# Fingerprint Biometric Research Tool
# Application Requirements Document

Luai Okasha, Yazan Abbas

2023 - 2024

# Contents

# 1 Introduction

## 1.1 The Problem Domain

Fingerprint biometrics is involved in various security systems and mechanisms of different fields which makes it a valuable target for malicious attacks, our project comes to introduce a fingerprint analysis stand-alone system for relevant researchers and investigators in the field. The system deals with conversions between fingerprint templates, fingerprint images, and 3d printing objects, templates matching with a scoring system, and providing assets visualization and statistical details for the user.

## 1.2 Context

Our system would be used as a research proof tool to prove an attack on fingerprint bio-metric systems based on that the research is providing an approach for enhancing the security of bio-metric systems. It will be used to analyze, improve, and build up a high-quality attack vector alongside statistics and details about the experiment.

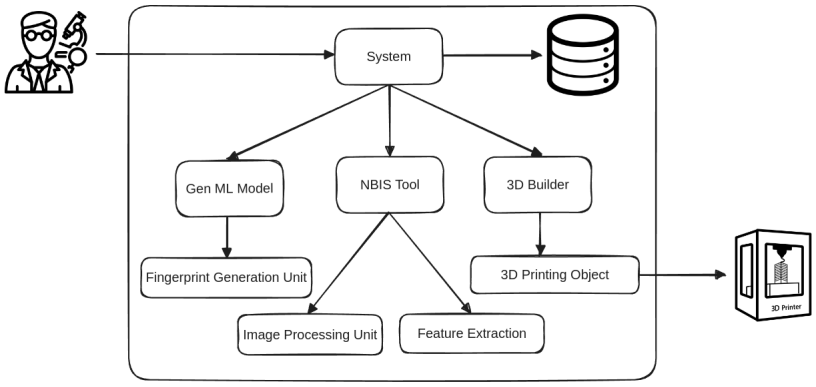


Figure 1: System context including external interfaces.

The system maintains the following external interfaces:

1. Fingerprint Generation - Machine Learning Model: we will integrate a machine learning model that is taking a fingerprint template as an input and generates a 2d fingerprint image as an output.

2. NBIS: NBIS is a system developed by the FBI for bio-metric identification, while NIST is a government agency that plays a role in setting standards and conducting research, including in the field of biometrics. we will maintain it in our system to have the advantage of its privilege regarding fingerprint image enhancement and feature extraction.

3. 3D Builder: the 3d builder is a component that is used to build up 3d printing objects given 2d fingerprint images, we will use deep learning/image processing external libraries to implement it.

## 1.3 Vision

The main goal of our software project is to provide a research tool that will help researchers to prove an attack on fingerprint biometric systems, we aim to achieve a high-accuracy solution by assuring the validity of accuracy of in-between stages alongside useful statistics and information.

## 1.4 Stakeholders

The customer of our product is a research lab at Cyber@BGU that is willing to adapt our product into their research, the contact person from the customer side is the head of Offensive AI lab. The direct users of our product are researchers or research teams who are involved in the fingerprints bio-metric research.

## 1.5 Software Context

Our system is a fingerprint analysis desktop application for bio-metrics research, the major inputs are a fingerprint template that contains the data about a fingerprint and a fingerprint image. The system is responsible for converting fingerprint templates to images and vice versa and converting fingerprint images to 3D printing objects. So the system outputs are fingerprint templates, images, and 3D printing objects.

A major use case would be importing a fingerprint template and converting it to a 2D fingerprint image, the system does such conversion using a machine learning model and will display how each step looks like, i.e displaying the template and the converted image, after the user could export that image to his local machine.

Another major use case would be importing a 2D fingerprint image and converting it to a 3D printing object, the system enhances the imported image using an integrated enhancer alongside NBIS. The system builds a 3D printing object using an integrated 3D builder and will display it to the user and be ready for exporting to his local machine afterward.

# 2 Usage Scenarios

## 2.1 User Profiles - The Actors

Our system interacts with one actor; the researcher is a person who is working on research in the fingerprint bio-metrics field with a need to analyze, visualize, and compare fingerprints(images and templates) and get a summary with statistics about his experiments, in addition to performing conversions from fingerprint templates to fingerprint images and vice versa and from fingerprint images to 3d printing objects.

## 2.2 Use Cases

### 2.2.1 Template to 2D Fingerprint Image Conversion:

- **Primary actor:** Researcher.
- **Description:** The Researcher imports a template (or directory) into the system and converts it to a 2D fingerprint image (or images directory).
- **Stakeholders and interests:**
  - The researcher wants to see the imported template and the converted 2D fingerprint image visualization in between different stages (after template importing and before image exporting).
  - The researcher may want to export the converted image/s to his local storage.
- **Pre-conditions:**
  - Imported template/s must be valid.
- **Post-conditions:**
  - The system displays the converted 2D fingerprint image and is ready for export.
- **Main success scenario:**
  1. The researcher imports a template (or templates directory).
  2. The system displays the template.
  3. The system displays the converted image.
  4. The researcher exports the converted image (or images directory).
- **Alternative flows:**
  - On system failure: a message will be displayed to the researcher with relevant info.
  - Importing invalid template: a message will be displayed to the researcher.

#### 2.2.2 2D Fingerprint Image to 3D Printing Object Conversion:

- **Primary actor:** Researcher.
- **Description:** The Researcher imports a 2D fingerprint image (or images directory) into the system, then the system converts it to a 3D printing object (or 3D printing objects directory).
- **Stakeholders and interests:**
  - The researcher wants to see the enhanced fingerprint image and the converted 3D printing object visualization in between different stages (after image importing and before 3D object exporting).
  - The researcher may want to export the converted 3D printing object (or 3D printing objects directory) to his local storage.
- **Pre-conditions:**
  - Must import a fingerprint image (or images directory).
- **Post-conditions:**
  - The system displays the converted 3D printing object and is ready for export.
- **Main success scenario:**
  1. The researcher imports a fingerprint image (or images directory).
  2. The system displays the fingerprint image.
  3. The system displays the converted 3D printing object.
  4. The researcher exports the converted 3D printing object (or printing objects directory).
- **Alternative flows:**
  - On system failure: a message will be displayed to the researcher.
  - Importing improper image: a message will be displayed to the researcher.
  - Some of the images in the directory are bad or low quality: the system will convert the good images and display to the researcher how many are converted successfully out of the total images.

#### 2.2.3 2D Fingerprint Image to Template Conversion:

- **Primary actor:** Researcher.
- **Description:** The Researcher imports a 2D fingerprint image (or images directory), and the system converts it to the template (or templates directory).
- **Stakeholders and interests:**
  - The researcher wants to see the fingerprint template image and template visualization in between stages.
  - The researcher may want to export the converted template (or templates directory) to his local storage.
- **Pre-conditions:**
  - Must import a fingerprint image (or images directory).
- **Post-conditions:**
  - The system displays the converted template and is ready for export.
- **Main success scenario:**
  1. The researcher imports a fingerprint image (or images directory).
  2. The system displays the fingerprint template image.
  3. The researcher exports the converted template (or templates directory).
- **Alternative flows:**
  - On system failure: a message will be displayed to the researcher.
  - Importing improper image: a message will be displayed to the researcher.

#### 2.2.4 Templates Matching:

- **Primary actor:** Researcher.
- **Description:** The researcher imports 2 template sets (i.e. single template file or directory) and compares the templates with one another, the system displays statistics for the comparison.
- **Stakeholders and interests:**
  - The researcher wants to see the statistics for comparing templates with others and to be able to export the matching score *.csv* file to his local storage.
- **Pre-conditions:**
  - Imported templates are valid.
- **Post-conditions:**
  - The system displays corresponding statistics.
- **Main success scenario:**
  1. The researcher imports template sets.
  2. The system displays comparison statistics.
  3. The system allows the researcher to export *.csv* scores file.
- **Alternative flows:**
  - On system failure: a message will be displayed to the researcher.
  - Importing improper template/s: a message will be displayed to the researcher.

#### 2.2.5 Delete Experiment:

- **Primary actor:** Researcher.
- **Description:** The researcher deletes a specific experiment.
- **Pre-conditions:**
  - Existing experiment.
- **Post-conditions:**
  - The experiment and all of its operations are deleted.
- **Main success scenario:**
  1. The researcher deletes an experiment.
  2. The deletes the experiments with all of its operations after the research confirmation.
- **Alternative flows:**
  - On system failure: a message will be displayed to the researcher.

#### 2.2.6 Rename Experiment:

- **Primary actor:** Researcher.
- **Description:** The researcher renames a specific experiment.
- **Pre-conditions:**
  - Existing experiment.
  - Valid new experiment name and is not already used.
- **Post-conditions:**
  - The experiment will be renamed to the new name.
- **Main success scenario:**
  1. The researcher renames an experiment.
  2. The experiment will be renamed while notifying the researcher.
- **Alternative flows:**
  - On system failure: a message will be displayed to the researcher.
  - Renaming to invalid or existing name: a message will be displayed to the researcher and the experiment will not be renamed.

#### 2.2.7 Delete Operation:

- **Primary actor:** Researcher.
- **Description:** The researcher deletes an operation from a specific experiment.
- **Pre-conditions:**
  - Existing operation inside an experiment.
- **Post-conditions:**
  - The operation will be deleted.
- **Main success scenario:**
  1. The researcher deletes an operation.
  2. The operation will be deleted.
- **Alternative flows:**
  - On system failure: a message will be displayed to the researcher.

#### 2.2.8 Viewing All Experiments and Operations:

- **Primary actor:** Researcher.
- **Description:** The researcher may want to see all the experiments and operations that he performed and to keep track of them (history).
- **Pre-conditions:**
  - Existing experiment.
- **Post-conditions:**
  - The system views all experiments and all of its operations.
- **Main success scenario:**
  1. The researcher requests to see all experiments.
  2. The system displays all experiments with all operations packed each one to its related experiment.
- **Alternative flows:**
  - On system failure: a message will be displayed to the researcher.

# 3 Functional Requirements

1. The user must be able to upload a fingerprint template file.
2. The user must be able to upload a fingerprint image.
3. The user must be able to convert a fingerprint template to a fingerprint image.
4. The user must be able to convert a fingerprint image to a 3d printing object.
5. The user must be able to extract the fingerprint template of a fingerprint image.
6. The user must be able to match templates:
   (a) One-to-one template matching
   (b) One too many templates matching
   (c) Many to many templates matching
7. The user should be able to delete an experiment.
8. The user should be able to rename an experiment.
9. The user should be able to delete an operation from a given experiment.
10. The user should be able to view all experiments and their operations history.

# 4 Non-functional Requirements

## 4.1 Implementation constraints

- **Safety & Security:** Since our system is not establishing or initiating network connections at all and everything is local on the host machine it is the user's responsibility to secure his local and private assets.
- **Portability:** our system is a stand-alone system which is designed to work as a desktop application on different operating systems based on *Python* portability, so *Python* interpreter is a prerequisite for installing the system.
- **Usability:** The users of our system are supposed to have basic knowledge about the fingerprint biometrics and stages of conversions from a fingerprint template till 3d printing object process and vice versa. The system is developed to be very intuitive with straightforward and visible access to the offered functionality for the users.
- **Availability:** Our system is developed in a stand-alone system manner, so the system is always available on the user's machine.

## 4.2 Platform constraints

We have to work with multiple Python-specific libraries therefore we may want to use *Conda* package manager alongside *PyCharm* to avoid package conflicts.

## 4.3 SE Project constraints

Our system inputs come straightforwardly from the user machine. The system doesn't require special hardware or special access rights, it will be developed on Linux based.

## 4.4 Special restrictions & limitations

Our project does not handle any I/O neither fingerprint scanners or 3D printers and it is assumed that it's the researcher's responsibility.

# 5 Risk assessment & Plan for the proof of concept

## 5.1 ML model risk

We estimate that the machine learning model for generating a fingerprint given its template would be a bottleneck in our project; we have read a paper on an existing model that is doing our aim.

## 5.2 3D Builder

Generating an *.stl* (3d printing object) given a 2d image of a fingerprint would be challenging and we plan to perform the following steps to prove the concept:

1. Transform the fingerprint image to grayscale.
2. Binarize the image such that each pixel is in white or black with a suitable threshold.
3. Perform enhancement for the fingerprint image.
4. Add fixed depth to the image.
5. Generate an *.stl* object using a proper open-source package.