Wavelets Interim Project Report
EE678

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1 Student Details

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2 Problem Statement

It is well recognised that wavelets and multiresolution techniques provide appealing and efficient solutions to address the issue of biometric information verification, identification, and authentication.

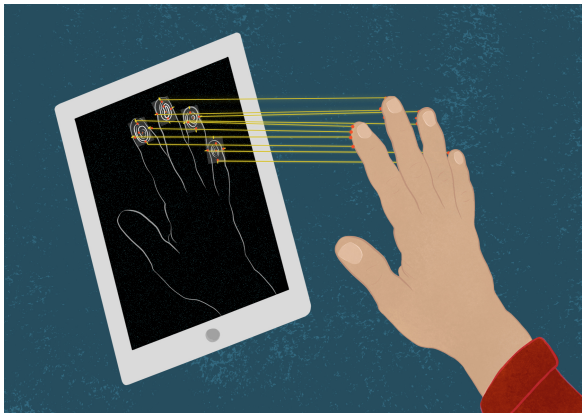
For this course project, we will only be working on physiological biometrics . These consist of fingerprints and iris scans in the beginning, followed by other biometrics like the ear, face, knuckles, and so on, which could be used in future.

Define and clarify what is meant by identification, authentication, and verification in relation to different physiological biometrics that define "figures of merit" for assessment.

Regarding fingerprints: Determine the most efficient way to depict fingerprints using wavelets. As Dr. Azhar explained, start with separable techniques, which are basically 'tensor product' approaches with one-dimensional wavelets. To complete the duties of identification, verification, and authentication, use these representations. Do this while introducing and studying as many potential distortions as you can. Also machine learning methodologies, might be utilised conjunction with the "scattering wavelet network" methodology developed by Stephane Mallat. Introduce strategies to enhance your performance, such as potentially using multiple fingerprints from distinct fingers for the same person or people, rather than just one.

In fact, multiresolution and non-separable wavelet techniques offer appealing biometrics possibilities. Shearlet and curvelet techniques are two examples. Nonetheless, a lot of researchers have a tendency to employ non-separable methodologies, either without fully utilising their benefits or without considering the possibility of combining the finest features of both separable and non-separable approaches. Clearly, combining the two of these ideas will only improve things. Show how to accomplish this with both iris and fingerprints. It will be necessary to do this by deftly using non-separable techniques, maybe in addition to separable ones. Without such expertise and understanding, merely using non-separable procedures is unlikely to provide positive outcomes.

Provide conceptual, analytical, or theoretical ideas that have surfaced during the course of your research and implementations to bolster your findings.



3 Motivation

This project will introduce particular field of signal processing research and development (R&D) and provide the knowledge and skills necessary to thoroughly examine a topic of contemporary significance from all perspectives: conceptual (theoretical, analytical), implementation (realisation, programming, benchmarking), and exposure.

It takes on extra significance because IIT Bombay is being considered by the Unique Identification Authority of India (UIDAI) to lead the country's development of cutting edge contactless biometric technology, which will undoubtedly benefit from strong performance in this course project.

4 Datasets Used

Initially we plan to use the fingerprint dataset : PolyU Contactless Fingerprint to Contact-based Fingerprint Database. This database contains 2976 contatcless 2D fingeprint images and conresponding 2976 contact-based fingeprint from 336 clients. Six contactless and contact-based fingerprint images (impressions) were acquired from each finger.

The size of each contatcless 2D fingerprint image is around 3.60 MB. The size of each contact-based fingerprint is around 64.00 KB. The size of each downsampled contatcless 2D fingerprint image is around 79.00 KB. The database contains contatcless 2D fingerprint images which are stored in bitmap and contact-based fingerprints which are stored in JEPG format.

The first session part of database was acquired from 336 different clients/fingers. Each of the client provided 6 different fingerprint samples (6 images). The second session part of the database contains images from corresponding 160 clients, and each of these second-session clients provided 6 fingerprint samples (6 images) after an interval of 2-24 months. Therefore, there a total of 5952 images were acquired for this database. Given are some of the sample images from the dataset.

Figure 1: Contact sensor image

Figure 2: Contactless sensor image(camera)

Figure 3: Processed Contactless sensor image (grayscaled)

5 Biometrics Image Pre-Processing

Preprocessing steps for fingerprint images are essential to enhance the quality of the images and prepare them for further analysis or recognition tasks. There are various preprocessing algorithms that can be used which each has there own advantages. Given below is a list of pre processing that can be used for biometrics fingerprints however we will need to try these methods before applying directly :

- Histogram Equalization : Histogram equalization is beneficial for fingerprint datasets because it can improve the visibility of features in the image, such as ridge patterns and minutiae points. This can make it easier for fingerprint recognition algorithms to extract and match features, leading to better recognition performance. Additionally, histogram equalization can help to normalize the brightness of fingerprint images, which can make them more robust to variations in lighting conditions.
- Binarization/ Adaptive Thresholding : Adaptive thresholding is a type of binarization that uses a different threshold value for each pixel in the image. This can help to preserve the fine details of the fingerprint, while still removing noise and artifacts.
- Minutiae Extraction :Minutiae points are unique and stable features of fingerprints which reduces the complex fingerprint image into a set of coordinates and orientations, significantly reducing storage requirements and computational complexity. This makes it easier to compare and match fingerprints efficiently.
- Sobel Operator : It is a simple and efficient edge detector that can be implemented using a convolution kernel. The Sobel operator calculates the gradient magnitude and orientation at each pixel in the image. The gradient magnitude is a measure of how strong the edge is at that pixel, and the gradient orientation is a measure of the direction of the edge. This operator is sensitive to noise but we will already use the noise cancellation to remove the noise.

6 Wavelet Application

We have tried to incorporate the non-separable approach for the image feature extraction. The non-separable methods include shearlets and curvelets as taught by Dr. Azhar. However, these are by default not available in python as library therefore we needed to code the shearlet from scratch. We have successfully been able to code and get transforms of the shearlets and these are the results till now. Since our feature extraction part is completed, we will now work on identify and using these features efficiently and accurately.

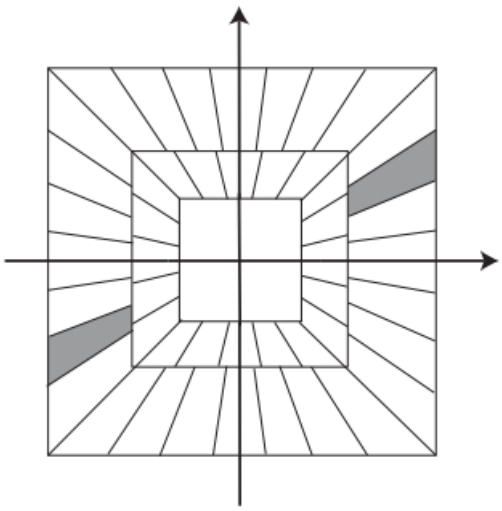
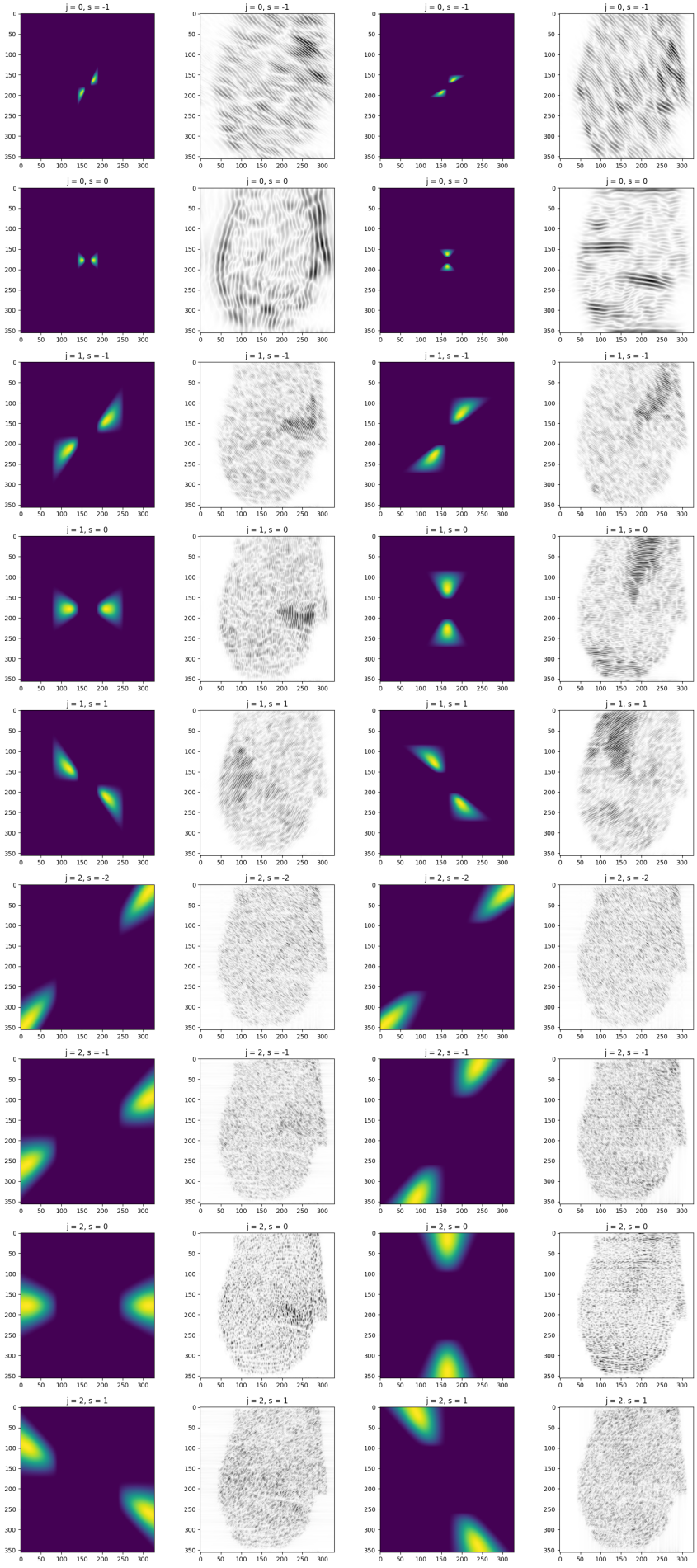


Figure 4: Tiling of Fourier domain induced by the cone-adapted discrete shearlet system associated with classical shearlets

Figure 5: Filter mask and filtered fingerprint for values of j and s for both ψ and $\tilde{\psi}$ of a scanned fingerprint



7 Planned Work

We plan to incorporate some Machine Learning Techniques to learn the features that are used to detect and verify fingerprints. Given below are 2 of the model techniques that we plan to implement :

- Siamese Model : This type of neural network is used to compare two inputs. It is particularly useful for fingerprint dataset models because it can be used to learn to extract features from fingerprints that are invariant to changes in rotation, translation, and scale. This makes it possible to build fingerprint matching systems that are more robust to noise and variations in the way that fingerprints are captured. In addition, Siamese networks can be used to learn to distinguish between genuine and fraudulent fingerprints. This is useful for building fingerprint-based authentication systems that are more secure.
- Few Shot Learning : Few-shot learning is particularly useful for fingerprint dataset models because fingerprint datasets can be difficult and expensive to collect and label for example our dataset has only 6 images per person, With few-shot learning, it is possible to train accurate fingerprint dataset models with only a small number of labeled examples in our case 6.

Other than these we will try to use scattering wavelet transform (SWT) which was explained in the lectures by Stephane Mallat. SWT works by decomposing the fingerprint image into a series of wavelet scattering coefficients. These coefficients capture the local texture and frequency information of the image. SWT is also able to capture long-range dependencies in the image, which is important for distinguishing between different fingerprint patterns.

8 Acknowledgement and Conclusion

Therefore the interim project report is competed. Thanks a lot to Professor Gadre to give such a great learning project.