Fingerprint Enhancement Using Unsupervised Hierarchical Feature Learning

Thesis Synopsis

Mihir Sahasrabudhe
200802023
Centre for Visual Information Technology

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The use of fingerprints is an important method for identification of individuals in today's world. They are also one of the most reliable biometric traits, besides the iris [1]. Fingerprint recognition refers to various tasks that are associated with fingerprint identification, verification, feature extraction, indexing and classification. There are a lot of systems, in a variety of domains, that employ fingerprint recognition. That being a given, precision in fingerprint recognition is essential.

Identification using fingerprints is done using a feature extraction step, followed by matching of these features [1]. The features that are extracted to be matched depend on the algorithm being used for identification. In large databases of fingerprints, like government records, fingerprints might be indexed before they are matched. This significantly reduces the time required to identify an individual from records, as comparing his/her prints with every entry in the database will take a enormous amount of time. In either case, feature extraction plays an important role. However, feature extraction is affected directly by the quality of the input image. A noisy or unclear fingerprint image might affect the extraction of features strongly [2]. To counter noise in input images, an extra step of enhancement is introduced before feature extraction and matching are performed. The goal of extraction is to improve quality of ridges and valleys in the fingerprint by making them clearly distinguishable, but in the process, also preserve information. The enhancement algorithm should not only not omit or remove existing information from the fingerprint, but also not introduce any spurious features that were not present in the original image.

The considerable research into fingerprint recognition, and in fingerprint enhancement, has contributed to the large number of existing algorithms for image enhancement. These include pixel-wise enhancement [3], contextual filtering [2, 4, 5], and short-time Fourier analysis [6], to name a few. Contextual filtering uses specific filters to convolve the input image with, the filters themselves being governed by certain parameters dependent on the input image. These parameters are determined by the values of certain features at every pixel in the input image. This requires extraction of pre-defined features from the fingerprint. For instance, the filter used at a point is affected by the ridge orientation at that point. Hence, to decide the filter to be used, the ridge orientation at that point needs to be extracted. A similar case can be observed in other types of algorithms too.

In this thesis, we propose that unsupervised feature learning be applied to the fingerprint enhancement problem. We use two different scenarios and models to show that unsupervised feature learning indeed helps improve an existing algorithm, and also when applied directly to greyscale images, can complete with robust contextual filtering and Fourier analysis algorithms. Our motivation lies in the fact that there is vast amount of available data on fingerprints; and with the recent advances in deep learning, and unsupervised feature learning in particular, we can use this available data to learn structures in fingerprint images.

For the first model, we show that continuous restricted Boltzmann machines [7] can be used to learn local fingerprint orientation field patterns, after which their learning can be used to correct noisy, local ridge orientations. This extra step is introduced between orientation field estimation and contextual filtering. We show that this step improves the performance of matching done on the enhanced images. In the second model, we use a 2-layered convolutional deep belief network [8] to learn features directly from greyscale fingerprint images. We show that having a deep neural network significantly improves the quantitative and qualitative performance of the enhancement. The deep network helps in predicting noisy regions, that were otherwise not reconstructed by the first layer only. Further, a trained convolutional deep belief network can estimate or extract other features from fingerprint images too. For instance, the orientation field used to determine the parameters of a filter used in contextual filtering is a feature that can be estimated by the neural network. This is possible by performing a weighted average of the values of these features for the first layer filters, weighted by the reconstruction performed by the network.

In conclusion, we have explored a new direction to attack the fingerprint enhancement problem. We conjecture that it is possible to extend this work to other problems involving fingerprint recognition too. For instance, synthetic fingerprint generation might be accomplished using the convolutional deep belief network trained on fingerprint features. Our experiments show a several potential experiments for the future which can give promising results. Future work also includes developing or training a single network that is capable of performing major fingerprint recognition tasks: enhancement, matching, and classification.

References

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