Design Document

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The **KNN Neural Network** is the foundation for the Fingerprint Identification System's implementation.

One of the most popular biometric authentication systems is the fingerprint recognition system, which functions primarily in two ways: enrollment and recognition. Biometric information is gathered from the sensor during the enrollment phase and is subsequently saved in a database, connected to the person's identity for identification purposes at a later time. In order to verify the user's identity, the biometric information is taken from the sensor once more and compared to the stored data in the recognition mode. In the end, the decision module decides on an identity.Every person has a fingerprint that is different from everyone else's due to the ridges and valleys that make up their fingerprint patterns on fingertip surfaces.

1 The Module for Pre-Processing

This module is responsible for optimizing the fingerprint (FP) image before it undergoes feature extraction. Its primary goal is to refine and improve the quality of the FP image, eliminating any potential noise that might be present, in order to ensure compatibility with the system's performance. The process involves various techniques for enhancing the image, such as Fourier domain analysis filtering and segmentation. These methods are utilized to refine the image and ensure that it is well-prepared for subsequent stages, particularly for extracting distinctive features from the fingerprint.

The enhancement of the fingerprint (FP) image involves a series of steps that begin with Fourier Domain Analysis, followed by Directional Field Estimation, Ridge Frequency Estimation, Energy Mapping, and finally, the process of enhancement. This progression aims to refine the FP image by analyzing its frequency components in the Fourier domain, estimating the directional flow of ridges, determining ridge frequencies, mapping the energy distribution, and ultimately enhancing the image. These sequential steps collectively work to improve the overall quality and clarity of the fingerprint image for further processing and analysis.

A local area within the fingerprint image can be thought of as a surface wave in Fourier domain analysis using the following equation:

$$\text{i(x,y)=Acos2f(xcos}\phi + ysin\phi)$$

The orientation ϕ and frequency f fully characterize this orient wave. Equations are utilized in order to obtain the Fourier spectrum and its inverse.

$$F(u,v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) e^{-j2\pi\left(\frac{ux+vy}{MN}\right)} \tag{1}$$

$$f(x,y) = \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} F(u,v) e^{-j2\pi\left(\frac{ux+vy}{MN}\right)} \tag{2}$$

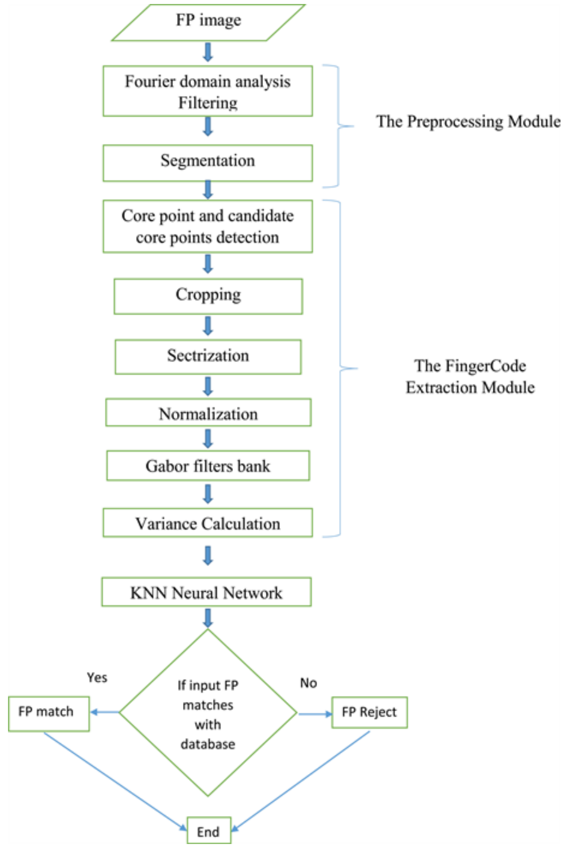

Figure 1: The outlined flowchart illustrates the structure of the proposed fingerprint recognition system. It delineates the sequential steps and components involved in the system's operation and demonstrates the proposed methodology for fingerprint recognition.

Directional Field Estimation refers to the method employed to ascertain the orientation, specifically the angles, of fingerprint ridges. This process is pivotal in determining the directional patterns of ridges present in a fingerprint image, allowing for the identification and analysis of the orientation of these ridges.

The local occurrence of ridges within a fingerprint is represented by the image frequency in Ridge Frequency Estimation. The estimation of the typical ridge frequency is similar to that of ridge orientation. As a random variable, the ridge frequency is represented by the probability density function, or f(r). After the frequency map is obtained, a refinement procedure is started. To smooth the gathered data, a 3×3 Gaussian mask is applied in this process. The frequency map must be improved and made more clear by this smoothing process in order to be ready for further in-depth examination and processing.

2 Matching fingerprints with a KNN neural network

The K-nearest neighbor (k-NN) classification method stands as one of the fundamental techniques in machine learning. Given a labeled dataset $\{xi\}$ and the objective to classify a new item y, the process involves identifying the k elements from the dataset that exhibit the closest proximity to y. Following this, the labels of these k neighboring elements are somehow aggregated or averaged to determine the label for y. This approach enables the assignment of a label to the new item based on the consensus or majority of the labels among its nearest neighbors.

The k-NN (k-Nearest Neighbors) prediction involves a two-step process utilizing feature matrices. Initially, distances between features in the new dataset (test set) and those in the existing dataset (training sets) are calculated. Subsequently, in the second step, the k-NNs (k nearest neighbors)

are determined by selecting the k smallest distances from the computed distance set. This process facilitates identifying the most similar or closest neighbors based on feature similarity, aiding in classification or regression tasks within the k-NN algorithm.
The mathematical equation used to determine the k-nearest neighbors (k-NN) based on the Euclidean distance is represented as:

$$d(x,y) = \sqrt{\sum_{j=1}^{N} W_j^2 (x_j - y_j)^2} \tag{3}$$

To calculate the distances between two scenarios in the scenario where 'd' is the number of forecast instances in the test set, a particular distance function d(x,y) is used. As sets, 'x' and 'y' here denote matrix scenarios with N features: x=$\{x_1, x_2, \ldots, x_N\}, y = \{y_1, y_2, \ldots, y_N\}$. The data length is indicated by the variable 'N'.

This process is repeated for all N input vectors after matching a suggested individual to each input vector. The process of calculating the most frequently suggested person and dividing this count by the total number of suggested persons (which is equal to the number of FP input image vectors, N) yields a matching score. The matching score is then calculated by multiplying this resultant ratio by 100.

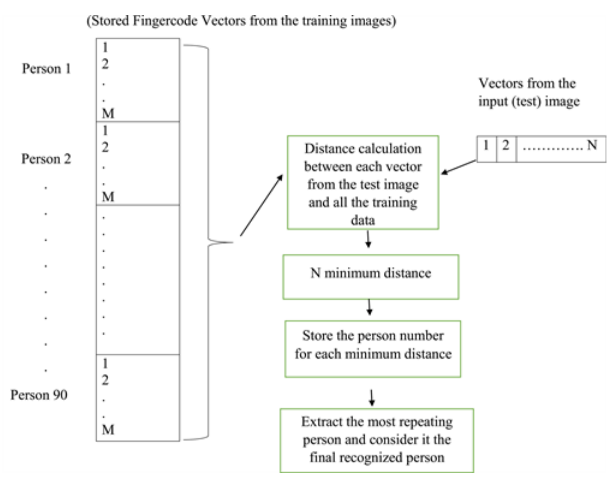

Figure 2: The flowchart represents the process flow for the dataset encompassing both the training and testing images. It should be noted that 'M' and 'N' signify varying quantities of feature vectors associated with each fingerprint image.

If the score of the test image or the unknown input image exceeds a predetermined threshold, the image will be deemed acceptable. Otherwise, if the score falls below the specified threshold, the image will be rejected