



## Operation Manual: Fingerprint Biometric Comparison

### 1. Uploading Images

Select the type of search: **1:1 (one-to-one)** or **1:N (one-to-many)**.

- For **1:1 searches**, you will need to upload a second image for comparison.
- For **1:N searches**, only the **Requester** image is required.

You can use the [Sample Images](#) from the dataset available on the project's main page.

The screenshot shows the 'Fingerprint Matcher' web application. At the top, it says 'Siamese Network – 1:1 or 1:N'. Below this, there is a prompt: 'Upload a fingerprint image and choose the comparison mode below:'. Under the prompt, there is a section labeled 'Query Fingerprint:' with a file selection box. The box shows 'Seleccionar archivo' and the filename '517\_\_M\_Left\_little\_finger\_Obl.BMP'. Below the file selection, there is a 'Comparison Mode:' section with a dropdown menu. The dropdown menu is open, showing three options: '1:N – Search against the fingerprint database' (selected), '1:1 – Compare with a specific image', and '1:N – Search against the fingerprint database'. Below the dropdown menu is a blue button labeled 'Run Comparison'. At the bottom of the interface, there are five links: 'Download sample images', 'Technical manual', 'View on GitHub', and 'Connect on LinkedIn'.

**1:N** – In the form, upload the fingerprint image from Requester:

# Fingerprint Matcher

## Siamese Network – 1:1 or 1:N

🔍 Upload a fingerprint image and choose the comparison mode below:

🖼️ Query Fingerprint:

Seleccionar archivo 517\_\_M\_Left\_little\_finger\_Obl.BMP

⚙️ Comparison Mode:

1:N – Search against the fingerprint database ▼

☒ Show heatmap (Grad-CAM)

[Run Comparison](#)

[Download sample images](#)

[Technical manual](#)

[View on GitHub](#)

[Connect on LinkedIn](#)

**1:1** - 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 format and should contain **complete or partial fingerprint scans**, such as those provided in the sample link below.

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

Seleccionar archivo 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="#">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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../		
<a href="#">1 M Left index finger.BMP</a>	07-May-2025 03:02	39690
<a href="#">1 M Left index finger CR.BMP</a>	07-May-2025 03:07	10966
<a href="#">1 M Left little finger.BMP</a>	07-May-2025 03:02	39690
<a href="#">1 M Left little finger CR.BMP</a>	07-May-2025 03:07	10966
<a href="#">1 M Left ring finger.BMP</a>	07-May-2025 03:02	39690
<a href="#">1 M Left ring finger Obl.BMP</a>	07-May-2025 03:07	10966
<a href="#">1 M Left thumb finger.BMP</a>	07-May-2025 03:02	39690
<a href="#">1 M Left thumb finger Obl.BMP</a>	07-May-2025 03:07	10966
<a href="#">1 M Right index finger.BMP</a>	07-May-2025 03:02	39690
<a href="#">1 M Right index finger Obl.BMP</a>	07-May-2025 03:07	10966
<a href="#">1 M Right little finger.BMP</a>	07-May-2025 03:02	39690
<a href="#">1 M Right little finger Zcut.BMP</a>	07-May-2025 03:07	10966
<a href="#">1 M Right ring finger.BMP</a>	07-May-2025 03:02	39690
<a href="#">1 M Right ring finger CR.BMP</a>	07-May-2025 03:07	10966
<a href="#">1 M Right thumb finger.BMP</a>	07-May-2025 03:02	39690
<a href="#">1 M Right thumb finger Obl.BMP</a>	07-May-2025 03:07	10966

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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.

### 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