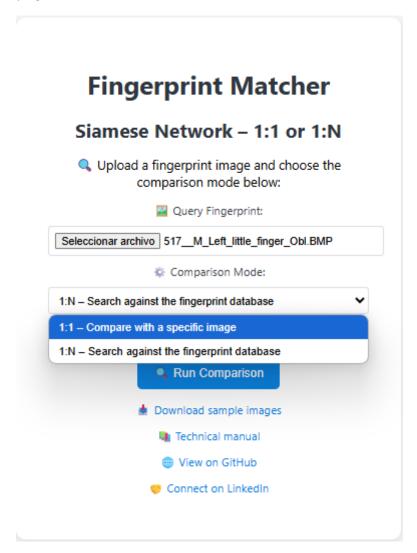
Operation Manual: Fingerprint Biometric Comparison

1. Uploading Images

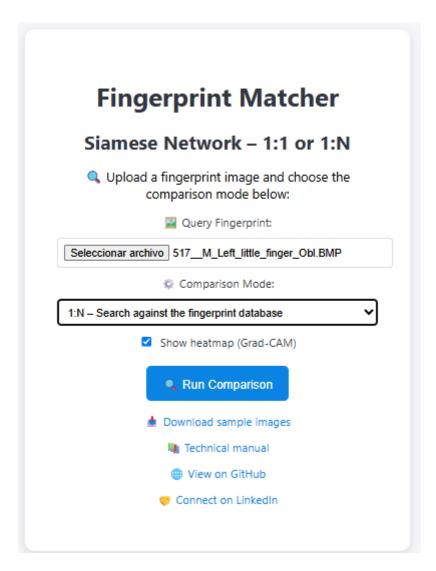
Select the type of search: 1:1 (one-to-one) or 1:N (one-to-many).

- 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 <u>Sample Images</u> from the dataset available on the project's main page.



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



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.



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:
 - o A clean (undistorted) version.
 - o A **distorted** version (with rotation, pressure, blur, or cropping).

Index of /demo_images/

/		
PERSON 1/	08-May-2025 22:21	-
PERSON 2/	08-May-2025 22:21	-

Index of /demo_images/PERSON 1/

/		
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 Lett little tinger.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.

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),
 - X 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).

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.



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.

📊 🥜 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.

X 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

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.

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

Tech Stack

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

Repository + Live Demo

- Live demo: https://projetos.tiago.cafe/
- Ø 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

☐ 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