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Improving Artificial Intelligence Techniques for Classifying the Vessels of the Grand Mosque of Al-Nuri

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Abstract – The Grand Mosque of al-Nuri is a historic mosque that preserves the civilized history of Mosul. It is one of the oldest mosques in the city and contains the Al-Hadba Minaret, which includes the same name as the city of Mosul. This minaret is distinguished by its architectural design and its varied and wonderful decorations. The architectural design of the mosque is unique. The mosque was damaged during the ISIS campaign in Mosul, and the majority of the vessels and relics within it were broken. As a result, it became important to conserve and electronically document the remaining archeological landmarks. So, in this study a hybrid was made between pre-training model to extract features and machine learning methods to classify the dataset of the vessels of the Grand Mosque of al-Nuri. Several pre-processing was applied to the images and then passed to DenesNet201 to extract features and send them to the Extra Tree and Random Forest methods to classify them into pottery and ceramic categories. The results showed that the two hybrid methods outperformed traditional machine learning methods with an accuracy of 98% and 93%, respectively.

Keywords: Al-Nuri, Machine Learning, Extra Tree, Random Forest, Hybrid Technique, Classification.

1. INTRODUCTION

In the 12th century in 1170 AD, Nur Al-Din Zengi constructed Grand Al-Nuri Complex. The complex includes two historical landmarks: the Al-Hadba Minaret, which is associated with the city of Mosul and is distinguished by its architectural design and varied decorations and the Grand Mosque of al-Nuri which was the second oldest mosque in Mosul. It is a historic mosque distinguished by its architectural design and bearing the history of Mosul's civilization. Both overlook the Tigris River from the west. The mosque was restored in 1942 with 40 marble columns, building stones, several marble arches, and a reinforced concrete roof [1]. Grand Mosque of al-Nuri underwent successive modifications from the late twelfth century until the second half of the nineteenth century [2].

It is a new architectural phenomenon not previously seen in Iraqi mosques. The mosque covers 5850 square meters and has three separate areas, including the prayer house on the southern side. The second area is the minaret, which is positioned in the mosque's north west corner, and the final area is the ablution area, which is located in the center of the mosque's courtyard. The prayer house is covered by a double dome, which is hemispherical on the inside and polygonal conical on the exterior, representing a unique architectural style that was unknown at the time [3].

In June 2017, during the war to retake Mosul from ISIS, the Grand Mosque of al-Nuri was tragically destroyed. As Iraqi forces advanced to liberate the city, ISIS fighters rigged the mosque with explosives and blew it up as a final show of resistance [4]. The explosion completely destroyed the mosque and its famous minaret, resulting in a massive cultural and historical loss.

The destruction of the Grand Mosque of AlNuri was a symbolic act of cultural vandalism, aimed at erasing Mosul's heritage and identity. The loss of such an important site highlighted the broader campaign of cultural destruction carried out by ISIS, which targeted many historical and religious sites across the region. Currently, efforts to rebuild the mosque, with international support, began with the aim of restoring this important symbol of Mosul's history and resilience. The United Arab Emirates, with the assistance of UNESCO, the European Union and the International Centre for the Study of the Restoration and Preservation of Cultural Property, has undertaken to finance the project to rebuild and restore the Grand Mosque of al-Nuri and its minaret. Rescue efforts have been carried out and a number of ancient artifacts have been reached, cleaned and preserved, some of which survived the explosion and others were broken. The process of classifying and preserving the artifacts required great efforts by the workforce and a lot of time, in addition to the need for experts in the field of antiquities. The great development in the field of artificial intelligence, especially machine learning and pre-training, has led to the availability of automatic classification of data without the intervention of human expertise. Many researchers have used machine learning methods to classify historical areas. Therefore, in this study, an intelligent system was created to sort the artifacts of the Grand Mosque of AlNuri, classify them faster and preserve them. This study is the first to classify the artifacts of the Grand Mosque of AlNuri using machine learning methods, as it relied on image data taken for the artifacts.

In this study, a hybridization of pretraining method and state of art machine learning methods were performed to benefit from the advantages of both types while also overcoming the problems of overfitting and underfitting that pretraining methods face, as well as the saturation problem that machine learning methods face when dealing with large amounts of data. The pre-training method (DenesNet201) was used and its outputs were fed into two machine learning methods (Extra Tree and Random Forest) for the purpose of classifying the artifacts in the Great Mosque of al-Nuri into pottery or ceramics after tuning the important hyperparameters of the machine learning methods using the Random Search algorithm.

Artificial intelligence research, particularly machine learning, is limited in the subject of classifying and preserving historical artifacts and vessels.The study [5] in 2019 aimed to classify archaeological sites and landmarks. The study used four algorithms: Averaged one dependence estimators, Forest by penalizing attributes, k-nearest neighbor and Multilayer perceptron. Results show that Multilayer perceptron outperformed other methods in accuracy 89%.

In order to understand the cultural origins of India, researchers in 2020[6], proposed a study to document and archive heritage architectural sites and provide information about these areas to tourists or architects. The study proposed a platform to classify images of archaeological sites and retrieve their names using mobile learning MobileNetV2. The model achieved the best results with an accuracy of 98.75%.

Also, in 2020 [7], researchers used a convolutional neural network to classify two Datasets of cultural heritage images, the first consisting of ten classes and the second of five classes, including the bell tower, dome, vault, mihrab, pillar, etc. The model achieved good accuracy, reaching 90%.

In 2022[8], researchers created a platform to preserve and classify the ancient decorations of Mosul based on several important factors such as shape, location, and material, which contributes to the preservation of the city's heritage, particularly after the emergence of modern electronic decorations, or to protect them from external attacks. The study used a qualitative technique, observing and visualizing the outcomes of the investigation using a checklist form.

In 2024[9], researchers utilized deep learning to classify 13 archaeological sites in Kolkata. The city is distinguished by its magnificent décor and architectural features. The study's goal was to visually classify and describe archeological sites and historical monuments using the Mononet algorithm. The proposed network employs a unique architecture that incorporates a Dense channel attention module and a Parallel-spatial channel attention module to capture delicate architectural elements within the images. The findings showed that the proposed model performed well, with an accuracy of 89%, precision of 87.77%, and recall of 86.61%

.In 2024 [10], researchers worked on classifying fine-grained images of Chinese cultural heritage, even though it was difficult to distinguish between these heritage images due to their fine grains. The work proposed using adaptive deep learning after preprocessing the images by handling incremental streams of new categories while maintaining its previous performance in old categories and preserving the old categorization of a cultural heritage image. The results showed that proposed model achieved good accuracy 85%.

In 2024 [11], researchers in India classified Kolam (a traditional art form of making various decorations on the ground) to preserve it from extinction due to the lack of interest in it at present. The study proposed using transfer learning (Efficient Net) to classify Kolam images, and achieving an accuracy of 81%.

2. MACHINE LEARNING ALGORITHMS

In this section we will explain the machine learning techniques used in this study.

2.1. Denes Net 201 Transfer Learning

It is based on the principles of CNN, and it is a type of transfer learning that is pre-trained on a known database (ImageNet) and then used by freezing the upper layers and changing the lower layers to benefit from the trained weights or prior knowledge to solve a new problem or task. It was introduced by Huang et al., and is characterized by its ability to reduce the problems of vanishing gradients due to its ability to reuse limited features [12]. Its working principle is transition layers and dense blocks, with features being sent to all previous and subsequent layers via feed-forward [13].

2.2. Extra Tree Algorithm

Random Forest is an ensemble method for ML models that relies on Decision Trees. Rather than depending on a single decision tree, the goal is to generate several decision trees from bootstrapped-random samples of training data. The testing data will be predicted on each DT, followed by voting to choose the final label [16],[17]. Figure 1 shows Random Forest Trees and algorithm 1 illustrates the steps of RF.

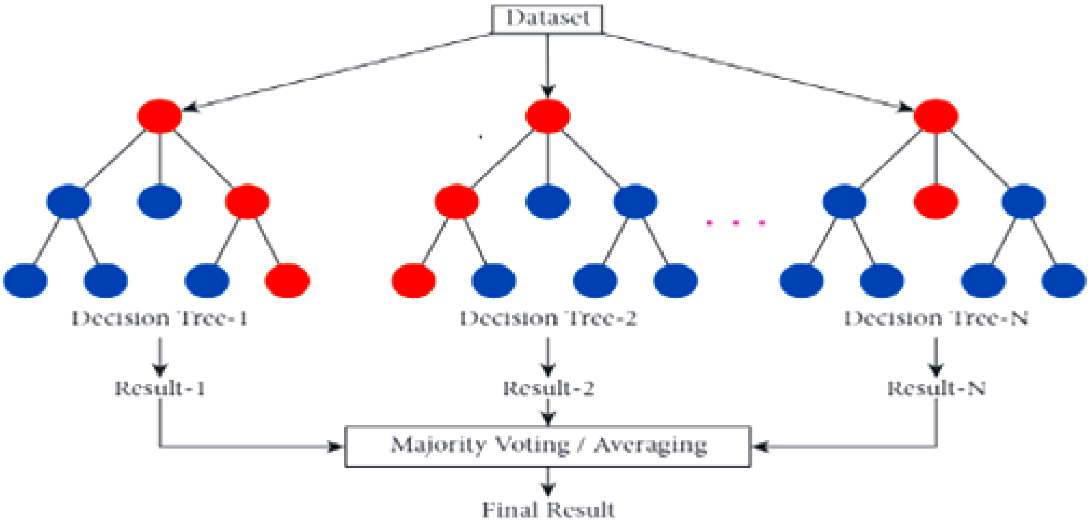

Figure 1. Random Forest Tree

Algorithm1: Random Forest Algorithm

Input:

- S: The original training dataset of size n.
- p: Input predictors and features
- X: Test evaluation (new input set of features).
- M: The number of trees to be created.
- v: The number of predictors to choose as split candidates for each tree.

Output

- Predicting new entry

Methods

for m = 1 to M do

Build a tree with S applying the following loop:

while it's not reached to minimum node size Do

- For the leave node of the tree randomly select v
- predictors out of the p
- choose the best split candidate pair.
- Divide the node into two child nodes.

End While

End For

3. RESEARCH METHODOLOGY

The suggested strategy involves a series of steps: preprocessing, Dataset splitting and feature extraction by applying DeneseNet201 pretraining model, followed by classification utilizing state of art machine learning techniques such as Extra Tree and Random Forest. Figure 2 depicts the procedure of suggested strategy which executed on the Windows 10 operating system and an Intel(R) Core (TM) i7-8565U quad-core CPU with a clock speed of 2.00 GHz. 16.0 GB of RAM. Anaconda and the Python programming language contain the Spyder tool.

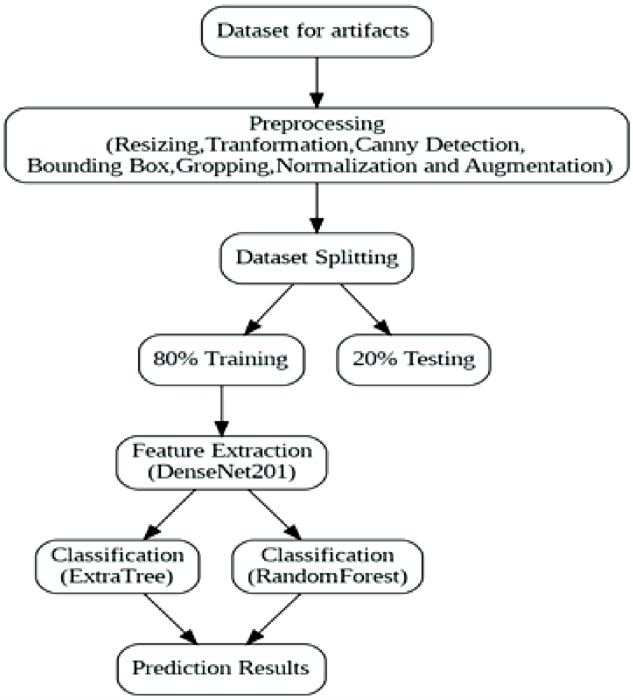

Figure 2. Workflow of Proposed Method

3.1. Dataset Description

The proposed models were tested on image data of vessels from the Grand Mosque of al-Nuri dating back to the 12th century. The dataset consists of (7680) images classified into two categories (pottery and ceramics). Dataset was divided in to 80% training and 20% testing. Figure 3 display samples of the ancient vessels of the Grand Mosque of al-Nuri.

Figure 3. Samples of the Al-Nuri Mosque vessels

3.2. Image Pre-Processing

Preprocessing is necessary to identify key features in a dataset and guarantee that it is appropriate for a specific type of research. Figure 4 depicts several preprocessing operations performed on digital images:

a. Resize images: The dataset's images are scaled using the Python resize function to 224 width * 224 heights.
b. Transformation: For the purpose of displaying the dataset images, OpenCV library and cvtColor function are implemented to convert images from BGR to RGB.
c. Image Detection: The canny algorithm is used to highlight the key edges of the Al-Nuri Mosque vessels images [18].
d. Annotation Approach: Inserting a rectangle around objects in an image to separate them from the rest of the image points and this called bounding box.
e. Cropping Approach: Remove unnecessary points and edges within the image and get the most important objects.

f. Normalization: It is an important image processing method whose goal is to change the range of pixel intensity to be within 0 and 1[19].
g. Data Augmentation: It has been applied on training and testing dataset to increase its number and take it from different locations in addition to preventing overfitting. Several data augmentation was used in this study, like: rotation=10, rescale=1/255, width shift=0.002, height shift =0.002, horizontal flip=True, vertical flip=False, shear =12.5, zoom=0.

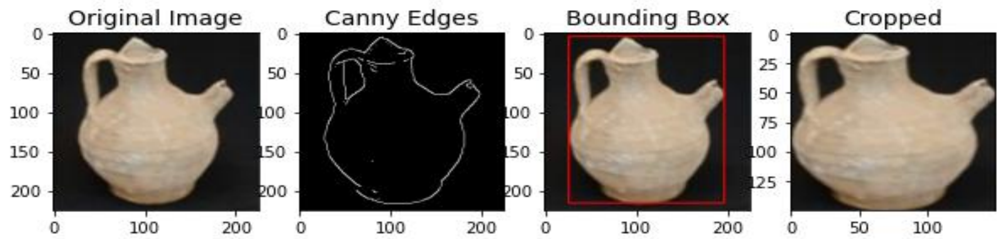

Figure4. Sample of Image Preprocessing

3.3. Feature Extraction

The DenesNet201 pre-training model was applied to get out the necessary features from the image dataset. DeneseNet201 model combines all of the layers, allowing each layer can receive input from the previous layers while forwarding the feature maps to the next layers. Where the upper layers were frozen in the DenesNet201 and the layer responsible for classification was cancelled.

3.4. Classification Process

In this study, machine learning methods were applied to classify the dataset of the Grand Mosque of Al-Nouri vessels. The Extra Tree is an ensemble of several decision trees that rely on criteria such as the Gini impurity to determine the best division of the trees and thus prevent overfitting. It is also characterized by its speed resulting from the randomness in choosing the features, which reduces the correlation between the trees and achieves generality when testing using new data. While Random Forest, it works on the principle of Extra Tree, but it is less random in choosing the features, which makes it sometimes suffer from overfitting. The Random Search algorithm was also used to justify the hyperparameters of the previous two algorithms and choose the best values that achieve high results. Table 1 shows essential hyperparameters.

Table 1. Hyperparameters Optimization

Models	Hyperparameters
Extra Tree	max depth=30, n estimators= 100, min samples split=5, min samples leaf'=2
Random Forest	max depth=20, n estimator= 100, min samples split = 10, min samples leaf= 2

3.5. Performance Evaluation

The performance of Extra Tree and Random Forest algorithms was evaluated using several performance testing metrics such as accuracy, precision, recall, F1 score, and AUC-ROC, which is used to classify classes. AUC-ROC is considered to be a perfect classification if its value is 1, while if it is 0.5, it does not show any classification between classes [20]. Accuracy is one of the most important performance metrics and measures the number of times it was correctly evaluated across all data samples. The following equations show the performance metrics (1), (2), (3), and (4) [4],[18]:

$$Accuracy = (TN + TP) / (TN + TP + FN + FP) \quad (1)$$
$$Recall = TP/(TP+FP) \quad (2)$$
$$Precision = TP/(TP+FP) \quad (3)$$
$$F1\ score = (2*Precision*Recall)/(Precision+Recall) \quad (4)$$

4. RESULTS AND DISCUSSION

In this part, the performance of the Extra Tree and Random Forest algorithms for classifying Al-Nuri Mosque vessel images was examined after being improved by hybridizing them using one of the pre-training approaches (DenseNet201).

Figure 5, illustrates that Hybrid Extra Tree algorithm`s Roc-AUC has the good result, that is 100% due to it utilizes randomness in selecting features, and decreases the correlation between the trees and achieves generalization. While Figure 6 shows that the Roc-AUC of the Hybrid Random Forest algorithm achieved slightly lower results.

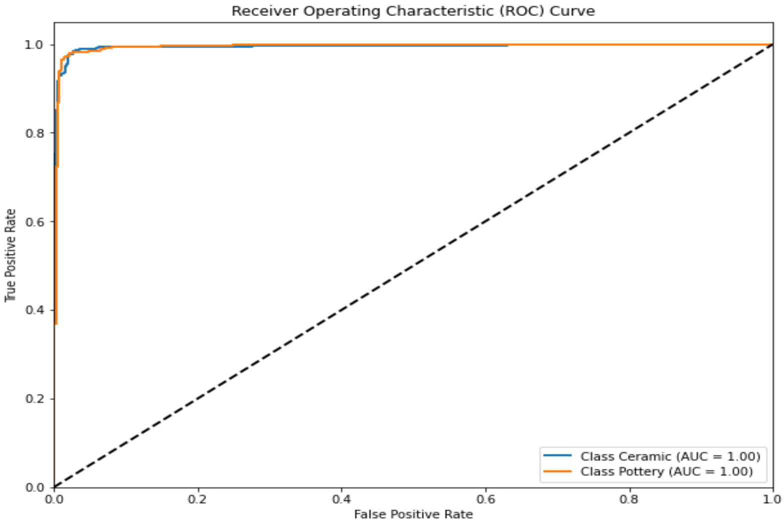

Figure5. Roc-AUC of Extra Tree Algorithm

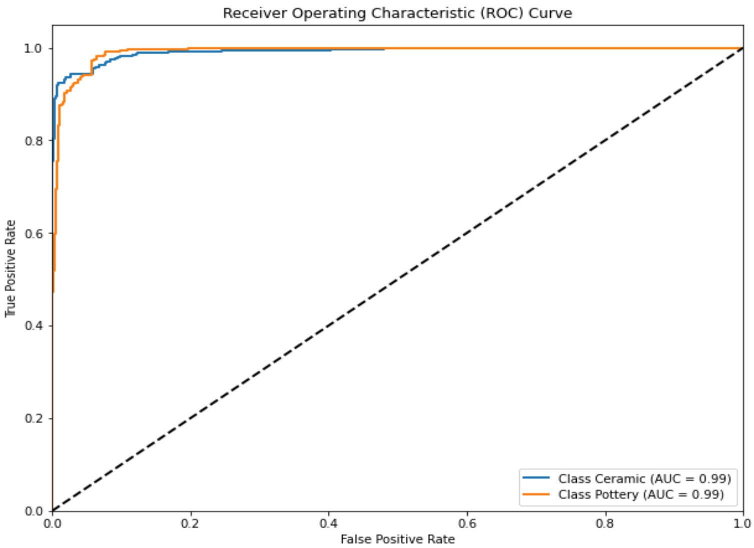

Figure 6. Roc-AUC of Random Forest Algorithm

Figure 7, displays the confusion matrix for classifying Al-Nuri Mosque vessel images for Hybrid Extra Tree algorithm. The Hybrid Extra Tree model accurately classified more values (diagonal values). It was also revealed that certain non-diagonal values existed, showing that the Hybrid Extra Tree model was effective in preventing class samples from being mixed together.

In Figure 8, the Hybrid Random Forest algorithm's confusion matrix contains more misclassified values, indicating mistakes in identifying pottery and ceramic classes.

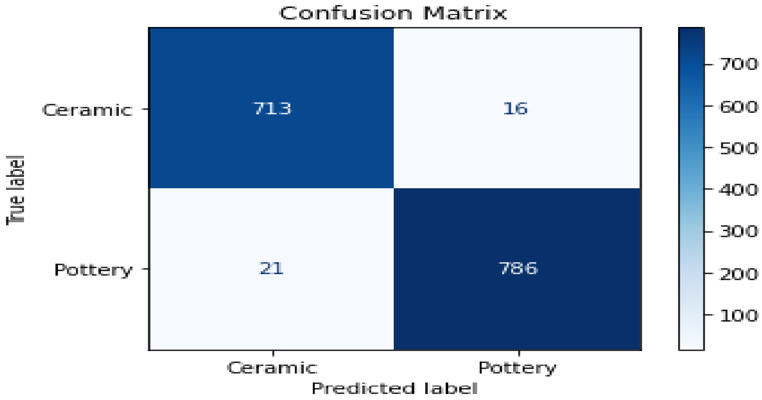

Figure 7. Confusion Matrix of Extra Tree Algorithm

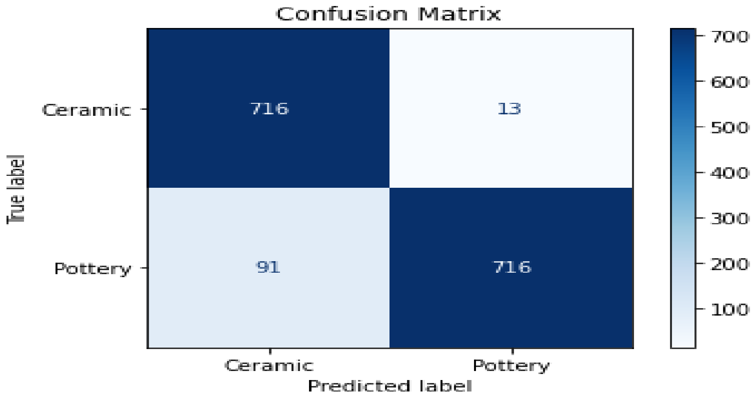

Figure 8. Confusion Matrix of Random Forest Algorithm

Table 2 shows that the Hybrid Extra Tree model surpassed Hybrid Random Forest in accuracy, precision, recall, and F1 score measures, indicating that it correctly identified more positive samples using the Grand Mosque of al-Nuri pottery images.

Also in Table 2, the comparison was made with traditional machine learning methods (K-Nearest Neighbor and Naive Byes). The results showed that Hybrid Extra Tree and Hybrid Random Forest algorithms outperformed other ML methods due to their hybridization with the pretraining method (DenesNet201) which extracted features only and this led to avoiding the overfitting. While in classification process, it was carried out using modern machine learning that avoided falling into the saturation state that machine learning methods suffer from.

Table 2. Performance Measures of ML Models

Evaluation Metrics	Hybrid Extra Tree	Hybrid Random Forest	KNN	NB
Precision	0.97	0.93	0.89	0.57
Recall	0.97	0.93	0.88	0.50
F1-score	0.97	0.93	0.90	0.48
Accuracy	0.98	0.93	0.89	0.50

5. CONCLUSION

Classification of artifacts, especially those that are in the spotlight of the world and are at risk from enemies, is of great importance; as developed countries are urged to automate and preserve rare artifacts because they indicate their countries' civilization, culture and history. Therefore, in this study, the Extra Tree model was improved by combining it with pre-training methods to create a multi-feature classification. DenesNet201 was applied to get out features, which sent to the Extra Tree model for classification. Random search method was applied to modify the necessary hyperparameters. The hybrid proposed model was evaluated using a number of performance metrics. The findings revealed that the Hybrid Extra Tree model performed the best, with 100% AUC-ROC as well as 99% accuracy, precision, recall, and F1 score.

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