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Early Screening Protozoan White Spot Fish Disease using Convolutional Neural Network

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ABSTRACT

Aquaculture is in critical need of both intelligence and automation control in order to maintain a sustainable level of production. Historically, the accuracy of the disease diagnosis is determined by a person's abilities, experiences and length of time spent. Due to the high level of expertise, time, and effort necessary to obtain an accurate diagnosis through manual inspection, inadequate early treatment could result in the rapid spread of the disease. As a result, there needs to be much focus on early-stage fish disease screening due to the rapid spread of infectious diseases in the vast fish system. This research focused specifically on Protozoan white spot disease, an infectious disease caused by *Cryptocaryon irritans* in saltwater considering the fact that the infection is contagious. Consequently, this research aims to create an intelligent system utilizing a convolutional neural network (CNN) algorithm, namely GoogleNet to detect infected fish based on raw underwater images taken. 90% accuracy achieved showed that the innovation could ease the process of fish disease screening. This effort could be a contributor to the aquaculture industry since humans rely on fish for survival in modern times for fisheries and livestock.

1. Introduction

Over the last decade, Malaysia's aquaculture sector has risen at a phenomenal rate as an essential engine of growth, hence the expansion of fish management and production should be prioritised since the sector is ultimately important for both food and livelihoods as stated by several authors as mentioned by several authors [1-3]. As the world population expands and fish is increasingly recognized as a highly nutritious protein source that could be easily digested, the demand for fish continues to rise. However, aquaculture systems are frequently impacted by outbreaks produced by infectious illnesses and associated with mortality, restricting their capacity to address common fish health issues and worsening the situation.

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Protozoan white spot disease is one of the most common parasitic diseases that affect mariculture fish due to overcrowding and the harsh environment of the system as declared by a few authors [4-7]. The infection caused by ectoparasite namely *Cryptocaryon irritans* could typically be detected for visual symptoms by noticing the presence of whitish to greyish pinhead-sized spot located at eyes, skin, fins and gills. However, in some worst cases, infected fish could experience impairments in the function of their major organs which could lead to paler gills, hazy eyes, sunken fins and changes in body colour as reported by Yanong [8]. Thus, the protozoan white spot disease epidemic poses a serious threat as it could easily travel through the water and is capable of causing widespread mortality.

Manual inspection of the disease could be one of the challenges affecting the production and cultivation of species and also might lead to a severe impacts on the development of the aquaculture industry as reported by Fathi *et al.,* [9]. In the context of Industrial Revolution, Artificial Intelligence (AI) has become a crucial driving force. It possesses the capability to enhance productivity, adaptability and agility across all industries through intelligent manufacturing, which in turn has the potential to substantially boost global income levels as expressed by Peres *et al.,* [10]. Thus, it is believed that the revolution in technology has provided an opportunity to develop new procedures that could resolve or minimize issues associated with the current manual approach. The convolutional neural network (CNN) is a well-known deep learning technique specifically for classification, which is advantageous to support the purpose of this research in detecting protozoan white spot disease at an early stage.

Previously, one research proposed by Shaveta *et al.*, [11] a machine learning and image processing algorithm for the identification of Epizootic Ulcerative Syndrome (EUS) and successfully increased the classification accuracy to detect the disease. Meanwhile, one research divides the work into two portions by pre-processing the fish images before extracting the disease features using Support Vector Machine (SVM), a machine learning algorithm. The results show SVM performs notably with 91.42% and 94.12% accuracy, respectively. The participation of a large number of features with a small sample size is one of the primary difficulties in feature selection as stated by Son Ng et al., [12]. Whereas another research by Sung *et al.,* [13] proposed a CNN algorithm, You Only Look Once (YOLO) Network to specificity enhance and optimise fish images for real-time fish detection. 62% classification accuracy achieved has proven the method outperforms the Histogram of Oriented Gradients (HOG) feature extraction algorithm.

2. Problem Statement

Conventionally, fish disease is detected manually by fish health experts or fish owners using human visual observation according to Barbedo [14]. Nevertheless, traditional human visualisation methods result in considerable gaps due to their time-consuming and imaginative tendencies since skilled diagnosis experts are required to effectively identify and treat all treatable conditions as stated by Divinely *et al.*, [15]. According to the death case investigation worksheet prepared by National Fish Health Research Centre (NaFisH), case sampling and on-site investigation would be conducted before the samples is tested in the laboratory. It is essential to have fish experts present on-site to examine and treat the infection that occur. Furthermore, due to the remote locations of farming sites, it is often impractical for fish farmers to have easy access to fish experts as said by numerous authors [16,17] Thus, failure to provide timely and appropriate care would result in the certain death of infected fish, despite their susceptibility to environmental stress and disease.

This research focused on the CNN algorithm, namely GoogleNet, to act as an alternative to detect protozoan white spot disease. CNN is a Deep Learning system that highlights the importance features of numerous elements or objects in an input image and differentiates them from one another. It requires far less preparation than other classification techniques since it is a learning process that relies on examples [18]. One research by Choi [19] combined GoogleNet with bilateral filter, a foreground detection to identify fish in underwater video. However, the fish tasks deal with the underwater video image; hence it was more challenging than the general image classification task and additional steps were needed for pre-processing and post-processing. Another research by Villon *et al.,* [20] also proposed GoogleNet for accurate and fast identification of coral reef fishes in underwater images. The correct identification rate was 94.9%, greater than the correct identification rate by humans (89.3%). Hence, more researchers believed that CNN also able to identify fish individuals partially hidden behind corals or other fish and was more effective than humans in identifying fish on smallest or blurry images, while humans were better at identifying fish individuals in unusual positions.

2. Methodology

The proposed method is intended to serve as an early screening strategy for protozoan white spot disease. Figure 1 provides a visual representation of the system architecture, and this section contains a comprehensive explanation of all processes.

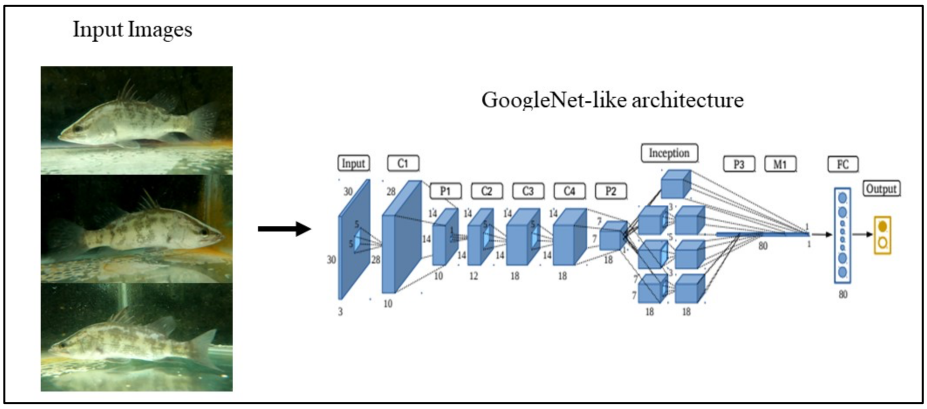

Fig. 1. System architecture

2.1 Architecture

i. Input images
During the initial phase, underwater images were collected at National Fish Health Research Centre (NaFisH), Fish Research Institute (FRI), Batu Maung, Penang, Malaysia. All the processes involved were under the supervision of NaFisH fish experts. Seabass fish type was used as the experimental fish since it is the key aquaculture species in Malaysia. All of the underwater images were captured using a GoPro Hero 9+ from 4K, 60fps footage with default exposure, colour temperature settings and a constant backdrop in the fish tank. No artificial light or were used, and parameters such as focus, angle and camera distance were not standardized across all recordings. The dataset consists of normal and infected fish images as validated by fish experts. Figure 2 below shows the fish tank setting.

Fig. 2. Fish tank setting

ii. Classification

The detection of protozoan white spot disease was carried out by analyzing the underwater images obtained using Convolutional Neural Network (CNN). Researcher stated that the most innovative aspect of GoogleNet, one of the CNN algorithm is its usage of the Inception architecture. Inception is a network inside a network where from the beginning to the end, the optimal local sparse structure of a vision network is repeated in space as stated by a number of authors [21,22]. The convolutional neural network, GoogleNet has 22 layers which could classifiy images into 1000 object categories.

During this phase, 3000 underwater images dataset has been trained using GoogleNet in MATLAB software. The images underwent evaluation by several connected layers to identify the features of protozoan white spot disease. The convolutional layer executed convolutional operations using multiple kernels or filters to extract edges and corners as features. Each kernel analyzed the input image pixel by pixel, resulting in a feature map. Subsequently, rectified linear unit (ReLU) operations were applied to the feature maps to introduce nonlinearity into the network. In the pooling layer, the size of the input images was reduced using max pooling. The pooled feature map was flattened into a long vector before being fed into the fully connected layers. In the fully connected layers, the features were combined to predict whether the image was infected or normal. The error was estimated in each cycle and backpropagated until the network was trained effectively. During the testing process, the CNN generated output indicating whether the image is normal or infected with protozoan white spot disease. Thus, 20 of the images' testing result has been taken to be included in this paper.

3. Results

The evaluation of the system's performance would be based on the confusion matrix, as presented in Table 1. This matrix comprises four components: True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN). The terms TP and TN signify accurate predictions, while FP and FN denote false predictions. The accuracy of the proposed model was calculated based on the confusion matrix using the formula shown in Equation (1).

$$\text{Accuracy (\%)} = \frac{(TP+TN)}{(TP+TN+FP+FN)} \times 100 \quad (1)$$

Table 1
Confusion Matrix

		Prediction	
		Positive	Negative
Actual	Positive	TP	FN
	Negative	FP	TN

A total of 20 images of both normal and protozoan white spot infected fish were tested. Table 2 below demonstrates the category, accuracy and time taken in seconds of the images tested to be compared and analyse. The category and accuracy below define the percentage of the classification model in screening the disease.

Table 2
20 underwater images' testing results

Image	Category	Detection accuracy (%)	Time taken (s)
1	Normal	88.1791	00:03:01
2	Infected	100	00:02:12
3	Normal	100	00:03:43
4	Normal	99.9972	00:04:51
5	Normal	99.9277	00:02:44
6	Infected	51.8663	00:02:18
7	Infected	99.8467	00:03:13
8	Normal	100	00:04:53
9	Normal	93.3819	00:02:12
10	Normal	100	00:04:07
11	Infected	99.9966	00:03:28
12	Normal	76.2121	00:05:42
13	Infected	100	00:03:58
14	Infected	99.7412	00:02:14
15	Infected	99.9985	00:03:06
16	Normal	100	00:02:28
17	Normal	99.581	00:04:15
18	Infected	99.985	00:02:37
19	Infected	100	00:03:48
20	Infected	100	00:04:05

Table 3
Confusion matrix of testing results

		Detection	
		Infected	Normal
Condition	Infected	10	2
	Normal	0	8

Based on the table 2 above, as detected using detection accuracy Equation (1), 8 out of 20 images have achieved 100%, the optimal accuracy, while only one image displayed the lowest accuracy of 51.86%. However, to prove that this system could work well as an early screening tools, confusion matrix accuracy has been recorded to see the effectiveness of the system. Thus, table 3 above demonstrates 10 infected images and 8 normal images were correctly detected. Meanwhile, 2 infected images were incorrectly detected as normal. According to Equation (1), 90% of accuracy has been achieved for the screening of protozoan white spot disease. Through what has been recorded, the accuracy results have shown the effectiveness of this effort in detecting protozoan white spot disease, and the time taken also testify that this innovation might be one of the ways to detect the disease at an early stage. Since the network has learned a wide range of feature representations, the capability of GoogleNet has successfully acted as the method to detect protozoan white spot disease.

4. Conclusions

This paper presents the performance of GoogleNet, a CNN performance in screening protozoan white spot disease based on underwater images. In conclusion, the results achieved by the early screening system for protozoan white spot fish disease is believed could be able to assist fish experts in identifying the disease in its early stages. In this situation, fish farmers and fish breeders could be aware of the disease infection and take early preventive measures to reduce significant losses in their aquaculture systems. This early screening system has been tested by certain professionals majoring in Intelligent Systems and feedback gathered has stated that since there is a possibility that this project could involve in aquaculture business due to its detection performance, it might be necessary to improve the system by adding additional features that ease the disease identification process such as pre-processing the underwater images to improve the images' quality to obtain maximal accuracy besides, highlighting the infection's area. This process could help fish farmers and breeders to recognise the disease and determine the severity, thus preventing any worst-case scenarios. Significant efforts made by all authorities if AI was used to its potential in the industry could guarantee food security to the nations and lead to sustain growth of aquaculture.

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