FINGERPRINT RECOGNITION ALGORITHM

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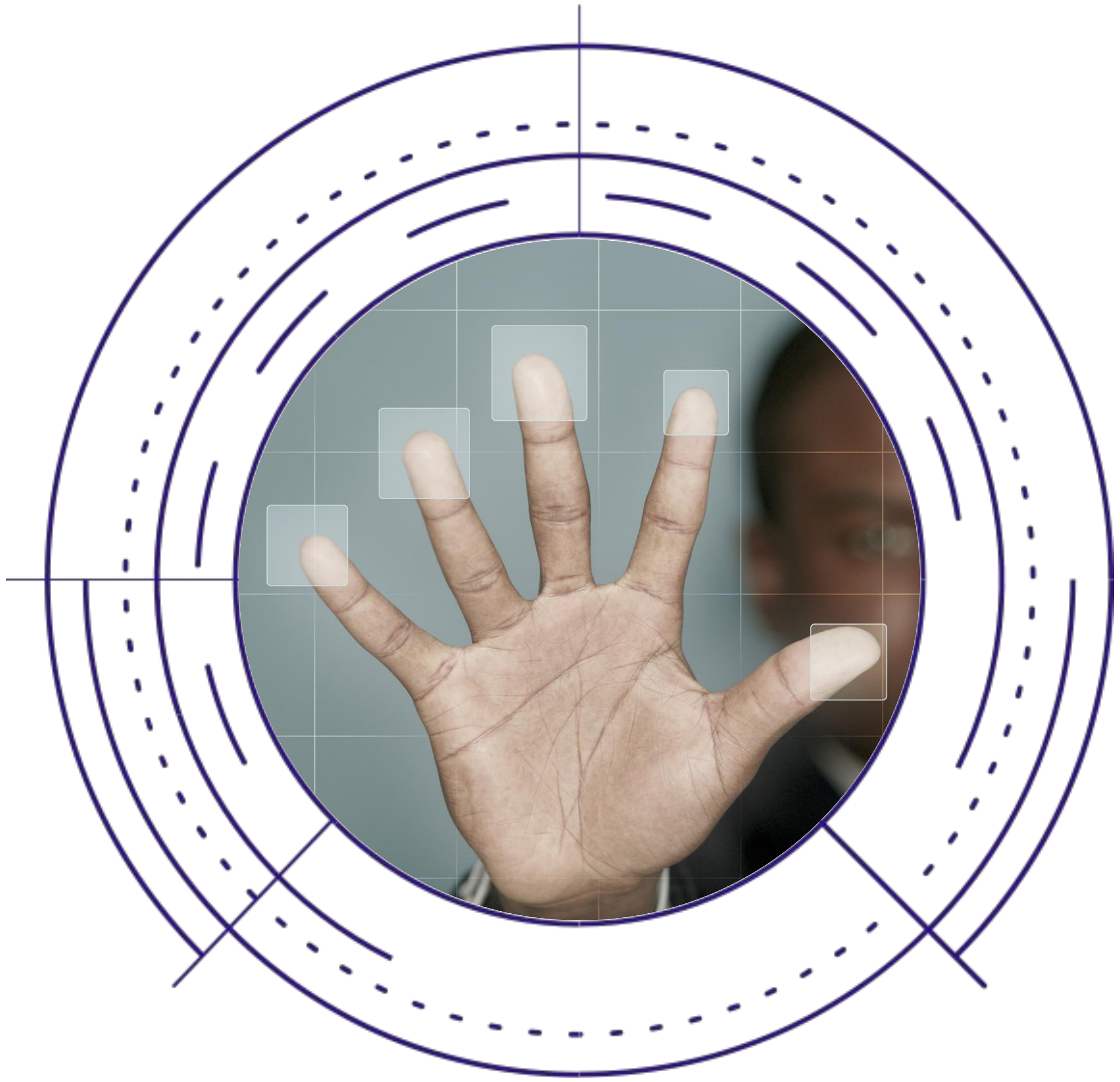
INTRODUCTION

Did you know that, no two people has ever been found to have the same fingerprint?

Fingerprints have been used for over a century dating all the way back to 1882, When Gilbert Thompson used his own fingerprint on a document to prevent forgery.

Because of this, fingerprints play a crucial role in today’s society, and it has spread to many aspects of our day to day life.
It can be used from something small like in forensic science to support criminal investigations and biometric systems such as civilian and commercial identification devices for personal identification.

This project aims to develop a algorithm for fingerprint recognition based on variance calculations and Gabor filtering. Using OpenCV lib.



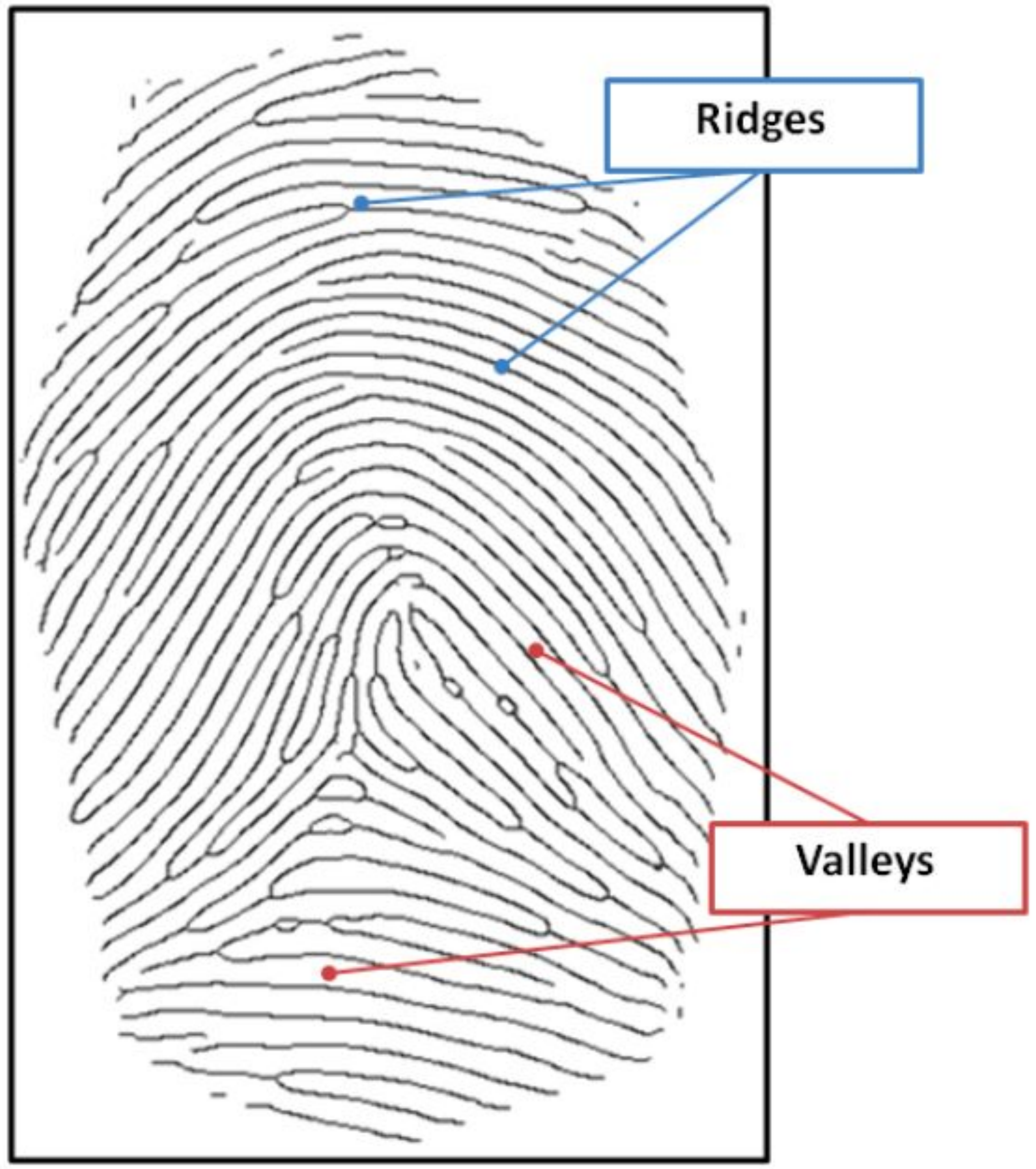


Fig. 1: Ridges and valleys in a fingerprint image.

A fingerprint is comprised of ridges and valleys. The ridges are the dark area of the fingerprint, and the valleys are the white area between the ridges.

An individual's fingerprint is unique and remains unchanged for over a lifetime.

The uniqueness of a fingerprint is exclusively determined by the local ridge characteristics and their relationships.

MINUTIAE POINTS

- Ridge ending is the point where the ridge ends suddenly.
- Ridge bifurcation is the point where a single ridge branches out into two or more ridges.
- Ridge dots are very small ridges.
- Ridge islands are slightly longer than dots and occupy a middle space between two diverging ridges.
- Ponds or Lakes are the empty space between two diverging ridges.
- Spurs are a notch protruding from a ridge.
- Bridges are the small ridges that join two longer adjacent ridges.
- Crossovers are formed when two ridges cross each other.

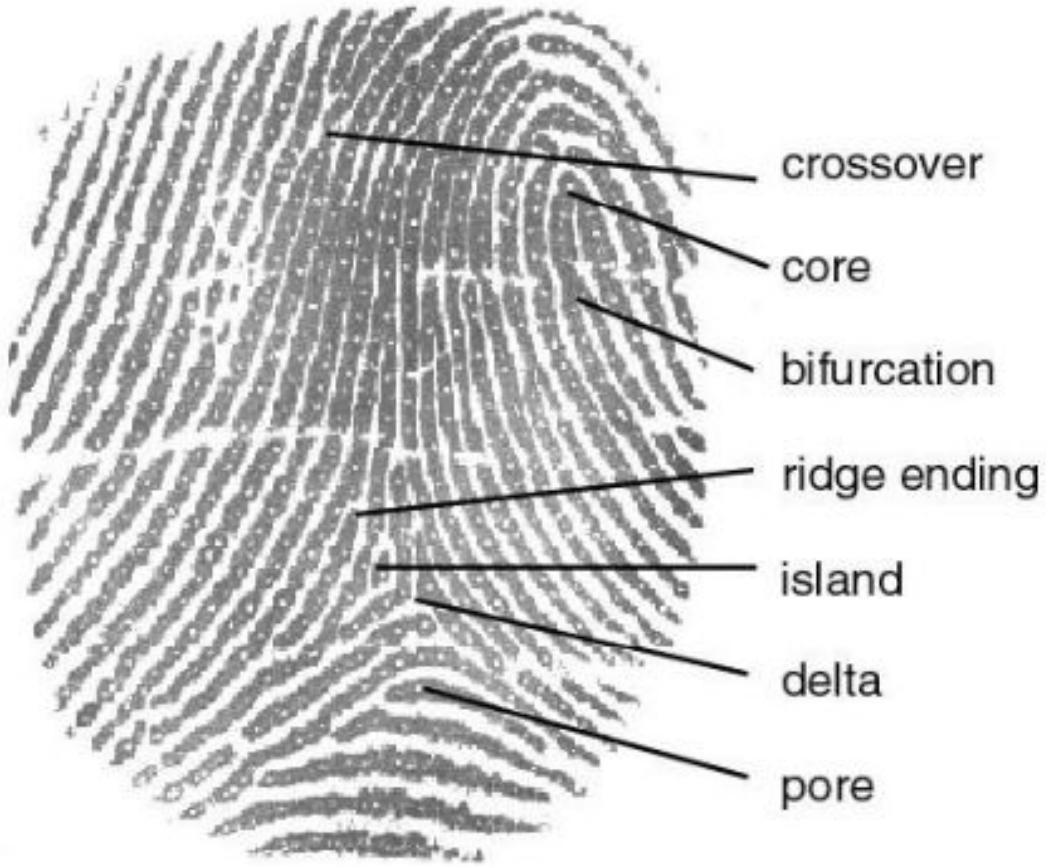


Fig. 2: Fingerprint Structure
Source: bayometric.com

4 Steps for Finger Recognition Algorithm

Step 1: Fingerprint Segmentation

Step 2: Estimation of Local Ridge Orientation

Step 3: Estimation of Local Ridge Frequency

Step 4: Fingerprint Enhancement

Step 1: Fingerprint Segmentation

```
# first of all we read a fingerprint image
fingerprint = cv.imread('fingerprint_sample.png', cv.IMREAD_GRAYSCALE)

# calculate the local gradient (using Sobel filters)
gx, gy = cv.Sobel(fingerprint, cv.CV_32F, 1, 0), cv.Sobel(fingerprint, cv.CV_32F, 0, 1)

# calculate the magnitude of the gradient for each pixel
gx2, gy2 = gx**2, gy**2
gm = np.sqrt(gx2 + gy2)

# integral over a square window
sum_gm = cv.boxFilter(gm, -1, (25, 25), normalize = False)

# use a simple threshold for segmenting the fingerprint pattern
thr = sum_gm.max() * 0.2
mask = cv.threshold(sum_gm, thr, 255, cv.THRESH_BINARY)[1].astype(np.uint8)

show(fingerprint, mask, cv.merge((mask, fingerprint, fingerprint)))
```

Step 2: Estimation of Local Ridge Orientation

```
# for each pixel, we will estimate the local orientation from the gradient [Gx,Gy], which we already computed in the previous step.
# the ridge orientation is estimated as ortoghonal to the gradient orientation, averaged over a window W.

W = (16, 16)
gxx = cv.boxFilter(gx2, -1, W, normalize = False)
gyy = cv.boxFilter(gy2, -1, W, normalize = False)
gxy = cv.boxFilter(gx * gy, -1, W, normalize = False)
gxx_gyy = gxx - gyy
gxy2 = 2 * gxy

# For each orientation, we will also calculate a confidence value (strength), which measures how much all gradients in
in W share the same orientation.
orientations = (cv.phase(gxx_gyy, -gxy2) + np.pi) / 2 # '-' to adjust for y axis direction
sum_gxx_gyy = gxx + gyy
strengths = np.divide(cv.sqrt((gxx_gyy**2 + gxy2**2)), sum_gxx_gyy, out=np.zeros_like(gxx), where=sum_gxx_gyy!=0)

show(draw_orientations(fingerprint, orientations, strengths, mask, 1, 16), 'Orientation image')
```

Orientation image

Source: A.M. Bazen and S.H. Gerez, "Systematic methods for the computation of the directional fields and singular points of fingerprints," in IEEE tPAMI, July 2002

Step 3: Estimation of Local Ridge Frequency

```
region = fingerprint[10:90,80:130]

# before computing the x-signature, the region is smoothed to reduce noise
smoothed = cv.blur(region, (5,5), -1)

# the x-signature is computed from the region and the ridge-line period is estimated as the average number of pixels between two consecutive peaks.
xs = np.sum(smoothed, 1)
```

```
[10697 10796 11245 11970 12058 11508 10815 10064  9314  9125  9707 10389
 10912 11370 11564 11116 10419  9916  9532  9250  9370  9833 10348 10899
 11430 11429 11180 10773 10152  9409  9243  9351  9847 10620 11430 11482
 11147 10536  9791  9010  8966  9337  9845 10431 10986 11071 10877 10416
  9732  9264  9514  9946 10642 11353 11533 11050 10398  9649  9345  9636
 10183 10614 10849 10646 10197  9827  9762  9908 10237 10529 10628 10437
 10203 10011 10108 10364 10658 10828 10986 11106]
```

```
# find the indices of the x-signature local maxima
local_maxima = np.nonzero(np.r_[False, xs[1:] > xs[:-1]] & np.r_[xs[:-1] >= xs[1:], False])[0]

# calculate all the distances between consecutive peaks
distances = local_maxima[1:] - local_maxima[:-1]

# estimate the ridge line period as the average of the above distances
ridge_period = np.average(distances)
print(ridge_period)
```

```
9.428571428571429
```

Source: L. Hong, Y. Wan and A. Jain, "Fingerprint image enhancement: algorithm and performance evaluation," in IEEE tPAMI, Aug. 1998

Step 4: Fingerprint Enhancement

```
# create the filter bank of 24 filters
or_count = 24
gabor_bank = [gabor_kernel(ridge_period, o) for o in np.arange(0, np.pi, np.pi/or_count)]

# filter the whole image with each filter
# note that the negative image is actually used, to have white ridges on a black
nf = 255-fingerprint
all_filtered = np.array([cv.filter2D(nf, cv.CV_32F, f) for f in gabor_bank])

y_coords, x_coords = np.indices(fingerprint.shape)

# for each pixel, find the index of the closest orientation in the gabor bank
orientation_idx = np.round(((orientations % np.pi) / np.pi) * or_count).astype(np.int32) % or_count

# take the corresponding convolution result for each pixel, to gather the final result
filtered = all_filtered[orientation_idx, y_coords, x_coords]

# convert to gray scale and apply the mask
enhanced = mask & np.clip(filtered, 0, 255).astype(np.uint8)

show(fingerprint, enhanced)
```

Sources

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Conclusion

In conclusion, fingerprint recognition has come a long way from where it began but we believe that it can go much further. Today, what we showed you barely scratches the surface of how fingerprint recognition is implemented and the benefits it brings to us on the daily.

THANK YOU!