using the Background Subtraction algorithm. Then, shrimp motion analysis is done with the assistance of the optical Flow algorithm. At the same time, shrimp body feature is extracted by Edge detection method for Shape analysis. Finally, the Decision Tree classifier is constructed to estimate the status of shrimp is alive or dead. Real-time video sequences of shrimp in pond aquaculture have illustrated the effectiveness of our process. The projected method shows that the results are more accurate to estimate the shrimp survival status as well as providing GMP (Good Manufacturing Practices) in shrimp cultivation to alert the aqua farmers in advance to avoid economic loss.

Key words: *aquaculture, Decision Tree Classifier, edge detection, motion detection, optical flow, segmentation, video analysis.*

INTRODUCTION

Typically, in an image, a three-dimensional visual image is created in the plane, meaning that each point forms a 2-dimensional pathway at a faster vector velocity (Anil, 1989). The changing state can be seen in the sequence of images. Action events observed over time are caused by the movement of objects or the viewer or both (Can and Weichuan, 2013). Changes in image frames provide features to detect moving objects or assess their habitat. Similarly, changing pixels in an image furnish a vital feature to determine and realize the objects.

Image segmentation refers to that whole image is divided into several regions containing each pixel with similar attributes is known as. The image is divided into two parts called background and foreground. The attentive portion of an image is called foreground, while the rest portion is called background (Hui et al., 2008). In a review by Zhang and Lu (2001), briefed numerous algorithms related to motion segmentation under two categories namely, motion and spatial-temporal based approaches. Based on motion approach is further subdivided into 2D motion and 3D motion methods. 2D method utilizes 2D image motion such as optical flow algorithm while 3D motion parameters are used in 3D method. Hariyono et al. (2014) applied optical flow algorithm and Histogram of Orient Gradients (HOG) for pedestrian recognition through moving vehicles. Pedestrian movements were determined by distinguishing the regions with the same optical flow in the image domain. Thereafter, linear SVM uses HOG features as an input for making decision as pedestrians and non - pedestrians. Simplest method to detect the object is described by Mahamuni et al. (2014).

In this method, the foreground image (attentive portion) from the gathered images is segmented first. Then, changes in features are evaluated from each subsequent frame with all possible directions of movement. The object location in the succeeding frame will be considered when it reaches certain threshold conditions. A comprehensive review by Beauchemin and Barron (1995) described many classical methods to estimate the velocity of moving objects through optical flow algorithm. Further it was classified into Intensity-based, Region-based and Frequency-based methods. A review by Yang et al. (2004), discusses the extraction feature on shape of an object. Shape of an object is one of the vital visual features in separation process, recognition process for Image content description.

Chesta and Abhilasha (2011) discuss understanding of an image using Decision Tree. It uses a supervised learning system to recognize in the image processing. With the help of critical defence application, the different stages involved in the image analysis process were described in their work. And also, the required rules to construct the decision tree for different attributes were discussed. Survival status of aqua fauna, particularly, in shrimp pond aquaculture, is performed by segmentation, feature extraction, motion analysis and classification from video sequences are discussed in this research article.

MATERIALS AND METHODS

Segmentation

Image and video segmentation is the process of separating the video frames/image into two distinct visual layers like the foreground of a scene from the background (Singh and Singh, 2010).

Let us consider an image R. The image R is segmented into multiple regions by dividing R_i, i = 1, 2, 3, ... , m, disjoint on empty regions. While segmenting the regions, the following conditions should be satisfied:

(1) The fusion of all the disjoint regions in R_i, retains its original image.

(2) The intersection of any two regions is the empty set.

An image is expressed as 2D function $f(x_1, x_2)$, while for video an additional third dimension time as a function is included. It can be expressed as $f(x_1, x_2, t)$, which represents the colour changes of a pixel in position (x_1, x_2), and along the temporal dimension t. Segmentation plays an important role for image/video analysis. Hemavathy and Shobha (2013), described the significance of segmentation process in an Image processing application. It plays a vital role for further processing of image/video content. As the computation of descriptors produce various results for different segmentation methods, which will impart the influence in recognition results. Separating the visual representation into relevant information associated with distinguishable and rigidly moving objects is the main objective of motion segmentation. In general, it is classified into two methods namely, binary or two label segmentation and multi-label segmentation (Sivakumar and Meenakshi, 2016).

Feature Extraction

"Features" are pieces of information can well describe the characteristics we need for our application in a frame or a sequence of frames (e.g., corners position or direction). "Feature extraction" will be the process of finding out the value of these features. In image processing, feature extraction is a technique for reshaping the original image into the desired, informative and non-redundant data for analysis or recognition purposes (Soumya and Leya, 2018). Feature extraction plays a vital role, so that the desired features are extracted first and simultaneously, assessment will be carried on the desired features.

Edge Detection technique for Shape descriptors:

A group of pixels continuously appear on the border of two distinct parts in an image are known as Edge. Edges are very important in digital imaging to determine the points where intensity changes sharply and find pixels discontinuity (Rashmi et al., 2013). In general shape is described as the external structure of an object having boundaries. An edge provides more information about shape of an image. Similar shape feature is matched and regained in a shape-based image retrieval application. Hence shape plays a key factor in image analysis and one of the primitive visual feature extractions (Drashti et al., 2015). Edges are directly related with shape descriptor through scattering of pixel intensities. Shape feature is analysed by object boundary detection using Edge detection technique (Ushma and Mohamed Shanavas, 2014). Boundary regions of low-quality images may be unclear and improper determination value being overcome by Edge detection method. Most widely used thresholding techniques of edge detection algorithms are Canny and Sobel - edge detection (Hankyu et al., 2002).

Optical Flow

For motion estimation, most widely used computer vision method is an Optical flow method. Due to wide varieties of applications such as 3D reconstruction, tracking or recognition of object, robot navigation and traffic analysis, it attracts more attention in the research community. Due to poor lighting, presence of occlusions and have been taken from bad angle, Video may be poor quality. To solve the above-mentioned problems, an optical flow algorithm is applied. Generally, optical flow is expressed as the movement of visual attributes like objects, corners, shapes, points, etc., in the environment through a periodical observation. Optical flow provides vector information that outlines the propagation of rational movement of pixels brightness in the video sequence (Barron et al., 1994). When a camera (observer) is moving or the feature (target) is moving or both are moving, this necessitates tracking. Tracking might further be useful to understand behaviour Tracking therefore is simply recognizing the same feature either frame to frame over time or could perhaps include finding the same feature as seen from two different viewing angles (Fennema and Thompson, 1979). The apparent flow of objects, points and edges within an observer (camera or eye) and the scene in a video can be assessed by using optical flow method.

Decision tree classification

The classification or regression model of decision tree algorithm develops like a tree structure. A decision tree classifier is a hierarchical step at each stage, a check is implemented to one or more feature values (Friedl and Drodley, 1997). It classifies by partitioning the entire dataset into many smaller subsets which gradually develops like tree structure to make decision or classification. **Decision nodes** and **leaf nodes** are the two outcomes of the tree. A decision node indicates an additional check on the attribute values of a branch of the tree to be performed and has at least two branches. Leaf node indicates that a classification or decision is made (Swain and Hauska, 1977). Classification continues by recursively dividing the information till to attain a leaf node. When the leaf node is attained, then the class label is assigned to the record. In this research, decision tree is selected for classification due to simple in construction, flexibility, lack of any assumptions, nonlinear relationship of features and classes can be handled easily. Also, quick training and fast execution leads to employ the decision tree. In addition to that feature selection/reduction can be performed by Decision Tree (Mingers, 1989).

General Framework of our system to estimate the survival of shrimp in pond Aquaculture

The main aspiration in designing the framework is, it has to automatically examine based on the assumption of low-level features. The framework (Figure 1) recognizes the object first and separates the attentive portion of video frames in the dataset. Followed by extracting the desired features in each frame and relevant features are marked. Hence, video content is reduced by marking the sequences between the specific features and consecutive frames.

This meaningful information is saved into a simple form. Optical flow executes this simple form for further analysis to extract low level features such as motion feature of shrimp. And simultaneously allows Edge detection technique to extract another low-level feature like shape of shrimp body. These two features determine the survival status of shrimp with the assistance of Decision tree classifier. Motion feature alone is not sufficient to estimate its survivability. This is because, while consuming food, shrimp won’t move. At this stage, shape of shrimp body to be considered. Shape of shrimp body will be straight in nature during its functioning in underwater environment (Figure 2), whereas, its shape may be bent during its inanimate period (Figure 3). Hence, Shape feature along with motion is considered for estimating the survivability.

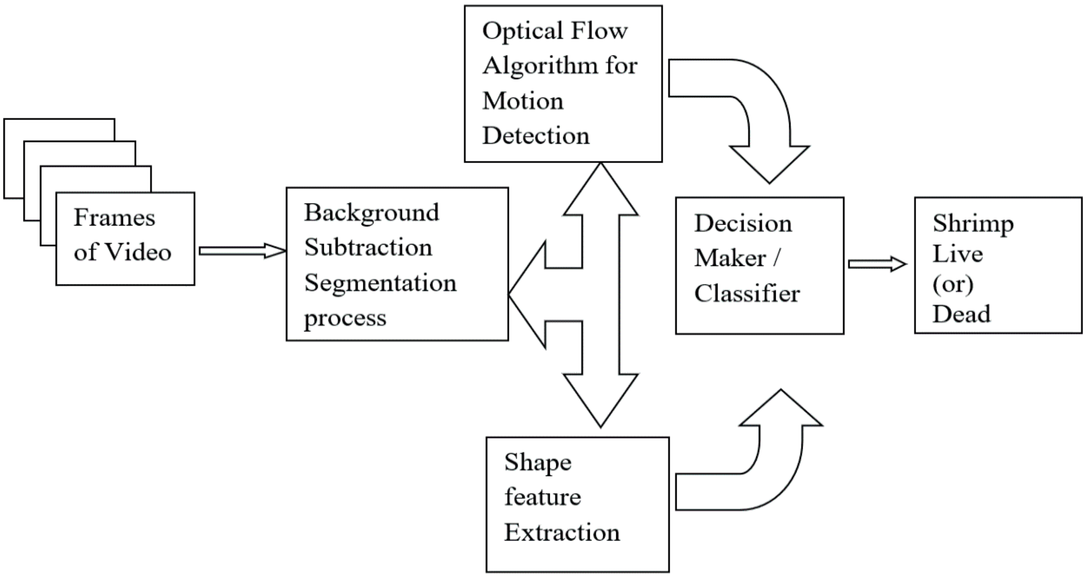


Figure 1. Outline of our system to estimate the survival status of shrimp

Figure 2. Shape feature of Live Shrimp Images (Body Shape is Straightened)

Figure 3. Shape feature of Dead Shrimp Images (Body Shape is bended)

Background Subtraction Segmentation (BGS Algorithm):

Video/Image can be separated into two different visual layers called foreground and background. Desired or attentive portion will be present in the foreground image layer and the remaining portion will be available in the background image layer. Foreground image is separated from background image with the help of Background subtraction (BGS) method in an image processing (Ashwani et al., 2006). BGS algorithm is also known as Foreground detection. Steps involved in BGS algorithm is as follows:

(1) Video frames of underwater camera data is converted into grey scale using the formula:

$$I = 0.2989\,R + 0.0870\,G + 0.1141\,B \qquad (1)$$

Where the Intensity of grey scale is denoted by "I" and R, G, B indicates the three grey level intensities like Red, Green and Blue respectively.

(2) Develop a recursive technique background model, as it does not require prior information about the background. First frame video is considered as initial background, in this algorithm. However, background is recursively updated based on each input frame.

(3) Detection of object or attentive portion of video frame is performed by subtracting pixel intensity of current frame with pixel intensities of previous frame from background model. Based on the intensity of pixels in two different frames, decision to be made as either background or object (foreground) by calculating the Diff _ frame as follows:

$$Diff\_frame = \left| Current\ frame - Previous\ frame \right| \qquad (2)$$

(4) Set threshold value. If the threshold is lower or equal to Diff _ frame value, it is considered as Background image, Else considered as

Object or Attentive portion of the image (foreground).

$$f(x, y) = \begin{cases} \text{Background}, & \text{if } |It(x,y) - Bt(x,y)| \geq T \\ \text{Object}, & \text{if } |It(x,y) - Bt(x,y)| < T \end{cases}$$

where:

I_t (x, y) is the existing frame intensity at location (x, y).

B_t (x, y) is the intensity of background model frame pixels in (x, y) location.

After background subtraction, the object or attentive portion is represented by white pixels. This procedure is executed till all the frames in the video are segmented.

Canny Edge detection for shape descriptor

Edge detection is one of the important aspects in the image processing application whereas the edge is major information provider to any image. An Edge of objects in an image is determined by the changes in brightness level. To extract the structure of object in an image, Edge detection plays a key role.

From the literature papers, we have observed that "Canny edge detection algorithm" is the most ideal edge detection algorithm compared to others.

Low error rate, Good localization and Single response are the key points to choose the canny edge detection algorithm (Avneesh and Rajesh, 2018). In edge detection algorithm, first step is to separate the background of the images to get the outline of the object by detecting all the edges.

Important aspect in edge detection is exact edges to be detected with their orientation to provide information about shape and orientation of the object.

Simple five steps involved in this algorithm are:

1. The horizontal (Gx) and vertical (Gy) gradients of each pixels in an image are computed first.
2. Based on the above information of each image pixel, magnitude (G) and direction is calculated.
3. Non-maxima are made as zero and suppressed. This process is called Non-Maxima suppression.
4. With the help of histogram of gradient magnitude of the image high and low threshold are computed.
5. Strong and weak edges are linked to obtain the best possible edge, by utilizing map hysteresis threshold. Pixels of an image having more than high threshold value is known as strong edge, whereas the pixel values lie between high and low threshold is known as weak edge. Hysteresis thresholding is utilized to make a decision that whether detected weak edges to be considered or not. Weak edges to be considered only when it is connected with one of the strong edges.

Motion Estimation using Differential Technique Optical flow algorithm

Continuous observation of visual features like points, objects, corners, shape, etc., motion in an environment is called as optical flow. Optical flow detects motion within each neighbourhood of pixels by registering changes in the colour and intensity of pixels from frame to frame (Figure 4).

Vectors indicating the direction and magnitude of detected motion are created, and groups of similar vectors are then segmented from each other (Chi-Cheng and Hui-Ting, 2006). The primary purpose of using optical flow estimation is to isolate individual moving objects within a video.

Differential technique optical flow algorithms are widely used for velocity estimation through spatial and temporal derivatives of image intensity. In (Barron et al., 1994), nine techniques were implemented which includs differential method, region based method, energy based and phase based techniques and found that second order differential method produce accurate and relatively dense measurements of 2D velocity. Shrimp movement in underwater is also dense motion, hence Lucas-Kanade method is used as differential technique optical flow for shrimp motion estimation.

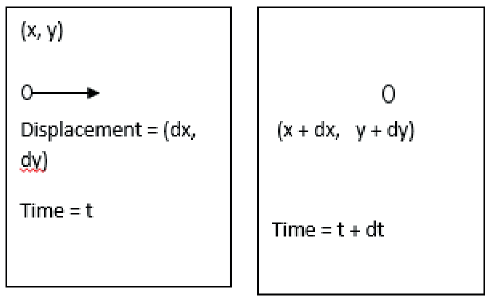


Figure 4. Optical flow motion estimation (frame 1 to frame 2)

Image Intensity (I) can be expressed as a function of space (x, y) and time (t) between two consecutive frames by assuming pixel intensities of an object are constant.

$$I(x, y, t) = I(x + dx, y + dy, t + dt) \quad (3)$$

In this differential method, two components of point motion are unknown. This can be solved by expanding Taylor series approximation of the RHS of eq. (3) and removing the common terms.

$$I(x + dx, y + dy, t + dt) = I(x, y, t) + \frac{\partial I}{\partial x}\delta x + \frac{\partial I}{\partial y}\delta y + \frac{\partial I}{\partial t}\delta t + ... \quad (4)$$

$$\ggg \quad \frac{\partial I}{\partial x}\delta x + \frac{\partial I}{\partial y}\delta y + \frac{\partial I}{\partial t}\delta t = 0 \quad (5)$$

To obtain the optical flow equation, divide eq. (5) by (dt), we get,

$$\frac{\partial I}{\partial x}U + \frac{\partial I}{\partial y}V + \frac{\partial I}{\partial t} = 0 \quad (6)$$

where:

$U = (\delta x / \delta t)$,

$V = (\delta y / \delta t)$,

$(\frac{\partial I}{\partial x}, \frac{\partial I}{\partial y}, \frac{\partial I}{\partial t})$ are the image gradients along with the horizontal axis, the vertical axis and time.

Optical flow can be estimated by solving "U" and "V". The above expression is having one equation with two unknown variables. Hence, it can't be solved directly. We have solved the equation using Lucas-Kanade method.

ID3 Decision tree classifier

ID3 algorithm is widely used simplest classify-cation algorithm. ID3 represents that "Iterative Dichotomiser 3". This algorithm works based on the Greedy approach. Decision tree is constructed by means of best attribute (feature) selection. High Information Gain (IG) or Low Entropy (H) is the key factor in selection of best attribute (Vadthe et al., 2014).

In our research, two attributes such as Motion and Shape of shrimp to be considered (Figure 5).

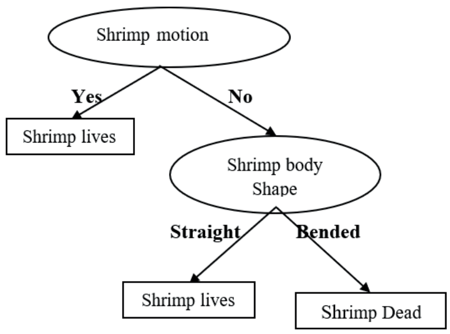


Figure 5. Decision Tree algorithm for estimating the shrimp status

Entropy (H): It is an assessment of the quantity of haziness in the dataset "S". It is represented mathematically as,

$$H(S) = \sum_{c \in C} - p(c) \log_2 p(c) \quad (7)$$

where: S - Entropy of current data set to be calculated; C - array of classes in S; p(c) - The ratio of the class "C" elements quantity to the set "S" elements quantity. Entropy having zero value is said to be leaf node. Otherwise, that branch to be spitted further to get the desired output.

Information Gain (IG): It provides information about how much haziness in the dataset "S" was reduced after splitting dataset "S" on attri-bute "A". It is represented mathematically as,

$$IG\ (\text{Attribute [A], splitting set [S]}) = H(S) - \sum_{t \in T} P(t)\, H(t) \quad (8)$$

where:

H(S) - Entropy of dataset "S";

T- The subsets generated by dividing dataset S through attribute A;

P(t) - The ratio of the number of determinants in "t" to the number of determinants in the set "S";

H(t) - Entropy of subset "t".

Information gain is computed for every attribute. The attribute having high Information gain is considered as decision node of the tree which will further divided to get the desired tree. Procedures for building decision tree are as follows:

1. Entropy of the given dataset is computed.
2. For each attribute, Entropy of all its distinguishable values and Information Gain of every feature to be evaluated.
3. Either largest Information Gain or lowest Entropy with feature is identified for splitting to decision node or branch of tree.
4. This process is repeated until we get the desired tree (output).

RESULTS AND DISCUSSIONS

One of the video frames is taken for analysis purpose is shown in Figure 7. With the help of Background subtraction segmentation algorithm, the attentive portion that is, shrimp position is separated for further analysis. Motion feature of shrimp is analysed by differential technique optical flow algorithm, whereas, shape of shrimp body feature is extracted with the help of canny edge detection method.

Direct processing on the video is difficult; as the images are captured continuously by the camera. Hence the video is converted into frames. Frames at different time period is converted and shown in Figure 6. A video can be represented as a function of x, y over time ‘t’ ie., f (x, y, t). When all the frames are converted then the background frame is initialized and considered as the reference frame or background frame B (x, y). Next step is the subtraction of background frames are performed with the current frames. The pixel by pixel (x, y) of the images will be subtracted on both frames (Ochs et al., 2014).
After subtraction process, the current image f (x, y) is marked as foreground. Foreground or attentive portion of image is obtained using equation (9).

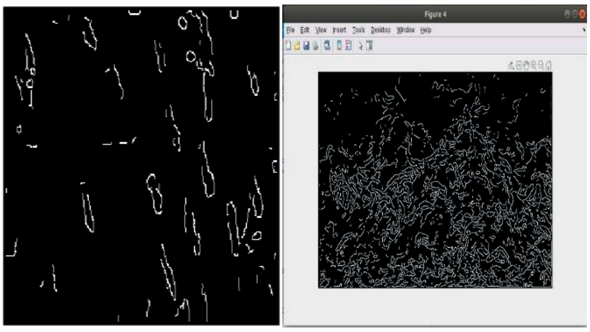
$$\text{if, } | f(x, y) - B(x, y) | > Td \quad (9)$$

where: Td is a predefined threshold.
Magnitude of motion vector from optical flow as well as entropy and information gain of edge detection leads to make a conclusion. Decision tree algorithm is applied to estimate the survival status of shrimp (Figure 7).

Figure 6. Image sequences of shrimp movement in pond aquaculture

(a) (b)

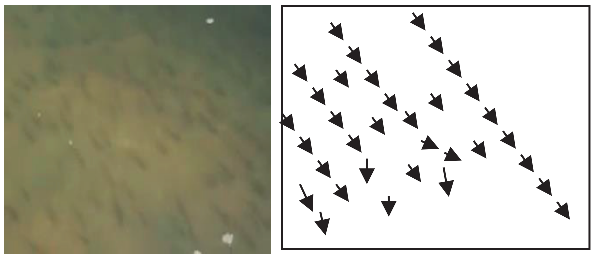
Figure 7. (a) Shrimp Movement in Pond Aquaculture; (b) Dead Shrimp in Pond Aquaculture



(a) (b)

Figure 8. The canny edge detector output for shape of shrimp body: (a) Live shrimp edges; (b) Dead shrimp edges

Presence of pixels in the outline of the image identifies the shape of the shrimp body. Canny edge detector appropriately distinguishes the pixels to detect the shrimp body shape. Canny edge detection uses double threshold to determine boundary pixels. The performance of the algorithm primarily depends on the changing parameters of threshold values. Horizontal and vertical edges were detected perfectly by the good performance of canny edge detector (Figure 8).
Using this edge detector, maximum edges get detected and this is the advantage of the canny edge detector (Javad and Hossein, 2012).



(a) (b)

Figure 9. (a) One of the video frame of shrimp movement in the pond; (b) Optical flow velocity estimation of shrimp motion in the pond

According to the Figure 9 we conclude that “two frames difference” optical flow method is suitable for simple motion detection.
Decision tree algorithm process the source of information into rule-based mechanism. Dataset for computing entropy and information gain to estimate the status of shrimp is presented in Table 1.

Table 1. Dataset for estimating the shrimp survival status

Attribute 1	Attribute 2	Output
Shrimp movement	Shrimp body shape	Shrimp status
Movement	Straight	Live
Non movement	Straight	Live
Non movement	Bent	Dead

Overall Entropy is calculated as follows:

H(S) = [- P (Live) $\log_2(Live)$ - P (Dead) $\log_2(Dead)$]

= - P (2/3) $\log_2(2/3)$ - P (1/3) $\log_2(1/3)$ = 0.9183 (10)

Similarly, Information Gain (IG) for each attribute is calculated to identify decision node and leaf node.

While computing IG, attribute 2 (Shrimp body shape) will be the decision node. While computing entropy for further analysis, leaf node (LIVE) is attained when its value is zero and when it is having nonzero value, considered as next output. That is shrimp is dead.

CONCLUSIONS

In this research, we approached a solution for the problem of recognizing aqua fauna, particularly shrimp in pond aquaculture and estimate the existence using Image processing Technologies. However, the proposed method not only detects the movement of aqua fauna (Shrimp), also take a binary decision about the survivability that is, alive or dead in the water environment. The work is modelled in such a way that it is able to recognise the shrimp motion and shape of shrimp body. Our proposed work results that image analysis (such as segmentation, feature extraction, motion analysis and classification) of shrimp in pond water aquaculture is more effective.

Moreover, this research is a partial work for developing automation system of monitoring the aqua-fauna, particularly, shrimp cultivation remotely. The outcome of this research can be developed as a product for monitoring aqua fauna cultivation in ponds, lakes or in small ponds created artificial. In addition to the work, we propose to address further prior optical knowledge into progressive machine vision approaches by model renovation and building up highly sophisticated models for productive remote aqua fauna monitoring system in underwater environment. Also, efforts have to be made to reduce the response time of the systems and make them online. Output of our research will be beneficial to Aqua farmer's community by preventing from huge economic losses.

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