Survey on Parameters of Fingerprint Classification Methods Based On Algorithmic Flow

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Abstract.

Classification refers to assigning a given fingerprint to one of the existing classes already recognized in the literature. A search over all the records in the database takes a long time, so the goal is to reduce the size of the search space by choosing an appropriate subset of database for search. Classifying a fingerprint images is a very difficult pattern recognition problem, due to the minimal interclass variability and maximal intraclass variability. This paper presents a sequence flow diagram which will help in developing the clarity on designing algorithm for classification based on various parameters extracted from the fingerprint image. It discusses in brief the ways in which the parameters are extracted from the image. Existing fingerprint classification approaches are based on these parameters as input for classifying the image. Parameters like orientation map, singular points, spurious singular points, ridge flow, transforms and hybrid feature are discussed in the paper.

Key words:

Singular points, Ridge flow, Orientation map, Spurious singular points, Multiple classifier, Transforms.

1 Introduction

Fingerprint Classification is an important sub-problem for the automatic fingerprint identification system (AFIS) and automatic fingerprint recognition system (AFRS). This database may be very large (e.g., several million fingerprints) in many forensic and civilian applications. In such cases, the identification takes a long response time. The authentication process can be fastened by reducing the number of comparisons that are required to be performed. It can be achieved by partitioning the fingerprint database into a number of classes. A fingerprint to be identified is then required to be compared only to the fingerprints in a single class of the database based on its features. The well-known Henry's Classification scheme divides a fingerprint structure into three major classes or patterns namely Arch, Loop and Whorl. Figure. 1 displays an algorithmic flow for selection of features and classification of fingerprint. Beginning with generation of orientation map or ridge flow, it follows the flow to be used for different methods for classification. Orientation map helps to locate singular points. It is possible to get false/spurious singular points while search for genuine singular points. Hybrid class is formed by the combination of the orientation map, ridge flow or real singular points.Transforms are used to extract features,thus making it easier to analyze image by reducing the dimension.. These features can be given as input to neural network, clustering algorithm, hidden markov model, rule based approach, genetic algorithm, etc to improve the performance of classification method.

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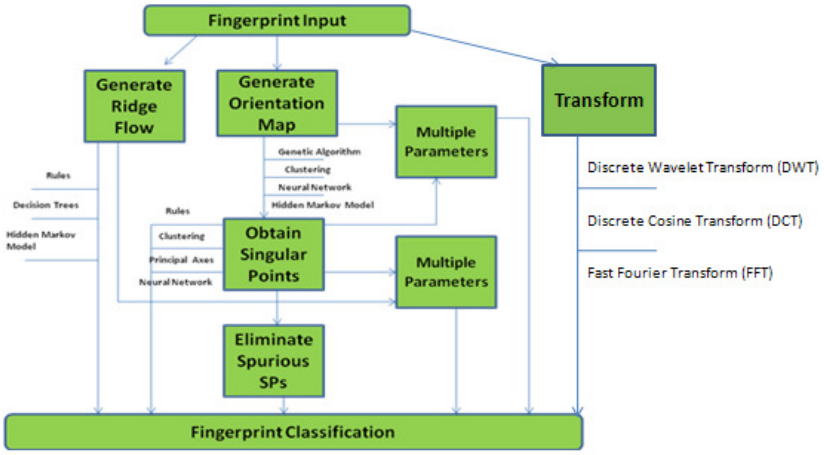

Fig 1: Algorithmic approach for classifying fingerprint image.

2 RELATED WORK

This section glances through various fingerprint classification methods based on the parameters extracted. The following parameters are used for differentiating between various methods: Orientation map, Singular points, spurious singular points, Ridgeline flow and Multiple parameters based methods[31].

2.1 Orientation Map

Orientation map describes the orientation of the ridge-valley structures. The Direction Field can be derived from the gradients by performing averaging operation on the gradients, involving pixels in some neighborhood [23]. Wei and Chen [14] have suggested an improvement in the computation of direction field which gives more accurate information about the ridges and the valleys as shown in figure 2.

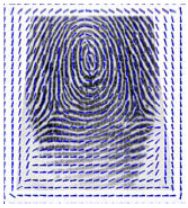

Fig 2: Smoothed Orientation Field

Cappelli et al. [8] have presented a new approach for fingerprint classification which uses masks for partitioning orientation image. Dynamic masks help to bring stability during partition process. Sylvain et al. [9] uses direction map to capture features which is given to Self Organizing Map for further classification. Guo et al. [10] have presented a statistical approach for fingerprint classification using Hidden Markov Model (HMM). HMM is like a finite state machine in which not only transitions are probabilistic but also output. Feature vector is obtained by getting the local orientation for each block. This observation vector is fed as input to HMM. Krasnjak and Krivec [11] have used quad tree principle to divide the direction map according to homogeneity,which is used as feature vector for neural network using MultiLayer perceptron. Xuejun and Lin [12] have proposed an algorithm based on genetic programming for fingerprint classification. In this paper genetic programming tries to explore a huge search space which cannot be done by human experts.Features are generated from orientation field using genetic programming.

Jiang et al. [13] have given a combined classification approach by performing exclusive and then continuous classification [26]. In exclusive classification, first clustering is performed to form similar groups of data in the database then the query image's orientation field is compared with the cluster representative which reduces search time. In continuous classification the query images orientation map is compared to the fingerprints in the received cluster. Luping Ji, Zhang Yi [15] have presented classification approach using Support Vector Machine (SVM). SVM is a learning theory useful in pattern classification. Four directions (0, $\pi/4$, $\pi/2$, $3\pi/4$) are used for orientation field representation. Fingerprints are then classified using the output of the trained classifier. Sivanandam and Anburajan [16] have used neural network for classification. Jiaojiao Hu, Mei Xie [18] have introduced a classification technique using combination of genetic algorithm and neural network. Orientation field is given as input to genetic programming process. Features are given as input to backpropagation network and Support Vector Machine (SVM) for classification of fingerprints.

2.2 Core and Delta points

Within the pattern areas of loops and whorls are enclosed the focal points which are used to classify fingerprints. These points are called as core and delta. The delta is that point on a ridge at or in front of and nearest the center of the divergence of the type lines. The core is present when there is atleast one ridge that enters from one side and then curves back, leaving the fingerprint on the same side as shown in figure 3.

Fig 3: Right Loop with core (red) and delta (green)

Approaches for singularity detection operate on the fingerprint orientation image. Poincare index proposed by Kawagoe and Tojo (1984) is an elegant and practical method to detect singular points. It is computed by algebraically summing the orientation differences between adjacent elements [22]. Poincare index is evaluated for every pixel in the directional image. M.Usman, Assia Khanam [19] have suggested an optimal way of locating core point by extracting the region of interest.

Wang and Zhang [1] have enhanced the fingerprint image to reduce the effect of noise and detected singular points using Poincare Index. Feature Vector is obtained by finding the region of interest [24] using core point. Finally clustering algorithm is

used for classification.Liu and Zhang [2],Klimanee and Nguyen [3] and Msizia and Ntsika [5] have preprocessed image and have presented a novel way of locating core and delta points.

Classification is done by defining rules based on the number of singular points.Classification is performed using principal axes in [3]. Srinivasan and Rakesh [4] have proposed a technique based on neural network. They have used PCA (Principal Component Analysis) to reduce the size of the feature space. Singular points detected are then given to SOM (self-organized map) which is an unsupervised learning neural network.

2.3 Ridgeline Flow

The flow of the ridges is an important discriminating characteristic. It is not always easy to effectively extract ridges from noisy fingerprints. It is a parameter more robust than singular points. The ridge line flow is usually represented as a set of curves running parallel to the ridge lines as in figure 4; these curves do not necessarily coincide with the fingerprint ridges and valleys, but they exhibit the same local orientation.

Fig 4 : Tracing of Ridges

Andrew [6] has described a classification technique based on the characteristics of the ridges. Two new classifiers have been presented in the paper. The first classification described is by using Hidden Markov Model (HMM). In fingerprint image the direction changes slowly hence HMM is suitable here for classification. The ridgelines are typically extracted directly from the directional image, then the image is binarized and thinning operation is performed, features are extracted that denotes the ridge behavior. The second classification described is using Decision Trees. Features are extracted and classified using a decision tree approach. Features are extracted at significant points on the ridges and a decision tree is constructed based on the questions about the features and the relationship between those features. Neeta and Dinesh [7] have presented an approach for classification based on ridge flow. To reduce computation high ridge curvature region is extracted using Sobel operator and direction map. HRC is calculated based on the values of the slope within the block. After locating HRC, Ridge tracing is performed. Hye-Wuk and Lee [17] have published classification approach using HMM. Features are extracted from orientation field by locating the direction of the extracted ridge which is then taken as input for HMM for designing fingerprint models.

2.4 Removal of Spurious singular points

Accuracy in finding singular points is reduced if the image is of poor quality as shown in figure 5.

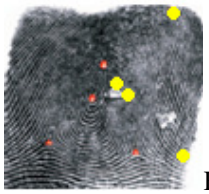

Fig 5 : Spurious Singular Points (yellow)

Zhou et al. [20] work is based on DORIC (Differences of Orientation values along a Circle) feature an extended form of Poincare Index. These are given to Support Vector Machine to design classifier. F.Magalhães et al.[29] uses constraints to remove extra singular points by treating them as centeroid if they are too close and deleting a pair of core and delta if distance between them is less than threshold. N.Johal et al.[30] presents an algorithm to fine tune orientation map by finding the direction of gravity. Blocks are found whose slope is in the range of 0 to pi/2 to obtain singular points.

2.5 Multiple Classifier

Different parameters potentially offer extra information about the patterns to be classified, which may be exploited to improve performance of algorithm.

Jain, Prabhakar, Hong [21] have come up with a novel scheme to represent ridges and valleys of a fingerprint. It uses orientation field to detect core and delta points. 2 stage classification is done, firstly K nearest neighbor to find most likely classes and secondly neural network for further classification.Zhang,Yan [25] have used core and delta points and ridge flow as feature vector. Using singular point, ridge is traced in opposite directions to find the turn number. It then uses rules for classification. Wang,Chen [14] is based on singular points and orientation map. Their feature vector includes number of singular points, angle from delta to core, average

of the directions in region of interest. Further, Fuzzy Wavelet Neural Network is used for classification.Wei and Hao [27] have used singular points and ridge flow mthods for feature extraction. In the first level ridgelines are classified and classification is done based on it. In the second level the ridge count between singular points is used for further classification.

2.6 Transforms

In Fourier Transform the basis function is sine wave whereas wavelet transform is based on small waves called wavelets of different frequency and fixed duration. Thus, providing frequencies and when it occurs. Fourier Transform gives only frequency information, time information is lost in transformation process. M.Mokji et.al have used Haar Wavelet transform is used to construct directional image. H.Neto et.al have used Discrete Wavelet Transform is used to extract feature and classification is done using neural network. C.Park et.al have constructed Directional image using Fast Fourier Transform. C.Jin et.al features are extracted using Discrete Cosine Transform (DCT).

CONCLUSION AND FUTURE WORK

Fingerprint classification is a challenging pattern recognition task that has captured the interest of several researches during the last 30 years. A number of approaches and various feature extraction strategies have been proposed to solve this problem.A Parameter based flow diagram has been generated which will provide a base for the user to understand the approach used for building the algorithm for fingerprint classification. Various approaches of fingerprint classification like rule based, neural network based, genetic algorithm based, ridge flow based reveals that neural network based classification provides better results compared to other techniques. Neural Network using back-propagation algorithm gives good results as it learns complex relationship but it consumes a lot of time for training. In Future we would like explore various pre-processing techniques so as to get accurate orientation map followed by final classification result.

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SUMMARY

Sr.No	Approach	Characteristic	Advantages	Disadvantages
1.	A.Senior, 2001	Hidden Markov Model Features are extracted by intersecting fiducial lines with ridges. Classification is done by calculating the probability of data with each class. Decision Trees Features are extracted at significant points on the ridges. Classification is made by constructing a decision tree based on the features extracted. PCASYS is used to classify fingerprint to improve accuracy.	Avoids extraction of global features. Improved accuracy due to combination of classifiers.	Computation increases Can lead to over fitting
2.	N. Nain, B. Bhadviya, B. Gutam, D.Kumar and Deepak, 2008	First stage : High Ridge Curvature region is extracted using Sobel operator. Blocks having slope in the range 0 to 90 are located. Second stage: Ridge is traced from center in both directions and features are extracted. Classification is done based on defined conditions for every class.	Avoids extraction of global features. Discontinuous ridges are joined by using Gabor filter.	Classifying a ridge outside HRC leads to wrong results.
3.	H. Jung, J. Lee, 2009	Ridge Direction is taken as feature. Markov Model is trained and used for classification.	Improved Accuracy	Deciding window size is crucial.

Table 1 : Summary of method for Ridgeline Flow parameter

Sr. No	Approach	Characteristic	Advantages	Disadvantages
1.	R. Cappelli and A. Lumini, 1999	It is a guided segmentation process. It partitions the directional image based on dynamic masks . Two methods are suggested for classification	It does not require singularities. It is rotation and translation invariant.	Segmentation approach might not always give same result for same image.
2.	S.Bernard, N.Boujemma, D.Vitale, and C.Bricot, 2001	Image is processed using gabor filter and orientation map is calculated. Poincare index is used for separation of SPs and is stored as features. Classification is done using Self Organizing Maps.	It resolves large intra-class variability.	Fails on poor quality images. Training consumes time.
3.	S.Mohamed and	Directional image in 4 directions is computed from a binarized image. SPs are calculated using range based	Accurate detection of singular points.	Generalization can lead to wrong results. Learning process is time

	H.Nyongesa, 2002	on observation. Features are encoded in a vector and given to fuzzy neural classifier for classification.		consuming.
4.	H.Guo, Z.Ou and Y.He, 2003	Orientation field is calculated using gradient method. Features are extracted block-wise. Vector is formed using orientation field. Classification is performed using Hidden Markov Model.	Enhancement of fingerprint image is not required. Singular points are not required.	Fails if image quality is low.
5.	L. Sha and X.tang, 2004	It combines exclusive and continuous classification. Singularity approach Exclusive method uses orientation map to classify images. Continuous method used parameters based on ridges and SPs to classify. FingerCode approach Reference point is located using orientation map and FingerCode is generated. Novel exclusive classification approach is proposed.	The proposed approach leads to smaller search space thereby saving time.	Missing SPs will lead to wrong results in singular based method. SPs are manually located to improve accuracy. FingerCode method can tolerate missing delta.
6.	X.Tan, B. Bhanu, and Y. Lin, 2005	Orientation map is based on gradient method. Computation and feature generation operators are used to generate feature vectors. Classification is done using Bayesian classifier.	Search space explored by genetic algorithm is beyond human experts.	Low quality images can lead to wrong results. Overfitting can occur.
7.	D.Krašnjak and V.Krivec, 2005	Orientation map is calculated and divided into 4 tiles. Homogeneity coefficient is computed for every tile till maximum level has reached. Homogeneity vector constructed is given as input to MultiLayer perceptron for classification.	Can learn complex relationships more quickly SPs are not required.	Training consumes a lot of time. Requires target values.
8.	X.Jiang, M. Liu and A. Kot, 2006	Clustering is performed to divide the database into respective classes. K-means algorithm is used to resolve intra class variability. Continuous classification is performed after clustering to improve the performance of classification.	This approach speeds the process of querying the database.	SPs are required for exclusive classification.
9.	W.Wang, J.Li and W.Chen,2006	Orientation map is generated using least mean square method. It is further improved by an estimation approach presented in the paper. Singular points are extracted using Poincare index. Features are extracted from SPs and given as input to fuzzy wavelet neural network.	Provides improved accuracy	Requires accuracy in locating singular points.
10.	K.Umamaheswaril, S. Sumathil,S. Sivanandaml and K. Anburajan, 2007	Orientation map is generated to fetch the minutiaes using least mean square method. Feature vector is given as input to Back Propagation network and Learning Vector Quantization for classification	Improved efficiency and accuracy in classifying images. Reduced computational complexity due to wavelet compression of feature vector.	Selecting initial parameter values is sensitive.

11.	Luping Ji and Zhang Yi, 2007	Least Mean square method is used to generate orientation map. Consistency is calculated to improve quality of orientation field. Feature vector is computed from the percentage of direction map blocks. It is given as input to Support Vector Machine for classification.	Improved accuracy in classifying images. SPs are not required.	Training period consumes more time than classification.
12.	J.Hu and M.Xie, 2010	Orientation map is calculated using gradient method. Features are generated from orientation field using Genetic Programming. Features are given as input to backpropagation network, if there is ambiguity in classification then SVM is used.	Combining Backpropagation network with SVM gives better results for classification.	Overfitting can occur. Approach is dependent on SPs

Table 2 : Summary of methods for Orientation_Map parameter

Sr.No	Approach	Characteristic	Advantages	Disadvantages
1.	B. Cho, J.Kim, J. Bae, I. Bae, and K.Yoo, 2000	Poincare Index is used to detect core. Number and curvature of cores are used for classification.	Delta is not required for classification.	False core point is not eliminated completely
2.	Y. Liu, S. Yuan, X. Zhu, Y. Zhang, 2002	It uses thresholding for preprocessing. Poincare index is modified to improve accuracy.	Efficient Classification results.	More computations due to modified Poincare definition.
3.	S.Wang, W. Zhang and Y. Wang, 2002	A new feature for fingerprint classification is used to effectively represent the structure of a fingerprint. K means classifier and 3 nearest neighbor is used for clssification	Can operate on low quality fingerprint images (missing core and delta).	More computations due to Euclidean distance.
4.	J.Malinen, V.Onnia, M.Tico, 2002	Gabor filters are used for feature extraction. Multiple Discriminant analysis is used for classification.	It reduces inter-class variance and keeps intra-class variance same.	Reference point might be lost if cropping is not properly done. Deciding Singular value and Gabor filter parameters is crucial.
5.	C. Klimanee and D. Nguyen	Every block is given ridge flow code. Singular points are present in the region where all six codes exists or converge. Singular point is found in the region where variance is maximum. Concept of principal axes is used for classification for classes that have same number and type of singular points.	Accurate location of singular points. Clearly differentiates arch and tented arch.	It fails when singular points are not detected.
6.	T.Srinivasan S.Shivashankar Archana.V B.Rakesh,2006	Features are extracted using PCA (Principal Component Analysis). Fuzzy ant clustering algorithm is used to find optimal cluster centers. Classification is done using LVQ2(learning vector quantization)	Improves accuracy of classification.	Computationally complex.

		technique and SOM(Self-organizing maps).		
7.	M. Akram, A.Tariq, S. Nasir, A. Khanam,2008	A novel idea is proposed for gradient based segmentation. Mean of gradients and their standard deviation is calculated. Orientation filed is estimated accurately. Core point is located using Poincare Index.	Works on low quality images. Optimal Core point is detected.	---
8.	I.Msiza, B. Leke-Betechuoh, F. Nelwamondo and N. Msimang,2009	Defines new rule-based classifier for classification.	Can classify fingerprints in case of missing data for loops.	Will fail if singular points are detected.

Table 3 : Summary of methods for Core n Delta parameter

Sr.No	Approach	Characteristic	Advantages	Disadvantages
1.	J.Zhou, F.Chen and J.Gu, 2009.	It is based on DORIC (Differences of Orientation values along a Circle) feature an extended form of Poincare Index. A two-stage classifier is designed, first stage, valid SPs are found using their DORIC feature, second stage, classifier is designed using SVM(Support Sector Machine)	Detects and Eliminates Spurious SPs.	Images with missing SPs will be rejected.
2.	F.Magalhães, H.Oliveira, A.Campilho, 2009	Spurious SPs are removed using post-processing constraints after applying Poincare Index. Later DORIC feature is used. Constraints : If two Cores or Deltas are too close then they are represented by a centroid. If the distance between a Core and Delta is less than threshold then both points are deleted.	More accurate and robust.	Efficiency degrades rapidly for very poor images, since SPs are not clearly visible.
3.	N.Johal, A. Kamra, 2011	An algorithm is proposed to fine tune orientation map. Direction of gravity is obtained to fine tune orientation field block-wise. Slope ranging between 0 to pi/2, such blocks are located to obtain singular points.	Gives accurate results.	Approach fails for images which are too oily or wrinkled.

Table 4 : Summary of methods for removal of spurious singular points.

Sr.No	Paper	Method	Advantages	Disadvantages

1.	M.Mokji et.al	Haar Wavelet transform is used to construct directional image. Directional image is quantized to one of the eight directions in the range -90 to 90. Classification is done based on the patter of alteration track.	Wavelet transform reduces the pixels to be processed so that the processing time can be reduced too. Easy to identify left and right loop.	Noise affects classification results.
2.	H.Neto et.al	Image is preprocessed using high pass filter then equalized using histogram equalization. Region of Interest is found using segmentation. Discrete Wavelet Transform is used to extract feature and classification is done using neural network.	Better results are achieved due to pre-processing of fingerprint image.	Algorithm is susceptible to rotation and translation
3.	C.Park et.al	Directional image is constructed using Fast Fourier Transform. Linear Discriminant Analysis is used to reduce intra class variability and maximize inter class variability. Classification is done based on centroid method.	Approach is effective on low quality fingerprint images. Computations are reduced during classification due to reduced dimension space.	
4.	C.Jin et.al	Features are extracted using Discrete Cosine Transform (DCT), Fuzzy c-means clustering technique and Fisher's Linear Discriminant technique to clearly distinguish inter-class images. Gaussian function is used as radial basis function (RBF) for approximating the data.	DCT reduces dimensions of a fingerprint image, thereby increasing the speed of processing. RBF provides faster training process.	Identifying the number of hidden neurons

Table 5 : Summary of methods for Transform parameter.