

Fingerprint matching using sift features

Chapter 2 -Literature Review



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# Introduction

A fingerprint is an impression left behind by the friction ridges of a human finger. They provide a reliable means of personal identification. All fingerprints contain unique \*characteristics\* known as ridges. These ridges are \*unique\* patterns on every finger that do no alter with age or growth. The practice of utilizing fingerprints as a means of identification is referred to as **dactyloscopy.** (Hoover, 2021)

Each ridge of the outer skin (epidermis) is filled with sweat pores for its entire length and is anchored to the dermis (inner skin) by a row of **papillae**. Injuries such as abrasions, cuts or superficial burns do not affect the structure of the ridge as the original pattern is duplicated in any new skin that grows. An injury that destroys the papillae however, will result in permanent obliteration of the ridges.

Any ridged area such as the hand or foot can be used for identification. However, finger impressions are the most preferred to those from other parts of the body since they can be extracted with a minimum amount of time and effort. Another reason why finger prints are mostly preferred is that they offer more distinct patterns and shapes that can be readily grouped for ease in filing. \*\***REREAD THROUGH taken from britannica\*\***

## History of fingerprint Identification

Fingerprint matching dates back to 200 BC in ancient Babylonia and China. They have been found on ancient clay, Chinese pottery, as well as the walls of Egyptian tombs. In ancient China, officials authenticated government documents with their fingerprints. With the advent of silk and paper in China, parties in a legal contract impressed their fingerprints on the document. Sometime before 851 CE, an Arab merchant, Abu Zayd Hassan witnessed Chinese merchants using fingerprints to authenticate loans. Although ancient people were not aware as to how fingerprints could uniquely identify individuals, references from the age of the Babylonian king show that law officials took fingerprints of people who had been arrested as evidence from a crime scene. \*\***REREAD THROUGH taken from wikipedia\*\***

**\*\* Europe In 17th and 18th Centuries \*\***

From the 16th Century onwards, scientific studies about fingerprints were spearheaded by European scholars. However, it was not until the mid-17th century that plausible conclusions were made. In 1686, University of Bologna’s Marcello Malpighi identified spiral loops and ridges left on fingerprint surfaces.

**\*\*19th Century \*\***

In 1823, University of Breslau’s Jan Evangelista Purkinje, who was an anatomy professor published his thesis discussing the nine fingerprint patterns. \*\***SOMETHING THAT LEADS TO EXPLANATION OF THESE VARIOUS PATTERNS\*\***

# Fingerprint Biometrics

Fingerprint biometrics is a form of biometric authentication. That is, it is a security process that relies heavily on the unique biological characteristics of individuals to verify who they say they are. Fingerprint biometric authentication compares a user’s stored fingerprint template in order to validate their identity. Since every human being is born with unique fingerprints, it serves as an “inherence factor” making them impossible to guess or alter. (Identity Automation, n.d.).

## Fingerprint Patterns

Fingerprints are usually taken from the ridges of each finger. Each finger contains a unique pattern and depending on the nature of the system, each finger’s unique pattern may be recorded. There are three basic patterns of fingerprint ridges, these are the arch, the loop and the whorl shown below in the image



### Loops

A loop is a type of pattern in which one or more of the ridges recurves back on themselves to form a loop shape. ( [Fingerprint Analysis: Principles (forensicsciencesimplified.org)](https://www.forensicsciencesimplified.org/prints/principles.html)). A loop fingerprint can start on either side of the finger. It curves up and around and exits on the same side from which it entered. Loops can be broken down further in three more variants. These are

1. Radial Loops: These types of loops run toward the radius bone and thumb. They are uncommon and usually found in the index of the hand.
2. Ulnar Loop: This variation runs in the direction of the ulna bone located in the forearm underneath the little finger
3. Central Pocket Loop: The type refers to a loop pattern that recurves around a central whorl

These variants are determined solely based the bones in the forearm where the loop begins and ends (Michelle Nati, 2019).

### Whorls

The whorl pattern consists of nearly concentric circles. The ridges of a whorl fingerprint can make a turn through at least one circuit. This type of pattern contains four (4) variants.

1. Plain Whorl: A plain whorl has one or more ridges that form a complete circuit.
2. Central Pocket Whorl: This whorl pattern has one or more recurving edges or a right-angle obstruction to the line of flow but no recurving ridge within the pattern is cut or touched. The ridges in a central whorl pattern complete a full circuit and may be any variation of a round shape, including a spiral, oval or circle.
3. Double loop Whorl: In this variation, two separate distinct loop formations make up a double loop. The double loop whorl has two different shoulders for each core. Between the loop formations is at least one recurving ridge within the inner pattern area. This ridge is touched or cut by an imaginary line
4. Accidental Whorl: This type of whorl combines two or more different types of subgroups.

### Arches

Arches are formed when lines cross smoothly at the center of a finger pad. There are two main variations to this pattern and these are:

1. Plain Arch: This is the simplest fingerprint of all. The ridges of a plain arch form on one side of the pad, rise in the center of the pad, then exit the other side. A plain arch fingerprint pattern often resembles a wave.
2. Tended Arch: This variation follows that of a plain arch in that it forms on one side, rises and exits on the other side. The similarities end there however, because unlike the plain arch, the ridges in the center cover each other as they thrust upward. Instead of looking like a wave as described in the plain arch, these resemble a pitched tent (Michelle Nati, 2019)

\*\*\* HAVE SOME TEXT THAT LEADS INTO HOW THESE PATTERNS LEAD TO USAGE

## Security

## How Fingerprint Biometrics are Used Today

Over the years, fingerprint biometrics have become one of the most well-known and publicized biometric modalities due to their consistency and uniqueness.

## Benefits of Fingerprint Biometrics

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# Fingerprint Algorithms

## Algorithm we will use against SIFT

### What is It

### Characteristics

### How it works

### Performance

## Scale-Invariant Feature Transformation

Scale-Invariant Feature Transformation (SIFT) is a computer vision algorithm to describe, detect and match local features in digital images. It locates certain key points and then furnishes them with quantitative information or descriptors that can be used for object recognition. These descriptors are invariant against various transformations such as image translation, rotation and scaling which might make images look different although they represent the same object.( [SIFT - Scale-Invariant Feature Transform (weitz.de)](http://weitz.de/sift/)) SIFT descriptors have also proved to be robust to a wide family of image transformations including viewport changes, noise, blur, scene deformation and contrast changes while remaining discriminative enough for matching purposes. The Scale-Invariant Feature Transform (SIFT) algorithm consists of two successive and independent operations. These are

1. The detection of interesting points (key points)
2. The extraction of a descriptor associated to each of them.

Since these descriptors are robust, they are usually used for matching pairs of images. ( [\*article.pdf](file:///C:\Users\Andy\Downloads\Documents\article.pdf)) . Video stabilization is another popular application of the SIFT method, however, the scope of this research will be limited to image recognition, **more specifically finger print image recognition**. **(KEYPOINT SECTION STARTED FROM HERE)** SIFT detects a series of key points from multiscale image representation. This multiscale representation consists of a set of increasingly blurred images. Each key point is a blob-like structure whose center position and characteristic scale are accurately located. The dominant orientation over a region which surrounds one of these key points. For each key point, the size, center and orientation are normalized. Due to this normalization the key points also remain invariant to any translation, scale change or rotation.

### The Gaussian Scale-Space

In order to attain this scale invariance, SIFT is built on a gaussian scale space. A Gaussian Scale-Space is a multiscale image representation simulating the family of all possible zoom-outs through increasingly blurred versions of the input image ( [\*article.pdf](file:///C:\Users\Andy\Downloads\Documents\article.pdf)). This blurring process simulates the loss of detail produced when a scene is photographed from farther and farther. The scale-space, therefore provides SIFT with scale invariance as it can be interpreted as the simulation of a set of snapshots of a given scene taken at different distances. (**YOU CAN EXPLAIN MORE ABOUT WHAT GAUSSIAN SCALE SPACE IS).**

A scale space is constructed by applying a variable gaussian operator on an input image. **The Difference of Gaussian (DOG)** images are obtained by subtracting subsequent scales in each octave. Octaves are the set of Gaussian-Smoothed images and image. (**MIGHT INSERT IMAGES HERE DETAILING HOW OCTAVES ARE OBTAINED)**

### Gaussian Blurring

In the realm of computing, the gaussian scale space is defined by a series of blurred images using the Gaussian Blur or Gaussian smoothing technique by a Gaussian function. It is a widely used effect in graphics software, typically to reduce image noise or image graininess. However, in computer-vision-based algorithms. It is used as a preprocessing technique in order to enhance images at different scales( [Gaussian blur - Wikipedia](https://en.wikipedia.org/wiki/Gaussian_blur)). In other areas of computer vision, the Gaussian blur is also used as a way to detect edges. Since most edge detection algorithms are sensitive to noise, the gaussian blur serves as a way to reduce the noise in order to make edge detection more accurate. This is a technique the SIFT algorithm uses in order to properly prepare images for feature point detection. In our case, it will be used to prepare fingerprint images for the detection of where the fingerprint arc, whorl or loop begins.

(**MIGHT INSERT SERIES OF IMAGES SHOWING HOW EDGE CAN BE SEEN AFTER BLURRING)**

### Key Point Definition

In SIFT, key points are defined as the **3D extrema** of the normalized scale-space. The extrema are detected by observing each image point in the Difference of Gaussian (DoG) space. The Local Extrema are detected by observing each image point in the Difference of Gaussian Space. A point is decided as a local minimum or maximum when its value is smaller or larger than all its surrounding neighbor points by a certain amount. If an extremum is decided as unstable or is placed on an edge. It is removed because it can not be reliably detected again with small variation of the viewport or lighting changes.

### Difference of Gaussians

Difference of Gaussians (DoG) here refers to a feature enhancement technique that involves the subtraction of one Gaussian Blurred version of an original image from another less blurred version of the original ([Difference of Gaussians - Wikipedia](https://en.wikipedia.org/wiki/Difference_of_Gaussians)). This technique ensures that the spatial information that lie between the (range of frequencies) are preserved between the blurred images, these include visibility of edges and any other key points present in the digital image. **(TLDR it is used to enhance edges to extract key points)**

### Extraction of Candidate Points (Keypoint Localization)

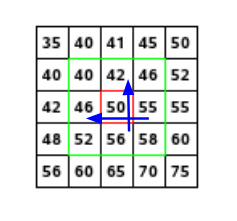
Continuous 3D extrema of the digital DoG are calculated in two steps. Firstly, the 3D discrete extrema are first extracted from each octave with pixel precision. Then their location is refined through interpolation of the digital DoG by using a quadratic model. The resulting image is then compared to its neighbors to detect the 3D discrete maxima and minima. These comparisons are possible due to the auxiliary images in the DoG. Although this process produces candidate points, we can work with, it is prone to noise and as such produces unstable detections and the key points chosen may be flawed since it is constrained to the sampling grid.

### Filtering Unstable Key Points

Noisy images produce erroneous candidate key points thereby making them unstable and unlinked to any particular structure in the image. SIFT attempts to eliminate these false detections by discard those candidate key points found outside the DoG threshold **(STATE WAY TO CALCULATE THRESHOLD).** Another unstable key-points are those on the edges of the image. These candidate key points are difficult to precisely locate due to the fact that an edge is invariant to translations along its principal axis. Such detections do not help define covariant key points and are also discarded.

### Orientation Assignment

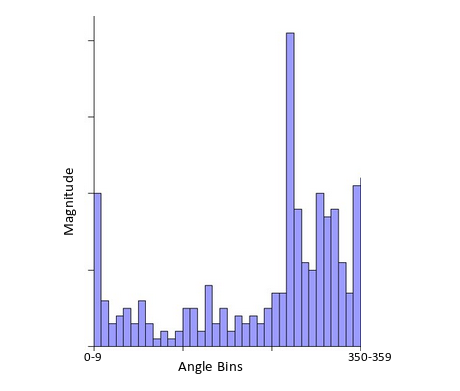
At this point, a set of stable keypoints have been generated and as such, an orientation can be assigned to each of these keypoints to make them invariant to rotation [SIFT | How To Use SIFT For Image Matching In Python (analyticsvidhya.com)](https://www.analyticsvidhya.com/blog/2019/10/detailed-guide-powerful-sift-technique-image-matching-python/#:~:text=SIFT%20helps%20locate%20the%20local,detection%2C%20scene%20detection%2C%20etc.). This is done by computing the magnitude and orientation for each keypoint and then followed by a histogram construction with which we can determine the peak orientation for that particular keypoint. An example is shown below



**LABEL FIGURE**

Consider the matrix above which is a matrix of pixels. To compute the orientation and magnitude for the pixel in red, the gradients in both the and directions are calculated as follows

The magnitude represents the intensity of the pixel while the orientation represents the direction of the pixel. From this a histogram is created by plotting the magnitude and orientation value for all the pixels. An example is shown below;



(**LABEL FIGURE)**

At some point the histogram peaks and from this the orientation of the keypoint is determined making it invariant to rotations.

### Key point Descriptor

In SIFT, descriptors refer to the use of neighboring pixels, their orientations and magnitudes to generate a unique key point.( [SIFT | How To Use SIFT For Image Matching In Python (analyticsvidhya.com)](https://www.analyticsvidhya.com/blog/2019/10/detailed-guide-powerful-sift-technique-image-matching-python/#:~:text=SIFT%20helps%20locate%20the%20local,detection%2C%20scene%20detection%2C%20etc.)). These descriptors fall into two categories, that is

1. Those based on properties of the image that are already rotation-invariant
2. Descriptors based on a normalization with respect to the reference orientation

For the scope of this project, we will use descriptors based on category **(i) (MAYBE EXPLAIN MORE?)**

### Matching

Keypoints between two images are matched by identifying their nearest neighbors. In the event that the keypoints are too close to each other due to image noise, the ratio of the closest distance to second closest distance is taken. The standard ratio for this distance is 0.8 and if they are greater than this, the points are rejected. This ensures that 90% of false matches are eliminated while only discarding 5% of correct matches. [Introduction to SIFT( Scale Invariant Feature Transform) | by Deepanshu Tyagi | Data Breach | Medium](https://medium.com/data-breach/introduction-to-sift-scale-invariant-feature-transform-65d7f3a72d40)

## SIFT on Fingerprint Images