Development of a Balinese Endek Classification Application Using Convolutional Neural Networks

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***Abstract*— Endek is a unique Balinese handicraft made using a special technique to produce beautiful and distinctive patterns compared to other Indonesian fabrics. Endek has immense potential both domestically and internationally, as evidenced by its presence at international events such as Paris Fashion Week. However, the Bali Provincial Research and Innovation Agency states that there is a need for efforts to help preserve traditional Balinese Endek, such as an application that makes it easy for the public and tourists to identify types of traditional Balinese Endek motifs in order to counter the existence of Endek motif imitations. Therefore, the author conducted research to create a mobile application that can detect the type of Balinese Endek using machine learning technology. This application will be built using the extreme programming method, and the convolutional neural network algorithm will be used to create the Endek type classification feature to obtain good accuracy. In this research, eight classes were used, where seven classes are types of Balinese Endek motifs and one additional class is a random image that is not Endek to be able to detect images that are not Endek or Endek fabrics that have not been included in the dataset. The application created can display the results of Endek classification which also contains additional information about the type of Endek. This application is made using Flutter, a framework developed by Google. The advantage of Flutter is that it can produce cross-platform apps with high performance. Model creation uses TensorFlow, which compares the performance of three types of transfer learning models: VGG16, VGG19, and MobileNetV3Small. Of the three models used, the MobileNetV3Small model achieved the highest accuracy of 90% in the testing results, so the MobileNetV3Small model was used in the application.**

Keywords*— *mobile application, endek classification, convolutional neural network.

I. INTRODUCTION

Bali is often referred to as the Island of a Thousand Temples and the Island of Paradise by foreign tourists because Bali Island indeed has very beautiful beaches and all its activities and natural charms that are pleasing to the eye [1]. Besides being famous for its charming beaches and having the best resorts in the world, one of the attractions of Bali Island is its rich culture. Culture plays an important role for the Balinese people. Bali tourism relies on its cultural sociology. The whole life of the Balinese people becomes the main attraction for tourists, and there are even domestic and foreign tourists who make Bali their inspiration [2]. Some of the results of this culture become a source of livelihood for the Balinese people, such as the craft of making statues, fabric production, carvings, weaving, coffee factories, and others. All of these sectors, coupled with the large number of tourists who visit Bali, provide the Balinese people with a source of livelihood. Therefore, many businesses such as travel, hotels, and handicraft shops have emerged among the people.

Of the various crafts in Bali, Endek fabric is one of the crafts that is favored by tourists. In addition to having unique ornaments, Endek also has high philosophical values. When viewed from its vocabulary, Endek comes from the word ngEndek or gEndekan which can be interpreted as staying or still or its color does not change. There are two types of ikat that are akat in Bali, namely double ikat or geringsing with its pattern using warp and weft, and also Endek or warp ikat with its pattern using only the warp direction [3]. Like batik, Endek has many patterns that have their own historical value. There are many types of Endek based on their patterns, including uang kepeng, rangrang, patra bali, geringsing, cepuk, wajik songket, jumputan patterns, and tumpal patterns [4].

Based on the results of a discussion meeting on the draft of cooperation between the Bali Provincial Government and Primakara University, Badan Riset dan Inovasi (BRIDA) Bali stated that traditional Balinese Endek is very vulnerable to counterfeiting. As often happens with batik fabric in Indonesia. This still often happens because it is difficult to acquire copyrights. Therefore, they states that there is a need for efforts to help preserve traditional Balinese Endek, such as an application that makes it easy for the public and tourists to identify types of traditional Balinese Endek motifs.

Previously, there were several similar studies that used Android applications for Balinese Endek information systems but had not yet applied artificial intelligence technology to classify types of Endek but only in the form of a display using augmented reality [4]. There is research that uses batik as its research object to create an Android application for classifying types of batik. Using the help of artificial intelligence and also detecting whether the batik is authentic or imitated [5].

Based on the description, the researcher is motivated to create a mobile application that is able to classify types of traditional Balinese Endek quickly, easily, and with accurate results. The process of recognizing types of Endek or creating a machine learning model will use the Convolutional Neural Network algorithm.

II. Related Works

A. Endek Bali

In Indonesia, Endek is known as ikat weaving. There are various types of ikat woven fabrics originating from each region in Indonesia. And Endek fabric is one type of ikat woven fabric originating from Bali. The production process of Endek fabric is quite difficult because of the complicated weaving technique. The creation of motifs on Endek fabrics also has its own unique characteristics, when compared to the creation of batik fabric motifs whose motifs are made after the fabric is finished, on Endek the motifs are made by arranging strands of thread that are arranged into a series or what is called the weaving process. So, in order to produce beautiful Endek motifs, it takes skill, perseverance, precision, patience and also a long time [6].

Traditional Balinese Endek has enormous potential in the eyes of the world as evidenced by the fact that in 2021, Christian Dior, a luxury fashion manufacturer from France, decided to use Balinese Endek fabric in their spring/summer collection [7]. Balinese Endek had the opportunity to appear on the international stage, namely Paris Fashion Week, which provides a direct picture of the enormous potential of Endek not only in the national market but also in the international market.

Fig. 1. Endek Motif

B. CNN

Computer vision has become an increasingly discussed topic in the field of image processing. With the proliferation of computer vision applications, there is a significant demand for automated object recognition. Convolutional Neural Networks (CNNs) have greatly contributed to the capabilities of computer vision by achieving high accuracy in video processing, object recognition, image classification and segmentation, natural language processing, speech recognition, and many other fields. Furthermore, the availability of large datasets and hardware has paved the way for further studies on CNNs. Several inspiring concepts for advancing CNNs have been developed to date, including alternative activation functions, regularization, parameter optimization, and architectural advancements [8].

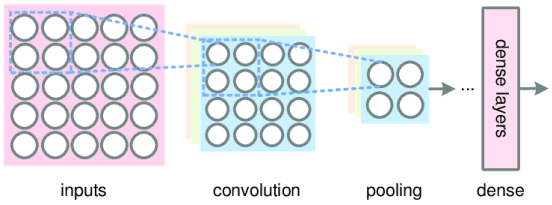

Fig. 2. Convolutional Neural Network Structure

There are many types or variants of CNNs currently, but their basic structure or components are very similar, consisting of three layers *convolutional layer, pooling layer* dan *fully-connected layers* [9].

C. State of The Art

Here are some related studies that have been conducted previously.

TABLE I. State of The Art

No	Year, Authors	Title	Result
1	2018, Kadek Dede Hendra Kusuma, I Ketut Adi Purnawan, Ni Kadek Dwi Rusjayanthi	Augmented Reality Application of Balinese Endek Pattern Information on Android Platform	The research result is an Augmented Reality application for recognizing Balinese Endek patterns
2	2020, Hendry fonda, Yuda Irawan, Anita Frebriani	Classification of Riau Batik Using Convolutional Neural Network (CNN)	The result of the research is a machine learning model that can classify types of Riau batik
3	2021, D.P. Prabowo, D.I.I Ullumudin, R.A. Pramunendar	Prototype of Wayang Kulit Recognition Application Using CNN Based on VGG16	This research has produced a prototype application capable of classifying types of wayang kulit puppets
4	2019, John Paul A. Madulid, Paula E. Mayol	Clothing Classification Using the Convolutional Neural Network Inception Model	This research has yielded a machine learning model capable of classifying various types of clothing
5	2019, Yudi Zhao, Kuangrong Hao, Haibo He, Xuesong Tang, Bing Wei	A Visual Long-short-term Memory Based Integrated CNN Model for Fabric Defect Image Classification	The outcome of this research is a machine learning model capable of classifying various types of fabric
6	2015, I Gede Surya Rahayuda	Texture Analysis on Image Motif of Endek Bali using K-Nearest Neighbor Classification Method	This research has developed a classification model using the K-Nearest Neighbor algorithm for the texture of Endek fabric
7	2022, I Gusti Agung Gede Arya Kedyanan	Development of Deep Learning Application for Identification of Balinese Endek	This research has developed a prototype of an application that can classify types of Endek fabric using a CNN algorithm

III. Research Method

In this research for a Bali Traditional Endek Motif Classification Application based on Artificial Intelligence using the Convolutional Neural Network algorithm, the Extreme Programming methodology is used. Extreme Programming is one of the agile techniques [10]. This method is best suited for project development that requires rapid adaptation to changes due to its flexibility to return to the initial stages if necessary. This allows for discussions with users if there are desired changes [11]. Extreme Programming is also suitable for projects with small teams and co-located members [12].

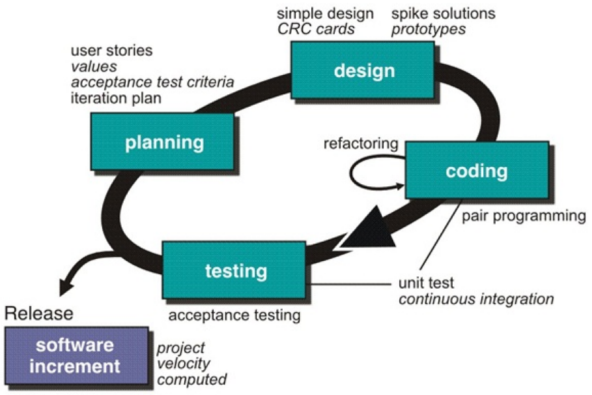

Fig. 3. Extreme Programming Method

The stages and flow of this research are described in the following image.

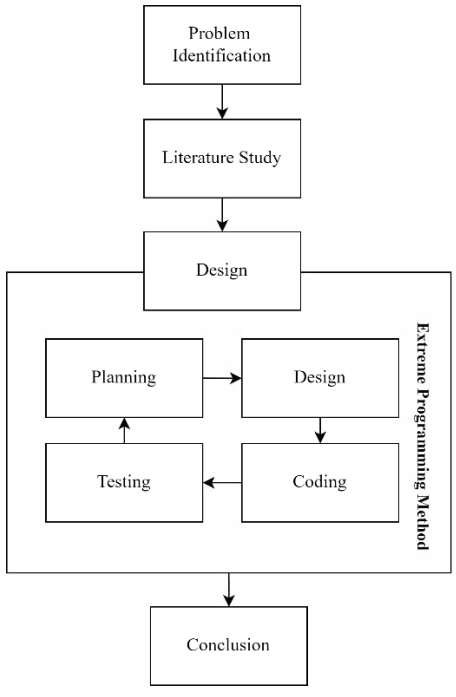

Fig. 4. Research Flow

he results of the research process described above in this study are as follows:

A. Identify the Problem

The initial step undertaken by the author is to identify a problem. The identification of this research problem was initially proposed by the Regional Research and Innovation Agency, namely BRIDA Bali. BRIDA mentioned that in order to preserve one of Bali's cultural heritages, Endek, efforts are needed to counter the abundance of imitation Endek that does not originate from Bali. Based on this problem, the author has developed an Android application capable of classifying types of Endek and providing additional information related to the motif, such as its history, use, and origin.

B. Literature Study

Once the problem has been successfully identified, the next step is for the researcher to conduct a literature review to find information about relevant scientific documentation through journals, books, articles, and previous research related to this study. This is done to strengthen the argumentation in the discussion of the problem

C. Design

The design process in the extreme programming methodology provides flexibility to iterate on any necessary stage. The design stages are as follows.

- Planning Stage

  During the planning stage, researchers conduct a general analysis of the system requirements needed for the application.

- Design Phase

  During the design phase, the developer creates the application's interface using Figma. The main interface consists of a home page, a camera page, and an information page about Endek. Additionally, a UML sequence diagram will be created to visually represent the processes occurring within the system.

- Coding Phase

  In this stage, the previously designed interface is implemented through coding. In other words, this stage involves the realization of the system that has been created. The first step in this phase is to create a machine learning model. The model creation process includes training, testing, and validation using the CNN (Convolutional Neural Network) algorithm. Afterward, the resulting model will be integrated into the Android application, which will be developed using the Flutter framework.

- Testing Phase

  At this stage, the author will conduct testing on the application that has been created to ensure it meets the desired requirements. The testing method used is black-box testing.

D. Conclusion

At this stage, the researcher draws conclusions from the results of the implementation and testing of the application that has been created. The results of these conclusions will later

become a reference for the development of a traditional Balinese Endek motif classification application based on artificial intelligence using the convolutional neural network algorithm.

IV. Result And Discussion

The results of this research are as follows.

A. Planning

At the planning stage, an analysis was conducted on the system's requirements. From this analysis, it was determined that the system must have several features. Firstly, it must have access to the smartphone camera to facilitate users in capturing Endek images. Secondly, the system must be able to access the gallery or image storage. Thirdly, it must be able to classify the type of Endek from the image inputted by the user. Lastly, the system must be able to detect if the image inputted by the user is not an Endek or is a type of Endek that is not yet in the dataset, thus the application will display the result "unknown".

B. Design

The Android platform was selected due to its convenience in obtaining image data. Users can directly utilize the device's camera to capture images of Endek patterns for classification.

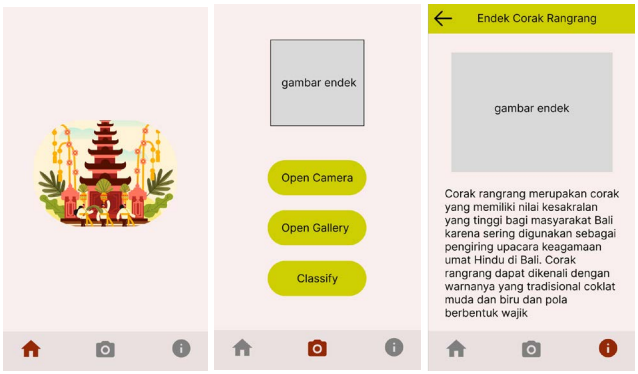

Fig. 5. Application Mockup

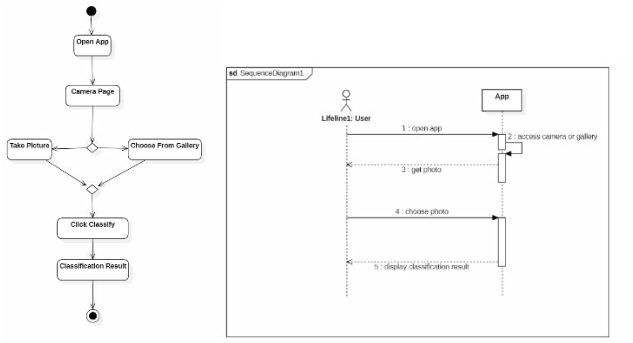

Fig. 6. Activity and Sequence Diagram

C. Coding

a) Preprocessing Data: Data preprocessing is done before the model training process. Data preprocessing is done to transform raw data into data that can be more easily processed by the model. The first thing researchers do is to clean the data by removing damaged and irrelevant images.

```
data_path = '/content/Endek Dataset'
train_datagen = ImageDataGenerator(rescale=1./255)
```

The next step is to apply several preprocessing steps such as resizing and cropping unnecessary parts of the image, resulting in an image with a size of 224x224, then normalizing the size and color of all images in the dataset.

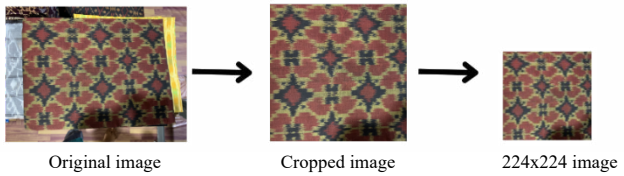

Fig. 7. Preprocessing Image

b) Data Labeling: To construct a model capable of recognizing each class, data labeling is conducted during the training phase. Labeling is performed by placing image data into respective folders according to their class name or Endek motif type. In total, there are 9 folders: 7 folders containing Endek images corresponding to their pattern names, one folder for testing data, and one additional folder containing random images named With the Unknown class. With a training data split of 80% and validation data of 20%, the number of images in the training data was 192, 47 in the validation data, and 40 in the testing data

c) Data Augmentation: Data augmentation is a technique to create a new dataset by modifying the original dataset. In image processing, data augmentation techniques can increase the amount of available training data by manipulating original images into new images with several modifications. Data augmentation techniques can improve the model's success in recognizing objects or images in previously unseen data, by introducing variations into the existing dataset and making the model more generalizable to patterns. The following are the data augmentations performed in this research

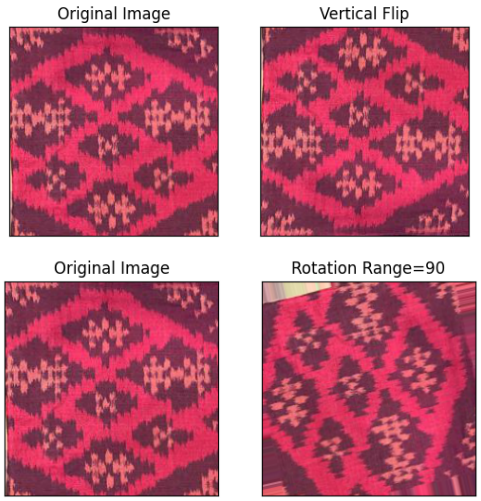

Fig. 8. Image Augmentation Results

By utilizing these parameters within the image data generator, we are able to perform random data augmentation,

which enriches the dataset and introduces diversity into the images used for model training. This enables the model to learn more effectively from the potential variations that might be encountered in the testing data.

d) Modeling and Training: A comparative analysis will be conducted on three models: VGG16, VGG19, and MobileNetV3Small. The model demonstrating the highest accuracy will subsequently be integrated into an Android application.

```
preprocessing_function=tf.keras.applications.vgg16
.preprocess_input
```

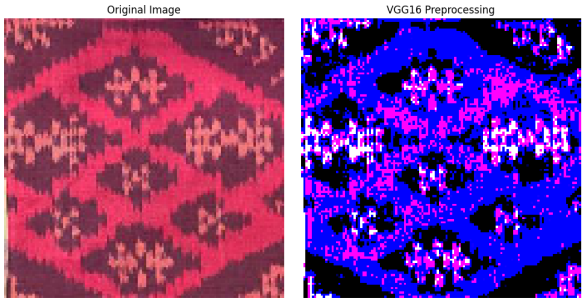

Fig. 9. VGG16 Preprocessing Results

The advantage of VGG19 lies in its ability to learn more complex and specific features compared to VGG16. This is due to the addition of deeper convolutional layers, allowing the model to capture features with higher levels of abstraction. However, like VGG16, VGG19 also has the drawback of a large number of parameters and longer training time.

```
preprocessing_function=tf.keras.applications.vgg19
.preprocess_input
```

Fig. 10. VGG19 Preprocessing Results

In the modeling and training phase using the MobileNetV3Small model, we continued to apply the same preprocessing methods as in the VGG16 and VGG19 models, including vertical flip, horizontal flip, shear range, zoom range, and rotation range. The difference lies in the application of MobileNetV3Small's specific preprocessing filter

Fig. 11. MobileNetV3Small Preprocessing Results

The accuracy values obtained by the three models, namely VGG16, VGG19, and MobileNetV3Small, can be said to be very good. The VGG16 model achieved a training accuracy of 94% and a validation accuracy of 92%. In the VGG19 model, the validation accuracy obtained was slightly better compared to the VGG16 model, where the training accuracy was obtained with a value of 92% and the validation accuracy reached 95%. MobileNetV3Small obtained a validation accuracy that is equivalent to the VGG19 model, which is 95%.

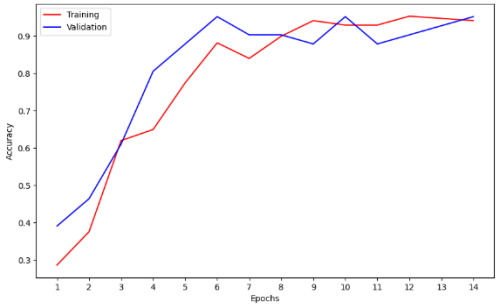

Fig. 12. MobileNetV3Small Accuracy Result

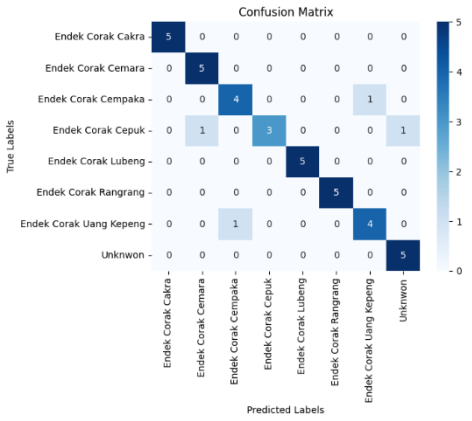

Fig. 13. MobileNetV3Small Confusion Matrix Result

From the confusion matrix of the three tested models, manual calculations can be performed to obtain the accuracy achieved by each model when trying to predict the testing data. The overall accuracy of the model can be calculated by dividing the number of correct predictions by the number of tested data. From the table below, it can be seen that the MobileNetV3 model produces the best performance, followed by VGG19

which can also be said to produce good performance on testing data with an accuracy difference of 7 percent. Meanwhile, the performance of VGG16 is the lowest with less than satisfactory accuracy, still below 70%.

TABLE II. ACCURACY COMPARISON

Model	Prediction		Accuracy
	True	False	
VGG16	31	9	78%
VGG19	33	7	82%
MobileNetV3	36	4	90%

e) Aplikasi Endek Vision: The following is the home display of the Endek Vision application

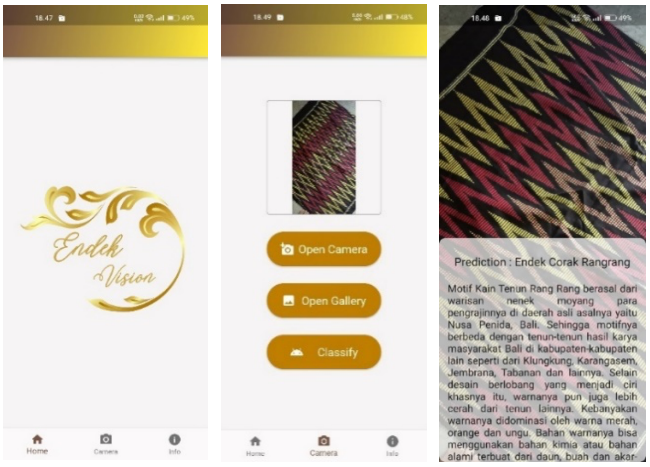

Fig. 14. Endek Vision Application View

f) Testing: In this research, black box testing was conducted to evaluate the application. The results indicated that the application functioned as intended.

V. CONCLUSION

Based on research on a traditional Balinese Endek motif classification application based on artificial intelligence using the convolutional neural network algorithm, comparing three machine learning models. The developed application is a combination of two different tools, namely Flutter and TensorFlow Lite. This research produces three models from the transfer learning method using the VGG16, VGG19, and MobilenetV3Small models. Where all three models successfully obtained very good training and validation results. VGG16 obtained a training accuracy of 94% and a validation accuracy of 92%. VGG19 obtained a training accuracy of 92% with a validation accuracy of 95%. MobilenetV3 Small has the best accuracy results compared to the other three with a training accuracy of 94% and a validation accuracy of 95%. However, despite obtaining high accuracy at the training stage, the model's performance at the testing stage shows different results. After the testing stage, the VGG16 model only obtained an accuracy on the testing data of 66%, which is the lowest result of the three models. The CGG19 model obtained fairly good accuracy with a figure reaching 86%. And the MobilenetV3 Small model obtained the highest accuracy with a figure reaching 91%. So it can be concluded that compared to the three models VGG16, VGG19, and MobilenetV3 Small, the best performing model to predict the type of Endek pattern is MobilenetV3Small. The researcher suggests increasing the number of datasets and also the types of Endek motifs so that the application's functionality becomes better and the model's performance becomes better.

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