MINISTRY OF EDUCATION AND SCIENCE OF THE RUSSIAN FEDERATION
Federal State Educational Institution of Higher Education
"South Ural State University" (National Research University)

A New Approach to Detect the Regions of Interest of Fingerprint Images

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Relevance

- Fingerprint Recognition based applications have been adopted in diverse scenarios, such as forensics area.
- Image processing technology supports most of the techniques used in biometrics.
- Among all the biometric techniques, fingerprint-based identification is the oldest method which has been successfully used in many applications.
- Everyone is known to have fingerprints unique.
- A fingerprint is made of a series of ridges and valleys on the surface of the finger.

Applications

- Banking Security - ATM security, card transaction
- Physical Access Control (e.g. Airport)
- Information System Security
- National ID Systems
- Passport control (INSPASS)
- Voting
- Smart Phone
- Identification of Criminals
- Identification of missing children

Motivation

- New products in a user friendly and low cost method. These challenges and possibilities motivated us to investigate innovative methods which would benefit large-scale fingerprint identification systems in terms of accuracy, speed and security.

Research Methods

- Our study depended on the methods of probability theory are used, Mathematical statistics, mathematical morphology, image processing, mathematics modeling, pattern recognition and machine learning.

Problem Statement

Segmentation in low quality images is challenging. The first problem is the presence of noise that results from dust and grease on the surface of live-scan fingerprint scanners. The second problem is false traces which remain in the previous image acquisition. The third problem is low contrast fingerprint ridges generated through inconsistent contact, dry/wet finger surface. The fourth problem is the presence of an indistinct boundary if the features in the fixed size of window are used. Finally, that is the problem of segmentation features being sensitive to the quality of image.

Accurate segmentation of fingerprint images influences directly the performance of minutiae extraction. If more background areas are included in the segmented fingerprint of interest, more false features are introduced; If some parts of the foreground

are excluded, useful feature points may be missed.

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Challenges

- New problems also emerge along with the extensive deployment of fingerprint recognition systems.

- During the recognition process, Accuracy of recognition and a shorter response time is always desirable when an individual needs to be identificion in a system with a database consisting of millions of fingerprints. In some systems, the database's size is continuously growing.

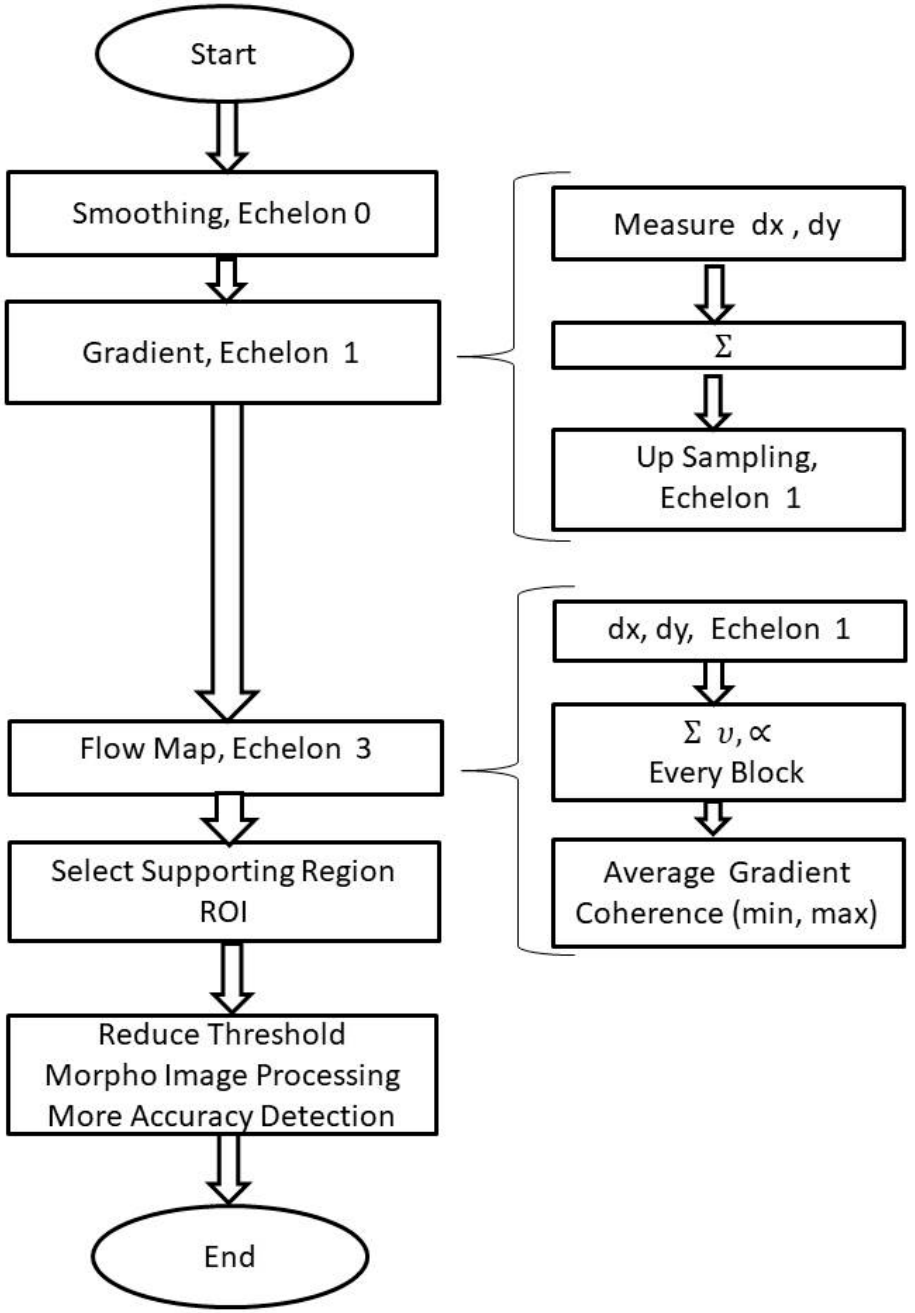
Model

- To develop a mathematical model for images smoothing, gradient calculation, flowmap bulding and region of interest segmentation .
- To develop algorithms for parallel image pressing to recognizes rigen of interast during shoutes time productivity .
- To develop a method and algorithm for constructing unique clustering method to recognize region of interest.
- Implement the developed models, methods and algorithms in the form of Program beast on C++ that allows segment fingerprint image .
- Carry out computational experiments confirming the effectiveness of the proposed methods.

Implementation

- Fingerprint image acquisition 500 dpi double fingerprint images 1000 dpi to calculating Gradient and Smoothing images by 1000 dpi and measuring up sampling different dx, dy images 1000 dpi. Then, calculate Magnitude and Argument Gradient Images by 500 dpi. than select maxim coherence for each block
- Building and measuring Gradient by using special scheme
- Measuring minimum and maxim coherence map, than select maxim coherence for each block.
- Measuring minimum and maxim magnitude of Flow map, than select minimum magnitude for each block.
- Compare between maxim coherence and minimum using special formal according human sense

Algorithm Flowchart



Fingerprint image (a) 500 dpi and (b) 1000 dpi

$$a(x,y)=(b(x,y)*\tau+b(x+1,y)(1-\tau))*\tau$$
$$+(b(x,y+1)*\tau+b(x+1,y+1)(1-\tau))*(1-\tau)$$

a, b

Smoothed image 500 dpi

$$\acute{S}=(f(x,y)+f(x+1,y)+f(x,y+1)+f(x+1,y+1)/4$$

(a) the difference along x axis and
(b) the difference along y axis,
based on the image 500 dpi

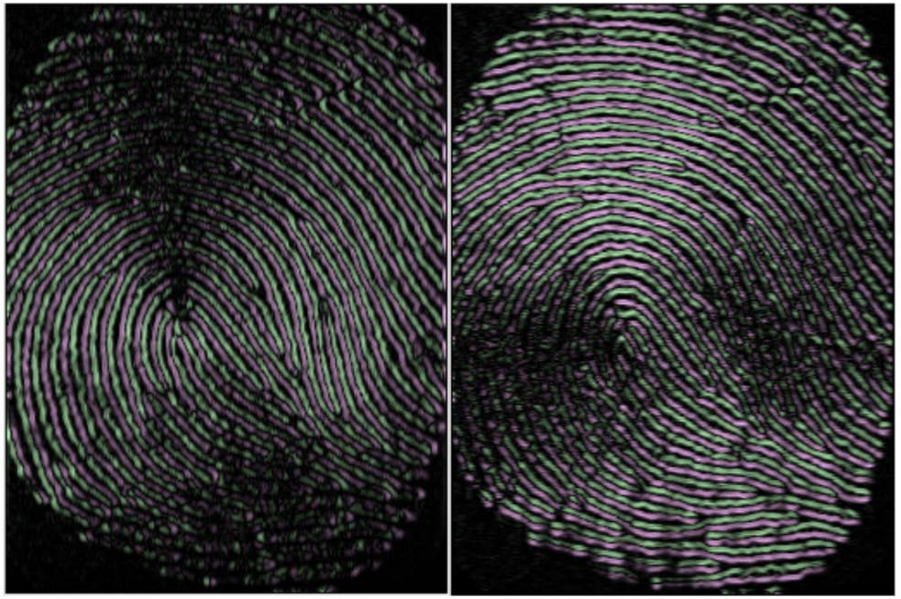
$$dx(x,y)=sh+sb-sf-sd$$

$$dy(x,y)=sb+sd-sf-sh$$

$$dxt\left(\frac{x}{2},\frac{y}{2}\right)=dx(x,y)$$

$$dyt\left(\frac{x}{2},\frac{y}{2}\right)=dx(x,y)$$

a, b



(a) Arguments of gradient $\propto (x, y)$,

$$\beta_i = Arctg\frac{Im\, S_i}{Re\, S_i},$$

(b) magnitude of gradient $m(x,y)$,

$$m(x,y)=\sqrt{dx_{\uparrow}^2\,(x,y)+dy_{\uparrow}^2\,(x,y)},$$

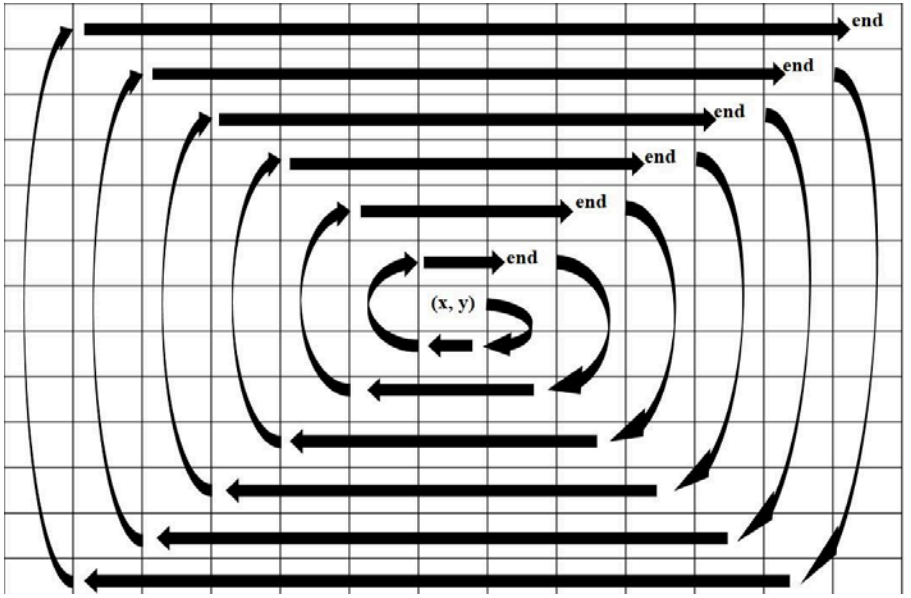
based on the image 500 dpi.

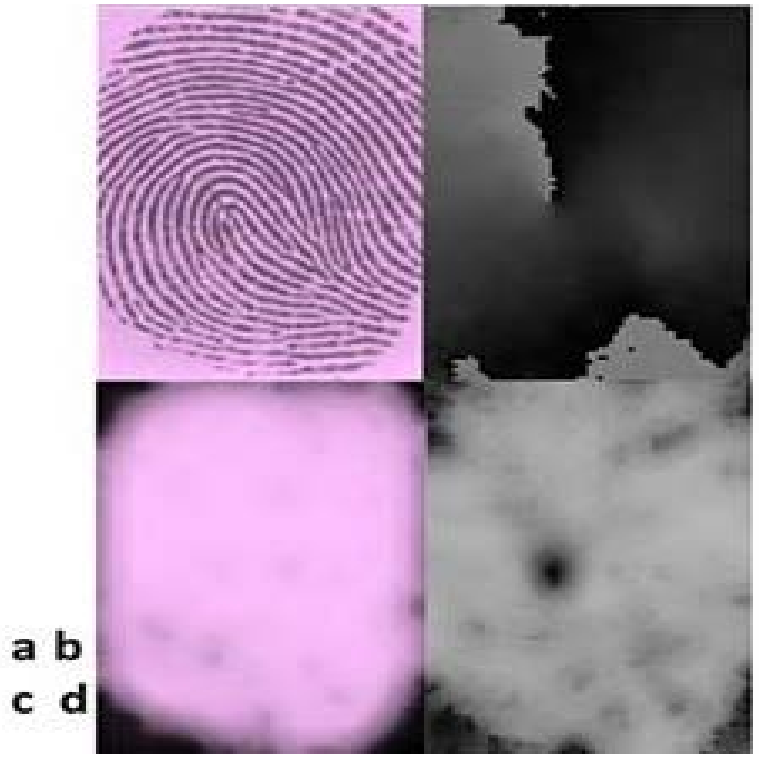
a, b

Develop our cluster, we select minimal coherence and maximal coherence

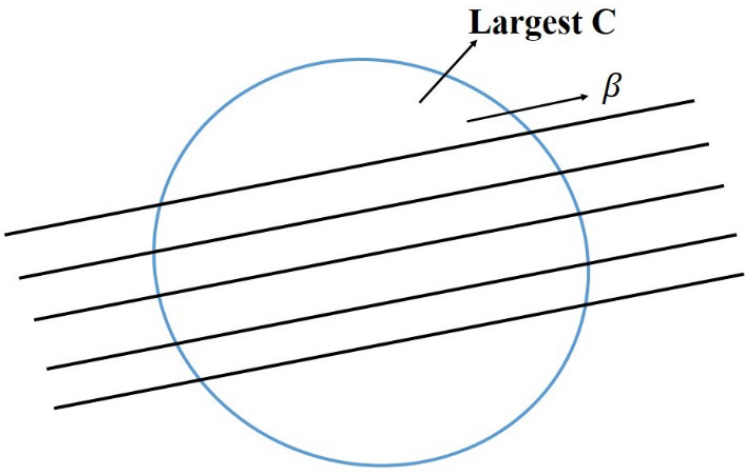
$$C_{min}(x,y) = \min_i C_i(x,y) ,$$

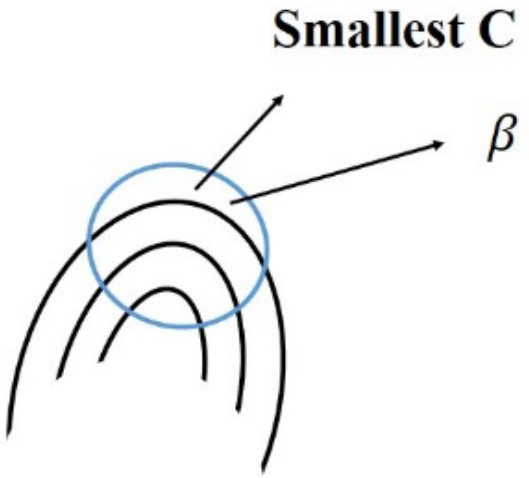
$$C_{max}(x,y) = \max_i C_i(x,y) ,$$





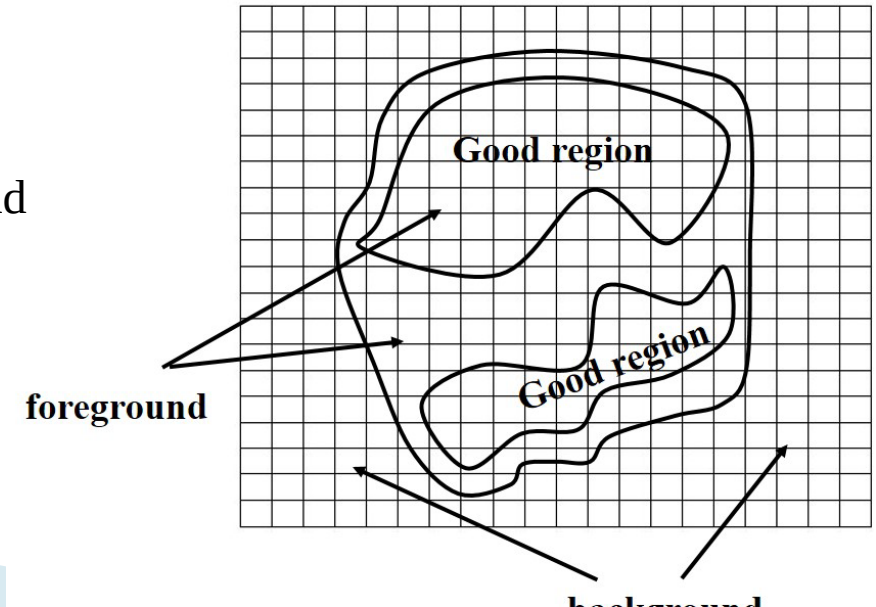
(a) Original image; (b) Argument; (c) Normalized minimum magnitude; (d)Minimal coherence.



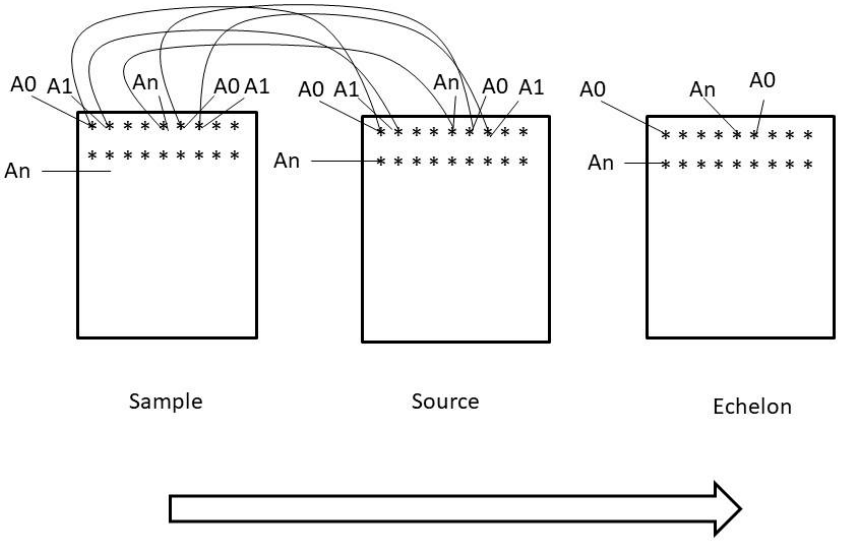


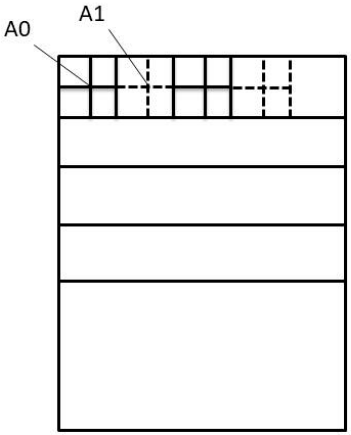
Our algorithm detects the highest coherence if clusters are in the area of parallel ridges, smallest coherence if the clusters are in the area of singularities, and it detected bad coherence when bad areas.

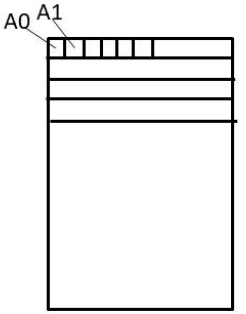
Background, foreground with good region and not good region



Agent Paradigm Used for Program Realization
Parallel Method Based on OpenMP







Different layers in one Echelon

Agent Paradigm in Different Echelon

Experiments

- The Reliability of scientific results that's obtained in the work is confirmed by result of experiments on the computer. Theoretical constructions are confirmed by experiments; conducted in accordance with generally accepted methods. The results can be used in scientific research. in the field of images processing , as well as in the development of applications that set tasks of reusing the results of relational queries.

FVC DATASET DESCRIPTION WITH SENSORS LIST

FVC	DB	Sensor type	Image Size	Patch Sizes 8, 10, 16		
2000	DB1	Optical“S.D. Scanner”	300x300	38x38	30x30	19x19
	DB3	Optical “DF-90”	448x478	56x60	45x48	28x30
2002	DB1	Optical “TouchView II”	388x374	49x47	39x38	25x24
	DB2	Optical “FX2000”	296x560	37x70	30x56	19x35
2004	DB1	Optical “V300”	640x480	80x60	64x48	40x30
	DB2	Optical “U.are.U 4000”	328x364	41x46	33x37	21x23

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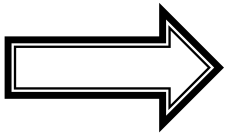
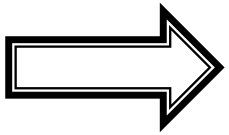
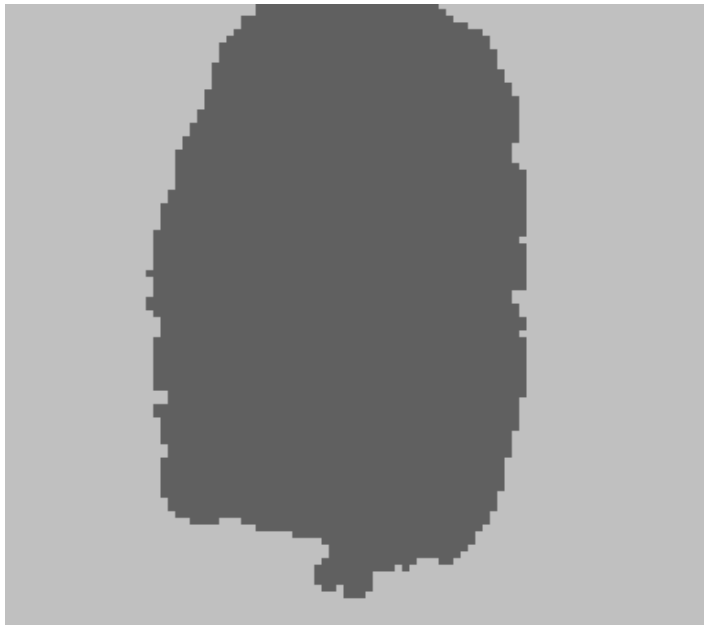
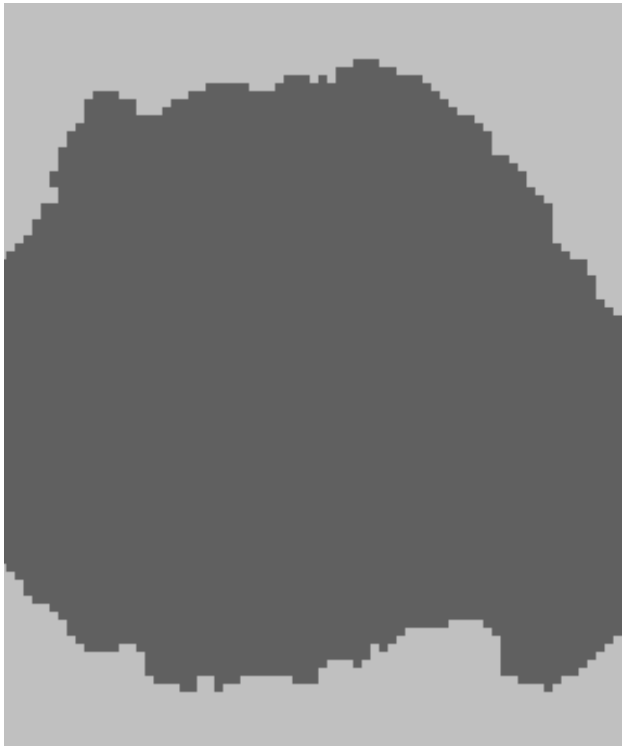
Experimental Results

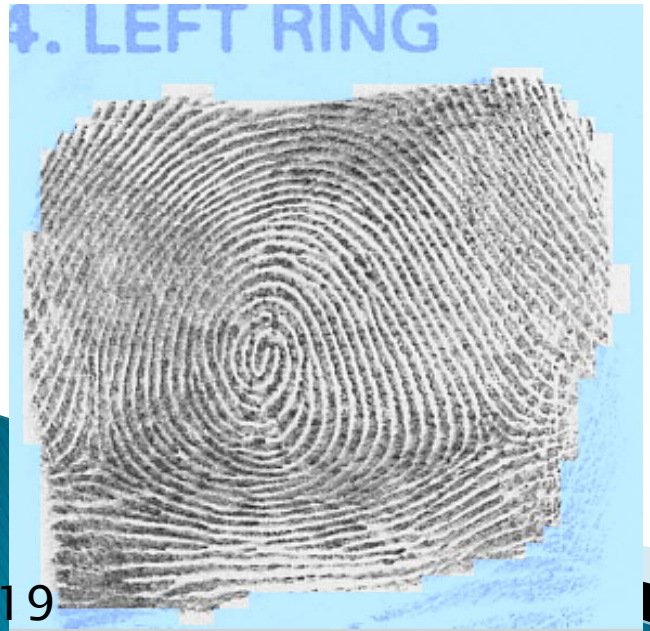






Experimental Results





Computational Environment Characteristics

LNet, ANet	Proposed Method
• OS: Ubuntu 18.04.1 64 bits; • RAM: 2 x 8GB DIMM DDR4 2400 MHz; • CPU: Intel® Core™ i7-8700K CPU @ 3.70GHz; • **GPU: NVIDIA® Titan Xp 12 GB**.	• OS: Windows 10 Pro, 64 bits; • Microsoft Visual Studio 2019/ C++; • CPU: Intel® Core™ i7-3632QM CPU @ 2.2GHz.

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DICE COEFFICIENT TO THE EVALUATED ALGORITHMS

FVC	DB	NFIQ2	SAFIS	Mind	FJ	LNet	ANet	Proposed Method
2000	DB1	82.48	83.62	93.34	63.74	97.30	97.36	96.11
	DB3	92.61	93.81	80.73	92.68	97.26	97.40	95.84
2002	DB1	92.48	94.16	96.44	94.91	97.37	98.18	97.67
	DB2	89.74	95.89	95.72	93.79	97.37	97.37	97.77
2004	DB1	91.40	84.66	95.68	76.27	97.95	97.88	96.76
	DB2	92.29	89.48	91.19	88.46	96.84	96.97	95.64
AVG		90,16	90,27	92,18	84,97	97,34	97,52	96,63

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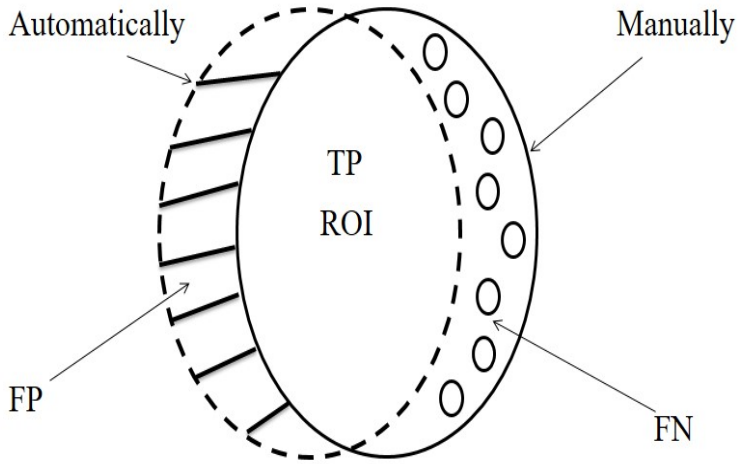
JACCARD SIMILARITY COEFFICIENT

$$Jac = \frac{TP}{TP + FP + FN}$$



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JACCARD SIMILARITY COEFFICIENT TO THE EVALUATED ALGORITHMS

FVC	DB	NFIQ2	SAFIS	Mind	FJ	LNet	ANet	Proposed Method
2000	DB1	76.46	78.61	89.98	60.51	95.78	95.86	92.66
	DB3	91.80	92.85	74.02	91.32	96.87	96.98	92.40
2002	DB1	93.11	94.39	96.54	95.38	96.66	98.22	95.52
	DB2	87.79	94.82	94.41	92.58	96.66	96.64	95.72
2004	DB1	95.78	91.57	97.76	83.66	98.92	98.89	93.86
	DB2	91.17	87.85	89.38	89.43	96.46	96.60	91.93
AVG		89,35	90,01	90,34	85,48	96,89	97,19	93,68

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Platform

- OS: Windows 10 Pro, 64 bits;
- Microsoft Visual Studio 2019/ C++;
- CPU: Intel® Core™ i7-3632QM CPU @ 2.2GHz.

Conclusion

- A robust interest point based fingerprint segmentation is proposed for fingerprints of varying image qualities. The experimental results compared with those of previous methods validate our algorithm. It has better performance even for low quality images, by including less background and excluding less foreground. In addition, this robust segmentation algorithm is capable of efficiently filtering spurious boundary minutiae. In this study proposed the new alternative method to recognize the region of interest, it's based on quality estimation of every block, assessing of first threshold and detected the supporting good areas, reduce the value of threshold to second threshold iteratively and spreading areas up to region of interest. Automatically adjustment of good regions help us correctly recognize region of interest. The results shown seems very correctly. This work presents promising fingerprint segmentation methods, which proved to be advantageous when subjected to analysis under similarity coefficients, regarding methods compared, when evaluating Dice coefficient and Jaccard similarity. Which suggests our approach has a competitive potential for segmentation problems in fingerprint-base biometric systems. In addition to that, we want to investigate how to use our solution for latent fingerprints and detect Singularity Recognition.

The Main Results of The Dissertation are Published in The Following Scientific Papers

Articles in journals from the list BAK

1. Wahhab H.I., Alanssari A.N. Survey of Primary Methods of Fingerprint Feature Extraction // Bull. South Ural State Univ. Ser. Comput. Technol. Autom. Control Radioelectron. 2018. Vol. 18, № 1. P. 140–147.
2. Alanssari A.N., Wahhab H.I., Behtold O. V. Development of the Subsystem for Fingerprints Image Analysis // Sci. Prospect. 2018. Vol. 9, № 108. P. 100–104.
3. Alanssari A.N., Wahhab H.I. Development of the Identification System by Fingerprints // Bull. South Ural State Univ. Ser. Comput. Technol. Autom. Control Radioelectron. 2018. Vol. 18, № 3. P. 22–30.
4. H. I. Wahhab, A. N. Alanssari, D.S. Rozhina, A.V. Agafonov A FINGERPRINT MATCHING ALGORITHM // Bull. South Ural State Univ. Ser. Comput. Technol. Autom. Control Radioelectron. 2019. Vol. 19, № 4.
5. A.V. Agafonov, D.S. Rozhina, H. I. Wahhab, A. N. Alanssari, ROBUST FINGERPRINT FLOW CHART ALGORITHM // Bull. South Ural State Univ. Ser Computational Mathematics and Software Engineering. 2019. Vol. 18, № 4.

Articles published by indexed in Scopus and Web of Science

6. Hany S. Khalifa, H. I. Wahhab, A. N. Alanssari and M. A. O Ahmed Khfagy. Fingerprint Segmentation Approach For Human Identifiaction // Appl. Math. Inf. Sci. 2019. Vol. 13, № 4.
7. Wahhab H.I. Clustering Method of Fingerprint Flow Map and Coherence // 2019 International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM). 2019.
8. Aliaa S. Jubair, Aliaa Jaber Mahna', H. I. Wahhab . Scale Invariant Feature Transform Based Method for Objects Matching // 2019 International Russian Automation Conference (RusAutoCon). Sochi, 2019.
9. Wahhab H.I. A Novel Method of Fingerprint Segmentation // 2019 International Russian Automation Conference (RusAutoCon). Sochi, 2019.

Articles in Conferences indexed in РИНЦ

10. H. I. Wahhab, A. N. Alanssari, V. Gudkov and O.V.B. A novel method for calculating a fingerprint gradient // J. Eng. Appl. Sci. 2019.
11. O.V. Behtold, H.I. Wahhab A. N. Alanssari. IMPROVED TRUST FACTOR-BASED FINGERPRINT LINE DIRECTION METHOD // 10th scientific conference of graduate and doctoral students.Chelyabinsk 2018. P. 120–123.
12. А.Н. Аль-Анссари, Х.И. Ваххаб О.В.Б. ОБЗОР ПРОБЛЕМЫ ИДЕНТИФИКАЦИИ // 10th scientific conference of graduate and doctoral students.Chelyabinsk 2018. P. 115–120.
13. A.N. Alanssari, H.K. Kuba H.I.Wahhab. Advantages and Disadvantages of Fingerprint Recognition // 11th scientific conference of graduate and doctoral students.Chelyabinsk 2019.
14. H. K. Kuba, V.J. Gudkov, A. N. Alanssari, O. V. Behtold, H.I.Wahhab . Description Basics of Images of Fingerprint // 11th scientific conference of graduate and doctoral students.Chelyabinsk 2019.
15. О. В. Бехтольд, Х. И. Ваххаб, А. Н. Аль-Анссари, К.К. Хасаниен, Улучшенный метод скелетизации изображения и решение проблемы изчезающих линий стандартных методов // 11th scientific conference of graduate and doctoral students.Chelyabinsk 2019.
16. Куба Х.К., Гудков В.Ю., Аль Анссари А.Н., Бехтольд О.В., Ваххаб Х. И., Лепихова Д.Н. Иерархическое описание дактилоскопических изображений // Интеллектуальные технологии: гуманитарные, социально-правовые и цифровые аспекты: материалы всерос. науч.-практ. конф. с междунар. участием (Миасс, 6 июня 2019г.).– Челябинск: Изд-во Челяб. гос. ун-та, 2019.– С. 53–58. ISBN 978-5-7271-1589-3.
17. Гудков В.Ю., Аль Анссари А.Н. , Бехтольд О.В., Ваххаб Х. И. , Лепихова Д.Н. Анализ градиента изображений отпечатков пальцев // Интеллектуальные технологии: гуманитарные, социально-правовые и цифровые аспекты: материалы всерос. науч.-практ. конф. с междунар. участием (Миасс, 6 июня 2019г.).– Челябинск: Изд-во Челяб. гос. ун-та, 2019.– С. 14–21. ISBN 978-5-7271-1589-3.

Registration Certificate of Program for ЭВМ

18. Wahhab H.I. Certificate of state registration of program for ЭВМ " Fingerprint Image Segmentation " No. 2019660767 from 13.08.2019.

The Scientific Specialization in Which The Dissertation was Prepared

09.06.01 Computer Science and Computer Engineering

05.13.17 theoretical foundations of computer science

list of Passed Candidate Exams

- Foreign language (English)
- History and Philosophy of Science
- State Exam

Thank you for your attention