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# Application of Artificial Intelligence in Digital Architecture to Identify Traditional Javanese Buildings

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**ABSTRACT**

Traditional buildings have a cultural philosophy and characterize the culture of an area. The occurrence of environmental changes, population growth, and the growth of modern buildings impact traditional buildings. Therefore, preserving those traditional buildings is needed to avoid extinction and make as cultural assets. The research aims to develop an application to help architects quantitatively measure the content of traditional architectural styles in their designs. This study uses the Artificial Intelligence (AI) method to identify buildings' similarities, acquiring traditional building data in roofs and ornaments images as a dataset totaling 650 images of roofs and 7,180 ornaments. Data processing was carried out by making architectural models, training, testing accuracy, and creating application interfaces. The algorithm used to identify similarities between building types was the Convolutional Naural Network (CNN) and the Support Vector Machine (SVM). The results of the accuracy-test using the Confusion matrix method reached an accuracy value of 99.5% in identifying building similarities and 85% in classifying building types.

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## 1. INTRODUCTION

In the Industrial Revolution 4.0, there was automation and digitization of documents in various sectors. In the industrial sector, management is also in the education sector. According to needs, digitization and automation of records have become part of the learning process in education with various models and scenarios [1]. In the era of digitalization, it can carry out learning activities with the help of computers. One of them is introducing the culture of an area using Artificial Intelligence (AI). The development of AI is so rapid in various fields. For example, speech recognition, predictive systems, automatic vehicles, translators, and documentation techniques contribute to digital architecture. Implementation of AI in Digital Architecture is a new solution for documenting, managing and accessing public data, and in general, any data containing information about the past as needed [2]. The use of AI in digital architecture serves to overcome problems in presenting physical objects that are not easy to find and explore. The existence of computer technology can help architects improve their ability to design from traditional to modern [3].

This paper discusses applying AI to digital architecture in identifying traditional buildings. The object of research focuses on traditional Javanese architecture. Traditional buildings are one of the cultural elements that develop with the existing culture in society and become a reflection of the culture of an area and shape the nature of a culture. The AI can predict, identify, analyze, and recognize problems in digital architecture. Documenting a building model by digital is done with 2D and 3D design tools that can be collaborated with other multimedia technologies. The disadvantage of this technique is that it cannot incorporate detailed information regarding the history of the building, location, and cultural philosophy into the device.

Along with the development of digital technology, the public and an architect can access complete information widely by using public data available on the Internet or specific web pages in the data acquisition process [4] [5]. AI can display information in a complex manner; for example, by detecting similarities between building models using specific parameters, the similarity values can be accurately expressed. There have been many studies using the concept of AI in digital architecture; for example, research to obtain certainty in identifying types of writing and images [6], application of AI for textual and visual processing of digital architectural models [7], and digital architecture in modeling heritage buildings [8].

This research used traditional Javanese buildings as objects. It uses ornaments and the roof's shape as a parameter to identify the type of building. The traditional Javanese buildings studied were five roof styles: Joglo, Limasan, Tajug, Kampung, and Panggang Pe. The thing that underlies the research to explore traditional Javanese buildings is that the number of buildings is large compared to other traditional houses in the area. Visually, traditional Javanese buildings look similar but differ in ornamentation and topology, which have different philosophies for each building. Furthermore, in traditional Javanese architecture, each ornament and roof shape has a different meaning, such as the Tajug style; it will have a different sense for houses and mosques. The background of this research is to overcome the problem of identifying the similarity of buildings and knowing the types of traditional Javanese buildings. Another factor of this research is the enrichment of digital architectural models that apply the concept of AI in traditional building problems.

Two AI concepts are used: the Support Vector Machine (SVM) algorithm and the Convolutional Neural Network (CNN). Support Vector Machine (SVM) is a method in supervised learning that works by defining the boundary between two classes with the maximum distance from the closest data. For example, getting the total length measures the hyperplane margin and finds the best hyperplane (separation line) in the input space. Margin is the distance between the hyperplane and the closest point of each class [9]. In addition, SVM can generalize the problem well with higher accuracy [10]. CNN is an algorithm with increased accuracy capabilities with automation processes in data training and accuracy testing [11] [12]. In this study, SVM is used to classify traditional buildings, while CNN builds architectural models and augmentations.

This research aims to create an application to apply artificial intelligence in digital architecture to identify traditional Javanese buildings. Furthermore, it provides digital education for the public to learn Javanese culture. At the same time, for an architect, it can be used as a reference for knowledge in traditional building architectural models, while researchers can add insight regarding the application of AI in digital architecture.

## 2. RESEARCH METHOD

This study uses several stages to apply the concept of Artificial Intelligence in digital architecture. The research phase begins with conducting research studies on digital architecture and Artificial Intelligence. Furthermore, data acquisition, data processing, data analysis with CNN, classification with SVM, application development, testing, and conclusion drawing.

### 2.1. Literature Research Studies

Literature studies explored international journals indexed in Elsevier and IEEE. The reviewed papers relate to digital architecture, Convolutional Neural Network, Support Vector Machine, and traditional Indonesian buildings.

### 2.2. Data acquisition

Data acquisition was a collection process carried out by direct or indirect data collection. The way to collect data directly was to come to traditional Javanese buildings in Yogjakarta, Kota Gede, Semarang, and Solo and interview architects and artists from different locations in Yogyakarta. It collects data in the form of ornament images and the shape of the roof of the building using DLSR cameras, drones, and smartphones. The indirect data retrieval method uses the Google Street View application and public data retrieval available on the Internet and architectural magazines. Tables 1 and 2 present the dataset results of roofs and traditional Javanese building ornaments obtained and the distribution of data usage.

### 2.3. Processing data

This step performed data processing on images of traditional building ornaments and roofs for data extraction, resizing image sizes, improving image quality, and labeling data. Stores data were labeled according to traditional building types and their parameters. This process then collects image data and separates data according to its type into folders. Then do the cropping process manually using the Photos application from Windows. This process takes the part of the image in the form of a roof.

### 2.4. Modeling and Model Analysis

After processing the data, the next step was to create an image data model architecture using the Convolutional Neural Network (CNN). CNN is a type of deep learning because of its high network depth and comprehensive application to image data. Deep learning is a branch of machine learning that can teach computers to do work like humans, just as computers can learn from the training process. CNN is a convolutional operation that combines several processing layers, using and inspiring the biological nervous system. Each neuron represents a 2-dimensional shape in CNN, so this method is suitable for processing image data as input. The CNN structure consists of several layers, including information, feature extraction process (feature learning), and classification process [13] [14]. Figure 1 presents the CNN Architecture Model.

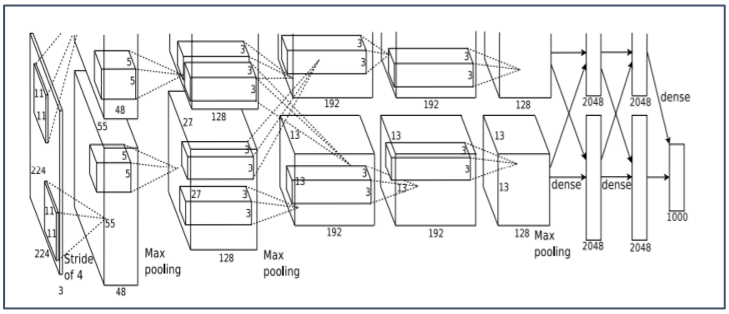


**Figure 1**. An illustration of the architecture of our CNN [15]

### 2.5. Classification

It classified the types of traditional buildings and divided them into five classes, namely Joglo, Limasan, Panggang Pe, Kampung, and Tajuk House. Parameters in the Support Vector Machine modeling were the default values for the "svm.SVC()" function, namely the C value '1.0', kernel' rbf,' gamma 'scale' and the toll value 0.001 (the reference value of tolerance when the classification will stop). The default values are in the "scikit-learn" library version 0.24.2. This step was followed by performing a hyperplane separation using the SVM classifier algorithm. The hyperplane calculation maximized the margin or distance of two sets of objects from two different classes. For the classification and training SVM on two different objects, we used equations (1). If given training data $x_i \in R^n$, i = 1 and label was given with $y \in R^1$ where $y_i \in \{1, -1\}$. [16]

$$\min_{w,b,\varepsilon} 1/2w^T w + C\sum_{i=1}^{1}\varepsilon_i \quad (1)$$

$$\text{for } y_i\,(w^T\ \emptyset(x_i) + b\,) \geq 1 - \varepsilon_i,\ \varepsilon_i \geq o_i = 1, \dots, l \quad (2)$$

### 2.6. App Creation

At this stage, we entered the interface to display the identification of traditional Javanese building types for interfaces made using the PHP and Python programming languages. One of the advantages of Python programming is that it can collaborate with various programming languages, called multi-platform. To use Python, we need first to install a flask. Flask is a microframework for creating or building web applications.

### 2.7. Accuracy Test

This stage used the confusion matrix method to measure the performance of a classification model made. Then accuracy, precision, recall, and f1-score were measured using equations (1), (2), (3), and (4), respectively, where TP is True Positive, FP is False Positive, TN is True Negative, and FN is False Negative. The equation is as follows [17] [18] [19]:

$$F_1 = \frac{2\,.TP}{2\,.\ TP + FN + FP} \quad (3)$$

The testing of the CNN model created was done automatically with Python programming. Therefore, the Validation Test model and training data can be presented in a matrix, as shown in Figure 2.

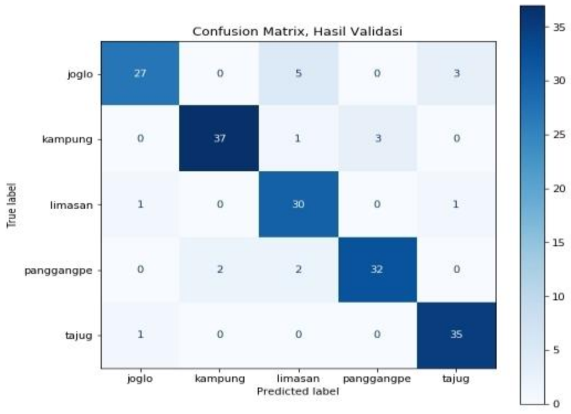


**Figure 2.** The results of the CNN architectural model performance test with the Confusion Matrix Method

Acquisition of traditional building datasetBased on the explanation of the research phase, we made a diagram for the research phase, as in Figure 3.

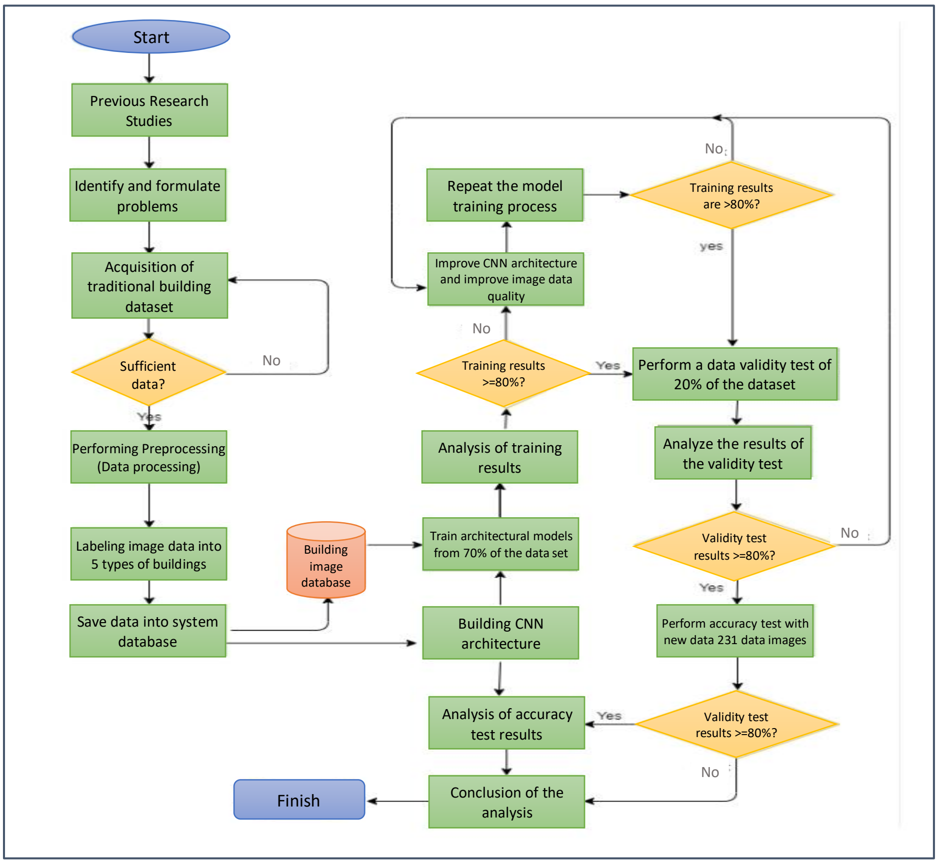


**Figure 3**. Stages of Research Application of AI in Digital Architecture for Identification of Traditional Buildings

## 3. RESULTS AND DISCUSSION

Referring to the research methodology in Figure 3, the explanations for the achievements and findings in this study are as follows:

### 3.1. Data Collection Results

Five traditional Javanese buildings were studied, namely Joglo, Kampung, Limasan, Panggang Pe, and Tajug Houses. The data collection resulted in 7,184 images for ornament data and 650 images for roof data representing the building typology criteria. The dataset was divided into two parts, used for training and testing data. The data was distributed 80% for training and 20% for data validity tests. Tables 1 and 2 present the dataset results of roofs and traditional Javanese building ornaments obtained and the distribution of data usage. The purpose of solving the data differs from the data used for testing during the training process. The amount of data for training was more so that the system was further trained to recognize building images and achieve the targeted accuracy results. Other samples were used for test data to know the application's ability to acknowledge building objects randomly.

**Table 1.** Data collection for traditional building roof shapes

| No. | Building Type | Data Extension | Dataset | Training data | Validation Data | Data testing |
|---|---|---|---|---|---|---|
| **1.** | Joglo House | .JPG | 130 | 84 | 36 | 10 |
| **2.** | Kampung House | .JPG | 130 | 84 | 36 | 10 |
| **3.** | Limasan House | .JPG | 130 | 84 | 36 | 10 |
| **4.** | Panggang pe House | .JPG | 130 | 84 | 36 | 10 |
| **5.** | Tajug House | .JPG | 130 | 84 | 36 | 10 |
| | **Total Data** | | **650** | **420** | **180** | **50** |

**Table 2.** Data collection for traditional building ornaments

| No. | Building Type | Data Extension | Dataset | Training data | Validation Data | Data testing |
|---|---|---|---|---|---|---|
| **1.** | Joglo House | .JPG | 2433 | 1890 | 472 | 71 |
| **2.** | Kampung House | .JPG | 2324 | 1766 | 442 | 116 |
| **3.** | Limasan House | .JPG | 438 | 325 | 80 | 33 |
| **4.** | Panggang pe House | .JPG | 953 | 744 | 181 | 28 |
| **5.** | Tajug House | .JPG | 1036 | 713 | 180 | 143 |
| | **Total Data** | | **7184** | **1355** | **391** | **7184** |

### 3.2. Pre-Processing

The obtained image data is processed to improve image quality and follow the analysis needs. The stages are done by cropping, converting, and resizing, as for the explanation as follows:

**a. Cropping**

This process separated the image data set according to its type into a folder. Then the image data was done by cropping or cutting manually using the Photos application from Windows. This process took the part of the image in the form of a roof. The purpose of cropping was to recognize objects quickly because it could minimize interference with other things in the picture. Figure 4 shows the results of cropping.

**Figure 4.a**. Original data before cropping

**Figure 4.b.** Data after cropping

**b. Resize**

Before changing the image data size, the image data was converted from a color image (RGB) to grayscale to make it more accessible during the extraction process. The next step is to change the ratio of the width to the height of the image to a size of 1:2 so that it will be easier to extract features in the following process. Finally, the image data was changed to the width to height ratio with the provisions of 180 x 180 pixels, resizing the image to equalize all the processed image data. However, with a width-to-height ratio size of 180 x 180 pixels, it will produce better feature results when compared to the opposite size ratio. This study used RGB images with three channels and values between 0 to 255. RGB images have three channels: red, green, and blue channels. Figure 5 shows the results of the resizing performed on the converted image data.

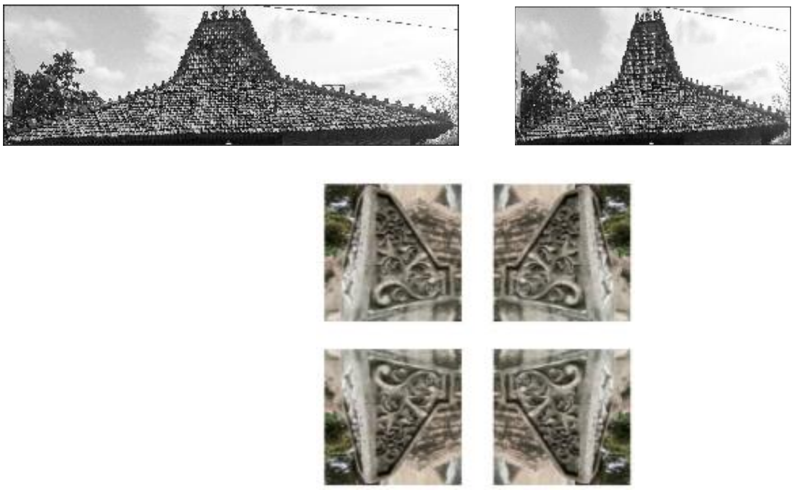

**Figure 5**. The results of resizing the image of the roof and ornaments of traditional Javanese buildings

#### 3.2.1. Constructing Architecture Model dan Training Data

Architectural models were used to train the application to identify traditional Javanese buildings. Using the built CNN architecture model, training computers to recognize Javanese buildings was carried out. Inside CNN contains three layers: input, hidden, and output layers. The CNN architectural structure used in this research is a feature extraction layer and a fully connected layer. The architecture consists of: one input layer, augmentation layer, recalling layer to normalize data, three convolutional layers with "reLu" activation, three max-pooling layers, a fully connected layer with dropout, and softmax activation (an output layer that has five class categories). In addition, a feature extraction process was conducted to get the unique characteristics of the building images used for the similarity identification process. The feature results extracted are the shape of the roof and the shape of the building ornament. The CNN architectural model to identify traditional Javanese buildings is presented in Figure 6.

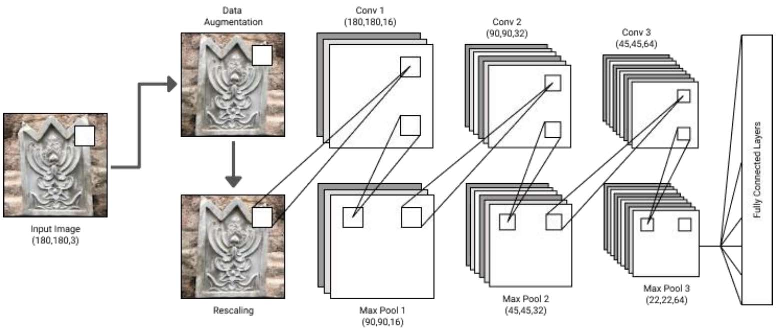


**Figure 6**. Feature extraction layer

After creating the CNN model architecture, the following process conducted data training based on the network architecture used in the training process; obtain the model from the architecture, as shown in Table 3. Data training was carried out to train computers to recognize Javanese style in the objects. The data input was data that resized to 80% of the 7,834 dataset (650 roof data, 7184 ornament data), which consisted of ornament data and roofs of traditional Javanese buildings. From Table 3, the model formed from the training results and the total parameters developed from the model were 3,989,156 neurons.

**Tabel 3.** Architecture Model CNN

| No. | Nama Layer | Size | Parameter |
|---|---|---|---|
| 1 | Input | 180,180,3 | 0 |
| 2 | Data Augmentation | 180,180,16 | ((3*3*3)+1)*16 = 448 |
| 3 | Rescaling | 90,90,16 | 0 |
| 4 | Convolutional (Conv2D) | 90,90,32 | ((3*3*16)+1)*32 = 4640 |
| 5 | Pooling (MaxPooling2D) | 45,45,32 | 0 |
| 6 | Convolutional (Conv2D) | 45,45,64 | ((3*3*32)+1)*64 = 18496 |
| 7 | Pooling (MaxPooling2D) | 22,22,64 | 0 |
| 8 | Dropout | 22,22,64 | 0 |
| 9 | Flatten | 30976 | 0 |
| 10 | Dense | 128 | (30976*128)+128 = 3965056 |
| 11 | Output | 4 | (128+1)*3 = 516 |
| | **Total** | | **3.989.156** |

Training and validation were obtained after several Convolutional Neural Network (CNN) algorithm processes. This process used 20 epochs. The training process resulted in 99.5% validation accuracy and 0.031% validation loss. Figure 7 shows the validation data (the orange line) and training data (the blue line). With an accuracy value of 0.99% obtained, it can conclude that the CNN architectural model has been able to identify the building with 99.5% confidence.

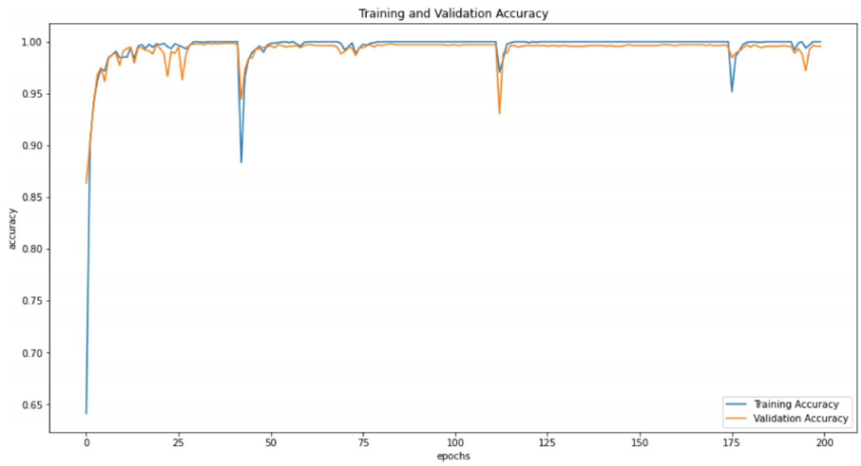


**Figure 7.** Graph of training data results and validity test

For testing the classification of buildings using the SVM algorithm, the results showed that the accuracy value for testing data got 90% accuracy from the 50 testing data tested, predicted 45 data to be correct, and expected the remaining data to be wrong. Table 4 details the results of testing data testing in the form of a confusion matrix table.

**Tabel 4.** Confusion matrix test results data testing

| | | Prediction | | | | | |
|---|---|---|---|---|---|---|---|
| | Class | 0 | 1 | 2 | 3 | 4 | **Total** |
| **Actual** | 0 | 10 | 0 | 0 | 0 | 0 | **10** |
| | 1 | 0 | 7 | 1 | 1 | 1 | **10** |
| | 2 | 1 | 0 | 9 | 0 | 0 | **10** |
| | 3 | 0 | 1 | 0 | 9 | 0 | **10** |
| | 4 | 0 | 0 | 0 | 0 | 10 | **10** |
| | **Total** | **11** | **8** | **10** | **10** | **11** | **50** |

Table 4 shows that the application correctly predicted all ten testing data from class 0 or Joglo styles. Testing data from class 1 or the Kampung styles predicted 7 data correctly and 3 data incorrectly. Meanwhile, the class data from class 2 or the Limasan type indicated 9 data precisely and one poorly. Like data from class 2, data from class 3 or the Panggang pe style accurately predicted nine and false 1. In class 4, the Tajug type, all 10 available data were indicated to be all correct. The testing method was the number of valid data predicted for each class divided by the incorrectly predicted and multiplied by 100%. The accuracy results in data testing were 90%. So the system can be said to be running quite well. Table 5 shows the results of the classification report in Python.

**Table 5.** Results of classification of building types with the svm algorithm

| | Precision | Recall | F1-Score | Support |
|---|---|---|---|---|
| **0** | 0.91 | 1.00 | 0.95 | 10 |
| **1** | 0.88 | 0.70 | 0.78 | 10 |
| **2** | 0.90 | 0.90 | 0.90 | 10 |
| **3** | 0.90 | 0.90 | 0.90 | 10 |
| **4** | 0.91 | 1.00 | 0.95 | 10 |
| **Accuracy** | | | 0.90 | 50 |
| **Macro Avg** | 0.90 | 0.90 | 0.90 | 50 |
| **Weighted avg** | 0.90 | 0.90 | 0.90 | 50 |

### 3.2.2. The Application results to identify traditional Javanese architecture styles

A system-related application to identify traditional buildings was created using Python for analysis and PHP programming for the system interface. The system was uploaded to the site at the address http://buildingcagarkultur.my.id. The public can use the system, especially students and architects, to identify traditional Javanese buildings. An architecture expert is a person in charge of knowledge related to building information, the meaning of the philosophy of the building, and the types of traditional Javanese buildings. Meanwhile, users from the community can only use it to find information related to buildings by uploading photos to seek data. Figure 8 shows the process flow of using the application.

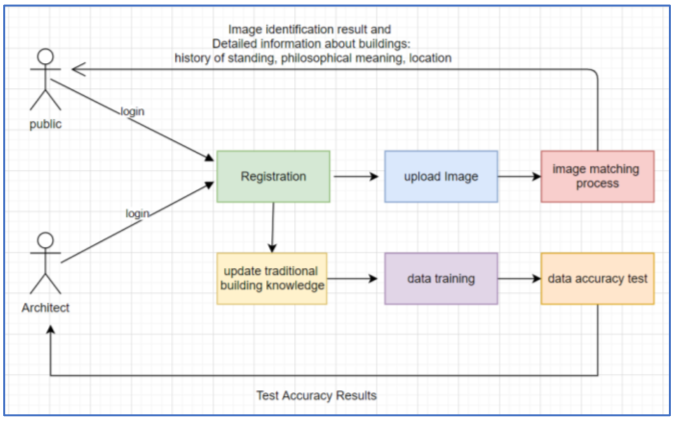


**Figure 8**. The flow of the use of the application to identify the type of traditional Javanese building

The registration process is needed to distinguish access rights from users because there are differences in features between expert users and ordinary users. For example, architecture expert users can use knowledge data management as the person in charge of knowledge management in the system and stored in the database. Figure 9 shows the process of identifying the object of a Javanese building using the designed application.

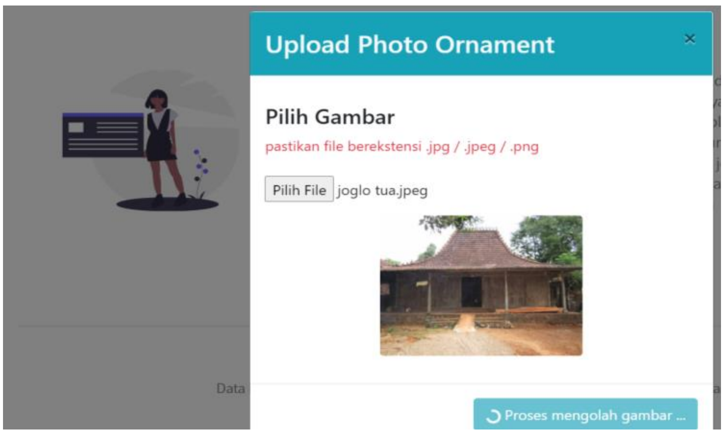

**Figure 9.** Initial view of building identification application

In Figure 9, after a user registers, the next step to identify the building is to upload an image via the upload menu. The system tracks it into the building image database; the data must be JPEG or PNG when uploading data. Other than these data types, the system will not read the data. Figure 10 shows the results of the identification of traditional buildings and their accuracy value with the accuracy value of the similarity of the building. (Notes for translations: *Pilih Gambar* = Select Picture, *pastikan file berekstensi* = accepted file extension, *Pilih File* = Select File, *Proses mengolah gambar* = picture processing)

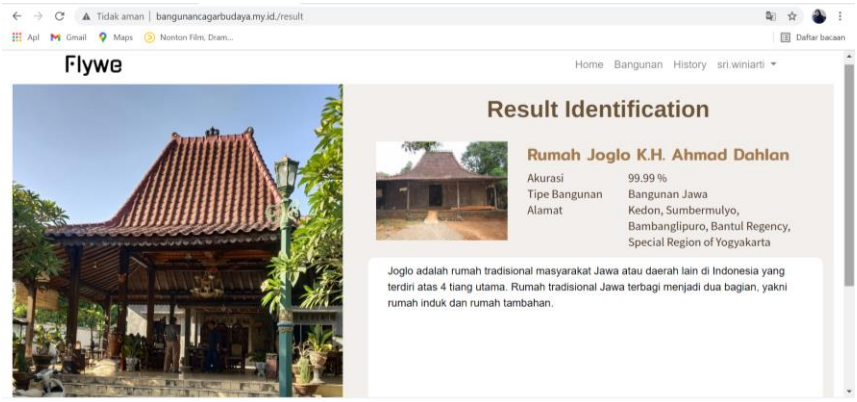


**Figure 10.** The results of the identification of buildings and their similarity accuracy values

## 4. CONCLUSION

Based on the training process and validity tests carried out for making applications to identify traditional Javanese buildings, this test has met the level of accuracy of 99.5% at the time of validity testing. Furthermore, for tests carried out with data taken randomly from the Internet, the system was declared accurate at 89.6% by using data as many as 50 images from the five types of Javanese buildings studied. Thus, it can be concluded that the application is acceptable for identifying traditional Javanese buildings with ornamentation and roofing parameters for the Joglo type, Panggang Pe, Kampung, Limasan, and Tajug types. Therefore, in terms of digital architecture, it proves the contribution of artificial intelligence in providing knowledge related to traditional Javanese buildings.

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| Sri Winiarti | The author is a Lecturer at the Department of Informatics, Ahmad Dahlan University. Now, the research focuses on Artificial intelligence, such as expert systems, Decision Support Systems, Data Mining, Image Classification, and Clustering. The study was conducted based on a Higher Education and Ahmad Dahlan University grant and published the research in reputable international journals and national journals indexed by Sinta. In addition, carry out the publication of articles through international and national conferences. |
| Heri Pramono | Author a postgraduate student at Atmajaya University Yogyakarta, where one of his research focuses on Digital Architecture and currently researching Digital Architecture using the concept of Artificial Intelligence to identify heritage buildings and traditional buildings. Presently the author is a lecturer at Sekolah Tinggi Arsitektur YKPN. |
| Andri Pranolo | The author is a Lecturer at the Department of Informatics, Ahmad Dahlan University. Minal The research focused on Artificial intelligence, such as expert systems, Decision Support Systems, Data Mining, Image Classification, and Clustering. Currently, the author is the manager of the IJAIN international journal and the supervisor of national journals in several universities. The author is studying further at the Hohai School of Science and Engineering University – China. |