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Fish Classification Using Deep Learning

M. N. Ayyad and Samy S. Abu-Naser

Department of information technology,
Faculty of Engineering and Information Technology,
Al-Azhar University, Gaza, Palestine
abunaser@alazhar.edu.ps

Abstract: *Fish are important for both nutritional and economic reasons. They are a good source of protein, vitamins, and minerals and play a significant role in human diets, especially in coastal and island communities. In addition, fishing and fish farming are major industries that provide employment and income for millions of people worldwide. Moreover, fish play a critical role in marine ecosystems, serving as prey for larger predators and helping to maintain the balance of aquatic food chains. Overall, fish play a vital role in supporting human well-being and the health of our planet. . Fishes have a lots of types such that: Red Mullet, Sea Bass, Striped Red Mullet and Shrimp. Each of them has its own shape and characteristics that differ from other types. We proposed a system that recognize nine types of fishes using deep learning. We trained the model with a dataset that contain 9000 images that were slit into 6300 images for training, 1350 for validation and 1350 for testing. The proposed model achieved accuracy (99.68%), precision (99.69%), recall (99.68%), and f1-score (99.68%). This indicates that our proposed model can effectively predicate and classify different types of fish with very high accuracy.*

Keywords: fish; classification; deep learning; transfer learning; image net.

1. INTRODUCTION

Fish play an important role in various aspects of life and the ecosystem. Here are some of their key benefits [1]:

- **Food source**: Fish is a major source of protein for humans and is an important part of many people's diets, especially in coastal communities.
- **Ecosystem balance**: Fish play a vital role in maintaining the balance of aquatic ecosystems, serving as both predator and prey.
- **Economic significance**: Fishing and aquaculture industries provide employment and income to millions of people worldwide.
- **Biodiversity**: Fish are diverse species that contribute to the overall biodiversity of the planet.
- **Climate regulation**: Fish play a role in the carbon and nutrient cycles of the ocean, which helps regulate the Earth's climate.

Overall, fish have a significant impact on human lives and the health of the planet, making it important to maintain sustainable fishing practices and protect their habitats.

Deep Learning is a subfield of machine learning that utilizes artificial neural networks with multiple layers to model and solve complex problems. These networks are designed to automatically learn and improve from experience, without being explicitly programmed [2]-[3].

Deep Learning algorithms are used in a variety of applications such as image and speech recognition, natural language processing, and autonomous systems. The "deep" in Deep Learning refers to the number of layers in the neural network, which can range from dozens to hundreds. These multiple layers enable the model to learn and represent increasingly complex and abstract features of the data [4]-[5].

In this paper, we proposed a deep learning model where it is used transfer learning concept. Based on VGG16 model we will use its conv base and replace its fully connected layers with another one that it is suitable for our problem at hand.

2. BACKGROUND

2.1 Deep Learning

Deep learning is a specific subfield of machine learning: a new take on learning representations from data that puts an emphasis on learning successive layers of increasingly meaningful representations [6]-[8].

The deep in deep learning isn't a reference to any kind of deeper understanding achieved by the approach; rather, it stands for this idea of successive layers of representations. How many layers contribute to a model of the data is called the depth of the model. Other appropriate names for the field could have been layered representations learning and hierarchical representations learning. Modern deep learning often involves tens or even hundreds of successive layers of representations and they're all learned automatically from exposure to training data [9]-[11].

In deep learning, these layered representations are (almost always) learned via models called neural networks, structured in literal layers stacked on top of each other. The term neural network is a reference to neurobiology, but although some of the central concepts in deep learning were developed in part by drawing inspiration from our understanding of the brain, deep-learning models are *not* models of the brain (As in Figure 1).

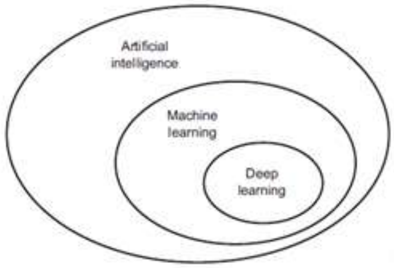

Fig. 1. Artificial intelligence, Machine Learning, Deep Learning.

2.2 Convolutional Neural Networks (CNNs):

CNNs are a specialized kind of neural network for processing data that has a known, grid-like topology. Examples include time-series data, which can be thought of as a 1D grid taking samples at regular time intervals, and image data, which can be thought of as a 2D grid of pixels. Convolutional networks have been tremendously successful in practical applications. The name “convolutional neural network” indicates that the network employs a mathematical operation called convolution. Convolution is a specialized kind of linear operation. Convolutional networks are simply neural networks that use convolution in place of general matrix multiplication in at least one of their layers [12]-[14].

2.3 Transfer Learning:

Transfer Learning is a research problem in machine learning that focusing on storing knowledge gained while solving one problem and applying it to a different but related problem [15].

2.4 VGG16 Architecture:

VGG16 is a convolutional neural network (CNN) architecture for image classification that was developed by the Visual Geometry Group (VGG) at the University of Oxford. It was introduced in a research paper in 2014 and has since become one of the most widely used image recognition models [16]-[17]

The architecture of VGG16 (as in Figure 2) is characterized by its simple design and the use of small convolutional filters (3x3) and max-pooling layers, which allows it to effectively capture the spatial hierarchy of features in an image. It also uses a large number of parameters (138 million) which gives it a high capacity for learning complex features [18]-[20].

VGG16 has been successful in various image recognition tasks such as the ImageNet Large Scale Visual Recognition Challenge (ILSVRC) and has become a popular starting point for many transfer learning tasks, where a pre-trained VGG16 model is fine-tuned for a specific task [21].

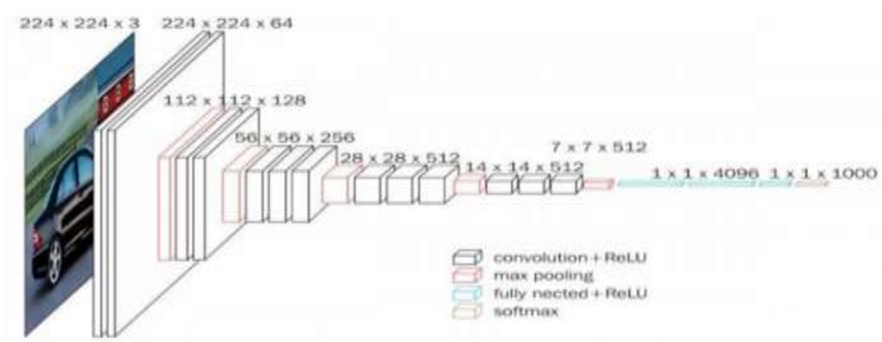

Figure 2. VGG16 architecture.

3. PREVIOUS STUDIES

There a quite few studies that handled the fish classification using different number of classes, datasets, number of images, size of the image, algorithm used and the accuracy. The F1-score accuracy ranged between 81.67% and 98.57%.

Table1. Comparisons between the previous studies.

Reference	# of classes	# of images	Size	Algorithm name	Database name	F1-score (%)
[22]	2	150	200 *200	SVM	Private	78.59
[23]	8	520	224 *224	BP algorithm	Private	94.00
[24]	10	8100	-	CNN	ImageNet dataset	93.30
[25]	28	1120	256 * 256	SVM, KNN, DT	AQUARIO28E40I	92.30

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					dataset	
[26]	6	100	256 * 256	Bayesian classifier	CNPq-Brazil	81.00
[27]	15	26400	200 * 200	ANN	F4K	98.88
[28]	4	250	256 * 256	TDA	Private	73.30
[29]	15	26400	200 * 200	Hierarchical partial classifier algorithm	F4K	93.80
[30]	6	100	224 * 224	multiclass SVM	Private	95.92
[31]	129	2580	692 * 425	RF	Private	87.30
[32]	20	200	720 * 576	SVM	knowledge database	88.50
[33]	30	900	800 * 600	ANN	FIRS database	81.67
[34]	15	20000	68 * 87	SVM	CLEF 2015	91.70
[35]	8	2600	256 * 256	SVM	BDIndigenousFish2019	90.00
[36]	15	26400	200 * 200	linear SVM classifier	F4K database	98.57

These studies demonstrate the effectiveness of deep learning techniques for fish classification and highlight the potential for using these methods in real-world applications such as monitoring fishing activities and improving sustainable fishing practices.

There is still room for improving the F1-score accuracy. Our current study uses different algorithm which is VGG16 and the dataset is different (collected from Kaggle) and the number of classes are 9.

4. METHODOLOGY

4.1 Dataset

We used a dataset from Kaggle (https://www.kaggle.com/datasets/crowww/a-large-scale-fish-dataset). It contains 9000 images for different types of fish. We split the data into 6300 images for training the model, 1350 images for validation and 1350 images for testing. Figure 3 provides some images from the dataset.

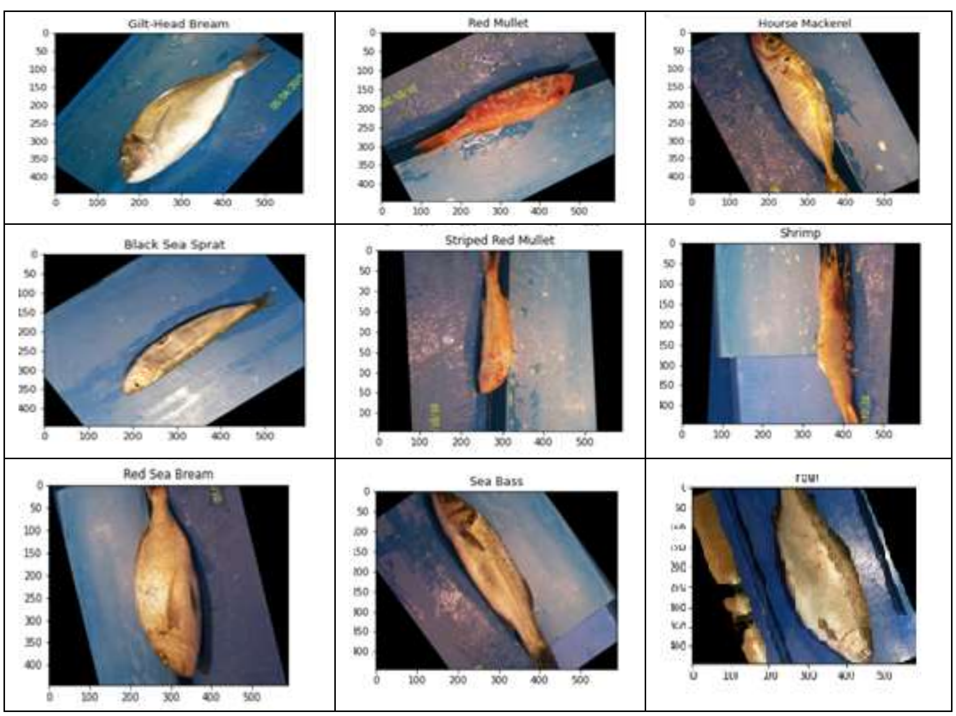

Figure 3: Some images form dataset.

4.2 Proposed Model

Figure 4 provide our model that used the conv base from the pertained model VGG16 and change the classification layer which replaced by a fully connect layer with 9 units as the output for the last layer which has the softmax activation to get the probability of the input image belongs to the different classes.

Layer (type)	Output Shape	Param #
input_1 (InputLayer)	[(None, 128, 128, 3)]	0
block1_conv1 (Conv2D)	(None, 128, 128, 64)	1792
block1_conv2 (Conv2D)	(None, 128, 128, 64)	36928
block1_pool (MaxPooling2D)	(None, 64, 64, 64)	0
block2_conv1 (Conv2D)	(None, 64, 64, 128)	73856
block2_conv2 (Conv2D)	(None, 64, 64, 128)	147584
block2_pool (MaxPooling2D)	(None, 32, 32, 128)	0
block3_conv1 (Conv2D)	(None, 32, 32, 256)	295168
block3_conv2 (Conv2D)	(None, 32, 32, 256)	590080
block3_conv3 (Conv2D)	(None, 32, 32, 256)	590080
block3_pool (MaxPooling2D)	(None, 16, 16, 256)	0
block4_conv1 (Conv2D)	(None, 16, 16, 512)	1180160
block4_conv2 (Conv2D)	(None, 16, 16, 512)	2359808
block4_conv3 (Conv2D)	(None, 16, 16, 512)	2359808
block4_pool (MaxPooling2D)	(None, 8, 8, 512)	0
block5_conv1 (Conv2D)	(None, 8, 8, 512)	2359808
block5_conv2 (Conv2D)	(None, 8, 8, 512)	2359808
block5_conv3 (Conv2D)	(None, 8, 8, 512)	2359808
block5_pool (MaxPooling2D)	(None, 4, 4, 512)	0
global_max_pooling2d (GlobalMaxPooling2D)	(None, 512)	0
dense (Dense)	(None, 512)	
dense (Dense)	(None, 9)	4617

Total params: 14,717,253
Trainable params: 14,717,253
Non-trainable params: 0

Fig. 4. Proposed model for fish classification.

4.3 Evaluation Metrics

We used the most common criterion for measuring the performance of the proposed VGG16 model:

- Precision is defined by True Positive divided by the summation of True Positive and False Positive as in equation 1.
- Recall is defined by True Positive divided by the summation of True Positive and False Negatives as in equation 2.
- F1-score is defined by 2 times Precision times Recall divided by the summation of Precision and Recall as in equation 3.
- Accuracy is defined by the summation of True Negative and True Positive divided by the

summation of True Negative, True Positive, False Positive and False Negatives as in equation 4.

$$\text{Precision} = \frac{\text{TP}}{\text{TP + FP}} \qquad (1)$$

$$\text{Recall} = \frac{\text{TP}}{\text{TP + FN}} \qquad (2)$$

$$F1 - score = 2 * \frac{\text{Precision x Recall}}{\text{Precision + Recall}} \qquad (3)$$

$$\text{Accuracy} = \frac{\text{TN + TP}}{\text{TN+FP+ TP + FN}} \qquad (4)$$

Where: FP = False Positive; FN = False Negative; TP = True Positive; TN = True Negative

4.4 Training and validating the proposed model

We have trained and validated the proposed model for 20 epochs (Figure 5). In terms of time consumption in training and validating the proposed model took (242 seconds). In terms of accuracy and loss the proposed model was effective.

```
Epoch 1/20
21/21 [==============================] - 31s 700ms/step - loss: 6.6414 - accuracy: 0.1652 - val_loss: 2.1174 - val_accuracy: 0.1978
Epoch 2/20
21/21 [==============================] - 9s 437ms/step - loss: 2.0446 - accuracy: 0.2478 - val_loss: 1.9318 - val_accuracy: 0.2744
Epoch 3/20
21/21 [==============================] - 9s 442ms/step - loss: 1.8137 - accuracy: 0.3318 - val_loss: 1.6899 - val_accuracy: 0.4178
Epoch 4/20
21/21 [==============================] - 9s 450ms/step - loss: 1.5016 - accuracy: 0.4836 - val_loss: 1.3984 - val_accuracy: 0.4656
Epoch 5/20
21/21 [==============================] - 14s 450ms/step - loss: 1.1176 - accuracy: 0.6017 - val_loss: 0.9519 - val_accuracy: 0.6506
Epoch 6/20
21/21 [==============================] - 9s 448ms/step - loss: 0.9349 - accuracy: 0.6689 - val_loss: 0.8997 - val_accuracy: 0.6783
Epoch 7/20
21/21 [==============================] - 9s 452ms/step - loss: 0.7231 - accuracy: 0.7470 - val_loss: 0.5877 - val_accuracy: 0.7961
Epoch 8/20
21/21 [==============================] - 9s 423ms/step - loss: 0.5525 - accuracy: 0.8051 - val_loss: 0.7167 - val_accuracy: 0.7411
Epoch 9/20
21/21 [==============================] - 9s 448ms/step - loss: 0.4383 - accuracy: 0.8404 - val_loss: 0.3286 - val_accuracy: 0.8911
Epoch 10/20
21/21 [==============================] - 9s 449ms/step - loss: 0.3156 - accuracy: 0.8899 - val_loss: 0.2635 - val_accuracy: 0.9144
Epoch 11/20
21/21 [==============================] - 9s 443ms/step - loss: 0.2123 - accuracy: 0.9270 - val_loss: 0.2445 - val_accuracy: 0.9122
Epoch 12/20
21/21 [==============================] - 12s 561ms/step - loss: 0.2019 - accuracy: 0.9308 - val_loss: 0.2039 - val_accuracy: 0.9278
Epoch 13/20
21/21 [==============================] - 9s 445ms/step - loss: 0.1453 - accuracy: 0.9535 - val_loss: 0.1402 - val_accuracy: 0.9500
Epoch 14/20
21/21 [==============================] - 9s 445ms/step - loss: 0.0884 - accuracy: 0.9714 - val_loss: 0.0966 - val_accuracy: 0.9656
Epoch 15/20
21/21 [==============================] - 9s 418ms/step - loss: 0.0639 - accuracy: 0.9804 - val_loss: 0.1018 - val_accuracy: 0.9656
Epoch 16/20
21/21 [==============================] - 9s 453ms/step - loss: 0.0582 - accuracy: 0.9814 - val_loss: 0.0013 - val_accuracy: 0.9658
Epoch 17/20
21/21 [==============================] - 9s 424ms/step - loss: 0.0582 - accuracy: 0.9807 - val_loss: 0.1348 - val_accuracy: 0.9483
Epoch 18/20
21/21 [==============================] - 9s 420ms/step - loss: 0.0647 - accuracy: 0.9844 - val_loss: 0.3111 - val_accuracy: 0.9017
Epoch 19/20
21/21 [==============================] - 9s 413ms/step - loss: 0.1104 - accuracy: 0.9684 - val_loss: 0.1100 - val_accuracy: 0.9686
Epoch 20/20
21/21 [==============================] - 9s 416ms/step - loss: 0.0517 - accuracy: 0.9859 - val_loss: 0.1002 - val_accuracy: 0.9628
Time elapsed in seconds: 242.3441960011615
```

Fig. 5. Accuracy and Loss for training, validation history for 20 epochs.

Accuracy of training and validating the proposed model is shown in Figure 6, while the loss of the training and validation is shown in Figure 7.

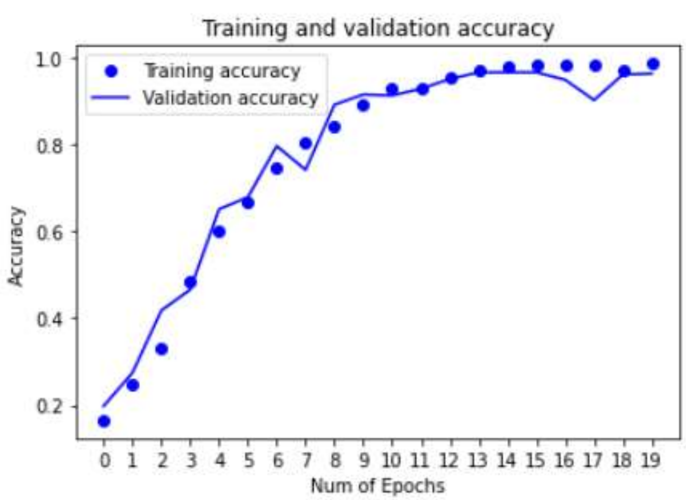

Fig. 6. Training and validation Accuracy of the proposed model

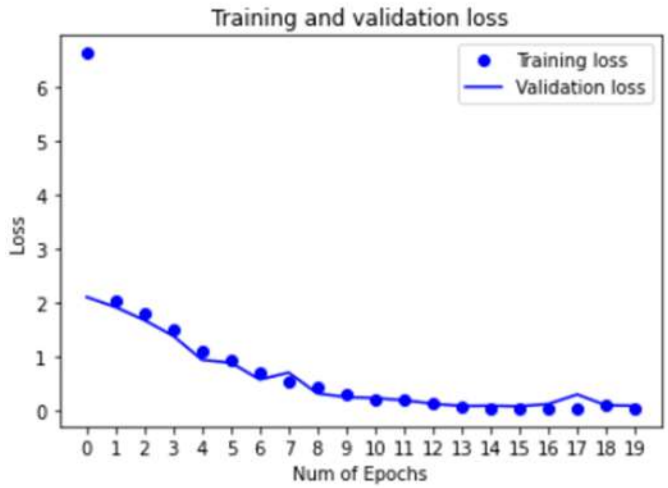

Fig. 7. Training and validation Loss of the proposed model

4.5 Confusion Matrix

In this work, the proposed deep learning network CNN was trained on the fish dataset. Afterwards, the model was evaluated on the test dataset, which showed good performance. Figure 8 presents the confusion matrix of the classification results, where each row represents the actual category, while each column stands for the predicted result. The model VGG16 achieved lower false positive and false negative rates, which demonstrates the effectiveness.

```
[167   0   0   0   0   1   0   0   0]
[  0 162   0   0   1   0   0   0   0]
[  0   0 207   0   0   0   0   0   0]
[  0   0   0 177   0   0   0   0   0]
[  0   0   0   0 163   0   0   0   1]
[  0   0   0   0   0 169   0   0   0]
[  0   0   0   0   0   0 195   0   0]
[  0   0   0   0   0   1   1 171   0]
[  0   0   0   0   0   0   0   0 168]
```

Fig. 8. Confusion Matrix.

4.5 Comparison between Performances on the Test dataset:

To evaluate the effectiveness of the proposed model, each class of the test dataset was evaluated on the test dataset by the accuracy rate, recall, precision, F1-score and number of supporting images (Figure 9).

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	precision	recall	f1-score	support
Black Sea Sprat	1.0000	0.9940	0.9970	168
Gilt-Head Bream	1.0000	0.9939	0.9969	163
Hourse Mackerel	1.0000	1.0000	1.0000	207
Red Mullet	1.0000	1.0000	1.0000	177
Red Sea Bream	0.9939	0.9939	0.9939	164
Sea Bass	0.9883	1.0000	0.9941	169
Shrimp	0.9949	1.0000	0.9974	195
Striped Red Mullet	1.0000	0.9884	0.9942	173
Trout	0.9941	1.0000	0.9970	168
accuracy			0.9968	1584
macro avg	0.9968	0.9967	0.9967	1584
weighted avg	0.9969	0.9968	0.9968	1584

Fig. 9. Precision, Recall and F1-Score of the proposed model.

5. CONCLUSION

Fish classification in a very important task in many field such as industrial or agriculture. In this study, we proposed an approach that uses deep learning-based learning of images of 9 different type of fishes from Kaggle website. We fine-tuned a pre trained CNN Model VGG16. In this paper, we trained and validated the proposed model and tested its performance with un-seen dataset for testing. The Accuracy rate we achieved was 99.68%, precision (99.69%), recall (99.68%), and f1-score (99.68%). This indicates that our proposed model can effectively predicate and classify different types of fish with very high accuracy.

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