Acta Scientific Veterinary Sciences (ISSN: 2582-3183)

Volume 5 Issue 6 June 2023

Case Review

The Power of AI in Fish Feeding and Behavior Management: A Comprehensive Review

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DOI: 10.31080/ASVS.2023.05.0679

Received: May 08, 2023

Published: May 31, 2023

Abstract

In this study, the use of computer vision and artificial intelligence technology is examined as a means of improving the efficacy and sustainability of fish feeding in aquaculture. The proposed approach employs machine learning techniques to estimate feeding requirements and optimise feeding schedules, while image analysis is employed to track fish behaviours and appetite. The method aims to increase the growth and health of fish while reducing waste and the environmental impact of aquaculture operations.

Keywords: Fish Feeding; Aquaculture; Sustainability; Optimization; Machine Learning; Artificial Intelligence; Computer Vision

Introduction

Aquaculture has grown into a booming business over the past 30 years, with an average annual growth rate of 4.5% expected from 2010 through 2030. The proportion of expenses connected to feed costs has increased as intensive farming has continued to grow. Costs have risen by 40-50% for Atlantic salmon, 60-80% for carp aquaculture, and up to 86% for some other species (catfish: 81-86%), for instance. The primary concern in aquaculture is fish feeding, which is crucial not only because it accounts for 40 to 50 percent of total production costs but also because the traditional feeding method causes a number of issues with farm productivity, fish productivity and uniformity, environmental impact on ocean floors in the case of open ocean cages, and fish welfare because of the high level of competition for food as a result of the traditional feeding method.

This study discusses the fundamental ideas and principles of the various intelligent aquaculture feeding control technologies, including acoustic approaches and computer vision, that have been created over the past 30 years and are responsive to the needs of fish. The relationship between fish hunger and growth (body length, weight, and quantity), feeding behaviour and feed distribution, intake and accumulation rate are also explored in this study.

Additionally, a variety of prospective tools and techniques that could be utilised to direct and control feeding operations are explored.

Factors effect on fish feeding behaviour

Many researchers have shown in their studies that the swimming speed, direction changing pattern during feeding are the behavioural reflection of appetite of fish [1].

Internal factors that influence feed intake and appetite in fish include those related to their physiological and nutritional requirements. The neurological and endocrine systems have been suggested to play a role in controlling fish feeding behaviour [2] and the physiological regulation of appetite is strongly tied to peripheral and central signals from the brain [3].

Neuropeptide Y affects the feeding behaviour and appetite [4] of fishes like Tilapia [5], Goldfish [6].

As fish feeding's primary goal is to meet the fish's protein and energy needs, which are closely correlated with feeding behaviour and feed intake, nutrition is another crucial internal aspect. The quantities of protein, lipids, and cholesterol are the most crucial nutritional components. For instance, rainbow trout would consume less feed as the protein to calorie ratio rises [7]. Different feed carbohydrate and vitamin E contents, dietary preferences, and other factors may also affect fish feed intake [8]. Additionally, fish hunger, which is reflected in fish development, can be directly impacted by nutrition. In actual production, a unique, non-destructive, and intelligent method or system is required to track fish growth in order to alter the feeding control strategy in real-time in response to the findings.

Some other external factors that affects the feeding behaviour of fish are temperature [9], photoperiod [10], dissolved oxygen, salinity, colour of surrounding environment (The colour of the environment around fish can influence how they feed and how big they get. For instance, flounder raised in white tanks usually grow more quickly than those raised in black tanks [11].

Methods for identifying feeding behaviour based on computer vision

Aquaculture has recently made extensive use of computer vision technologies [12]. It has been used for counting, measuring size, identifying gender, evaluating quality, identifying species and populations, and keeping tabs on welfare and behaviour [13]. A practical way to conduct real-time, autonomous, and contactless research is made possible by the widespread application of computer vision technology [14]. Light can be classified as visible or infrared depending on the various wavelengths used by cameras. Most cameras use visible light as their source of illumination.

Recognition of direct feeding behaviour

The shape, texture, area, dispersion, and swimming activity of the fish shoal, as well as other factors are the direct method of reorganization using the measured photos [15]. According to Saberioon., *et al*. (2017), [16] computer vision technology has been utilised to detect the presence, number, length, and behaviour of fish. Recent research has demonstrated that it can also be used to accurately feed fish by estimating their hunger [17,18]. The texture, colour, shape, area, and number of fish feeding simultaneously alter when fish exhibit different feeding intensities [19]. Additionally, there are variations in fish aggregation levels, angular velocity, velocity, and acceleration [20]. Single cameras, underwater cameras, stereovision, or near-infrared vision can be used to detect individual behaviours, and other helpful data regarding fish feeding, such as fish length, average weight, and distribution, can be gathered. Using this knowledge, farmers can create feeding strategies that are more productive.

The foregoing data can be collected more efficiently with a single camera, and research has shown that a fish's mass is closely proportional to the area of its image [21]. For instance, the pixel area of grey mullet, carp, and tilapia can be used to determine their mass [22]. Machine vision has been used to automatically supply feed and detect the presence and number of fish [23] .A single camera-based system has been designed to measure behavioural differences [24] at each feeding stage with low frame loss in order to give data for intelligent feeding.

Research on single-camera computer vision also focuses on how fish behave differently under stress. Researchers can analyse fish feeding behaviour by examining how changes in the environment are reflected in behaviour by escalating stressful situations [25].

A unique infrared reflection (IREF) system was proposed by Pautsina., *et al*. (2015) and is based on the water's potent NIR light absorption properties. To enable three-dimensional tracking of fish, the distance of the fish is determined based on the brightness of the fish target on the image [26]. This system has advantages over the typical stereo vision system, including lower hardware costs and less computation. The tracking precision is still subpar, though. A multi-fish tracking technique was proposed by Qian., *et al*. (2016) [27] based on the identification of fish heads and employed the form and grayscale characteristics of fish head images to pinpoint their location. The findings demonstrated that, in a low-density experiment, this technology is capable of determining the motion trajectory of several fish.

However, according to Marti-Puig., *et al*. (2018), [28] there is room for improvement in the precision of monitoring group motion targets. Structured-light (SL) sensor use effectively increases three-dimensional tracking accuracy (98%) while lowering system costs [29] The discipline of computer vision is still grappling with how to make multi-target tracking algorithms for groups robust and reliable [30].

For regulating the feeding process, stereo vision is significantly more advantageous in determining fish size and three-dimensional (3D) position. In recent years, stereo vision has been employed to count fish [31], predict fish biomass [32] conduct real-time classifications [33] measure fish size [34].

The direct linear transformation method has been used to estimate fish's body length and 3D distribution, which gives helpful information for feeding [35]. It is broadly applicable to fish monitoring in a variety of scenarios. The use of calibration equations to estimate resources from images taken from cages has also been studied by researchers [32,56] and cameras have also been improved [36,37] to improve measurement accuracy and the ability to capture moving objects [31,36]. However, using stereo vision necessitates locating the same spot in two or more cameras, which makes developing these systems more challenging.

In 2016 Hamzah S. AlZubi [38] developed an intelligent behaviour based fish feeding system, which tracks the feeding behaviour of the fishes using the webcam and develops a system which can feed the fishes automatically without the help of human or anything. Using this system the fishes learned to feed their selves own with in 8 days. They 1stly used the Time feeder which feeds the fishes at regular interval of time this creates the Time Feeder Index (TFI) after 2 days they shifted to Smart feeder because 70% of fishes learnt the behaviour. The algorithm could analyse when fishes are coming to the feeding area are it drops the feed automatically, it also can analyse the behaviour of the shy fishes which are unable to take feed due to bold fishes. The algorithm also helpful to feed these shy fishes.

This type of AI powered algorithm based smart feeder system is very helpful to control the water pollution problem, under feeding or overfeeding problem due to uneven feed distribution.

Infrared imaging

Since visible light intensity has no bearing on near-infrared (NIR) computer vision technology, it can produce improved imaging effects in relatively dark settings [39]. It can be used to recognise fish behaviour in low-light situations [40].

The process of fish feeding is seen and fish feeding behaviour is identified in recent studies using near-infrared imaging technologies. One study [40] collected photos of fish feeding using a near-infrared industrial camera set above water. Using image processing software, binary pictures of each fish were obtained. Additionally, the splash and reflection effects on the findings are reduced using the classification approach and elimination of reflect ion frames based on support vector machines and grey gradient co-occurrence matrices.

Compared to conventional cameras, infrared sensors and near-infrared imaging technology are better appropriate for measurements in murky water with complex lighting circumstances [39].

It is increasingly employed in behavioural analysis, positioning of fish populations, 2D or 3D tracking [46], and aquaculture to estimate biomass. Before such technology may be used in commercial fish farms, more investigation is required to get a larger sample size.

Methods for identifying feeding behaviour based on acoustics

Although simple and affordable, the computer vision approach has certain drawbacks. For instance, clean water is typically the sole use of computer vision technology. The camera system might not be able to get an accurate image of the fish if there are many fish in the bottom of the cage or away from the light source. Although infrared light can be used in the dark, using the right infrared filters may not improve the image quality enough to watch movement. Acoustic techniques can be used to correct these flaws. According to Smith and Tabrett, 2013 [41] there are two types of methods for gathering acoustic data: those that use passive and those that use active acoustics.

Passive acoustic

There are new requirements for modifying feed quantity in accordance with the needs of high-density intensive farming It is crucial to maximise feed intake for the fish while minimising waste hence finding a signal that is specifically related to feed intake has been a key area of study [42,43]. Fish make sounds when they capture, ingest, or chew food [44]. These sounds may be the result of sudden acceleration during prey capture [45] rapid changes in mouth pressure during feed inhalation, or friction between the teeth and the food [46,47].

Specific algorithms (AQ1SYSTEMS 2014) are utilised to predict feed demand in real time using a hydrophone installed in the feeding area to gather sound signals made during feeding.

The use of feeding noises to gauge feed consumption is supported by all of the aforementioned investigations. The correlation between feed intake and consumption must, however, be measured and confirmed. Additionally, environmental noise at the breeding site is primarily periodic noise in an actual production process, whereas feeding noises are random signals; hence, reducing environmental noise will boost this method's accuracy.

Acoustic training

Acoustic training of fish has been found to be successful [48]. A study of fish biological and acoustic abilities discovered that most fish have a hearing range of 50-1500 Hz [49], and some fish can detect different frequencies [50] and variations in sound signals [51].

A recent study found that groups of trained common carp can distinguish sound signals associated with a specific pulse of pure food; the fish may learn to distinguish the sound signals that call them to the feeder from other irrelevant background signals in their environment [33,52].

Many wild fish, for example, were demonstrated to be drawn to specific places for regular feeding using low-frequency audio signals [53]. Furthermore, regular fish training is an efficient way for feeding practises. Acoustic training is frequently utilised in large-volume fixed-point feeding systems, where it can successfully prevent blind and disordered feeding while also reducing feed waste and water pollution.

Discussion and Conclusion

This study evaluates and analyses the most recent advancements in fish feeding behaviour recognition (evaluation of fish feeding intensity) approaches, as well as summarises the most relevant technological methods based on computer vision technology and Acoustic-based technology. Computer vision is a real-time, non-invasive, and cost-effective technology for identifying feeding behaviour. Surface reflection and poor image quality continue to limit its use in aquaculture. Because the quality of near-infrared imaging is unaffected by visible light intensity, it can alleviate this restriction to some extent. Light intensity and water turbidity have little effect on acoustic behaviour recognition. However, its application accuracy is still generally modest and rather expensive.

Monitoring has enabled feedback systems and feeding management approaches to become increasingly intelligent, and the parameters of interest are linked to growth status as well as environmental and behavioural changes. The evolution of feedback and control systems is moving towards the integration of images, video, and analytical software.

By gaining a thorough grasp of the ongoing effects of environmental, physiological, and feed quality aspects on fish feeding, as well as improvements in artificial intelligence technology, big data, the Internet of things, and other emerging technologies, It is expected that in the near future, various intelligent optimisation algorithms will be developed and used, high precision and multi-function sensing and feedback control devices will be equipped, improved, new or potential methods will be proposed to provide more and more intelligent solutions to measure as many feeding characteristics as possible, and methods, feeding machines, and systems based on the aforementioned technologies will also be more sophisticated.

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