





## Operation Manual: Fingerprint Biometric Comparison

### 1. Uploading Images

In the form, upload **two fingerprint images**:

-  **Requester**: the fingerprint image of the person to be verified.
-  **Candidate**: the fingerprint image to compare against.

The images must be in .bmp or .png format and should contain **complete or partial fingerprint scans**, such as those provided in the sample link below.

1\_\_M\_Left\_i...x\_finger.BMP

1\_\_M\_Left\_i...ger\_CR.BMP

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### 2. Sample Images for Testing

To run real tests using valid data, download sample images from the following link:

 [Download Sample Images](#)

The dataset is organized as follows:

- Each individual has **10 fingers**, and each finger includes **two images**:
  - A **clean** (undistorted) version.
  - A **distorted** version (with rotation, pressure, blur, or cropping).

## Index of /demo\_images/

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<a href="#">../</a>		
<a href="#">PERSON 1/</a>	08-May-2025 22:21	-
<a href="#">PERSON 2/</a>	08-May-2025 22:21	-

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## Index of /demo\_images/PERSON 1/

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1	M Left index finger.BMP	07-May-2025 03:02	39690
1	M Left index finger CR.BMP	07-May-2025 03:07	10966
1	M Left little finger.BMP	07-May-2025 03:02	39690
1	M Left little finger CR.BMP	07-May-2025 03:07	10966
1	M Left ring finger.BMP	07-May-2025 03:02	39690
1	M Left ring finger Obl.BMP	07-May-2025 03:07	10966
1	M Left thumb finger.BMP	07-May-2025 03:02	39690
1	M Left thumb finger Obl.BMP	07-May-2025 03:07	10966
1	M Right index finger.BMP	07-May-2025 03:02	39690
1	M Right index finger Obl.BMP	07-May-2025 03:07	10966
1	M Right little finger.BMP	07-May-2025 03:02	39690
1	M Right little finger Zcut.BMP	07-May-2025 03:07	10966
1	M Right ring finger.BMP	07-May-2025 03:02	39690
1	M Right ring finger CR.BMP	07-May-2025 03:07	10966
1	M Right thumb finger.BMP	07-May-2025 03:02	39690
1	M Right thumb finger Obl.BMP	07-May-2025 03:07	10966

These variations are designed to test the **accuracy of the comparison algorithm**, determining whether it can still match fingerprints from the **same person** despite differences in capture conditions.

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### 3. Performing the Comparison

After uploading both images:

1. Click the **"Match Now"** button.
2. The system will process the fingerprints, identify **relevant matching regions**, and return:
  -  **Match** (if both belong to the same person),
  -  **No Match** (if they belong to different people),
  -  **\*\*Caution message\*\*** if the score falls into an uncertain range.
  -  Optionally, a visual explanation highlighting the areas that influenced the decision (e.g., using Grad-CAM or overlay visualization).

### 4. Visual feedback options:

🔥 **\*\*Grad-CAM heatmaps\*\*** (highlight key activation regions),

🧬 **\*\*Minutiae maps\*\*** (automatically detected keypoints plotted on each fingerprint).

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## Technical Detail



### Fingerprint Matcher Using Siamese Neural Network + Grad-CAM

Over the past few days, I've developed an educational project focused on **fingerprint comparison using deep learning techniques**. The solution is built on a **Siamese Neural Network architecture**, using [MobileNetV2](#) as a lightweight feature extractor — and incorporates a **Grad-CAM visualization module** to highlight the most relevant fingerprint regions used during biometric verification.

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### Technical Overview

This project offers an alternative approach to traditional biometric verification systems. While classical methods rely on heuristic algorithms for **minutiae extraction** (e.g., ridge bifurcations and endings), this solution leverages a neural network that **automatically learns vector representations (embeddings)** directly from image pixels.

These embeddings are then compared using **Euclidean distance**, providing a similarity measure that is robust to noise, rotation, distortion, and low-quality captures — all common challenges in real-world biometric environments.

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### Training Dataset — SOCOFing






The [SOCOFing](#) dataset was used for training, comprising over **6,000 BMP-format fingerprint images** with artificially applied variations (cuts, noise, rotation, dirt). This allowed for realistic simulation of forensic and administrative scenarios.

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### Training Architecture

- 📐 Image size: 96×96 px (RGB)

-  Batch size: 32
-  Epochs: 5
-  Loss function: Binary Crossentropy
-  Optimizer: Adam
-  Output model: model/siamese\_model.h5

Custom lightweight CNN with:

- 2 Conv2D layers
- 2 MaxPooling2D layers
- 1 Flatten + Dense (128-dim embeddings)
- Lambda layer for Euclidean distance

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### Web Inference + Grad-CAM

The app.py application was developed using **Flask**, with a simple and interactive web interface for uploading .bmp images. The system:

- Processes input image pairs
- Generates embeddings
- Returns a similarity score + **MATCH / NO MATCH**
- Optionally displays a **Grad-CAM heatmap** over the image, highlighting the neural activation regions most responsible for the decision.

The heatmap can be enabled via a checkbox and enhances interpretability of the matching process.

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### Execution Environment (Oracle Cloud)

- Ubuntu 20.04 (Canonical)
- Instance: VM.Standard.E2.1 (1 vCPU, 8 GB RAM)
- TensorFlow CPU-only (no GPU)
- NGINX + Gunicorn + systemd

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## Tech Stack

- TensorFlow 2.x + Keras
- Flask, OpenCV, Matplotlib, Pillow
- Custom Grad-CAM implementation
- Automated deployment via setup.sh + NGINX reverse proxy

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## Repository + Live Demo


 **Live demo:** <https://projetos.tiago.cafe/>

 **GitHub repository:** <https://github.com/algodas/BiomatchML.git>

Includes:

- Full codebase (app.py, train.py, cam\_utils.py)
- Demo fingerprint images
- Auto-install script (setup.sh)
- Grad-CAM integration and web-based reprocessing

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 If you work with biometrics, computer vision, or are interested in applying Siamese Networks in contexts like signature verification, face recognition, document comparison or voice matching — let's connect!

#DeepLearning #Biometrics #SiameseNetwork #ComputerVision #GradCAM  
#Flask #TensorFlow #Keras #MobileNetV2 #AI #MachineLearning #GitHub  
#OpenSource #EducationalProject #NeuralNetworks #FingerprintRecognition