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# A Vibration Processing Analysis Approach to the Development of Fish Feeding Regime System

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## ABSTRACT

**Abstract:** Feeding is important in life cycle of fish, whereas one of the major challenges facing aquaculture industry is the inefficient management of the feeding. Excess feeding results in left over feed which eventually produces negative environmental effect. Feeding fish based on their demand will reduce feed wastage to the bearest minimum and effectively address the problem of water contamination. This paper proposes a feed dispensing algorithm using vibration processing analysis. The intent is to develop a feeding regime system that can identify fish behavioral activities to determine when fish is hungry, and provide them with precise amount of food as demanded. The dataset adopted in this study was obtained using data logger incorporating tri-axial gyroscope, accelerometer and magnetometer. The gyroscope used to determine the changes in angular velocity with respect to x-, y- and z-direction, while accelerometer and magnetometer employed to determine the changes in acceleration in x-, y- and z-direction. These patterns were further process using sliding window analysis. The mechanical differences between these patterns is proposed to be used for classify when fish are hungry from other activities. It is expected that the proposed system will has potential of reducing overfeeding and increase fish productivity.

**Keywords:** Accelerometer, Aquaculture, Feed, Feeding System, Fish, Fish Behavioral Pattern.

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## 1. INTRODUCTION

The Exponential increase in fish consumption owing to it been a reliable source of protein has increased the demand for fish worldwide (Grainger, 2002). This continuous inclination which runs for over a decade has catalyzed the growth of aquaculture industry globally (Statistics, 2008). Nevertheless, high protein demand; deficiency in fish supply; Climate change, increment in land rental rate and diseases are some of the reasons researchers are involved in improving and exploring new technologies for the aquaculture industry. This has leads to the development of innovative systems, process and new management approach (Shaari et al., 2011). All these issues might be interrelated with each other. For example, high land rental rate contends the fish farmers to practice intensive fish farming, which means to accommodate high stock density per ponds it requires high degree of control. However, poor management of aquaculture system such as feeding causes water contamination which leads to disease spreading and eventually result to low fish productivity.

The fish feeding process is one of the most important aspects in managing aquaculture system, where the cost of fish feeding is around 40 to 50% of the total production costs (Chang et al., 2005; Al-Zubi et al., 2016). The method of feed delivery is essential to obtain the maximum profit or return by aquaculture entrepreneurs. It has been estimated that over 60% of the feed placed into an aquarium ends up as waste particulates (Timmons & Losordo, 1994; Atoum et al., 2015). The accumulation of this particulates result in the water contamination which further decomposes and produce ammonia-nitrogen and other toxic substances such as hydrogen sulphide that could eventually be harm the growth of the fish. However, the extend of these effects demand on the feeding techniques or mechanism adopted. In the traditional feeding mechanism, fishes are fed by throwing feed unevenly on the surface of the water at fixed schedule such as four meals a day. This scheduled feeding leads to a number of problems such as feed wastage, Non-uniform fish growth and Environmental effect (Krisna et al., 2014; Wu, 1995; Navarrete-Mier, et al., 2010; Reddon & Hurd, 2009 and Binoy, 2015).

The Automated feeding mechanism entails the use of devices such as automatic feeders in dispensing feed at the stipulated times. These feeders are calibrated such that they dispense the right amount of pellets at a particular time. The mechanism allows for feeding in the right schedule and amount pre-defined by user, thereby eliminating the issue of undue labour of the manual feeding. However, these mechanism is not efficient enough due to the fact that the feeding habit of fish changes as a result of changes in growth rate, age, size or weather condition. But with this mechanism feed schedule does not vary in accordance with these factors (Noor et al., 2012).

Therefore, precise quantities of food should be provided to avoid water contamination and economic losses due to feed wastage as well reduced the risk posed to the fish as a result of toxic substances that could result from decomposition of the excess feeding. In order to ensure efficient feeding, intelligent feeding system is required. The system should ensure fish are fed only when they are in need of food and the feeding rate should be determined based on response of the fish to the food.
In view of the challenges, this work proposes to address the inefficiency in managing feeding system as well as providing fish famers ability to handle full and self-regulating feeding operation. To achieve this, a fish behavioural pattern identification algorithm that can classify fish behaviour to determine when fishes are in need of food has been formulated and presented herein this paper.

The rest of the paper is organized as follows: In section 2.0, review of related work is given. Section 3.0 provide the proposed methodology to be adopted, section 4.0 Present the results; while 5.0 concludes the paper.

## 2. LITERATURE REVIEW

Recently, a number of researches have been carried out to optimize the feeding operation process. Noor et al., (2012) developed an automatic fish feeding system using PIC microcontroller. The system aims at reducing the cost of hiring labourers in feeding operations by allowing manual delivery of feeding cycle to suit the user. The limitation of this work is that the system is not intelligent to monitor the feeding rate of the fish and provide feed accordingly to avoid wastage. A PIC microcontroller based automatic feeder with efficient pellet-distribution device on a DC motor rotational speed proposed feeder by Noor et al., (2012). The system is made up of a feeder stand, keypad, DC motor, pellet storage, former and PIC microcontroller. This feeder was tested with the keypad programmed to determine the motor speed range suitable to the user considering the pond size and pellet distribution. However, the system operation was limited to predefined timing specified during the design.

Papandroulakis et al., (2000) developed a fuzzy logic controller (FLC) system for feeding fish using linguistic estimations and rules for the daily feeding managements of sea bream larvae. A related feed monitoring and Control System based on groups of sensors in a marine fish farm proposed by Garcia et al., (2010). The sensors used includes: oxygen sensors, temperature sensors, displacement speed sensors, biomass distribution sensors, and pellet detection sensors. The information acquired from this group of sensors were used to determine when the fish are in need of food. The results obtained, proved to be effective for controlling feeding process, saving feed wastage; thus, reducing fish production cost. However, system implementation is highly expensive due to large number of sensors applied.

In 2010, (Garcia et al.,) propose a monitoring and control sensor system for fish feeding in marine fish farms using underwater transducers to monitor the movement of fish in sea. The system reduces reduce manual method of feeding. However, feeding rate of the fishes is not taken into account. Kamisetti and Shaligram (2012) developed a smart electronic system for pond management in fresh water aquaculture which continuously measures and control several hydro-biological parameters responsible for growth of fishes. These factors are majorly used for cleaning the pond. The system also possesses intelligence through Predictive Decision Support System (PDSS) for predicting stress factor on-line. However, there is a need for efficient feeding system in order to reduce the wastage thereby contributing to keeping the pond clean.

Lee et al. (2013) applied computer vision technology in a sustainable aquaculture feeding system. The system uses Labview as well as integration of various components such as actuators, webcam, Intel processor, Bluetooth device. An algorithm was developed to detect the presence of fishes and count their numbers. The limitation of this work is that it can only infer the appetite of fishes based on their number, there is no means to validate if really the fishes are hungry and the consumption rate of the fish.

## 3. PROPOSED FEEDING REGIME SYSTEM

The proposed methodology consists of five steps: fish behaviour vibration patterns identification, data acquisition, feature extraction, algorithm development as well as testing and performance evaluation of the developed system using k-fold validation technique. The method of realizing each module is described in subsequent subsection.

### 3.1 Data Acquisition

The datasets used in this study was obtained from the study conducted by Takuji et al., (2014). The setup used for the acquisition of data include a data logger incorporating tri-axial gyroscope, accelerometer and magnetometer. The data logger is cylindrical in shape (diameter: 3 cm, length:17 cm) with a mass of 108 g in air. The logger measured and stored all the sensors outputs in an internal micro SDHC memory (32 GB) at a sampling frequency of 500 Hz with measurement average size of 1.0 Gauss, 16g and 1500 degree per second for the magnetic field, acceleration and angular velocity respectively. One week prior to the feeding and escape response measurements, the length and mass of the fish were measured under anaesthesia induced with phenoxyethanol (0.05%). A plastic plate (3618 $cm^2$) was sutured to the dorsal musculature just above the centre mass (CM; 43% of the TL) of the fish using cable ties. The plate formed the base of the data logger. The temporary attachment of the gyro logger to the base plastic plate was accomplished using cable ties and the fish were sedated using anaesthesia during this process. The mass of the data logger less than 3% of the body mass of the fish.

### 3.2. Feature extraction

The feature extraction techniques adopted in this work are classified as mean, standard deviation and variance of the acceleration and gyroscope value. The purpose of this process is to generate feature vector that are suitable for individual identity recognition. Mathematical model in (3.1) to (3.3) was applied to extract feature in time domain.

$$\mu = \frac{\sum_{k=1}^{N} A_k}{N} \qquad (3.1)$$

$$\sigma = \sqrt{\frac{1}{N}\sum_{k=1}^{N}(A_k - \bar{\mu})} \qquad (3.2)$$

$$var = \left(\sqrt{\frac{1}{N}\sum_{k=1}^{N}(A_k - \bar{\mu})}\right)^2 \qquad (3.3)$$

Where $\bar{\mu}$ represent mean, $\sigma$ represent standard deviation, $var$ represent, N represent number of data and $A$ represent the summation of the data from k = 1 to N.

### 3.3 Algorithm Development

The proposed algorithm for feed dispensing will classify fish behaviour to determine when fish is feeding and disturb by predator. Figure 3.1. illustrates the block diagram representation of the proposed fish dispensing algorithm. The dataset will be divided into two sets namely: training dataset and testing dataset. The training dataset will be used to train the proposed algorithm whereas the testing dataset will be used for the testing. The mathematical model in (3.4) illustrate model of neural network.

$$\square_k = \sum_{j=1}^{n} w_{kj} x_j + b_k \qquad (3.4)$$

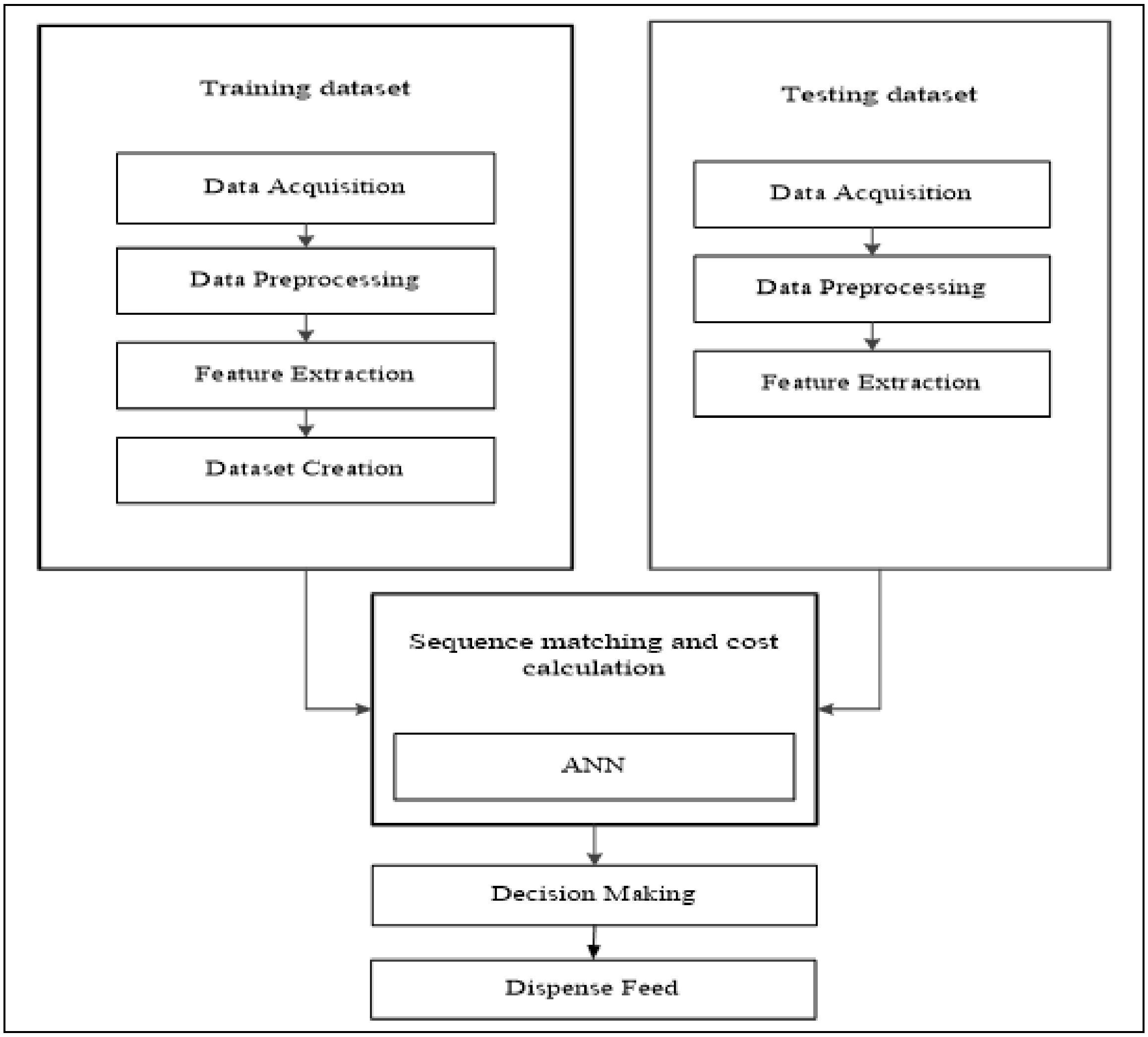



**Figure 3.1: Proposed feed dispensing algorithm**

Where $U_k$ represent Neuron output, $x_j$ represent input signal, $w_{kj}$ stand for weight from the $jth$ to $kth$ neuron and $b_k$ represent bias value.

Back-propagation algorithm proposed to be use for training the network in order to fine a set of connection weights that minimizes an error function. The proposed algorithm involves the following steps (Ogunlela et al., 2015):
The first step is the computation of the error derivative using mathematical model in (3.5)

$$EA_j = \frac{\partial E}{\partial_{yj}} = y_j - d_j \qquad (3.5)$$

Where E denotes Error, $y_j$ represent activity level of the $jth$ unit and $d_j$ represent anticipated output of the $jth$ unit.
The second step involve the computation of how fast the error varies as the total input received by output is changes using mathematical model given by (3.6)

$$EI_j = \frac{\partial E}{\partial_{xj}} = \frac{\partial E}{\partial y_j} X \frac{\partial y_i}{\partial_{xj}} = EA_{\square}\, y_j(1 - y_j) \qquad (3.6)$$

The third step is to model how fast changes in error as the weight on the connection into an output unit is changed. The mathematic model is given by (3.7)

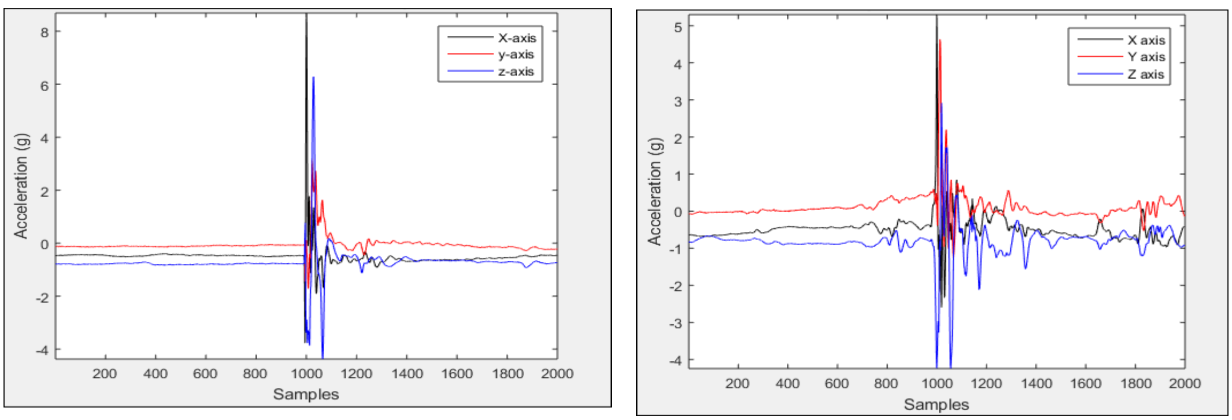
$$EWi_j = \frac{\partial E}{\partial w_{ij}} = \frac{\partial E}{\partial x_j} \; X \; \frac{\partial x_i}{\partial_{xj}} = El_j \, y_j \qquad (3.7)$$

The last step is the computation of how fast the error fluctuations as the movement of a unit in the preceding layer is changes using mathematical model in (3.8)

$$EA_i = \frac{\partial E}{\partial y_i} = \frac{\partial E}{\partial x_j} \; X \; \frac{\partial x_i}{\partial_{xj}} = \sum El_j \, w_{ij} \qquad (3.8)$$

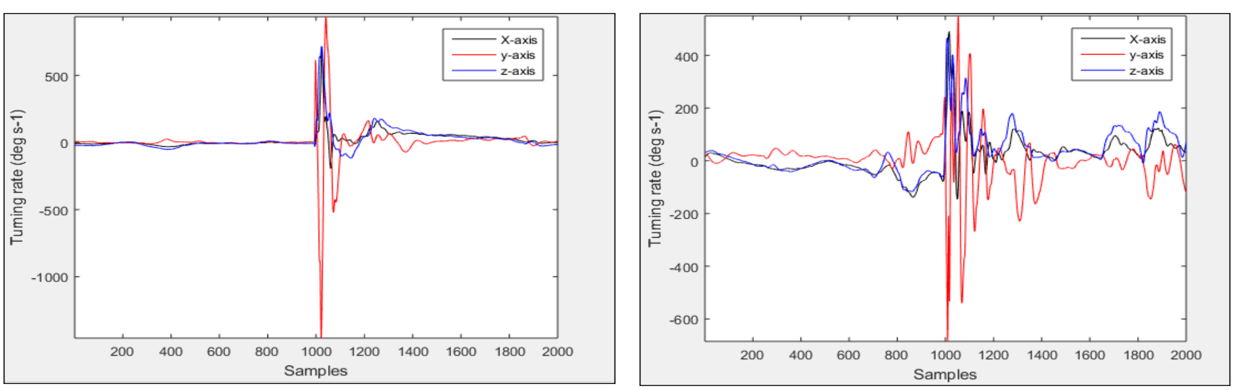
## 4. RESULTS AND DISCUSSION

The analysis technique adopted extracts the data using mathematical methods described in section 3.3 to statistically analyze the parameters of the fish activities. The raw accelerometer data obtained along the x-, y- and z-direction for the escape and feeding movements are shown in Figure 4.1, while the Figure 4.2 shown raw gyroscope data for the escape and feeding movements.




(a) Escape movement (b) Feeding movement

**Figure 4.1: Raw Accelerometer data for the (a) Escape and (b) Feeding movements**

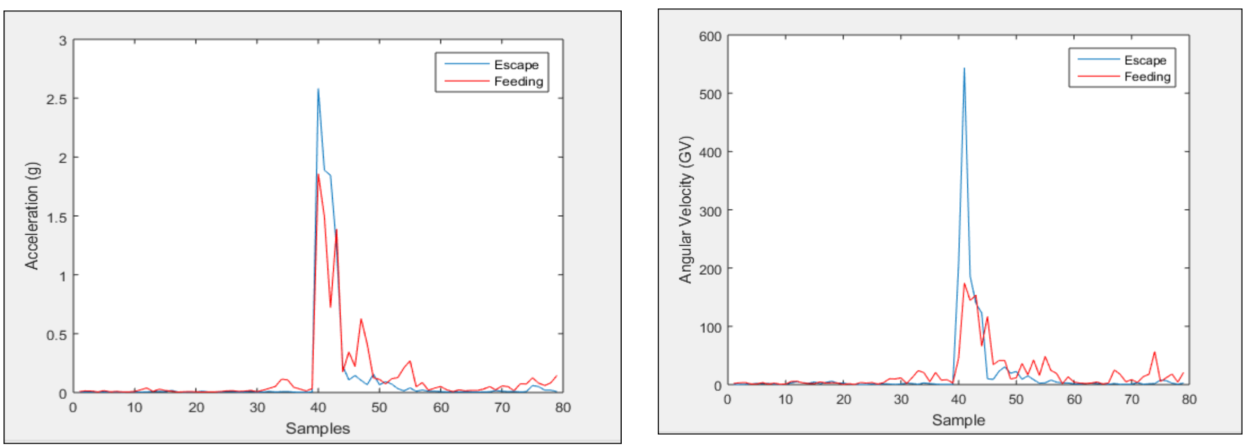



(a) Escape movement (b) Feeding movement

**Figure 4.2: Raw Gyroscope data for the (a) Escape and (b) Feeding movements**

By observing the raw accelerometer data of Figure 4.1 (a) and (b). It can be visually seen that escape movements typically had a maximum acceleration in the x-direction than observed in the feeding movements, which replicates the lower intensity of the beating of the caudal fin during feeding activity compare with escape movements. It can also be deduced that the range of maximum acceleration in escape movement occur in orders of x-, z- and y-direction, while the order of acceleration in feeding movements take place in order of x-, y- and z-direction. For the raw gyroscope data (Figure 4.2 (a) and (b)), the turning rate of the escape event had a higher degree than feeding activities. However, feeding activities poses multiple rate of turning during feeding than escape activities. The differences may be due to different strategies that are involved in the movements, where feeding activities requires the adjustment of movement to capture the food, the escape requires a considerable amount of turning to avoid threats.

The raw data in Figure 4.1 and Figure 4.2 offers a little fact in obtain a feature that can be useful to differentiate between feeding and escape activities. It was noted that differences between the maximum and minimum acceleration and angular velocity provided some beneficial information, however, it is not apposite to relies on it because it may be affected by other factors such as motivation of the fish, attach location of the data logger and environmental factors. To determine the feature vector that are suitable for the classification of these activities, inter-axial differences, mean, Standard Deviation (SD) of the Magnitude Acceleration (MA) and angular velocity (summation of x-, y- and z-direction) were considered using sliding windows analysis. A windows size of 25 sample was applied to the raw accelerometer and gyroscope dataset to determine the mean, SD and variance of the magnitude acceleration and angular velocity for the periods and optimal threshold (feeding and escape location) for each activity were established. The obtained results for the SD were shown in Figure 4.3.




(a) Accelerometer processed data (b) Gyroscope processed data

**Figure 4.3: Standard deviation of the (a) Accelerometer (b) Gyroscope processed data**

By observing the standard deviation of magnitude acceleration (Figure 4.3 (a)), it can be seen that feeding movement actually exist between 30sample to 60sample, while the escape area only limited to the between 39sample to 55sample with the maximum acceleration. The standard deviation of the gyroscope reading (Figure 4.3 (b)) shows that escape activity exists between 39sample to 55sample with maximum turning rate, while the feeding activity indicate existence of multiple turning rate between 30sample to 60sample and 65sample to 75sample respectively.

## 5. CONCLUSION

This paper proposed an efficient vibration processing analysis approach to the development of fish feeding regime system. The procedure for the realization of the system can be summarized as following: The data after being acquired it was processed to remove noise. Feature extraction process was then applied to isolate unique features that are suitable to generate vector apposite for identifying behavioral patterns of the fish. From the obtained result, it was observed that maximum acceleration in escape movement occur in orders of x-, z- and y-direction, while the order of acceleration in feeding movements is x-, y- and z-direction. For the raw gyroscope data, the turning rate of the escape event had a higher degree than feeding activities. However, feeding activities poses multiple rate of turning during feeding than escape activities. The differences may be due to different strategies that are involved in the movements.

The procedure for the vector selection was based on visualization and statistical process. The processed data will be divided into training and testing dataset, follow by sequence matching and cost calculation using Multi-Layer Back Propagation Network (MLBPN). The next is the decision making that will be taken whenever feeding activity pattern is identified, this results in dispensing of the feed. This work is proposed to address inefficiency management of fish feeding system as well as provide fisheries with capability to handle full and self-regulating feeding operation. To achieve this, a fish behaviour pattern identification algorithm that can classify fish behaviour pattern to determine when fish is searching for foods was formulated. It is expected that the proposed system will has tendency of reducing overfeeding and inrease fish productivity. Our intention in this paper forms a preliminary step in a long term research geared towards development of feeding regime system that are capable of handle full and self-regulating feeding operation.

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