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Finger Vein Based Biometrics Identification

Bachelor of Science in Computer Science

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Certificate

We accept the work contained in the report titled "Finger Vein Based Biometrics Identification", written by Mr. Osama Manzoor AND Miss. Zobia Faiz as a confirmation to the required standard for the partial fulfillment of the degree of Bachelor of Science in Computer Science.

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Abstract

Form past few decades' biometrics has gained a whole lot of attention due to its enormous benefits in the security field. Like every other system, the biometric identification systems also have their limitations and drawbacks, yet the best trait amongst all of them so far is vascular biometric. In our project, the subject of interest are finger veins which are captured using infrared imaging system. Since veins are internal traits so they can neither be contaminated nor captured without user willingness. This project is implemented using Convolutional Neural Network (CNN) but a typical problem with CNN is that after training we cannot add new subject to the dataset. To deal with that problem we have also implemented our system using Siamese network. In short, this project is implemented using two techniques named as CNN and Siamese Network.

Acknowledgments

First of all, we praise Almighty God for helping us not only take advantage of this tremendous opportunity to increase our expertise, but also give us enthusiasm and wisdom for passionate work and planning. We owe a deep debt of gratitude to our worthy supervisor. Dr. Samabia Tehsin, for her guidance, support, patience and understanding. She is our source of inspiration and we are honoured to be supervised by her. No word in any dictionary can admit the sacrifice, love and moral support that our beloved family gives us. In any case, their prayers never let us isolate.

OSAMA MANZOOR
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November 2019

*"We think someone else, someone smarter than us,
someone more capable, someone with more resources will solve that problem.
But there isn't anyone else."*

Regina Dugan

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Chapter 1

Introduction

Nowadays in this advancing age, individuals have to be to ask for a high level of security to keep their belonging and credentials safe. Almost all of the places are providing a certain level of security by using any biometric identification system or PIN etc. Those systems somehow have several disadvantages because these features are seen from the human eye so it is easy to copy them fraudulently. Besides that, these features are also prone to damage, an example of such trait includes a fingerprint. A while ago biometric traits have gained a whole lot of attention due to their enormous benefits but vascular biometrics is on the top these days and is also viewed as a desirable biometric trait as compared to other biometric modalities. The reason being the subject of identification is invisible and completely internal, which can undoubtedly result in an immense level of security.

1.1 Background

From decades there is an increased demand for reliable and user-friendly identification systems for personal recognition, the reason is that due to the fast progressing information society, forging an individual's identity and committing a crime using that is quite easy. It can originate in any region of the world without being recognized because the legacy system such as PINs and passwords can be sharded and intercepted, so, spoofing them does not require much effort. In the above-mentioned scenario, biometric systems seem like a perfect fit because they utilize body parts for identification purposes. For years, different biometric techniques such as fingerprints, iris recognition, etc. have been used for an individual's identification. Biometric authentication is a more authentic indicator of identification as compared to legacy systems and can also be utilized as a hedge against identity theft. Like any other system, they also have their flaws e.g. biometric traits may change as people age such as fingerprint and besides they may get afflicted by the environment as well. Methods such as iris recognition and face recognition although produce good results nevertheless they are expensive. So, an effective yet inexpensive solution is vascular biometrics, which has gained a whole lot of attention these days and is also viewed as a desirable biometric trait as compared to other biometric modalities. The reason being the subject of identification is invisible and completely internal, which can undoubtedly result in an immense level of security. The vascular pattern under the skin is captured using devices having an infrared imaging system. These devices can operate in a contactless manner hence keeping the hygiene intact which is very important especially in the medical field. The potential of this biometric modality was initially introduced in the 1990s and later in 2003, its first commercial product was released and up until now, its market is continuously expanding due to its tremendous benefits.

1.2 Problem Description

Almost all the current biometric techniques endure some shortcomings. For example, a drawback of fingerprint recognition is that it can be replicated very easily and in worst-case scenario criminals can even slice off a person's finger to get past the scanning device. On contrary face recognition also have its drawback i.e. a person must be looking straight at scanning device for successful recognition because this technology focuses on face from down the hairline. Another technique which is utilized on large scale is Iris-scan but it is difficult to capture iris when a person is putting on glasses, also the eye can be easily hidden by eyelids, eyelashes, reflections from the cornea and contact lenses.
Since biometrics modalities such as palm vein, finger vein, etc. are difficult to acquire without user's willingness so, they can be used as a reliable modality for biometric identification. These images are taken using an infrared light scanner. This light gets absorbed by hemoglobin thus making veins appear as a pattern of dark lines. Regardless of several advantages, there are spectacular challenges that we need to deal with to achieve efficiency. Up until now, most of the existing system does not perform well with the images of poor quality. There are several different reasons which may affect the quality of an image such as poor infrared light or poorly designed hardware. While capturing the image, absorbance of infrared light may get afflicted by the thickness of the finger which results in an image with irregular shading thus making the recognition process difficult. The resultant image also contains an unnecessary background (as shown in figure 1.1). Since image size is large as compared to the size of our region of interest it will end up consuming additional time while processing.

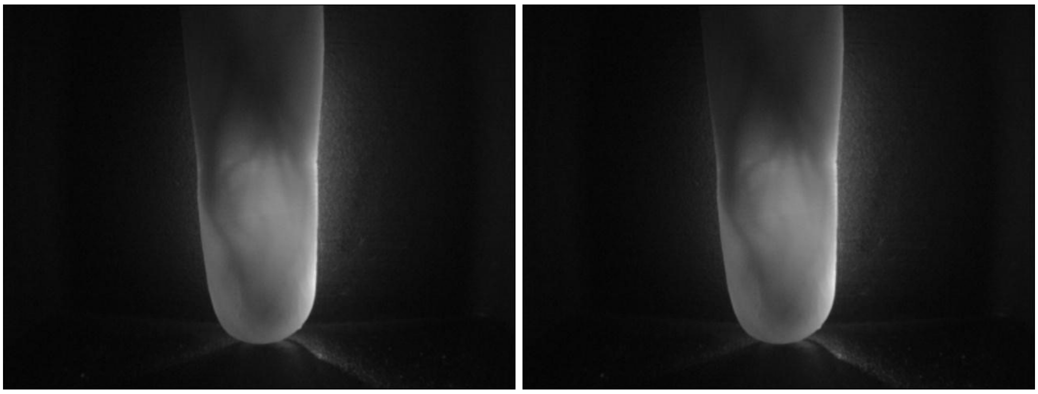


Figure 1.1: FV-USM [1] Database Sample

1.3 Project Objectives

This project is being developed with the main objective of individuals identification more specifically a finger vein based biometric identification system to identify individuals using deep learning more specifically using the convolutional neural network (CNN) [2] . Our focus is to develop an identification system that produces highly accurate results regardless of the quality, translation, rotation, scaling of an image. Another aspect which is of prime importance nowadays is execution time consumed by the proposed model, so the optimization process will be carried out in order to minimize time consumption. In order to prove the effectiveness of this model, we will apply it on at least three to four publicity available databases.

1.4 Project Scope

Our project involves the development of a biometric identification system using CNN. Since CNN is being utilized, so, we do not need to perform feature extraction manually which will eventually lead us to an accurate solution. Our project specifically involves processing of finger vein images instead of a palm vein or wrist vein. Since other biometric modalities can either be forged or they are costly, vascular biometrics appears to be the best among all of them, so, for the systems which requires high levels of security such as physical admission into secured area, electronic record management in law enforcement agencies etc. this appears as a perfect fit because it cost far less as compared to iris and facial recognition. Due to its less costly infrared camera this system can be easily deployed on Automated Teller Machine(ATM), in colleges, universities offices, etc. Cloud computing is center of attention form past few years yet still its security is of main concern which can be resolved using this biometric on smart space, access control software and intelligent environment, etc. finger vein scanner from Hitachi is shown in figure 1.2 which is being vastly utilized on commercial-scale

Figure 1.2: Finger Vein Scanner From Hitachi

1.5 Summary

Form past few decades' biometrics has gained a whole lot of attention due to its enormous benefits in the security field. Like every other system, the biometric identification system also has its limitations and drawbacks yet the best trait amongst all of them so far is vascular biometric. In our project, the subject of interest is finger veins which are captured using infrared imaging system Since veins are internal traits so they can neither be contaminated nor captured without user willingness. This project is implemented using CNN for better results. The gathered images are pre-processed for Region of Interest (ROI) extraction and then they are subjected to CNN architecture which has 4 convolutional layers, 1 Rectified Linear Unit (ReLU), 3 max-pooling, and a SoftMax layer. The typical problem with CNN is that after training we cannot add a new subject to the database. To deal with that problem we have also implemented our system using Siamese network. In short, this project is implemented using two techniques named as CNN and Siamese network.

Chapter 2

Literature Review

The literature review provides us a clear perception of the shortcomings, which the existing state of the art models possesses. There are many biometrics that are utilized today and some of them are still in the prior phase of development. Therefore, biometrics can be categorized into two groups: those that are utilized currently across a range of environments and those that are still under development. In this chapter ,comparative analysis of all the biometrics is presented along with literature survey of the finger vein based biometric.

2.1 Comparative analysis of all biometrics

In this era where people demand a high level of security, biometric modalities have proven them as a viable source to provide what they need. The literature says that biometrics modalities can be grouped into two types named as physiological biometrics and behavioral biometrics. Physical characteristics such as fingerprint, face, iris, palm vein, etc. are included in physiological biometrics and they perform comparatively better than behavioral biometrics that is learned over time such as keystrokes, voice, signatures, etc. Compared with other biometrics, Finger Vein offers remarkable benefits such as high resistance to unlawful tampering, good accuracy rates and speed of authentication. Advantages that finger vein biometric offers can be seen from the comparison of different biometric technologies as given in table 2.1:

Table 2.1: Comparative analysis.

Biometric attribute	**Pros**	**Cons**	**Sensor**	**Security**	**Cost**
Voice	Natural and convenient	Noise	Non-contact	Normal	Low
Finger-vein	High-security level	Few	Non-contact	Excellent	Low
Fingerprint	Widely	Contaminated Skin	Contact	Good	Low
Face	Remote capture	Lighting conditions	Non-contact	Normal	Low
Iris	High precision	Glasses	Non-contact	Excellent	High

2.2 Previous work on finger vein biometrics

The literature review provides us a clear perception of the shortcomings, which the existing state of the art models possesses, and mainly they utilize feature extraction approaches which require a lot of human intervention and another problem which they come across is that when images of poor quality are subjected to the current state of art model, they usually do not produce good results. Quality of an image can be affected by several factors such as fat finger, poorly designed device [3], poor lightning, cold weather, etc. Another problem that we came across is the rotation and translation of an image that may harm the segmentation-based algorithm.

Mainly three approaches are being utilized up until now and they are known as a conventional approach, machine learning, combination of machine learning and conventional approach. In the conventional approach, images are subjected to a series of typical image processing techniques. In this method, either image is subjected to complex preprocessing techniques to improve the quality which eventually leads us to a simple mathematical model [4] [5] or simple preprocessing techniques with the complex mathematical model are applied [6]. In these methods the subject of interest is first preprocessed then complex feature extraction techniques are applied such as Local Binary Pattern (LBP), Local dynamic thresholding, Morphological Dilation, etc. and then classifier algorithm. These processes in a row can be too much time consuming which is quite impractical. Wenming et al. [4] has reached the accuracy of 100 percent by applying combination of preprocessing techniques named as Background Elimination , Image enhancement ,Noise reduction, Normalization then Local dynamic thresholding, Size normalization , Median filter , Vein direction and location coding, Morphological operation for feature extraction and then template matching as a classifier . One way to contract the number of preprocessing steps

is by implementing an adaptive image obtaining procedure to guarantee that the procured image has better lighting conditions [7].
In biometrics, we always have a fuzzy comparison because traits are usually a bit different when captured the second time. So, different machine learning techniques i.e. fuzzy logic, neural network, etc. can perform better than conventional techniques. Another advantage which this approach has is that it is robust to noise thus making an efficient learning model in which we do not need to work on noise removal. Wu and Liu proposed a model for identification on an in-house data set having 10 subjects and each subject has 10 samples. The accuracy of the proposed model using space vector machine (SVM) [8] and ANFIS (neuro-fuzzy system) [9] classifier is 98% with the execution time 0.015 seconds and 99% with the execution time 45 seconds respectively. The work in [10] has clearly shown the practicability of implementing neural networks on the finger-vein identification issue. The accuracy of 93.00% for 14 samples (2 samples per subject) was achieved. In [11] Local Binary Pattern Variance (LBPV) is utilized to extract feature and then SVM is applied for image recognition. The database incorporates 10 individuals with 80 pictures each. For the ring finger, they have accomplished the accuracy of 96.00%. Souad et al., 2014 [12] have accomplished 98.75% accuracy for 48 samples. The correspondence of the above-mentioned model is that they have utilized machine learning for classifying rather than extracting features. Another researcher, Syafeeza et al., [13] has proposed a model that has achieved an accuracy of 99.38% in only 0.1574 seconds using CNN but the weakness which this model has is that it did not perform well with non-ideal finger images. The vast majority of the researches involved using a few numbers of subjects during testing. The shortcomings might be brought about by the yield of highlight extraction or pre-processing stages. Yet it shows the limitations of machine learning

2.3 Commercial products

From the past few years, personal authentication and identification are of prime importance. To deal with the increasing demand Different companies have developed different technologies. Some of the commercially used finger vein authentication product is given below:

2.3.1 Hitachi Finger Vein Authentication Technology

Hitachi uses the near-infrared light to capture a finger vein image as shown in the figure. The picture procured utilizing transmitted light is then processed using a system that makes up for variations in the way that how the image is exhibited to the scanner by recognizing the finger outline and correcting that by enlargement or rotation etc. Next, an algorithm for feature extraction [14] is utilized to separate finger veins from other components. finally, the vein pattern is compared with the template present in a database for identity verification. Although the method used for feature extraction is robust against fluctuations in brightness and vein width, yet the mismatch ratio is 2.83% on average. Image procurement and authentication procedure are described in figure 2.1.

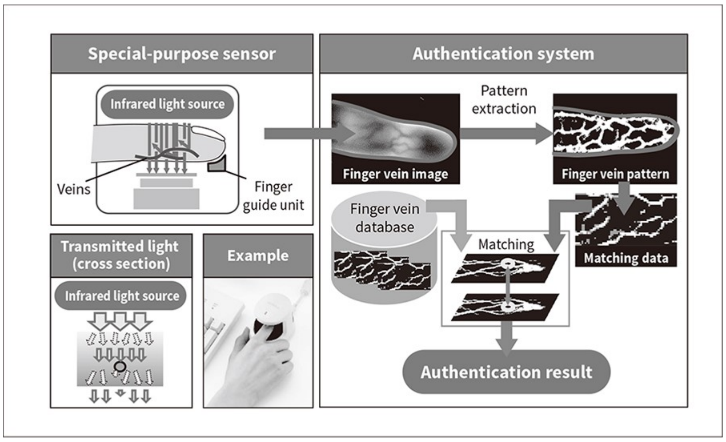


Figure 2.1: Image procurement and authentication in Hitachi finger vein Authentication system

2.3.2 Mofiria's Technology

Their product utilizes a reflective dispersion method that is when infrared light is emitted from the source it reflects inside the finger which is captured using the CMOS sensor. The gadget is little so it can be embedded in different devices. They have their specific ROI and vein pattern extraction methods. Moreover, authentication Speed is approx. 0.3 sec. at ARM9 96MHz, 5ms at Intel Pentium 1GHz [15]. If the finger is not placed inside the gadget as it was during enlistment, the validation may fail. Although they have developed some algorithm that adjusts finger position automatically which subsequently match the vein pattern.

2.3.3 CAMABIO Finger Vein Scanner

To obtain the required features, an individual needs to place a finger into a scanner which contains a light-emitting diode (LED) emitting near-infrared light and a monochromatic charge-coupled gadget(camera). The hemoglobin in the blood assimilates near-infrared LED light, which makes the veins present in the finger appears as a pattern of dark lines.

The camera records the picture, at that point different procedures are applied to digitize the picture and make a template of finger vein data and spare it in database or gadget. An image of CAMABIO finger vein scanner in given in figure 2.2.

Figure 2.2: CAMABIO finger vein scanner

2.4 Future prospects

Customary finger vein validation technologies utilize near-infrared light to acquire a high-contrast picture of veins, so they require peculiar equipment. these high-contrast images though provide high accuracy yet, also, makes difficulties for use in the money related business-to-customer merchandise such as limited portability, price competitiveness, etc.

2.4.1 Finger Vein Authentication Using Visible-light Cameras

Since visible-light cameras have turned out to be exceptionally ordinary today and are also found in tablets and cell phones. Different organizations have been working on an innovation empowering finger vein identification utilizing colored pictures taken by these cameras. This technology will result in significant cost reduction and it will also be eradicating the need for specific equipment. It altogether improves flexibility by running on the cell phones and tablets as of now in pervasive use, giving finger vein verification whenever and wherever required. Moreover, the software and the information it contains can be crushed and erased securely when it is no longer in use.

2.4.2 Self-checkout at Retail Stores

In this model, the shopping carts accommodated with tablet gadgets are provided to the client. The client first scans their fingers over the tablet using a visible camera to confirm their identity and afterward watches that their name and other information are correct before continuing. The client at that point utilizes the tablet camera to filter item scanner tags as they place them in the tumbrel.

Whenever completed, they push their cart towards the checkout procedure where the weight of the cart is examined against scanned items and checked whether they match. Once this procedure is done payment can be made easily against the bought item by only one click hence saving a customer from spending their time in checkout lines.

Chapter 3

Requirement Specifications

In this chapter, we will elaborate the behavior of the system to be developed. Before developing any system, the first thing that needs to be done correctly is the requirements specification. Requirements specification is done to provide a direction to the developers that what needs to be done and how it should be done.

3.1 Existing Systems

The world today is known as the smart world. Technology has been incorporated in almost every field. The world has become a global village and information travels with the speed of light. Technology has made customers very smart and demanding. The user today prefers secure and time-saving systems. Human physiological and behavioral features have a huge scope in providing solutions for security issues. Though the current biometric systems are unpredictable as far as time or on the other hand space or both are concerned. So, they are not suitable for providing high security. Some of the existing solutions utilizing finger vein authentication are described below:

3.1.1 Finger Vein identification for vehicle security and Personal authentication

Finger vein identification framework for validation on cell phones has been proposed by Zhi Liu et al. [16]. This framework is executed on a demand-side platform. On a database having 50 subjects this framework takes just about 0.8 seconds to authenticate one sample and accomplishes an equal error rate of 0.07%. This proposed framework works only for identification on mobile devices

3.1.2 A Real-Time embedded Finger-Vein identification System

This framework comprises of four modules: human-machine correspondence module, radio frequency authentication system (RFID), embedded mainboard, image acquisition module. RFID module will begin the initial correspondence among devices and users. The finger vein image of the user is gathered using an image acquisition module. Afterward, the mainboard consisting of memory (flash), microcontroller chip and communication port is utilized for execution of the identification algorithm.

3.1.3 Individual identification using finger images

According to the proposed system, finger vein images and low-quality fingerprints are acquired simultaneously for an individual's identification. This framework is a combination of two approaches, nonlinear fusion and holistic, joining finger texture and finger vein. This model was excessively exorbitant and was hard to implement under all the circumstances.

3.2 Proposed Systems

In our proposed project we will be performing finger vein based biometric authentication by utilizing different deep-learning techniques. Deep learning utilizes neuron in the way that is almost the same as the human brain. Deep-learning techniques such as CNN are made up of several convolutional and layers that ultimately produce a fully connected layer. Our main goal is to achieve stable authentication performance regardless of the image quality. To prove the efficiency of the proposed network [16], we will testing this approach on three publicly available databases.
Other technique which we will be exploiting in our proposed project is Siamese network. Siamese network is the type of artificial neural network that utilizes the same weights to generate two vectors of two different input and then compare them to check similarity. often one of the vectors is already computed. Our network will be utilizing raw images (without ROI extraction) and is composed of convolution and max-pooling layers. We have proposed to implement this network as well because CNN lacks the ability to add new subjects in the pre-trained system. A simple representation of the Siamese network is given in figure 3.1.

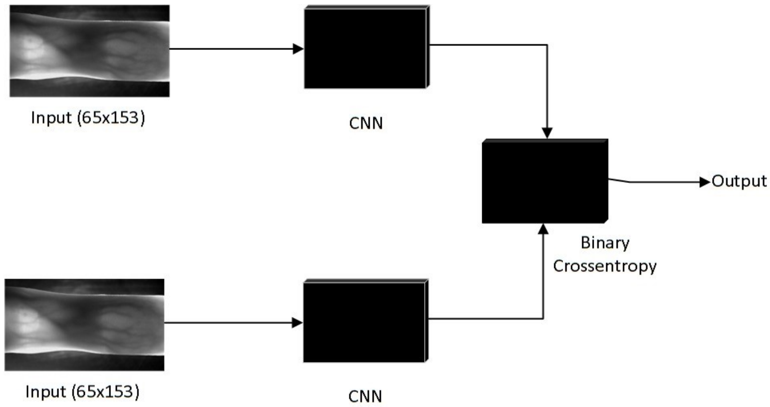


Figure 3.1: Basic structure of Siamese network

3.3 Requirements Specifications

Before developing any system, the first thing that needs to be done correctly is the requirements specification. Requirements specification is done to provide a direction to the developers that what needs to be done and how it should be done. The requirement detail will be partitioned into three sections, general requirements that incorporate the method of deployment mostly. Besides, functional requirements are straightforwardly related to the functionality of the proposed system and lastly, the non-functional requirements, which are related to the quality and performance of the proposed product. The functional, non-functional and general requirements of the proposed system are given below.

3.3.1 General Requirements

- The system should be able to handle the occurrence of an error in a friendly way.
- The system must have a user-friendly interface.
- The application shall not take longer than three seconds to load the user interface.

3.3.2 Functional Requirements

3.3.2.1 Sign up

- The system must provide the option for sign up to register new user.
- Every field of the sign-up form must be filled with valid information.
- No field shall be left empty.

3.3.2.2 Sign in

- Only registered users can sign in the system.
- Required credentials must be correct for successful sign in.
- The login page must be user-friendly so a user can sign in/sign up easily.
- The registered user can sign in by providing id and password.

3.3.2.3 Add record

- The system must include the option to register a new subject
- The user must provide at least 1 image per finger while registering a new subject.
- The user must not provide images captured using a visible camera.
- The images shall not contain anything other than finger vein.

3.3.2.4 Search

- The System shall allow the user to perform graphic validation only.
- The system shall start searching after the user has clicked submit button.
- An acknowledgment of whether or not the sample belong to the dataset must be triggered after validation.

3.3.2.5 Acknowledgment

- After successful registration of the user, an acknowledgment must be triggered.
- The acknowledgment must contain the respective message.
- Acknowledgment after successful/unsuccessful registration of the subject must also be triggered.

3.3.3 Non-functional Requirements

3.3.3.1 Performance Requirements

The system should consider time constraints while processing i.e. identification(searching) process should take no longer than two seconds to the response. The system must be able to restart itself in case of failure. If a user request cannot be processed, the correct error message should be displayed.

3.3.3.2 Integrity Requirements

After providing an id and a password, the user can access our system. User information must be protected. As this system is being implemented to improve security so a person's credentials must be stored in a secure place.

3.3.3.3 Scalability Requirements

This identification system must be capable to expand and beat the future updates for security and technology, the system must be portable.

3.3.3.4 Legislative Requirements

Implementation of a finger vein based biometric system ensures occupational safety and privacy and if properly implemented using a valid database it would also help the law enforcement agencies to track a criminal. As the data of an individual is collected with its consent so it does not break any laws either.

3.3.3.5 Usability Requirements

The user interface must be user-friendly so that many users can easily use it without much difficulty. The application should be design in such a way through proper structure that It can be easily expanded in the future.

3.3.3.6 Flexibility Requirements

If there is a need to add a new subject, the system must be able to handle that need efficiently.

3.3.3.7 Reusability Requirements

Components of a system must be designed in such a way that they can be re-utilized as a module in other such projects.

3.4 Use Cases

Main System Use Case Diagram

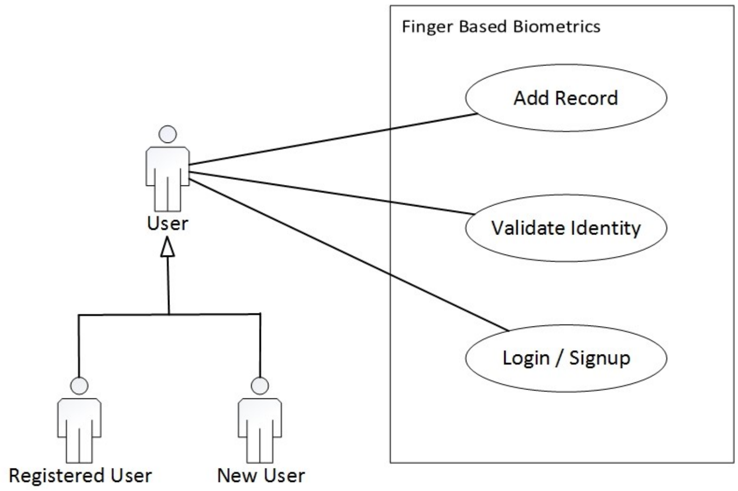


Figure 3.2: Use-case diagram

Table 3.1: Sign-up Use-case.

<table>
<tr><td>Use-Case Name</td><td colspan="2">Sign up</td></tr>
<tr><td>Use-Case ID</td><td colspan="2">01</td></tr>
<tr><td>Priority</td><td colspan="2">High</td></tr>
<tr><td>Primary Actor</td><td colspan="2">new user ,registered user</td></tr>
<tr><td>Description</td><td colspan="2">This use case description table describes the registration process of a new user.</td></tr>
<tr><td>Pre-condition</td><td colspan="2">Application must be loaded and running.</td></tr>
<tr><td rowspan="3">Basic Flow</td><td>Actor</td><td>System</td></tr>
<tr><td>Step 1: New user selects the sign-up option.</td><td>System will open sign up page.</td></tr>
<tr><td>Step 2: New user enters their id and password along with id and password of already registered user.</td><td>System will validate registered user id and password and send acknowledgment.</td></tr>
<tr><td>Alternative Flow</td><td colspan="2">Invalid credentials of already registered user will lead us to unsuccessful sign up</td></tr>
<tr><td>Post-condition</td><td colspan="2">User is successfully registered.</td></tr>
</table>

Table 3.2: Sign-in Use-case.

Use-Case Name	Sign in
Use-Case ID	02
Priority	High
Primary Actor	Registered user
Description	To utilize the developed system, the actor must login the system
Pre-condition	Application must be loaded and running.
Basic Flow	**Actor**: **Step 1:** User enters their id and password. — **System**: System will validate user and take control to msin menu.
Alternative Flow	Invalid credentials of user will lead to unsuccessful sign in
Post-condition	User will be at the home page

Table 3.3: Add subject Use-case.

Use-Case Name	Add Subject
Use-Case ID	03
Priority	High
Primary Actor	User
Description	This use case description table describes the registration process of a new subject using browsed finger vein images.
Pre-condition	user must on the sub-menu page .
Basic Flow	**Actor**: **Step 1:** Selects add record option from menu. — **System**: System will open add record page. **Actor**: **Step 2:** Clicks on browse button to select images. — **System**: System will open browsing pane. **Actor**: **Step 3:** Save the browsed images into the database. — **System**: System will perform transfer learning using Siamese network on images and save them in the system.
Alternative Flow	Images of new subject cannot be saved
Post-condition	User will be given acknowledgments for successful/unsuccessful scenario.

Table 3.4: Search Use-case.

Use-Case Name	Search /Validate identity
Use-Case ID	04
Priority	High
Primary Actor	User
Description	This use case description table describes the search process that checks the existence of the subject in database
Pre-condition	user must be logged in to the system .
Basic Flow	**Actor** / **System**
	Step 1: user selects search option from menu. / System will open search page.
	Step 2: Click on browse button to select image / System will open browsing window.
	Step 3: user initiate searching processes by clicking search button. / System will start searching to find match.
Alternative Flow	A message that tells user that subject does not exist in the system
Post-condition	User will be given subject folder name if subject exists in the system

Chapter 4

System Design And Architecture

In this chapter, we will elaborate on the design and architecture of the proposed system. Further, we will look into the detail of the interface, design constraint, methodology, etc.

4.1 System Architecture

System architecture describes components and sub-components along with their implementational detail. It is the structural design of a system. In our project, we have utilized layered architectural patterns because it is easier to hide the complexity and implementational detail of a layer within itself. In figure 4.1 the system architecture of our application is shown. the system architecture includes:

- **Presentation tier:** In this layer different Graphical User Interface(GUIs) are developed to perform a different task such as searching, adding a record or deleting record, etc.
- **Application tier:** This layer hides the main functionality of the system that is implementing the neural network to perform all those operations mentioned in the presentation tier accurately.
- **Data-tier:** This layer stores all the data set on which application layer is performing operations

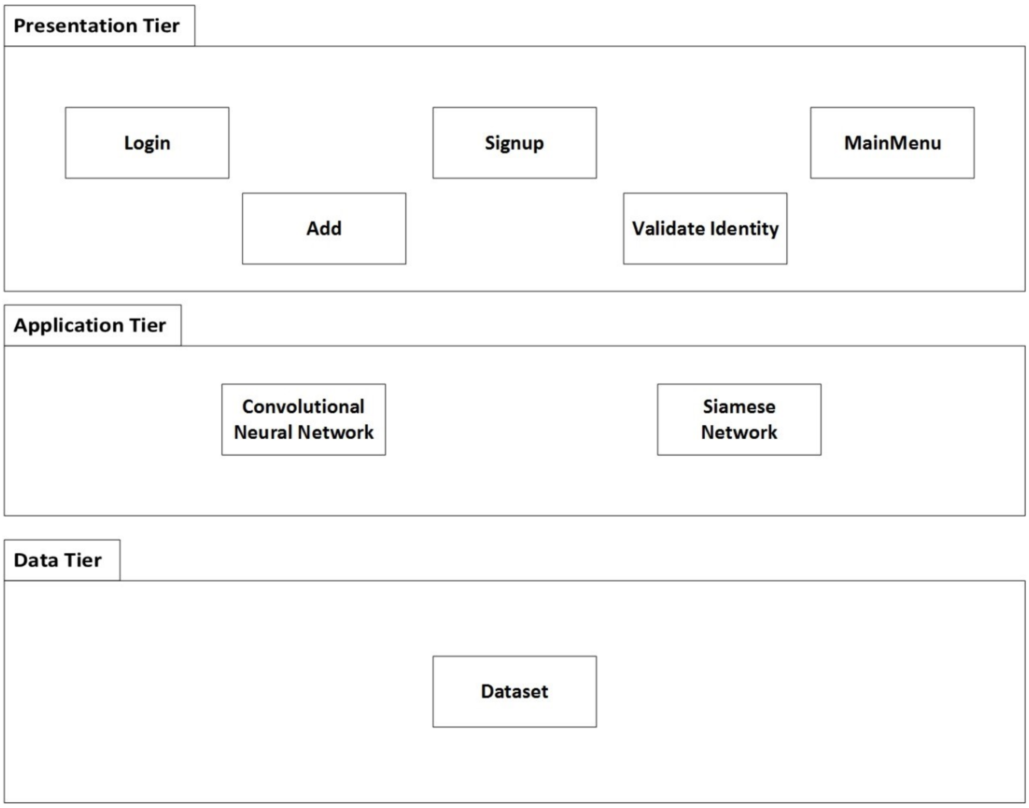


Figure 4.1: System architecture

4.2 Design Constraints

The system must be developed using 3-tier architecture to avoid any implementational complexity because in layered architecture details are hidden within the layer itself. This project is based on deep learning, which is computationally intensive, so for fast learning, we require Graphics Processing Unit(GPU). In typical deep learning adding a new subject/class is in a fully developed system is not possible so to deal with this problem we can use the Siamese network.

4.3 Design Methodology

Our Software that is being developed is purely based on a data-flow oriented design also known as structured design. In this approach, the main focus is toward the flow of data. All the modules of the system take some data from the user, process it and then produce results. This flow of data is shown in the data flow diagram (DFD).

4.4 High Level Design

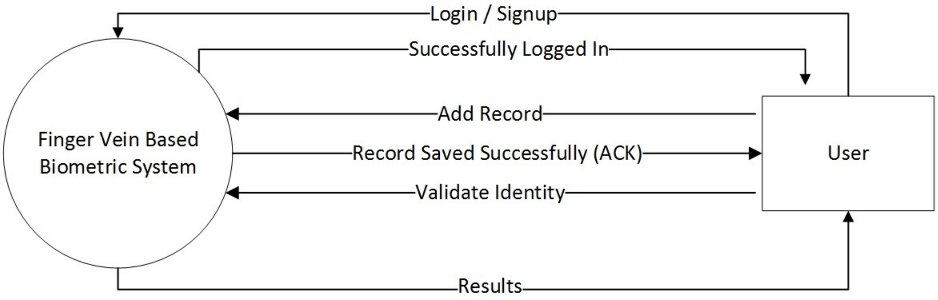


Figure 4.2: Data Flow Diagram (level 0)

DFD Level 0 is also called a Context Diagram. In our proposed project, the user is the entity that will be interacting with the system. there are connectors (data flow) between the entity and process that show how information is being exchanged between the system and entities.

4.5 Low Level Design

The figure 4.3 shows the level 1 DFD, which is the decomposition (i.e. break down) of the proposed system process shown in the context DFD.

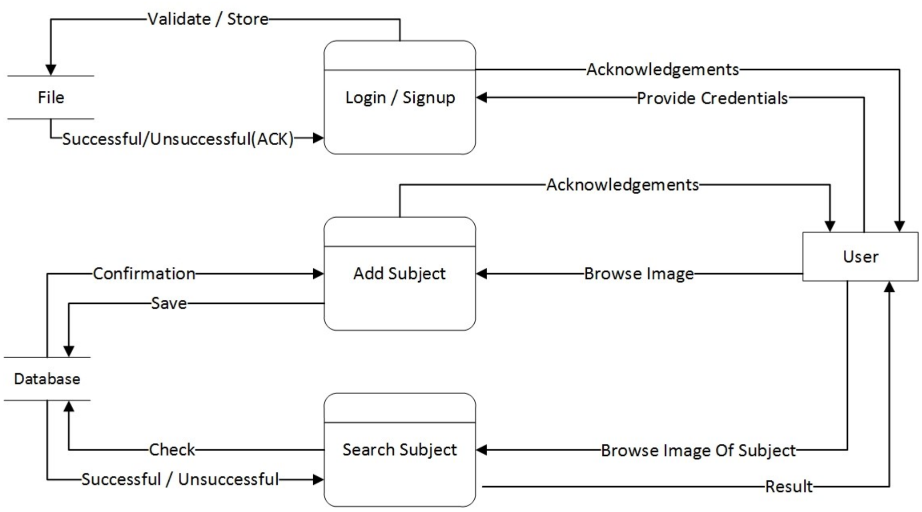


Figure 4.3: Data Flow Diagram (level 1)

The proposed system's DFD contains three processes, one external entity, and two data stores.

- Login / Signup process receives the credentials from the users and then validate them.

- Add Subject Process take the images from the user as input and then store them into the database respectively.
- Search Subject process take input from the user in the form of image and then initiate the searching process.

4.6 GUI Design

The language used for the development of this project is the python, which provides different options for graphical user interface (GUI) development, out of all those options we have utilized Tkinter interface. This interface is an object-oriented representation of the Tk GUI toolkit. Our system has simple GUI consisting of login/signup, main menu, add record and validation pages.

4.6.1 Login/signup

Registered users can simply log in using their valid credential but those users who are not registered can only sign up successfully with the validation of registered users. This validation process is done via registered users providing their credentials in the signup process.

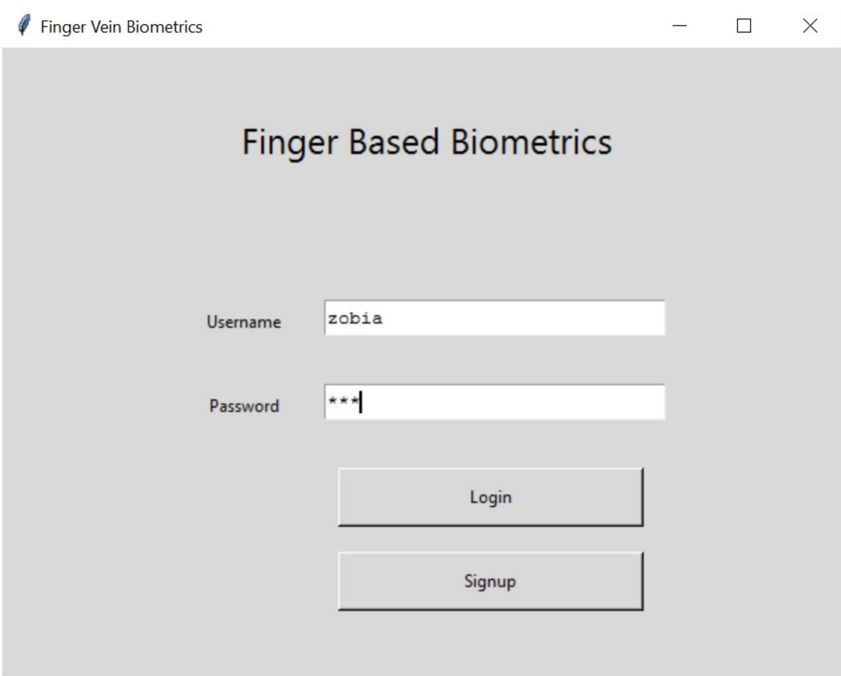


Figure 4.4: Login page

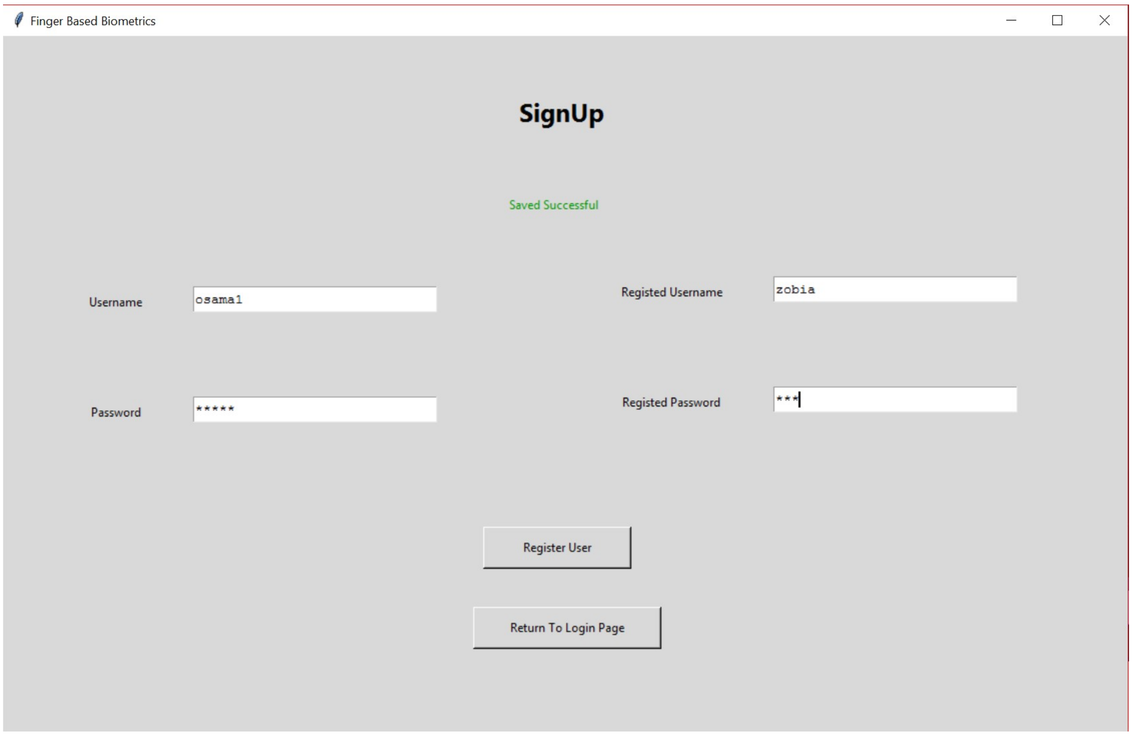


Figure 4.5: Signup page

4.6.2 Main menu

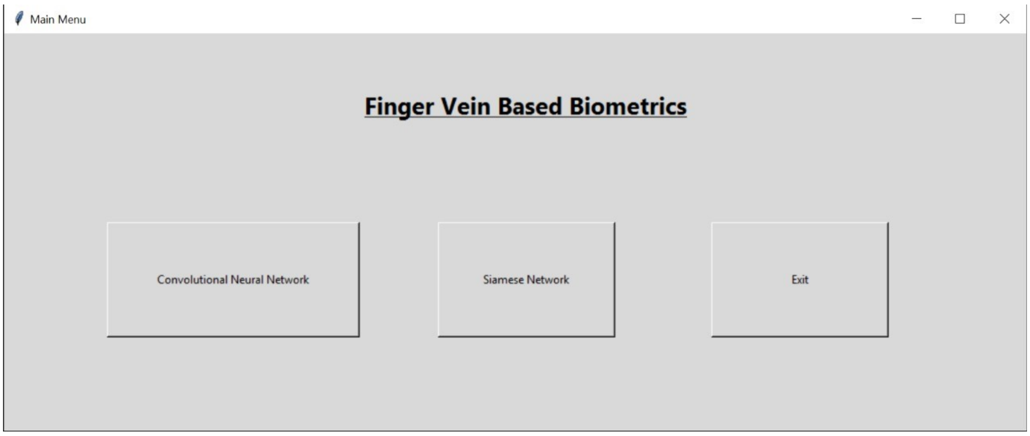


Figure 4.6: Main menu

4.6.3 Sub menu

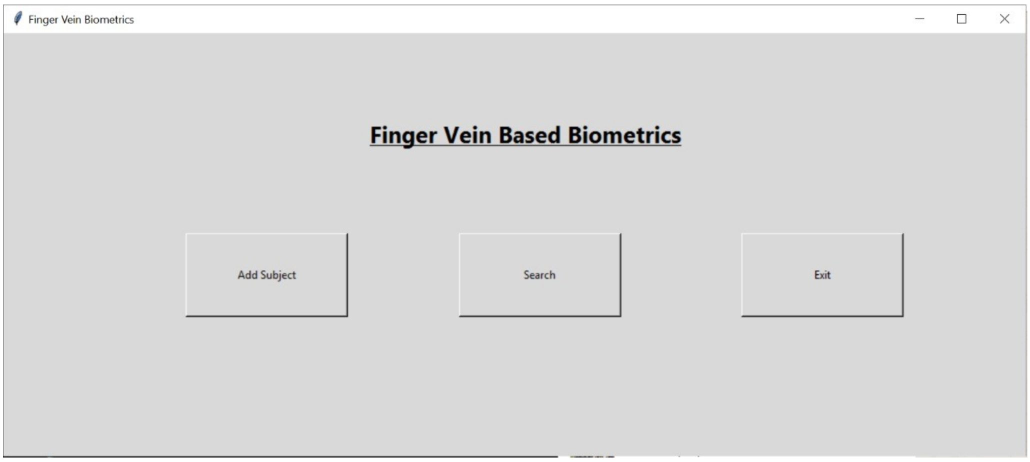


Figure 4.7: Sub-menu(Siamese network)

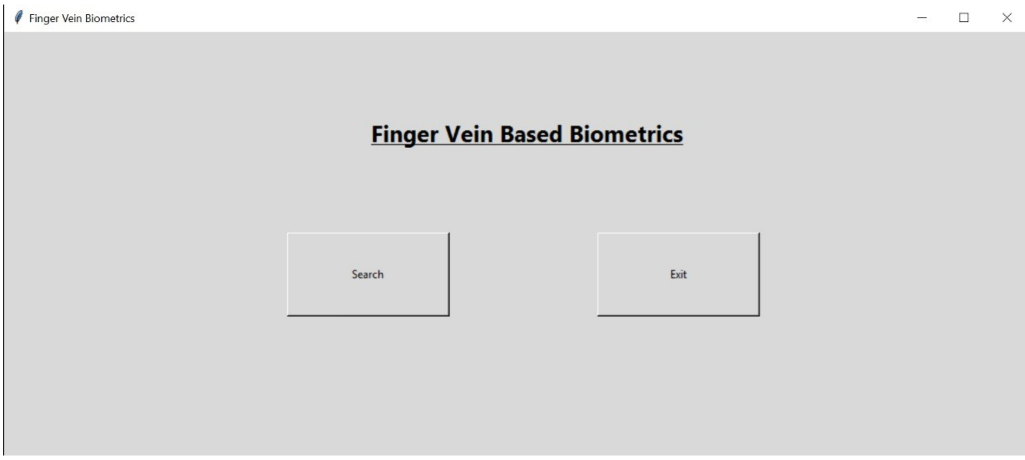


Figure 4.8: Sub-menu (convolutional neural network)

4.6.4 Add User

To add a new subject, you can simply browse their finger vein images and then store them in the database.

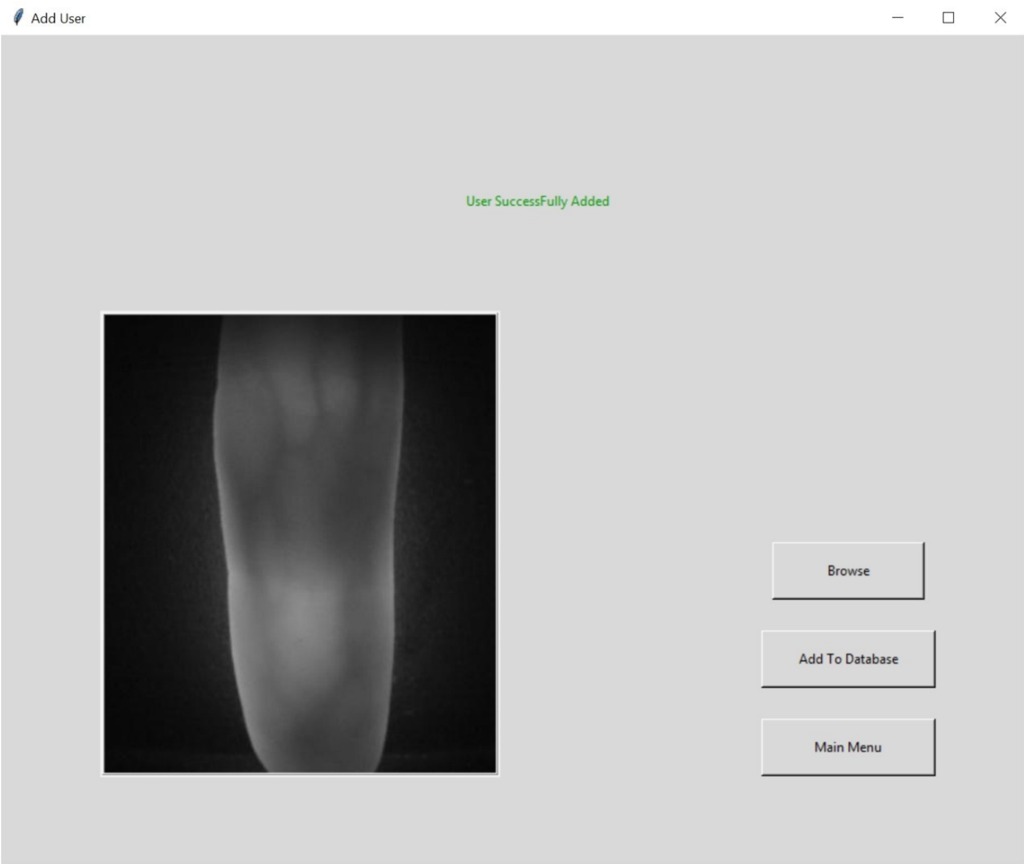


Figure 4.9: Add record interface

4.6.5 Validation

Select a random image from the folder and then click the search button. This click will start the process of checking whether this subject belongs to our dataset or not.

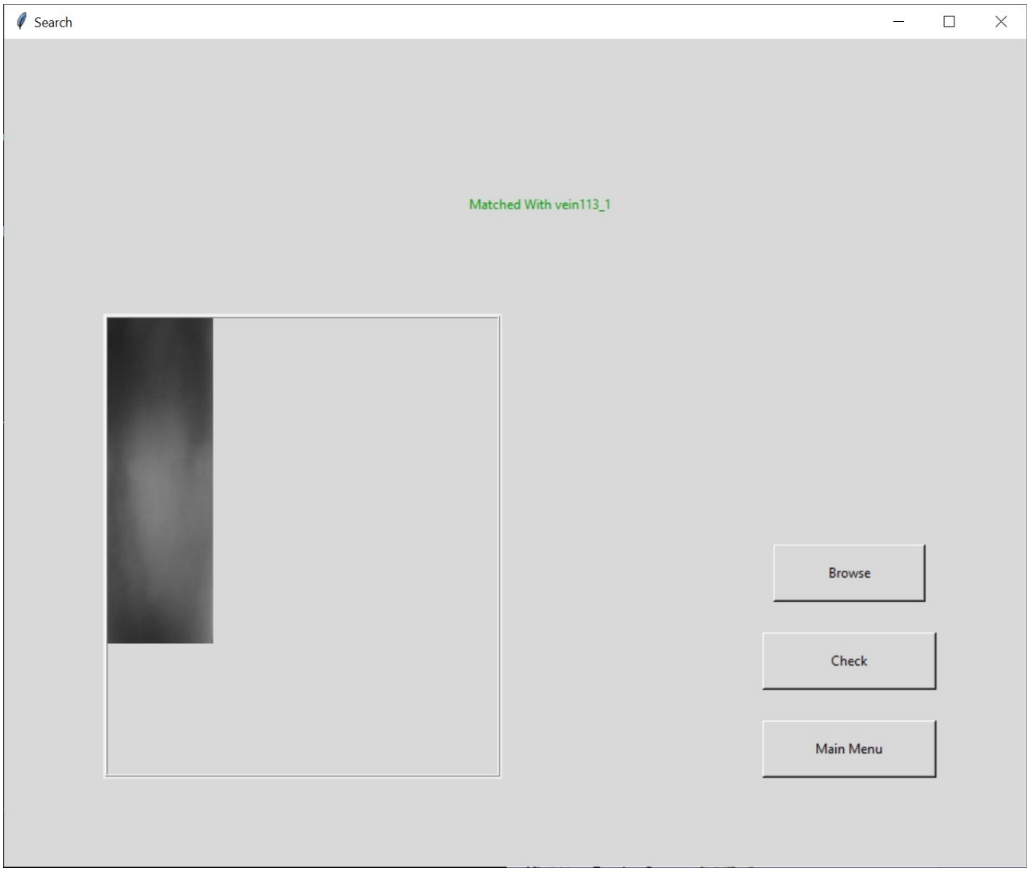


Figure 4.10: Searching interface

4.7 External Interfaces

The system being developed is not integrated with any hardware so it does not have any external hardware interface, but it can be extended by connecting an infrared light-based finger vein scanner to add new subject in the system.

Chapter 5

System Implementation

In this chapter, we will define how the system is being developed along with the tools and technology used also ensuring that it meets the requirements and quality standards properly

5.1 System Architecture

Since system architecture describes the conceptual design in terms of System internal components, Functionality of the components, Communication between the components, etc. This project is implemented using two techniques one is deep learning (CNN) and the other is Siamese network.

5.1.1 Convolutional Neural Network

A CNN is a type of artificial neural network. CNN is used for object recognition in image processing in general. The main advantage of using CNN is that it automatically extracts features inside hidden layers. Overall our system has convolutional layers, max-pooling, and ReLU and a SoftMax loss layer. Convolutional Layer performs the typical convolution operation on pre-processed image whereas on the other hand max pooling reduces the input size by down sampling. The purpose of the ReLU and SoftMax loss layer is to introduce nonlinearity and predict the probabilities respectively. The captured images are pre-processed for ROI (Region of Interest) extraction and then they are subjected to CNN. Graphical representation of each module is given below:

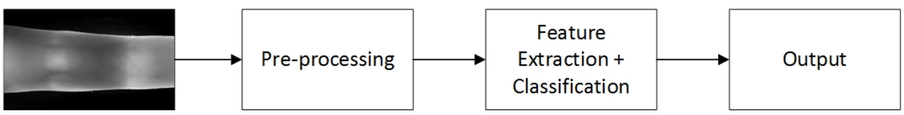


Figure 5.1: Modular Representation

5.1.1.1 Preprocessing stage

In this stage, images are subjects to a simple binary filter to extract only the foreground (that is finger vein image only) and to remove all the background that contains unnecessary information. The filters used for this process is given below:

-1	-1	-1	-1
-1	-1	-1	-1
1	1	1	1
1	1	1	1

(a) Upper Edge

1	1	1	1
1	1	1	1
-1	-1	-1	-1
-1	-1	-1	-1

(b) Lower Edge

5.1.1.2 Feature Extraction And Classification

In this module, we have utilized the convolutional neural network to train our system as CNN can perform better when it comes to image processing as compared to other learning algorithms. CNN is used for object detection because it can extract information automatically inside their hidden layers from raw input. Our CNN model utilizes different layers such as convolution layer, rectified linear unit (ReLU), pooling layer and fully connected layer. We have implemented our architecture using python. The architecture used in the project has 5 convolutional layers, 1 ReLU, 3 max-pooling, and a SoftMax layer. The learning rate set for this network is 0.00001. Further insight into each detail is given below:

- **First Layer (L1)**
  This layer is simply an input layer where an input image of size [64x153] is provided to the network. The resultant image of the preprocessing step is input for this layer.

- **Second Layer (L2)**
  This is the first hidden layer it consists of 153 convolutional filters along with the max-pooling layer. The size of the max-pooling layer and the convolutional filter is [2x2] and [5x5] respectively. The dimensions of the resultant features of this layer are [30x74x153] after downsampling and convolving.

- **Third Layer (L3)**
  This is the second hidden layer which transforms the output of the first hidden layer into [13x35x512] features. It consists of 512 convolutional filters along with the

max-pooling layer. The size of the max-pooling layer and the convolutional filter is [2x2] and [5x5] respectively.

- **Fourth Layer (L4)**
  L4 is the third hidden layer consisting of a max-pooling layer of the size [2x2] and a 768 convolutional filter of the size[5x5]. This layer transforms the output of the second hidden layer into [4x15x768] features.

- **Fifth Layer (L5)**
  The fourth hidden layer consisting of a 1024 convolutional filter of the size[4x15] and a ReLU layer that transforms the input into a [1x1x1024] feature map.

- **Sixth Layer (L6)**
  This layer is fully connected, and it calculates the probabilities of the input image of its belonging to any exiting classes. The SoftMax function is used in this layer to calculate the loss using backpropagation.

Graphical representation of the layers present in this network is given below:

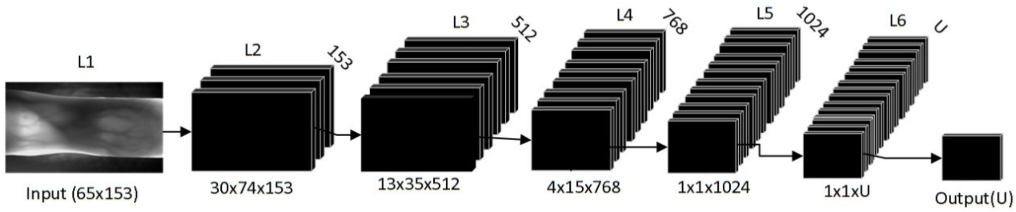


Figure 5.2: CNN architecture diagram

5.1.1.3 CNN algorithm

X1 = Make Training Sets from Datasets
Y1 = Labels of Training Sets
X2 = Make Test Sets from Datasets
Y2 = Labels of Testing Sets
X3 = Any Random Image from the Dataset
Reshape both X1 and X2 and X3 as (65,153,1)
Model = Sequential
Conv2D (153, KernelSize= (5,5), inputshape= (65,153,1))
Maxpooling2D (poolSize= (2,2))
Conv2D (512, KernelSize= (5,5), inputshape= (30,74,153))
Maxpooling2D (poolSize= (2,2))
Conv2D (768, KernelSize= (5,5), inputshape=(13,35,512))

Maxpooling2D (poolSize= (2,2))
Conv2D (1024, KernelSize= (4,15), inputshape= (4,15,768))
Flatten ()
Activation (RELU)
Dense (Total Number of Classes)
Activation (Softmax)
Opt = Adam [LR=0.00001]
Model.compile (loss=categoricalcrossentropy)
Model.fit (X1, Y1, Batchsize= (According To database))

5.1.2 Siamese network

Siamese network is the type of artificial neural network that utilizes the same weights to generate two vectors of two different input and then compare them to check similarity. often one of the vectors is already computed. Graphical representation of each module is given below :

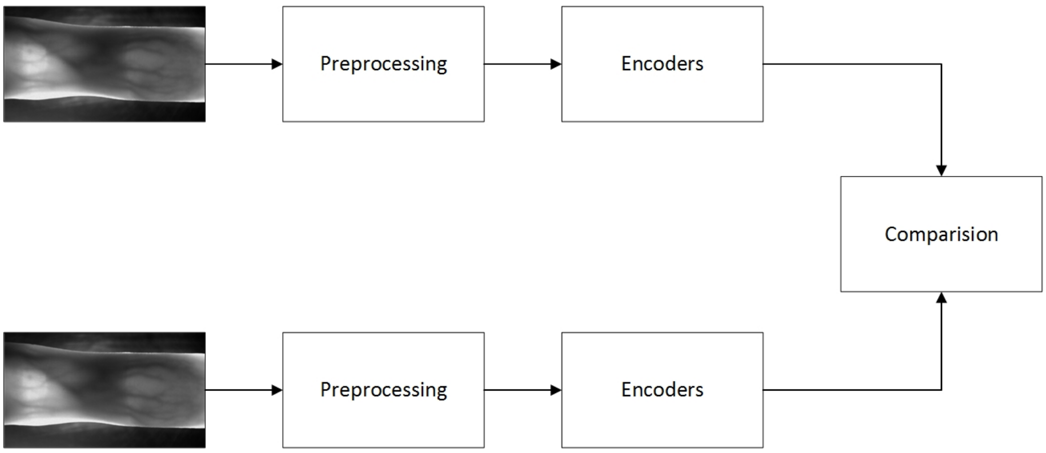


Figure 5.3: Modular Representation

5.1.2.1 Pre-processing

In this stage we resize the image into the input size of the CNN (Convolutional Neural Network) layers. In our case the input size is 65x153.

5.1.2.2 Encoders

The proposed system is composed of 4 convolution and 2 max-pooling layers. In this network, we have trained our system on 3 images initially. Detailed description of each layer present in figure 5.4 is given below

- **First Layer (L1)**
  In this layer, two convolution layers having 32 convolutional filters each of the size[4x4] followed by max-pooling layer having the pool size[3x3] are present.
- **Second Layer (L2)**
  In the second layer, two convolution layers having 64 convolutional filters each of the size[3x3] followed by max-pooling layer having the pool size[2x2] are present.

Graphical representation of this network is shown below:

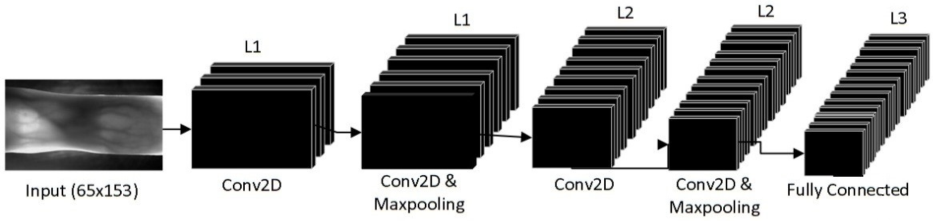


Figure 5.4: Siamese network architecture diagram

Encoders are array of numeric values that are captured from the fully connected layer of network and then manually stored into the system

5.1.2.3 Comparison

In this step we compare two encoders, one is pre-computed and it exist in the database and the other is computed from test image at a runtime. we have utilized euclidean distance to compute the difference between those two encoders , if difference is above certain threshold that means images are not similar and vise versa.

5.1.2.4 Siamese network algorithm

Since Siamese network store encoding of the images so whenever a new image is added it will go through network once and then its encoding will be saved.

Training of a Siamese network
Make Positive and Negative Pairs of 2 Images. Positive means both images are same and negative means both images are different. Positive pair is label as 1 and negative pair is labelled as 0. (One Positive Pair and One Negative pair)
X = First Image
X1 = Second Image

Y = Labels Described above
Reshape both X and X1 as 65,153,1
Model
Conv2D (32, Kernelsize= (4,4), Strides=1, Activation=RELU)
Conv2D (32, Kernelsize= (4,4), Strides=1, Activation=RELU)
Maxpooling2D (poolsize= (3,3), Strides=1)
Conv2D (64, Kernelsize= (3,3), Strides=1, Activation=RELU)
Conv2D (64, Kernelsize= (3,3), Strides=1, Activation=RELU)
Maxpooling2D (poolsize= (2,2), Strides=1)
Flatten
Dense (64, Activation=SIGIMOID)
Euclidian Distance = ABSOLUTE (Encoding of X - Encoding X1)
Model (input = [X, X1], output = Euclidian Distance)
Loss Function = BinaryCrossentropy
LR = 0.000001
Epochs = 900
Batch Size = 6

Algorithm for matching
X = Test Image
Reshape X as 65,153,1
Model
Conv2D (32, Kernelsize= (4,4), Strides=1, Activation=RELU)
Conv2D (32, Kernelsize= (4,4), Strides=1, Activation=RELU)
Maxpooling2D (poolsize= (3,3), Strides=1)
Conv2D (64, Kernelsize= (3,3), Strides=1, Activation=RELU)
Conv2D (64, Kernelsize= (3,3), Strides=1, Activation=RELU)
Maxpooling2D (poolsize= (2,2), Strides=1)
Flatten
Dense (64, Activation=SIGIMOID)
Encoding1=Get Value of Dense64(Test)
Encoding2=Get Other Precomputed Dense64 Values saved in database
Result = Subtract(Encoding1,Encoding2)
Result = Get Square of 64 Values (Result)
Result = Get Sum of 64 Values (Result)
Result = Get Squareroot (Result)
If (Result <1.24)
Subject found in database
Else

Subject not found in database

5.2 Tools and Technology

The tools and technologies used for the development of this projects are as follow

- Keras
- OpenCV
- Numpy

5.3 Development Environment and Languages

- Configuration of the CPU of system on which this project was developed is:
  - 16 GB RAM
  - 3.5 GHz processor base frequency
  - 6-Cores
  - Intel Xeon E5 with 12MB L3 cache and Turbo Boost up to 3.9GHz
- GPU configuration:
  - Dual AMD FirePro D500 graphics processors with 3GB of GDDR5 VRAM each
- Anaconda distribution
- Spyder IDE
- Python (for CNN and Siamese)
- Tkinter (for GUI)
- PAGE (for GUI)

5.4 Application Access Security

The user of the system can only access this system after logging in. Registered users can simply log in using their valid credential but those users who are not registered can only sign up successfully with the validation of registered users. This validation process is done via registered users providing their credentials in the signup process.

Chapter 6

System Testing and Evaluation

Software testing is the procedure which tests whether the developed software meets the functionality requirement or not. It also ensures that developed software is defect-free by running a different test on the application. The most ideal approach to be effective from vulnerabilities is to be set up ahead of time and comprehend what to search for. Testing is the way toward running a framework(system) with the goal of finding errors. Testing improves the uprightness of a framework by recognizing deviations in plan and mistakes in the framework

6.1 Training and testing

We have applied different selection strategies on different data. Detailed description of the number of training and testing images utilized in CNN along with the training batch size are given in the table below:

Table 6.1: Detailed description of training and testing images

Database	**Total Classes**	**Total Images**	**Sessions**	**Training**	**Testing**	**Batch Size**
FV-USM[1]	492	5,904	2	3 images from each session	Remaining 3 images from each session	3
SDUMLA-HMT[17]	636	3,816	1	4 images	Remaining 2 images	4
UTFVP[18]	360	1,440	2	1 image from each session	Remaining 1 image from each session	2

The accuracy of the CNN network is calculated by simply by comparing actual and predicted values. Accuracy is calculated using this formula:

Accuracy = Correct Predications / Total Number of Predications

Classification Rate or Accuracy for true/false users in Siamese network is given is given by the relation:

Accuracy = True Positive+True Negative/True Positive+True Negative+False Positive+False Negative

However, there are problems with accuracy. It assumes equal costs for both kinds of errors. So, to eliminate that problem we calculate recall and precision. Recall can be defined as the ratio of the total number of correctly classified positive examples divide to the total number of positive examples. High Recall indicates the class is correctly recognized (small number of False Negative). Recall is given by the relation:

Recall = True Positive / True Positive + False Negative

In precision we divide the total number of correctly classified positive examples by the total number of predicted positive examples. High Precision indicates an example labelled as positive is indeed positive (small number of False Positive). Precision is given by the relation:

Precision = True Positive / True Positive + False Positive

6.2 Results and discussion

The results after applying CNN on in house databases are:

Table 6.2: Results and discussion.

Database	**Accuracy(%)**	**Loss**	**Epochs**
FV-USM	96	0.47578	85
SDUMLA-HMT	65	16.9343	592
UTFVP	81	4.79219	1700

By the result given in the above table, we can conclude that our system has performed better on FV-USM and UTFVP as compare to SDUMLA-HMT for whom data was gathered only in one session which did not allow our CNN to train effectively. In the case of the Siamese network, we have 5 subjects in database (40 images more specifically) out of them 30 images belongs to true subjects and 10 images belongs to false subjects. The confusion matrix for true users and false user is given in table 6.3 and 6.4 respectively.

True User:

Table 6.3: Confusion Matrix For True Users

n=40	**True**	**False**
True	26	1
False	4	9

False User:

Table 6.4: Confusion Matrix For False Users

n=40	**True**	**False**
True	28	1
False	2	9

Classification Rate or Accuracy for the users is 92.5% and recall and precision is 0.96,0.86 respectively. High recall and low precision shows that most of the positive examples are correctly recognized (low False Negative) but there are a lot of false positives.

6.3 Approaches for testing

This section includes the approaches through which the developed system is being evaluated. In the next few section different approaches for testing have been described along with their test cases. Some of the test fields which will be described in this chapter are:

- Graphical user interface testing
- Usability testing
- Software performance testing
- Security testing

6.3.1 Usability testing

This testing technique helps us in identifying the user interface and design related issues. Mainly in this test we focus on whether users have been able to finish their task successfully or not and how much time does the system take to finish one task. It also helps us in evaluating that to what extent our application meets our objectives.

Table 6.5: Usability Test-case.

Case ID	T1
Description	For testing usability of system
Applicable for	Desktop application, Windows
Initial condition	Running environment is configured as per requirement
Steps	**Task and expected result** .
1	Open the application.PASS
2	Verify that all button/texts are relatable. PASS
3	Verify that the user can move back and forth on different pages easily. PASS
4	Verify that system is performing all tasks. PASS
5	verify that without selection the result will not be generated. PASS

6.3.2 Graphical user interface testing

In this testing GUI of the application is tested against various test to check that either the system is working or not. GUI of an application contain different controls like buttons, image box etc. And to pass this test every control should react positively to user interactions.

Table 6.6: Gui Test-case.

Case ID	T2
Description	For GUI testing
Applicable for	Desktop application, Windows
Initial condition	Running environment is configured as per requirement
Steps	**Task and expected result** .
1	Open the application.
2	Verify that all controls are placed in user friendly manner. PASS
3	Verify that each input field is excepting data properly. PASS
4	Verify that important features are not suppressed and clearly noticeable. PASS

6.3.3 Software performance testing

This testing involves the processes that checks system responsiveness, speed and stability. It helps us in identifying the area where an application may lag

Table 6.7: Performance Test-case.

Case ID	T3
Description	For performance testing
Applicable for	Desktop application, Windows
Initial condition	Running environment is configured as per requirement
Steps	**Task and expected result** .
1	Open the application.
2	Verify that the response time against user input is small. PASS
3	Verify that application is taking minimum time to load. PASS

6.3.4 Security testing

This testing technique is used to ensure that the developed software is free from any threats, risks and vulnerabilities that may cause major problems. The goal is to identify any potential vulnerabilities and fixing those through coding

Table 6.8: Security Test-case.

Case ID	T4
Description	For security testing
Applicable for	Desktop application, Windows
Initial condition	Running environment is configured as per requirement
Steps	**Task and expected result** .
1	Open the application.
2	Verify that the system is only allowing access to authorized users. PASS
3	Verify that the password is in encrypted form. PASS
4	Verify that nonregistered user cannot use this software

Chapter 7

Conclusions

In this project, we have proposed a finger vein based biometric system using CNN which gives us effective results on different databases despite the fact that they have the different lightning condition, image quality or other environmental conditions. The benefit of this network is that it requires minimal human intervention while extracting different patterns during training but despite of its several benefits this network lacks the ability to add new subject in the database after the network is trained so to deal with that problem we have also implemented our system using transfer learning more specifically Siamese network. Although both modules of the system produce good results, but they can be improved further by applying different image normalization and enhancement techniques along with ROI extraction. However, doing this project has been a good boost to our confidence as the future IT member of our global village.

Appendix A

User Manual

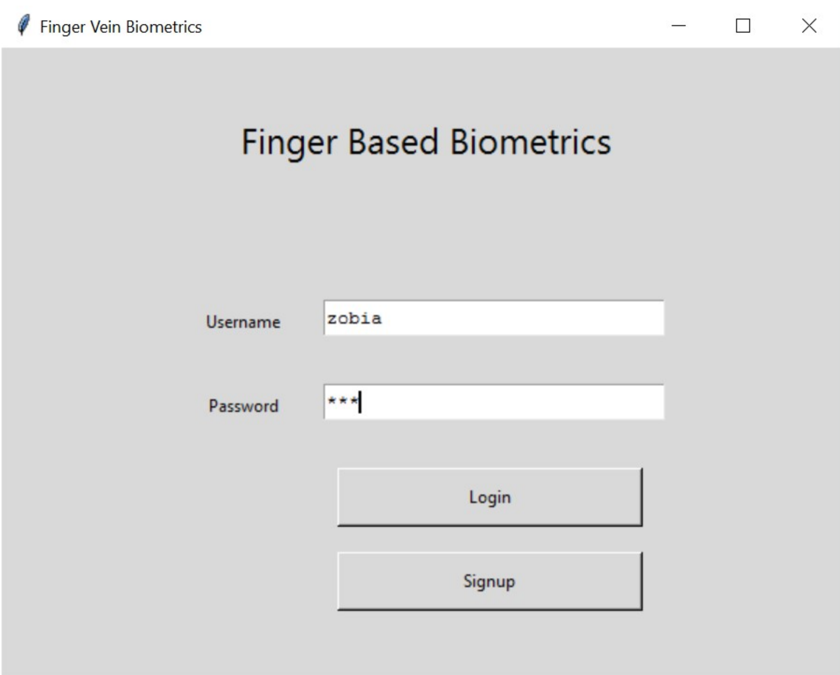
Login/Signup

When you run the application, you need to login or sign up

Login

Registered users can log in to the system by following these steps:

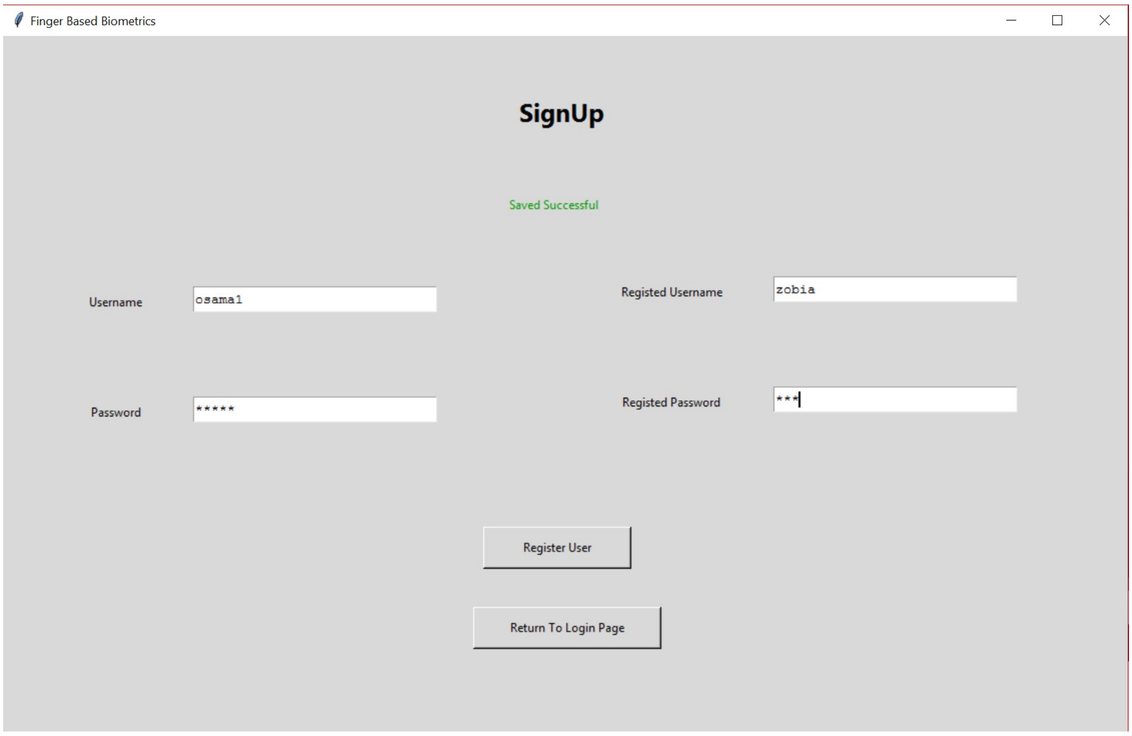
- Enter valid username and password in the respective field
- Press the login button



Signup

If you are a new user, please register yourself by clicking the Sign-up button.

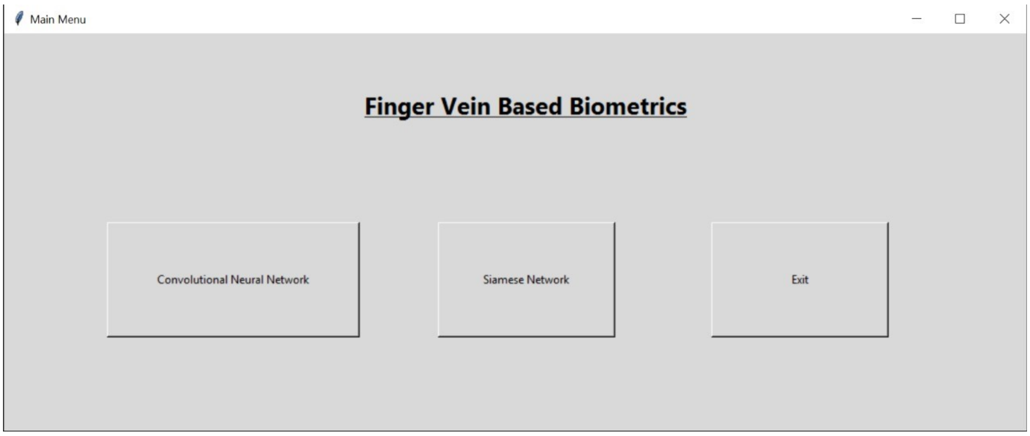
- You will be directed toward the sign-up screen. Please fill the required data.
- For validation, step ask registered user to enter their username and password
- Press the register user button



Main Menu

This system consists of two modules and those modules are completely discrete:

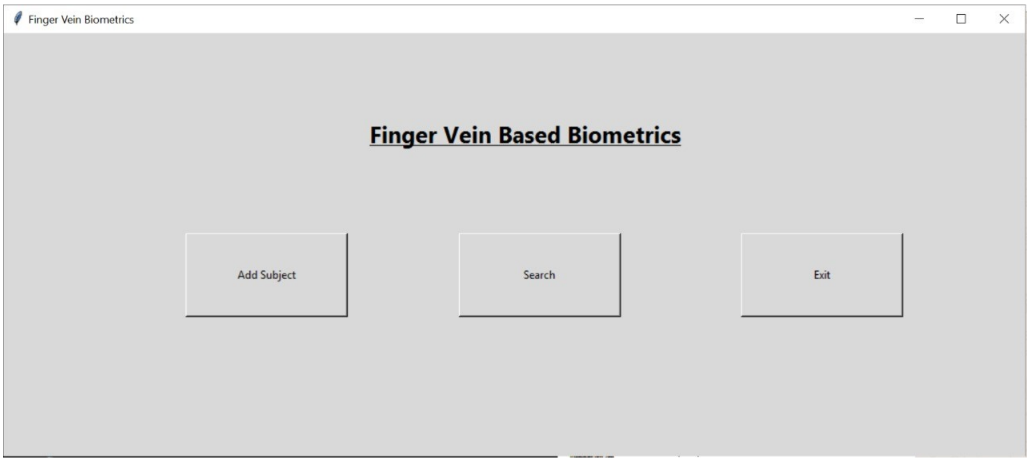
- To access the functionality implemented using convolutional neural network press convolutional neural network button.
- To access the functionality implemented using Siamese network press Siamese network button.
- To close the application press exit button.



Sub Menu(Siamese Network)

The screen contain functionality implemented using Siamese network:

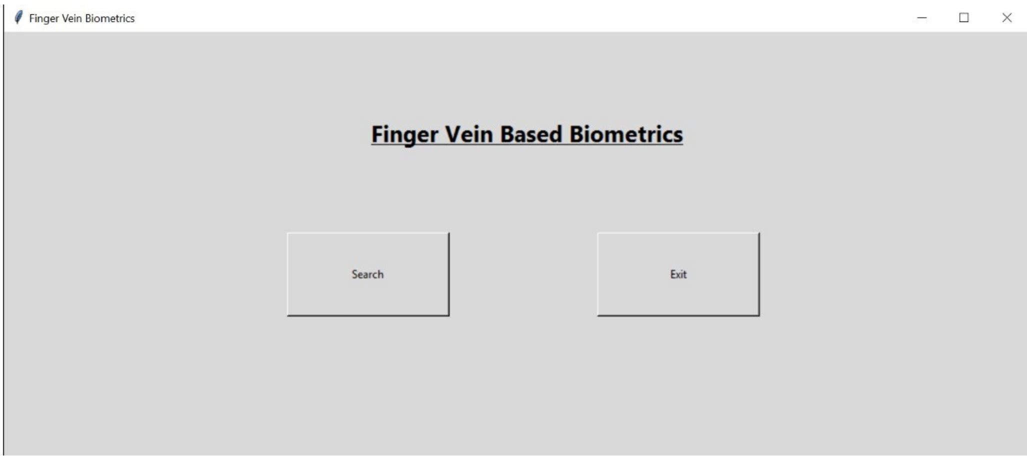
- To add new subject into the database press add subject button
- To search/match from already registered subject click search button
- To close the application press exit button.



Sub Menu(Convolutional Neural Network)

The screen contain functionality implemented using Convolutional neural network:

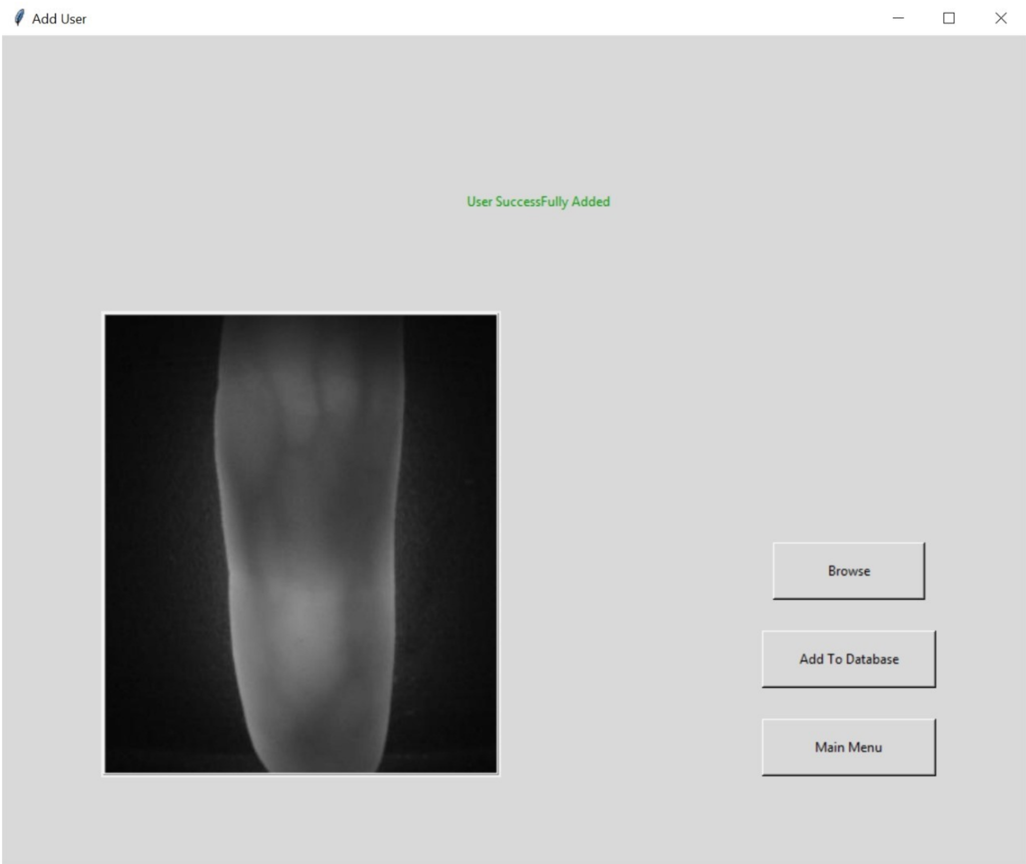
- To search/match from already registered subject click search button
- To close the application press exit button.



Add Record

To add a new subject into the database:

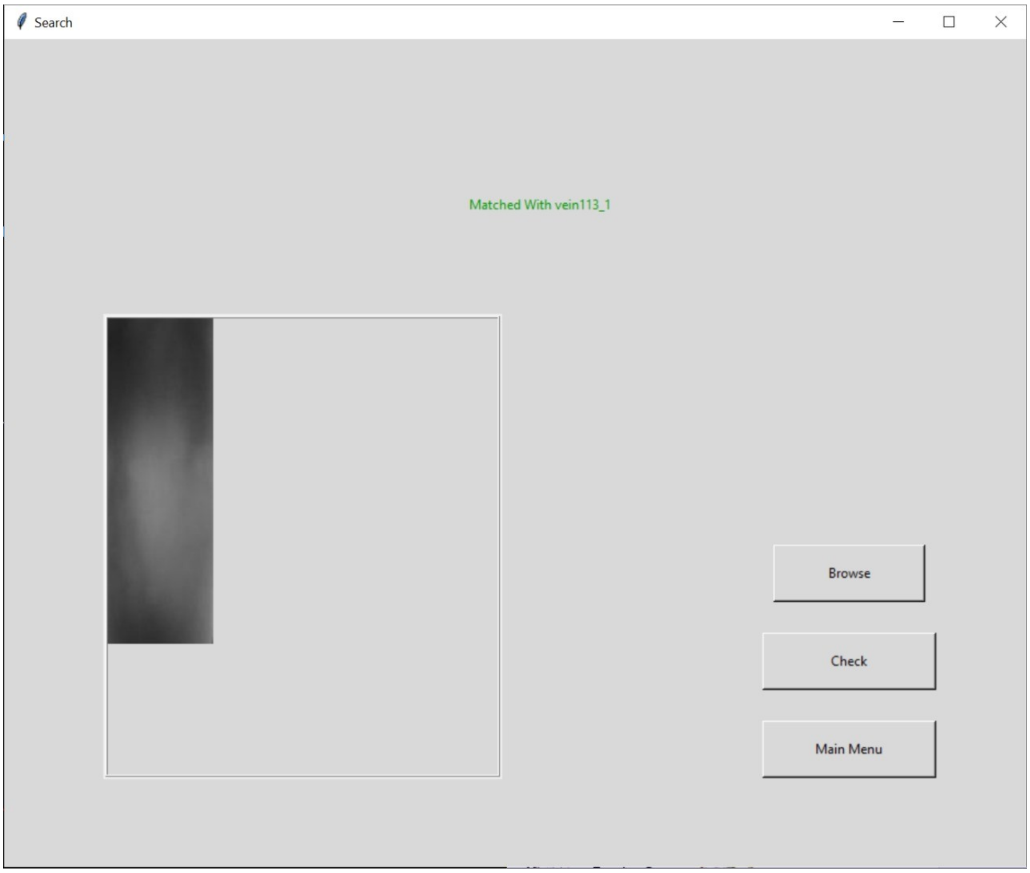
- Press browse button to browse finger vein image
- Store browse image into the database by clicking add to database button
- You can go back to main menu by clicking main menu button



Searching (Validation)

To match an image with already the images that are stored in database:

- Press browse button to select image
- To perform matching step click check button
- You can go back to main menu by clicking main menu button



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