

The application of visual programming technology to classify mango leaves using a convolutional neural network

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ABSTRACT

Leaf images are representations of leaves captured using digital cameras, which visually display the morphology and structure of the leaves. The classification of mango fruit can be identified from the type of leaves by using a convolutional neural network (CNN). The aim of this research is to obtain information on the type of mango fruit based on leaf type using image processing. The experimental setup involved the application of the test data set and the training data set to the classification of mango leaves, utilising iterations on both the training and testing data sets. This process involved the use of images exhibiting slight variations in shape, both in terms of image position and leaf type, to facilitate a comparison with images of the intended leaf type and leaves not included in the training classification. The experimental results yielded an accuracy level of 80.76%, validating the efficacy of the approach.

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1. INTRODUCTION

Computer vision is a branch of artificial intelligence (AI) that aims to recognize or classify images [1]. Computer vision gives computers the ability to 'see' and understand the visual world in the same way as humans do. This involves the development of algorithms and technologies that enable computers to understand and analyze images and videos, as well as to identify patterns, objects and features within them [2]. Visual programming and artificial intelligence technologies have taken center stage across various sectors, including agriculture. The implementation of visual programming technologies has attracted many researchers to investigate their use in object classification, one example being the classification of mango leaves using a convolutional neural network (CNN) to determine the variety of mango [3]. The classification of mango leaves has unique characteristics and can provide information regarding the characteristics of the mango plant.

Visual programming technology and the use of CNNs are part of artificial intelligence (AI) that relates to techniques or algorithms for recognizing or identifying a specific object [4]. The identification of an object is used to classify or describe its characteristics, shape and texture based on the visual features of the object under examination [5]. Classifying mango leaves can help to distinguish between different mango varieties and identify the types of fruit growing in the field, monitor the growth of mango trees more accurately, predict crop yields, and can also be used to identify leaf diseases in mango trees [6]. The process of classifying mango leaves using a CNN involves image processing. This process involves collecting image data of mango leaves to be used for training the CNN model [7]. This data must include various types of mango leaves from different varieties to serve as a reference for creating test and training datasets in the process of identifying mango leaf types using a Convolutional Neural Network (CNN). Image processing in the identification of mango leaf types can be carried out through image feature analysis, which involves

the extraction of specific attributes from images that can be used to distinguish between different types of mango leaves. These features may include texture, shape, color, or distinctive patterns on the leaves. Techniques such as edge detection, texture extraction, or Fourier feature extraction can be used to identify key characteristics of mango leaves [8]. CNN has the ability to automatically learn relevant features from image data, making it highly effective for image classification tasks [9]. The aim of this study is to obtain information regarding mango varieties based on leaf morphology, and the findings of this study can be utilized to identify mango plant diseases in leaf images [10].

2. RESEARCH METHODS

This study employs an experimental quantitative approach using a deep learning-based system development method, specifically a Convolutional Neural Network (CNN), implemented via visual programming technology. The study aims to develop and evaluate a mango leaf classification model based on digital image processing.

2.1. Image Processing

Image processing is the process of identifying or recognizing specific objects within an image. It involves the manipulation, analysis and transformation of digital image data to produce more useful information or achieve specific objectives [11]. Image processing is used in a wide range of fields, including computer science, computer vision, remote sensing, medicine, robotics, and so on [12]. The aim of image processing is to improve the quality, usability and interpretability of digital images [13]. Image processing can manipulate image data to generate more useful information, facilitate further analysis, and support decision-making in a wide range of applications [14]. The stages of image processing are as follows:

2.1.1. Data Collection

The data collection phase involved compiling a dataset of mango leaf images representing various types or varieties of mango. The dataset was designed to reflect the morphological characteristics of the leaves of each variety, such as leaf shape, length and width, surface texture, and venation patterns. Data diversity was carefully ensured by including variations in camera angles, leaf size, background, and lighting conditions, so that the model is capable of generalizing effectively under real-world conditions.

Data sources were obtained through two main approaches. Firstly, the use of public datasets available on the Kaggle platform (kaggle.com), which provides a collection of plant images for machine learning and computer vision research. Datasets were selected based on the suitability of variety categories, image resolution quality, and the completeness of class labels. Second, additional data was obtained from reliable literature sources and websites, such as academic repositories, agricultural research publications, and plant databases managed by educational institutions or official research bodies. Samples of mango leaf types can be seen in Figure 1.



Figure 1. Samples of mango leaf varieties.

All the images collected then undergo a selection and verification process to ensure consistency in variety labeling, adequate visual quality, and suitability for the research objectives. This stage is crucial to ensure that the dataset used is sufficiently representative and valid to support the training and evaluation of a Convolutional Neural Network (CNN)-based classification model.

2.1.2. Preprocessing

Pre-processing was performed to prepare the images for classification using a Convolutional Neural Network (CNN)-based model. This stage aims to enhance data quality while ensuring image format consistency before the training process. The collected images were first resized to 256×256 pixels to match the network architecture requirements and reduce computational complexity. Subsequently, pixel intensity normalization was applied to scale the pixel values into a controlled range of 0 – 1, thus improving training stability and accelerating model convergence.

Image enhancement techniques were also employed to improve image quality by increasing contrast, enabling clearer visualization of leaf morphological characteristics such as vein patterns and leaf edge structures. In addition, noise reduction was performed to eliminate irrelevant visual disturbances, ensuring that the features extracted by the CNN model accurately represented the characteristics of the mango leaf varieties under investigation. The overall pre-processing workflow is illustrated in Figure 2.

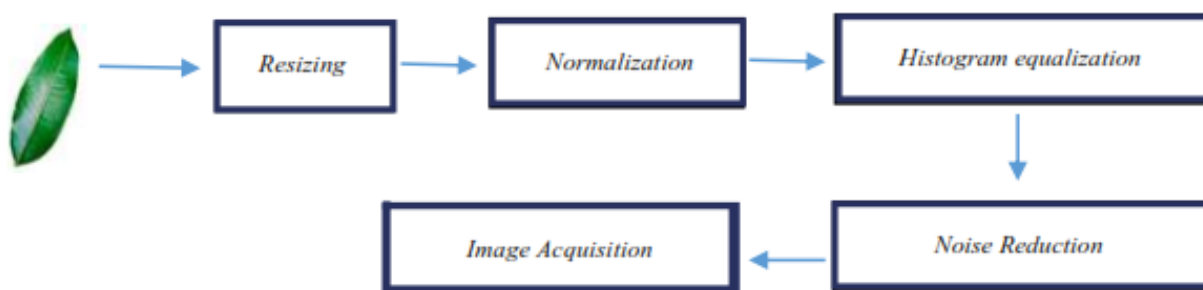


Figure 2. Preprocessing steps.

2.1.3. Data Partitioning

At this stage, the prepared dataset was divided into two primary subsets: a training set and a testing set. The dataset was partitioned using a ratio of 70% for training and 30% for testing of the total dataset. This proportion was selected because it provides a balanced distribution between sufficient data for model learning and an independent dataset for performance evaluation. The training set was utilized to train the Convolutional Neural Network (CNN) classification model to learn and identify the morphological patterns and characteristics of each mango leaf variety. Meanwhile, the testing set was employed to evaluate the model's generalization capability on previously unseen data. By applying this data partitioning strategy, the evaluation results can more objectively reflect the actual performance of the model while minimizing the risk of overfitting to the training data.

2.1.4. Model Training

The classification model in this study was developed using a Convolutional Neural Network (CNN) architecture designed to automatically extract discriminative features from mango leaf images. During the training process, the network learns by iteratively adjusting the weights of each layer through the backpropagation mechanism and the optimization of a loss function. The convolutional layers are responsible for extracting essential features, including leaf vein patterns, surface texture, and leaf edge characteristics, which serve as distinguishing attributes among different mango varieties. These extracted features are subsequently processed through pooling layers and fully connected layers to generate higher-level abstract representations before the final classification stage. Through an iterative learning process over a predefined number of epochs, the model gradually learns to associate the extracted features with their corresponding class labels. As a result, the CNN model becomes capable of accurately distinguishing various mango leaf varieties based on their visual characteristics.

2.2. Convolutional Neural Network

A Convolutional Neural Network (CNN) is a type of artificial neural network specifically designed to process image data in the field of computer vision [15]. CNNs are capable of classifying images, detecting objects, object segmentation and so on [16]. CNN is an extension of the Multilayer Perceptron used for data processing; it has a three-dimensional neural network structure (width, height, depth) [17]. Width and height are the dimensions of a layer; depth refers to the number of layers. The components of a CNN (to explore advances in CNN architecture) are shown in Figure 3.

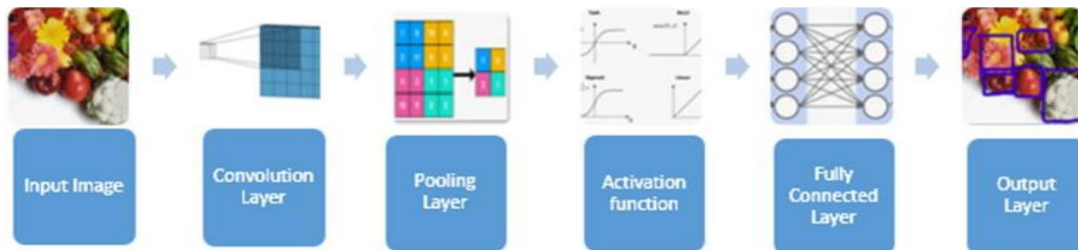


Figure 3. CNN components.

Convolutional layers utilize filters to extract meaningful features from mango leaf images provided as input. These filters contain learnable weights that are used to detect specific characteristics of the object, such as edges, curves, textures, and color patterns. The convolution operation produces a linear transformation of the input image while preserving the spatial information embedded within the data. In this process, an input image is processed using one or more filters that slide across the image to generate feature maps representing the detected visual patterns. The architecture of the CNN convolutional layer is illustrated in Figure 4.

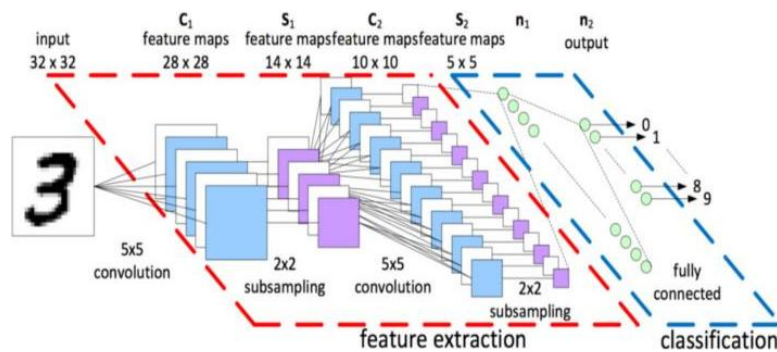


Figure 4. Convolution layer CNN.

The way in which a CNN classifies an object is as follows:

1. Preprocessing

This process is the first step in normalizing the image with respect to the pixel intensity used.

2. Convolution Layer

The input image passes through a sequence of convolutional layers, and each layer consists of a number of kernels that extract features such as angles, edges and textures from the image.

Generally, these layers are divided into two types, namely:

- a. The image feature extraction layer, located at the start of the architecture, consists of multiple layers; Each layer contains neurons that are connected to local regions of the previous layer. The first layer is called the convolution layer and the second layer is the pooling layer. An activation function is applied to each layer.
- b. The classification layer consists of multiple layers, each of which contains neurons that are fully connected to the other layers. This layer is responsible for receiving input from the output of the image feature extraction layer in the form of vectors.

3. Activation Function

This activation function introduces non-linearity into the network, enabling the CNN to learn more complex feature representations.

4. Pooling Layer

The purpose of the pooling layer is to make the feature representation more invariant to small shifts in the position of objects in the image.

5. Fully Connected Layer

This layer consists of fully connected neurons and is typically used to generate class predictions by performing classification based on previously extracted feature representations.

6. Output Layer

The output layer consists of neurons that represent the possible classes in the classification task (e.g., object categories in image classification). Each neuron produces a probability score indicating the likelihood that the input image belongs to a particular class. The class with the highest probability is then selected as the final prediction of the model.

Classification of mango leaf types using leaf image processing with a Convolutional Neural Network (CNN) is as follows:

- Convolution:

In convolution, a convolution operation is performed between a filter or kernel and the input image to generate relevant features. The convolution operation at point (i, j) in the input image I and filter K can be calculated using the following formula:

$$(I * K)(i, j) = \sum_M \sum_N I(i - m, j - n) \cdot K(m, n) \quad (1)$$

where:

$(i - m, j - n)$ = pixel position in the input image;

(m, n) = pixel position in the convolution filter (kernel);

$I * K$ = output of the convolution operation.

- Activation Function:

A commonly used activation function is ReLU (Rectified Linear Activation Function), which is defined as follows:

$$f(x) = \max(0, x) \quad (2)$$

where x is the input to the function.

- Pooling:

Pooling is used to reduce the spatial dimensions of the features produced by the convolutional layers and to reduce the number of parameters in the network. The pooling formula is as follows:

$$\max - \text{pooling}(x, y) = \max(X_{x,y}) \quad (3)$$

where $X_{x,y}$ is the pooling region around the coordinates (x, y) in the input.

- Fully Connected Layer:

The fully connected layer is used at the end of a CNN network to connect the results from the previous layers to the desired class or label output. Mathematically, this operation can be described as follows:

$$Z = W \cdot x + b \quad (4)$$

where:

Z = the output, which is then fed into the activation function;

W = the weight matrix;

x = the input from the previous layer;

















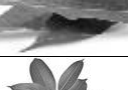


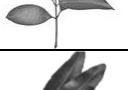




b = the bias vector.

3. RESULTS AND DISCUSSIONS

In this study, the classification of mangoes based on leaf type was carried out using leaf images represented visually through digital photographs. The dataset used included various types of mango leaves obtained from a photography process conducted under controlled lighting conditions and shooting angles. These visual representations formed the basis for the feature extraction process using a deep learning approach.

The classification model was built using a Convolutional Neural Network (CNN) architecture capable of automatically learning leaf morphological patterns, such as shape, texture, and venation patterns. The training process was carried out using training data to form an optimal model, while test data was used to evaluate the model's generalization ability on new samples. Recognition results were obtained based on output probabilities indicating the model's confidence level for each mango leaf class. Through this approach, the system is able to identify mango varieties indirectly through the visual characteristics of their leaves. The method used allows the classification process to be carried out objectively and measurably based on the model's performance. The sample data for mango leaf variety classification used in this study is presented in detail in Table 1.

Table 1. Ground truth results for mango leaf type classification.

Types of mango leaves	Original image	Grayscale	Ground truth
Arumanis			
Madu			
Apel			
Gedong gincu			
Gondaria			
Indramayu			
Manalagi			
Golek			

The data on the types of mango leaves were then analysed. The analysis was carried out using the Matlab R2024a software. The steps involved in the analysis are as follows:

1. The process of reading images from the image files in the training data folder;
2. Next, label the data according to the type of mango leaf shown in the image of the mango leaf;
3. The dataset is then divided into three subsets: training data, validation data and test data. The training data is used to train the model, the validation data is used to monitor the model's performance during training, and the test data is used to evaluate the model's performance once training is complete.

Based on these stages, the results of the mango leaf classification can be applied using a Convolutional Neural Network by placing images of mango leaves into the training and test image folders. The progress of the mango leaf training can be seen in Figure 5.

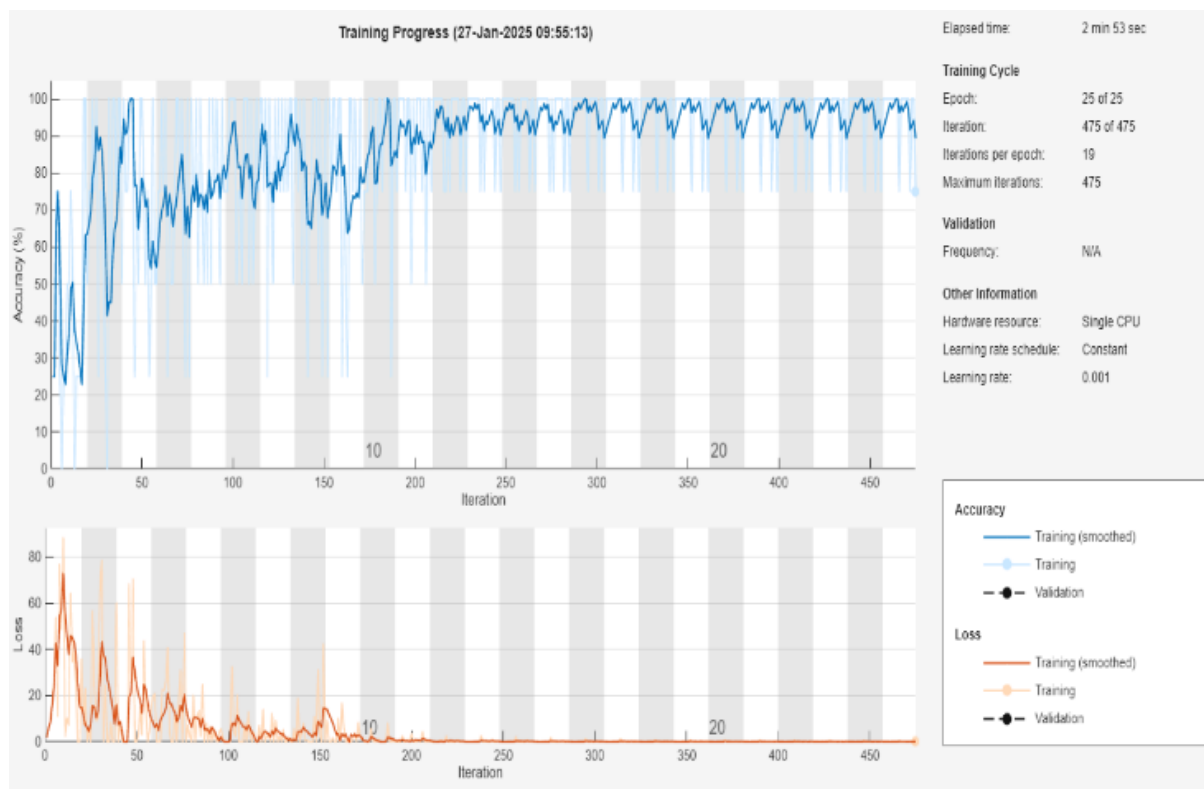


Figure 5. CNN training using mango leaf types.

The training process was carried out over 475 iterations, with the best validation point achieved at a maximum of 25 epochs. The results of the testing, based on the iterations performed on the training and test data, were obtained using images with slightly different characteristics, both in terms of image position and leaf type, to compare images of leaves that were classified correctly with those not included in the training classification; the test results yielded an accuracy rate of 80.76%. For details of the accuracy results using a Convolutional Neural Network (CNN), see Figure 6.

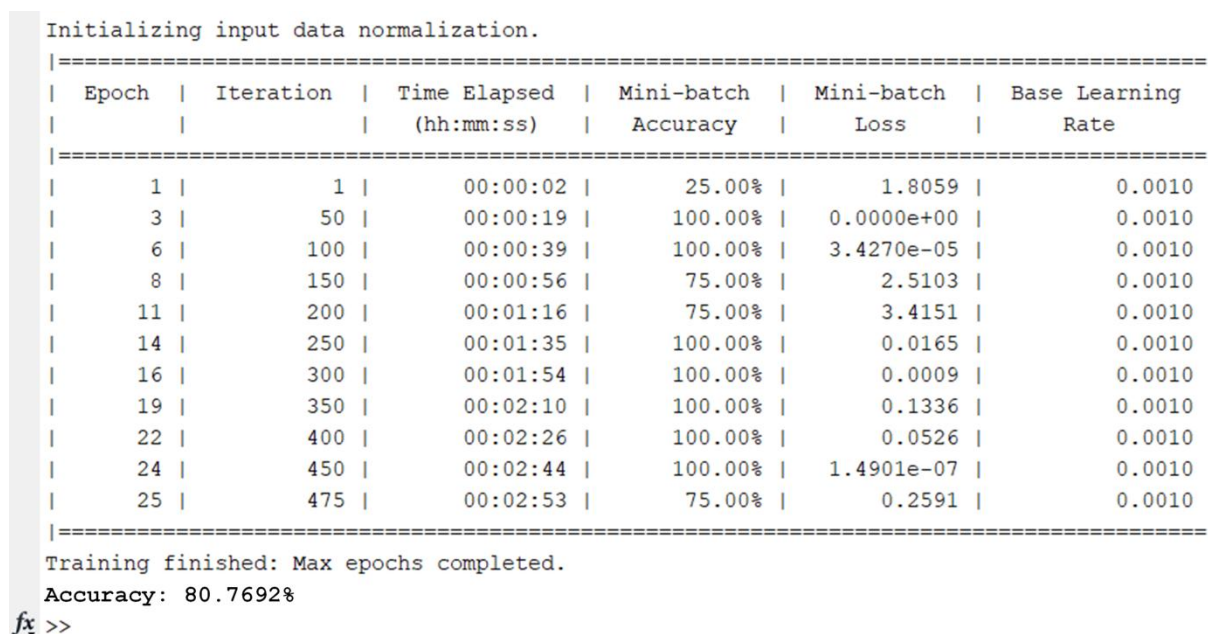


Figure 6. Accuracy results using CNN.

Subsequently, following the training and testing phases using a Convolutional Neural Network (CNN) model, results were obtained for the classification of mango leaf images based on predefined varieties. The training process was carried out to build a model capable of automatically recognizing leaf patterns and morphological characteristics, while the testing phase aimed to evaluate the model's generalization ability on previously unseen data. The classification results obtained were then implemented in a Graphical User Interface (GUI) using MATLAB software. The GUI was designed to facilitate the interactive and informative visualization of the model's prediction results.

Through this interface, users can upload images of mango leaves and obtain information on the classification results immediately. In addition, the system also displays the probability or confidence level of the prediction for each available class. The implementation of this GUI aims to improve usability and demonstrate the application of the CNN model in a more practical form. The display of the mango leaf image classification results via the GUI in MATLAB can be seen in Figure 7.

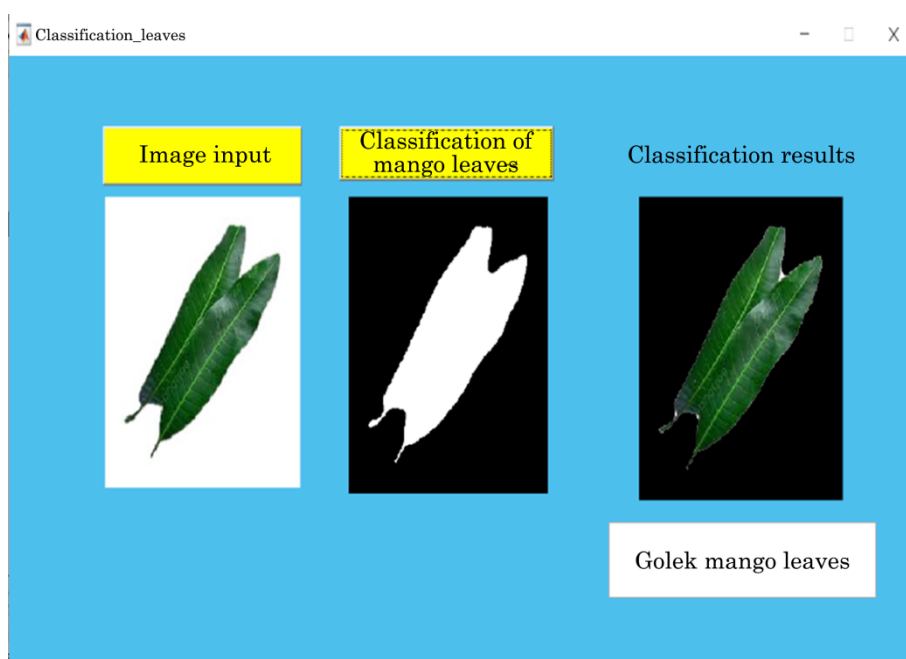


Figure 7. Mango leaf calcification.

The process of classifying mango leaves, which is displayed visually via the GUI in MATLAB, consists of image input—that is, displaying an image of the original mango leaf—after which the mango leaf is automatically classified using a Convolutional Neural Network (CNN) model, and the application can identify the type of mango leaf by displaying a label indicating the result of the classification.

4. CONCLUSION

The conclusion of this study on the application of visual programming technology to classify mango leaves using a convolutional neural network is that the study aimed to classify mango varieties based on leaf type through image processing. The results of the mango leaf classification using a Convolutional Neural Network (CNN) were able to identify mango varieties with an accuracy rate of 80.76%.

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