New method for recognition whorls, loops and deltas on the fingerprint images

Alanssari Alaa Neamah Azeez

Supervisor

Pro. Гудков В.Ю

Relevance

- 100 years ago.
- Galton, Henry and FBI.
- criminal investigation ---- border control, computer logon, mobile payment, and so on.

Relevance

- The growth of crime and terrorism explains the need to create highly reliable automated fingerprint information systems (AFIS).
- more than a hundred AFIS in the world.
- Japanese NEC system, the French SAGEM system, the Canadian PRINTRAK system, the American COGENT system and others.
- All models is aimed at increasing the efficiency of the system.
- No single best and with no problem is known yet.

Relevance

- The singular point is one of the most important and obvious global features for the fingerprint.
- Some problem in real fingerprint image (dirty, deformed, blurry, and your finger may have scars or burns)

Research methods

Methods of image processing, pattern recognition, set theory, graph theory, probability theory and mathematical statistics were used to develop, research and substantiate mathematical models and methods for processing digital image. In C ++, effective numerical methods and algorithms were implemented in the form of complexes of problem. To check mathematical modules and algorithms a lot of experience were completed using original digital images of fingerprint. The results were obtained in the form of new mathematical methods, computational algorithms and new method to detect the types of patterns that characterize digital image.

Fingerprint image capture

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

Smoothing filter

1	1	1
1	1	1
1	1	1

linear filter (3*3)

1	0	1	0	1
0	0	0	0	0
1	0	0	0	1
0	0	0	0	0
1	0	1	0	1

Modified Dual Linear Filter (MDLF) (5*5)

linear filter size (3*3)
new filter The Modified Dual Linear Filter (MDLF) size (5*5)

$$f(x,y) = \sum_{i=-2}^{2} \sum_{j=-2}^{2} \mathrm{w(i.j).f(x+i,y+j)}$$

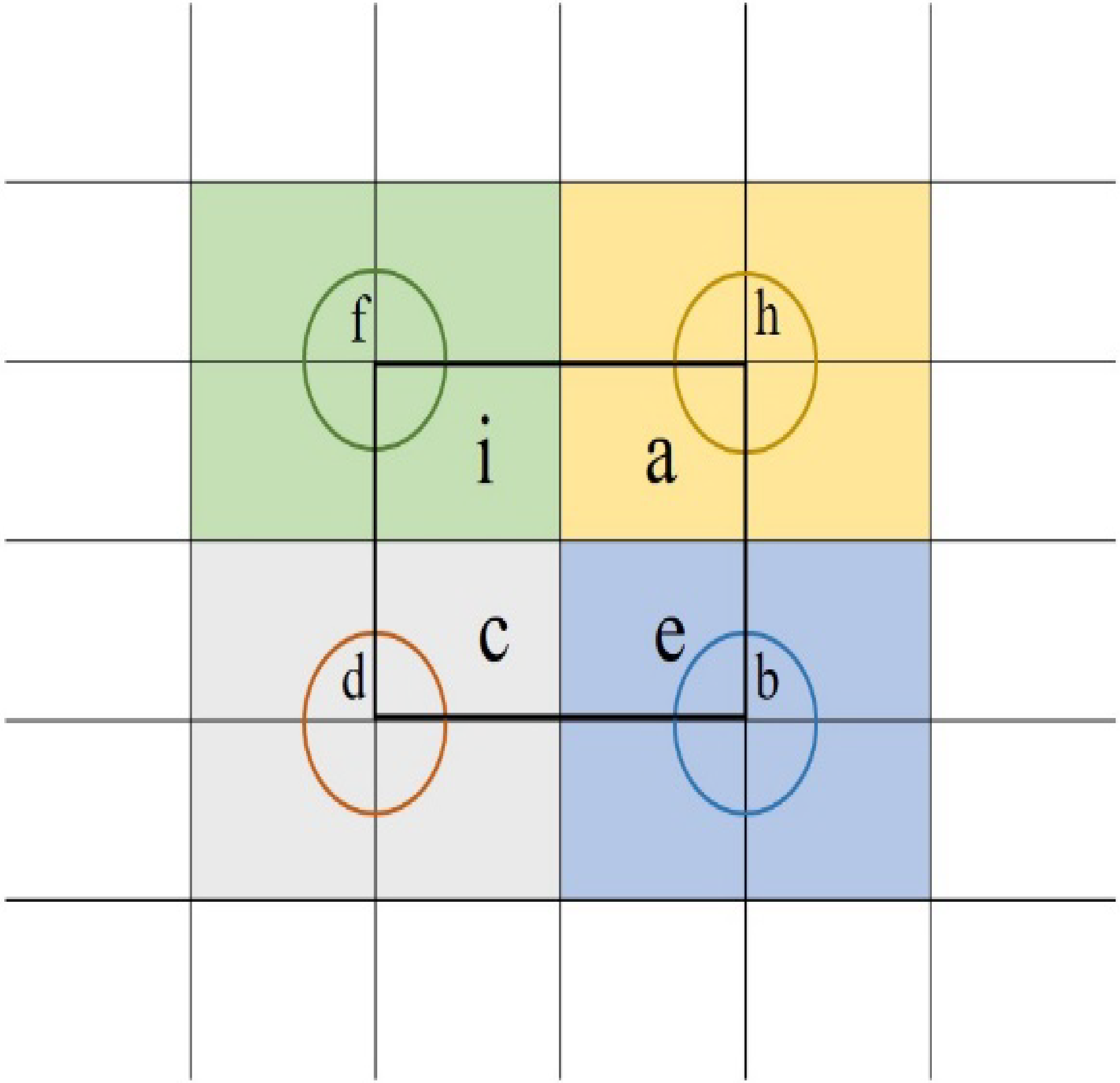
Smoothing image

- calculate average brightness for every 2x2 block
- prepare the similar smoothed image for 500 dpi

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

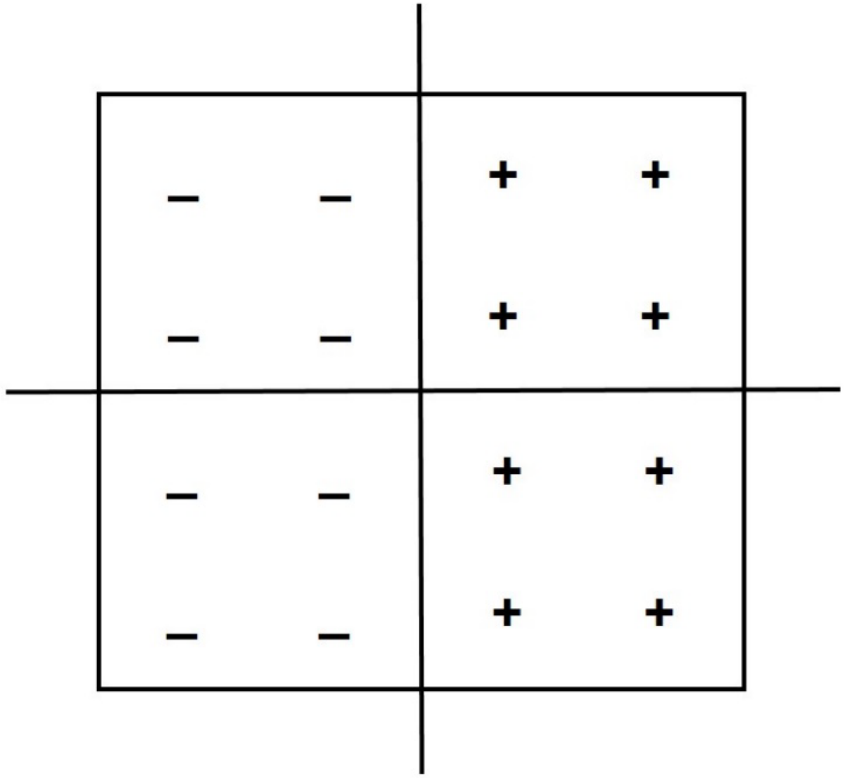
Difference up sampling

- $Sh(x,y) = f(x+1,y-1) + f(x+2,y-1) + f(x+1,y) + f(x+2,y)$
- $Sb(x,y) = f(x+1,y+1) + f(x+2,y+1) + f(x+1,y+2) + f(x+2,y+2)$
- $Sd(x,y) = f(x-1,y+1) + f(x,y+1) + f(x-1,y+2) + f(x,y+2)$
- $Sf(x,y) = f(x-1,y-1) + f(x,y-1) + f(x-1,y) + f(x,y)$



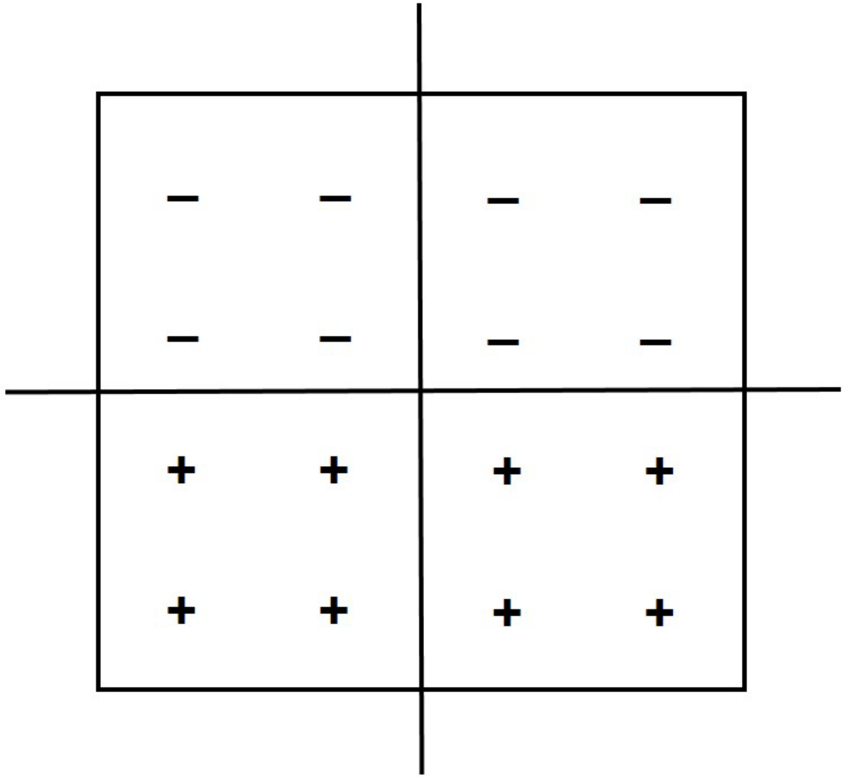
Difference up sampling

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



difference along x-axis

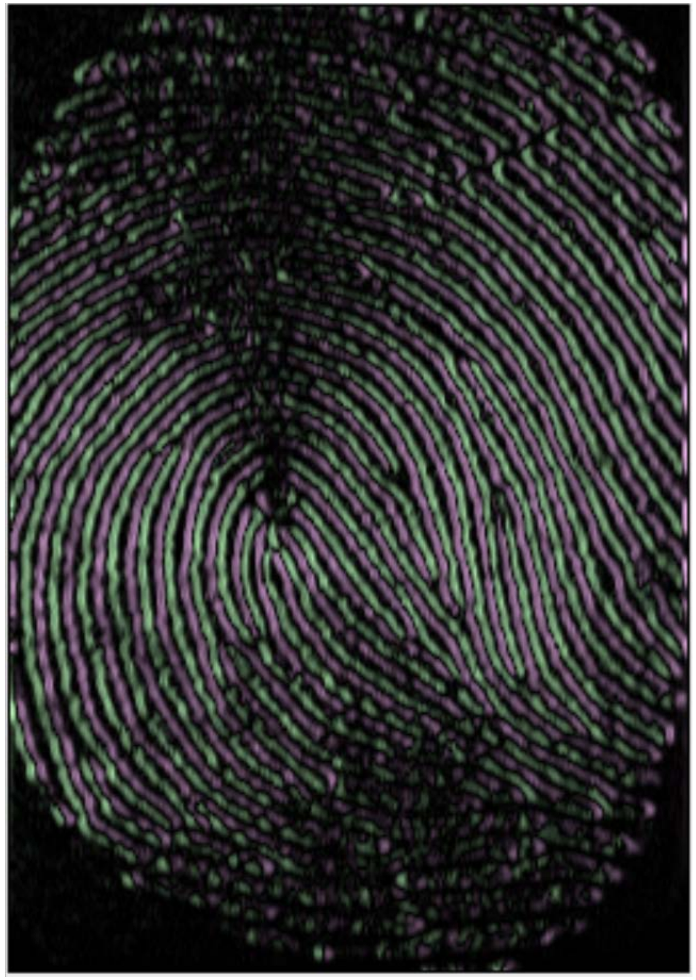
$$dy(x,y) = sb + sd - sf - sh$$



difference along y axis

Difference up sampling

$dx \uparrow (\frac{x}{2}, \frac{y}{2}) = dx(x,y)$



$dy \uparrow (\frac{x}{2}, \frac{y}{2}) = dy(x,y)$

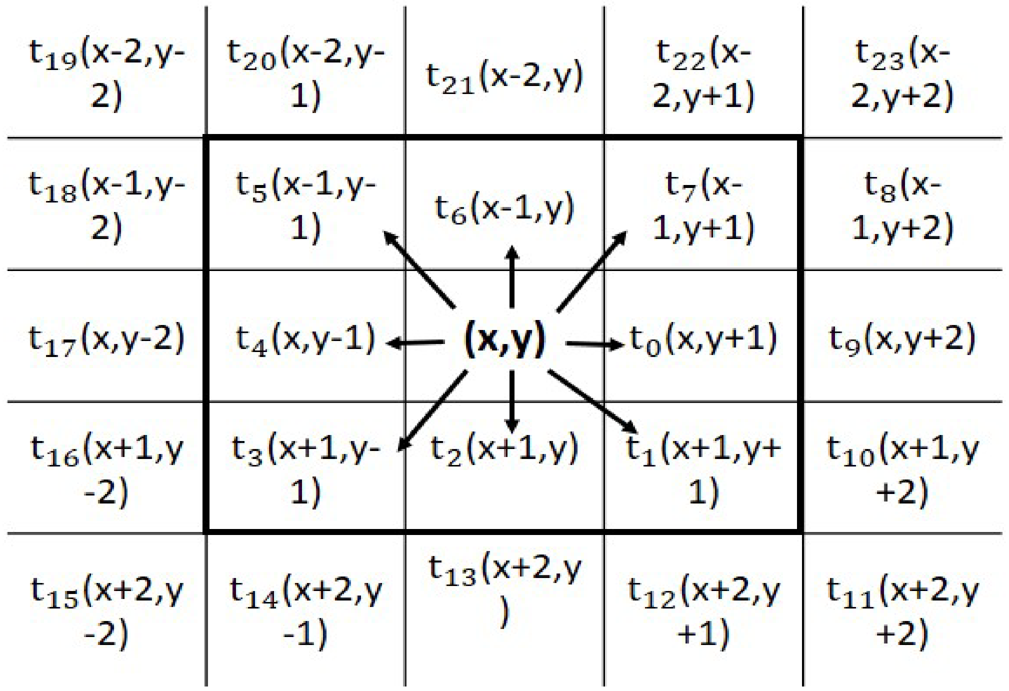
Gradient calculation

$$\propto (x,y) = \underset{0\to 360}{\text{Arctg}}\left(\frac{dx_{\uparrow}}{dy_{\uparrow}}\right)$$

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

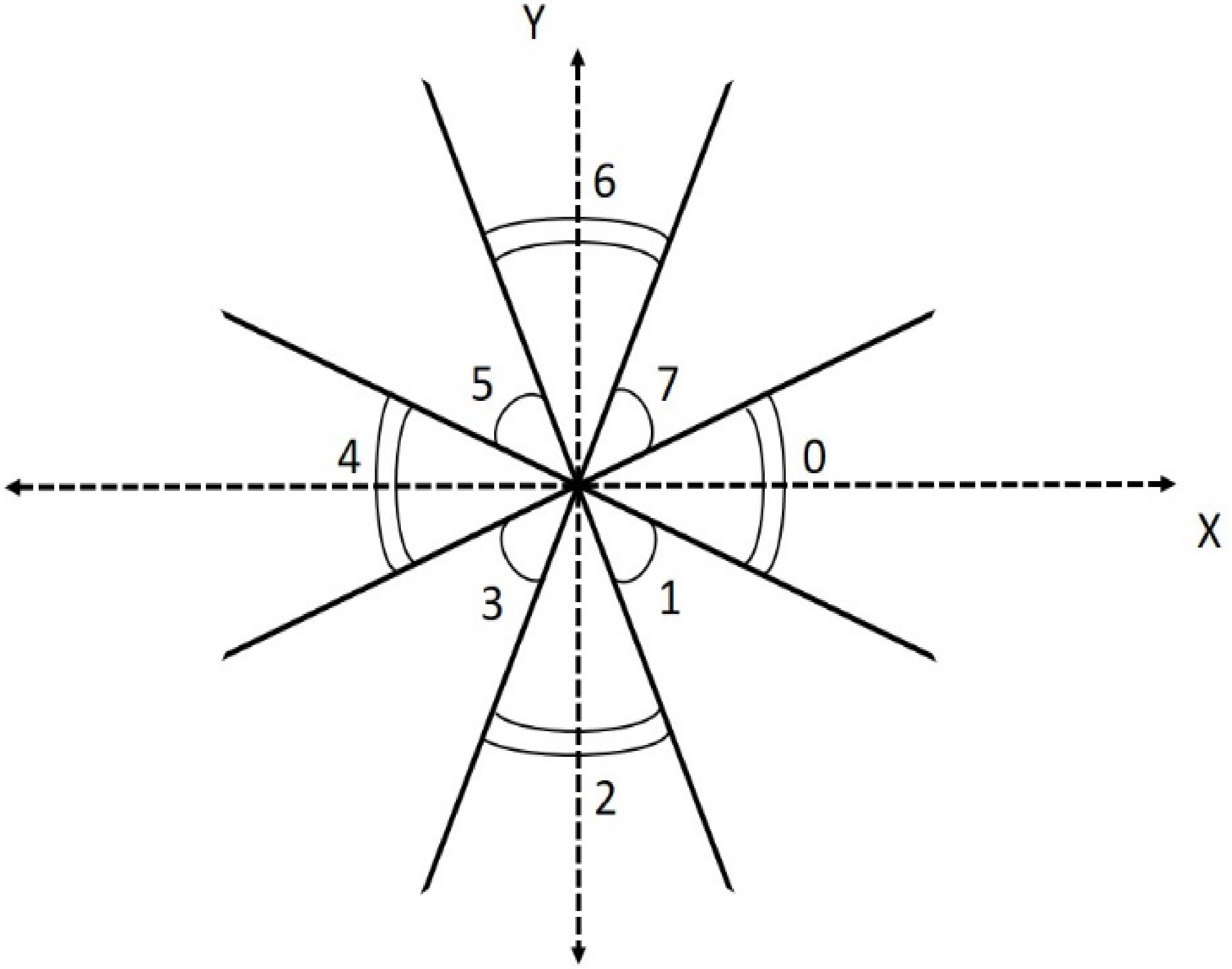
Structure of Cluster

- used cluster with size from 3×3 to size 13×13
- ∝ the direction of center
- the difference between ∝ and ti to get φi
- φi (the key information how to build petals)

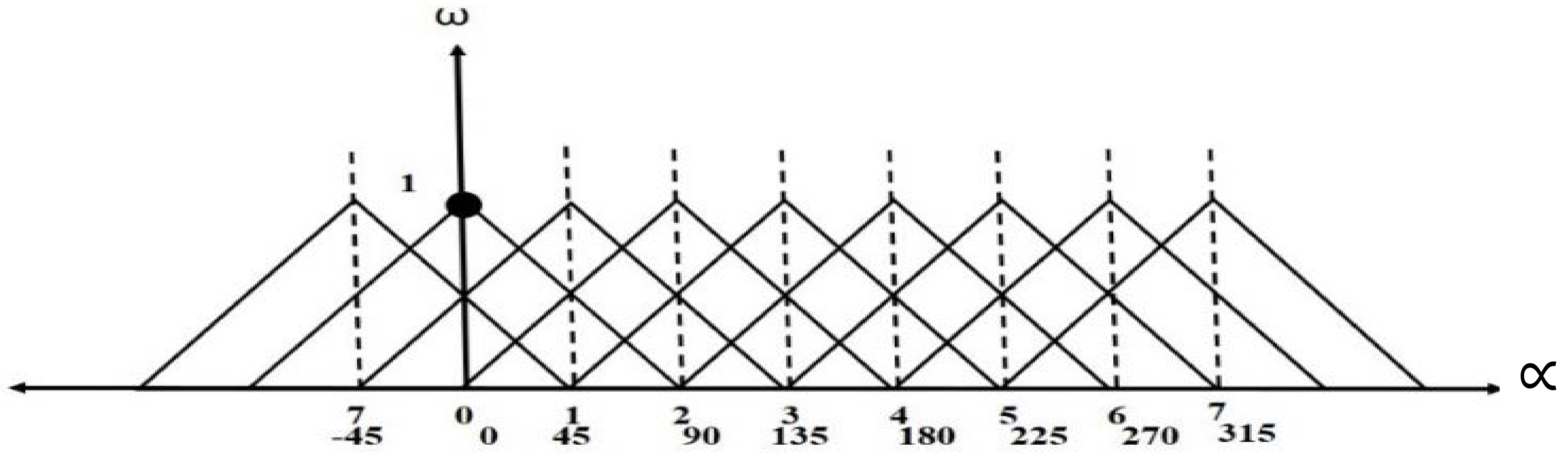


Structure of Petal

- build the petal from 8 parts for all rings
- size of angle between petals 45 degrees {0, 45, 90, 135, 180, 225, 270, 315}
- direction for center item ∝=0
- the mean directions γ_i for every petals



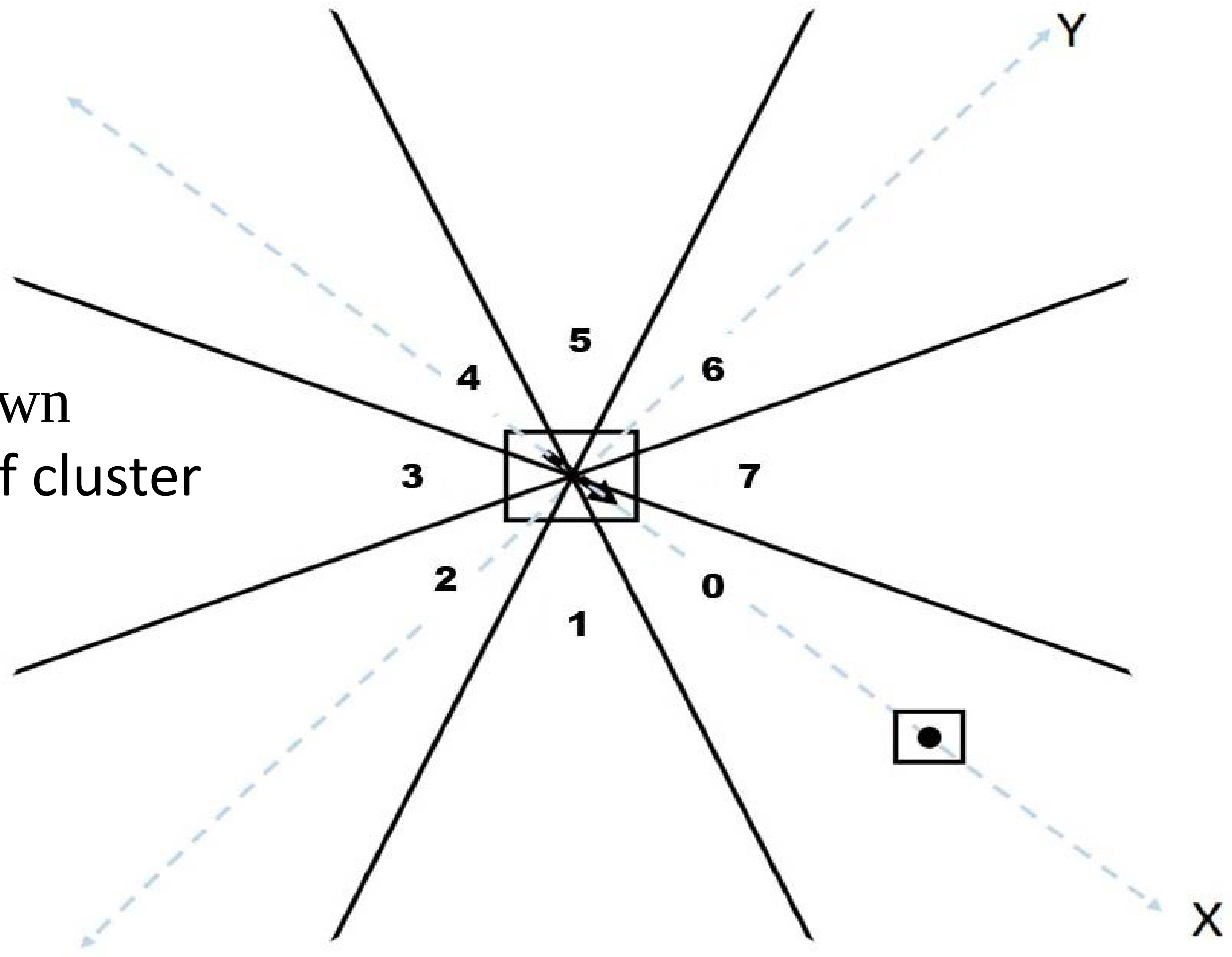
Weight functions associated with petals



- calculate the weight for every item in our cluster associated with selected petal
- The angle ∝ is calculated from the central x of selected petal so every item influences to every petal according to Wight function
- Here angle ∝ is deference between x axis and orientation from cluster center to item

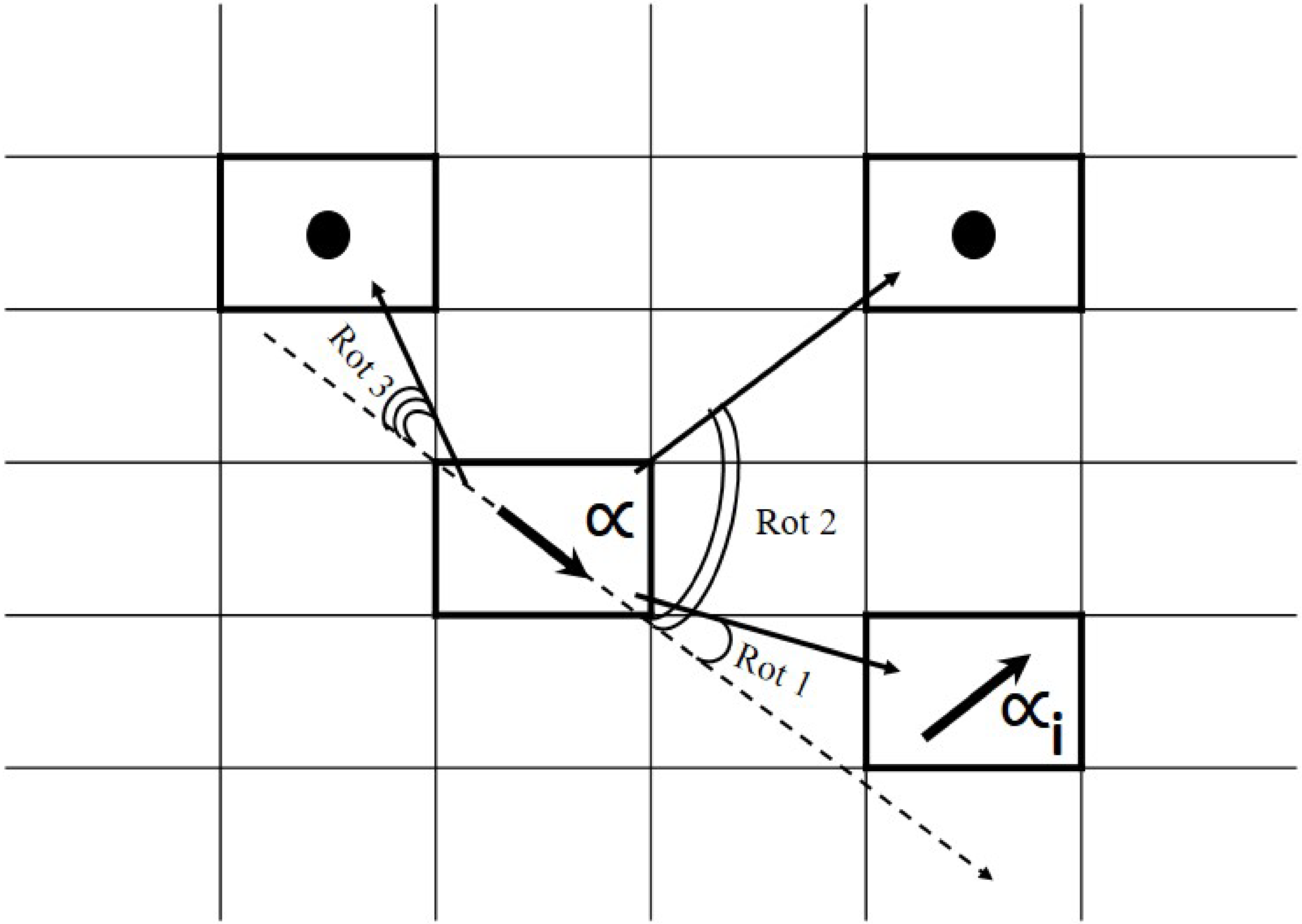
Scheme of petal in the oriented cluster

- If ∝ is not zero the cluster is rotated as shown
- Here angle ∝ is the orientation of center of cluster

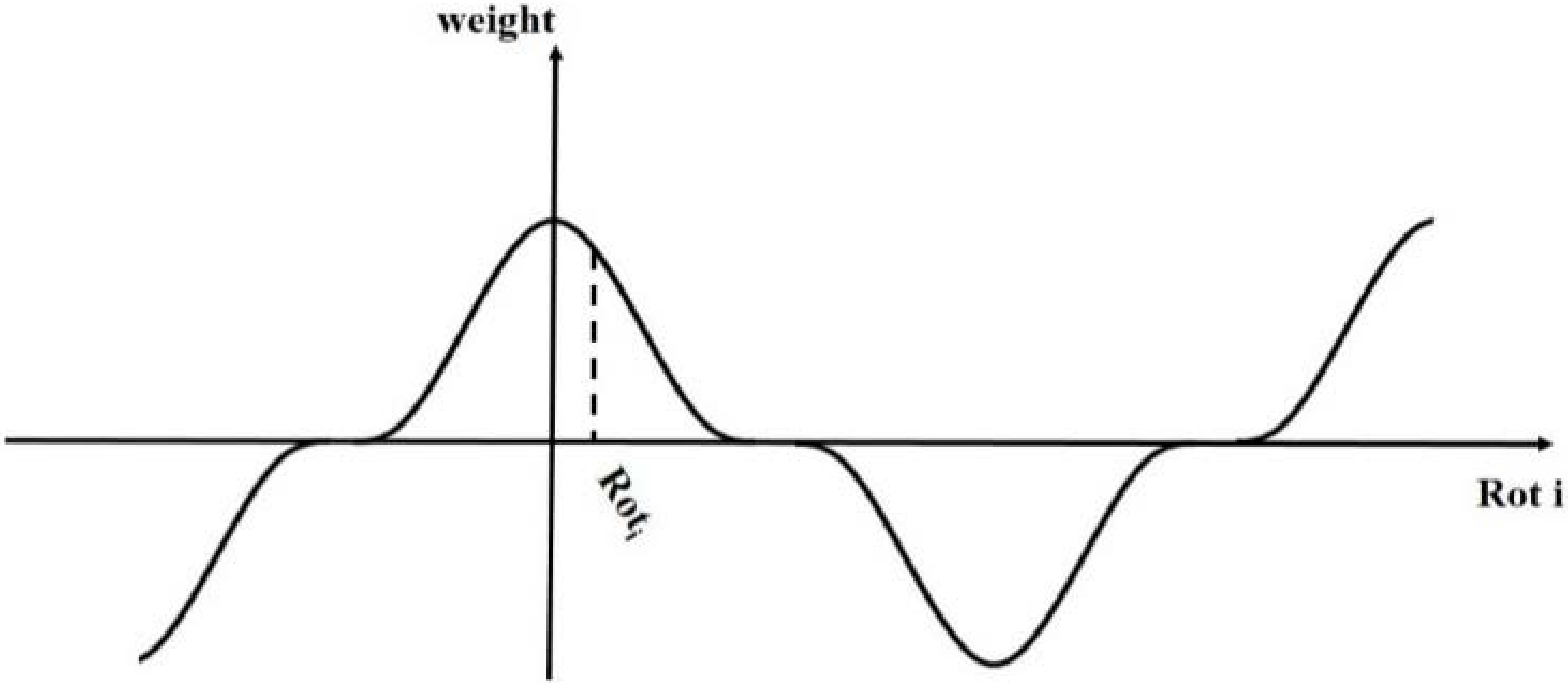


Tulip Approach

- used hard tulip method to get weight
- calculate real and imaginary part
- calculate the angle between directions of $\propto$ and $\propto_i$
- directions of γ_i, to get rotor

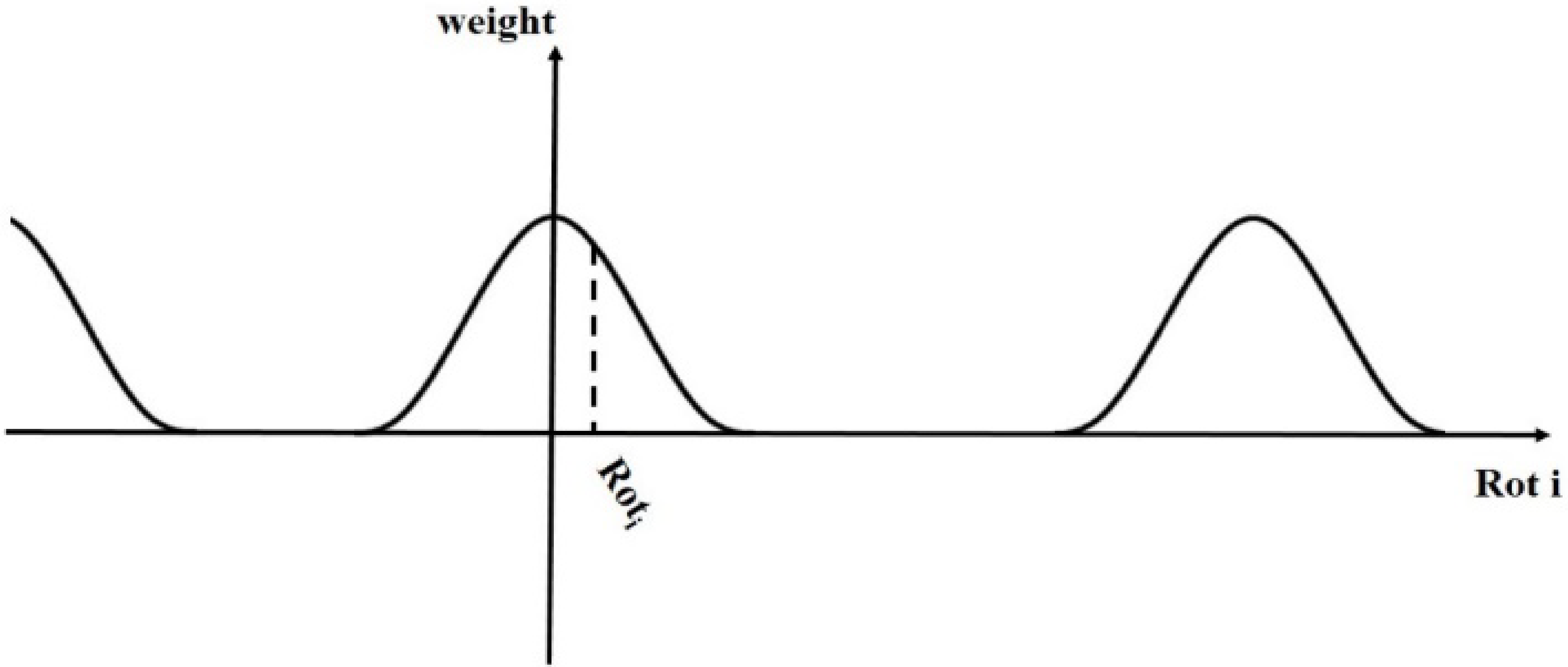


Example of weight function using doubled cosine form



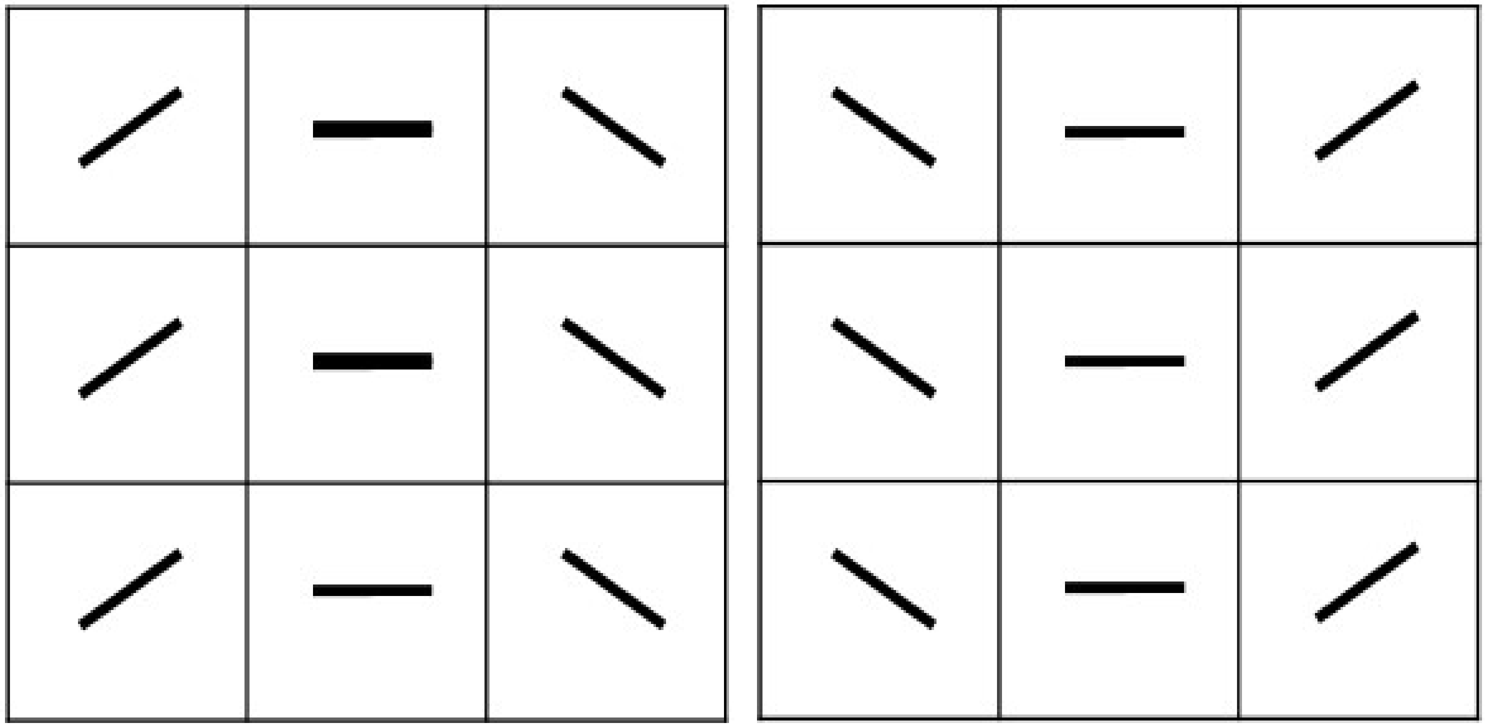
- representing rotor in cosine schema to get the weight
- represent weight for every item with γ_i and rot_i values for every petal

Example of weight function without negative values



- calculate influence only positive value in the cosine function, negative value will be equal zero
- multiply the item's weight by value for real and imaginary part, and accumulate the result for every j-th petal, j∈0..7.

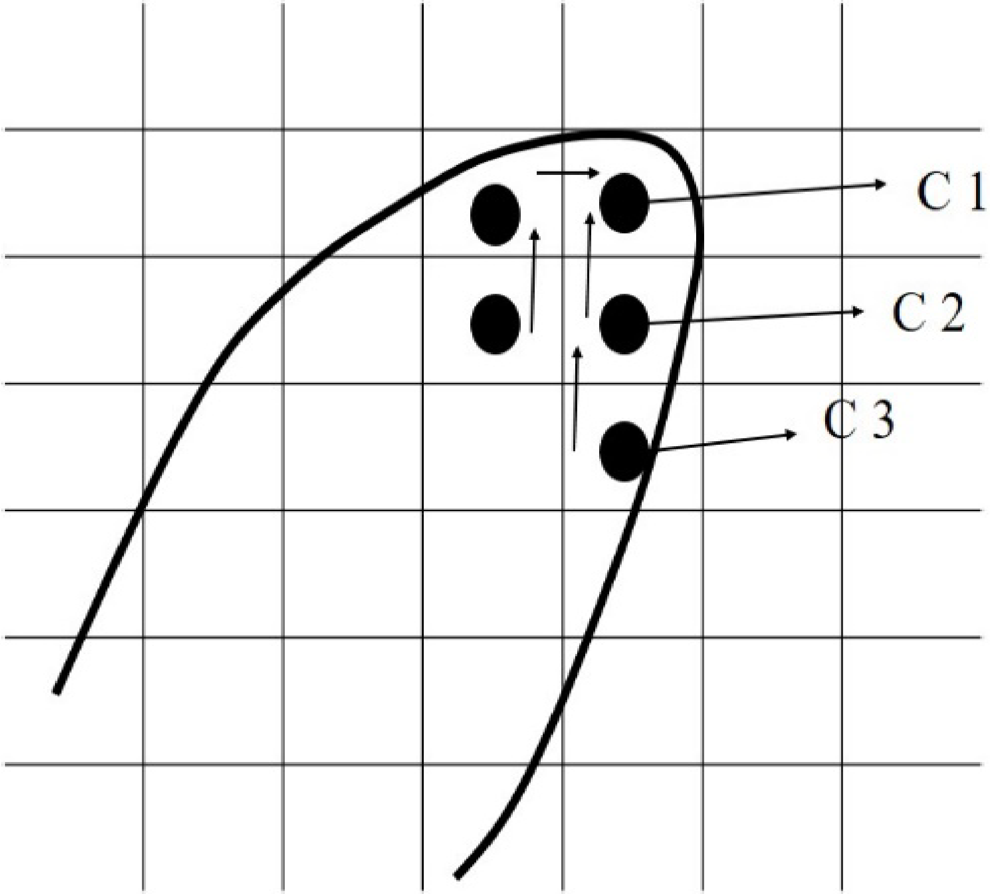
Typical flow map for the area without singularity



- accumulated real and imaginary part for all items.
- The result of recognition depends on the size of cluster, we prefer 7×7.
- measure the deference of directions for petal number 0 (S0) and petal number 4 (S4).
- finally we have got the curve value for every cluster.

The probability positions for one loop in the area of loop

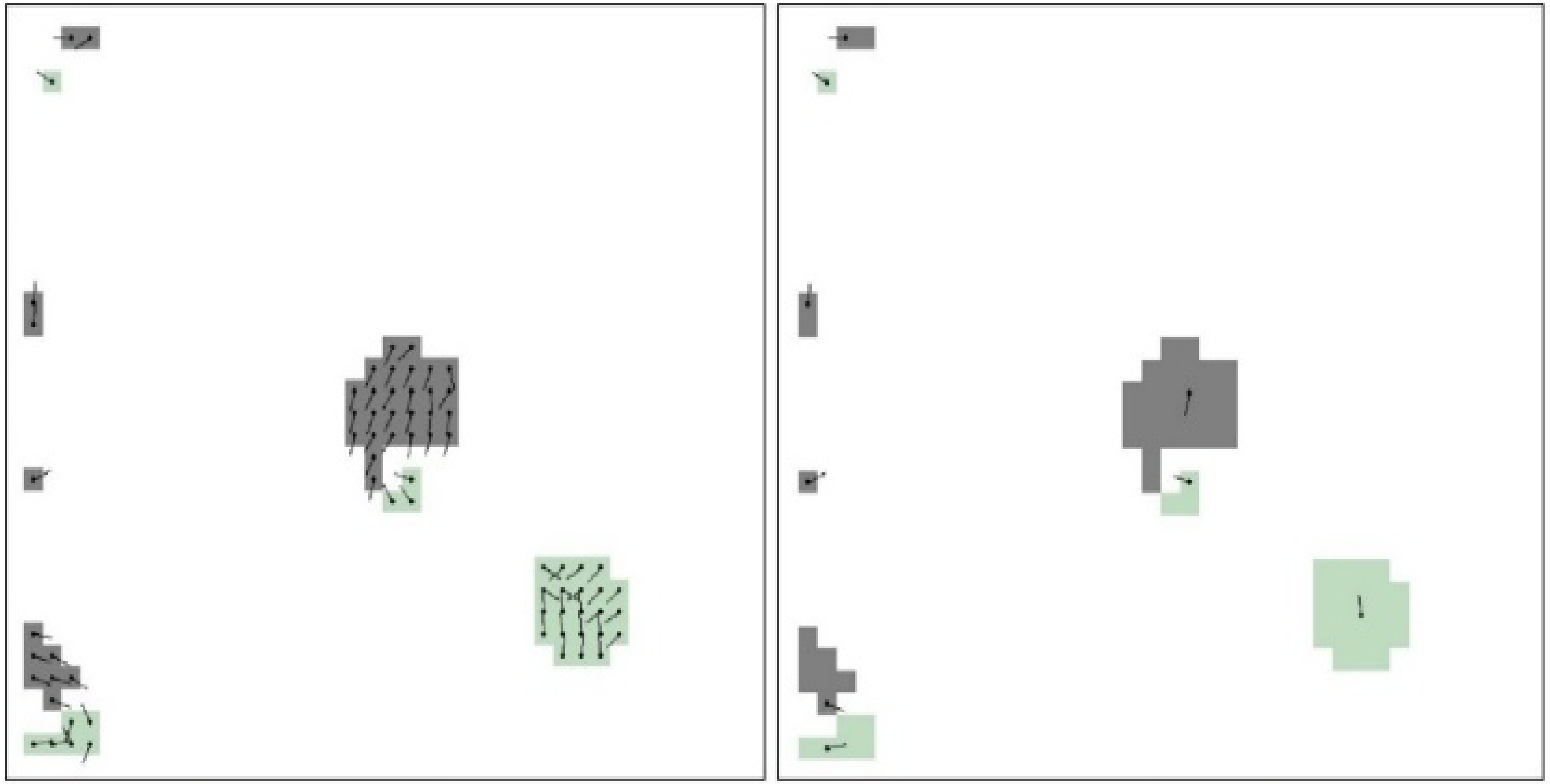
- position (x,y) associated with the item p^0
- Set the stack ST= $\{p^0\}$
- target set $V = \{p^0\}$
- initial value of curvature v=0



$$P = \{p | p \in N_8(ST) \land p \notin ST \land J(p) \to ST = ST \cup \{p\}\},$$

Loops and deltas before and after merging

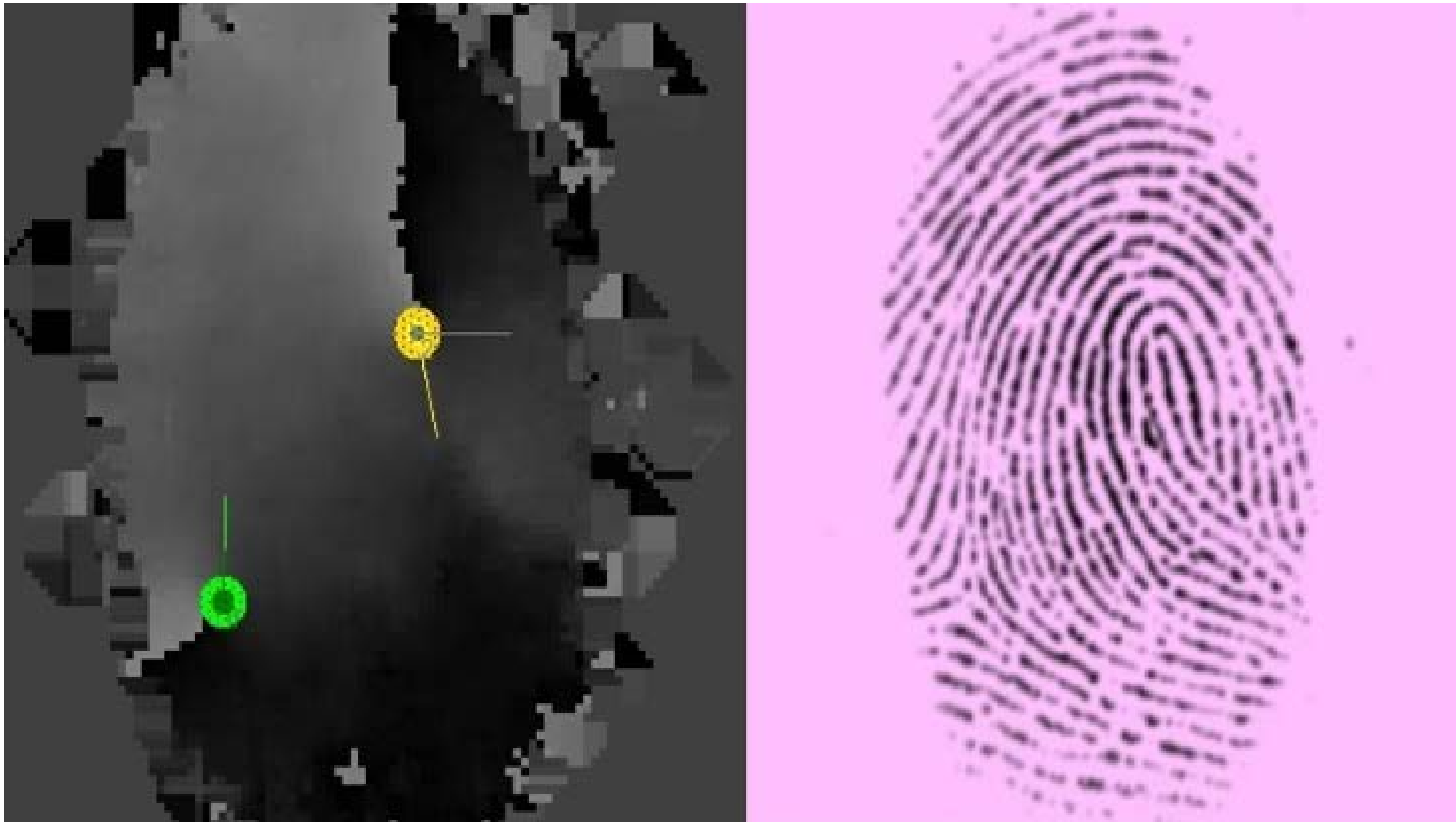
- merge the position for every singularity is selected as highest value of curve
- We merge the singularity only in its native area



A- Loops and deltas before merge　　B- Loops and deltas after the merger

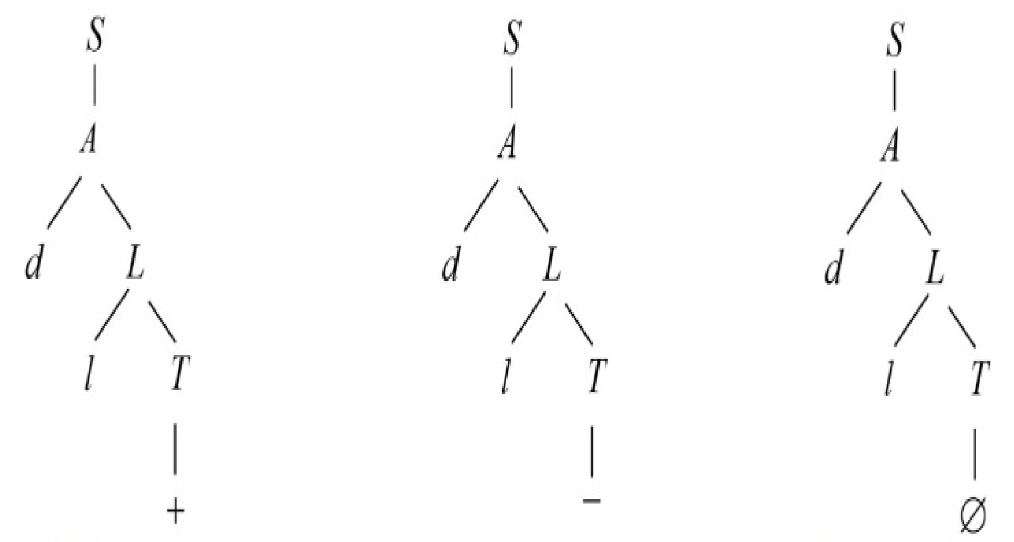
Singularity positions and orientations

- Result of processing of image.
- The results were obtained using my program.
- There were selected more probability singularities



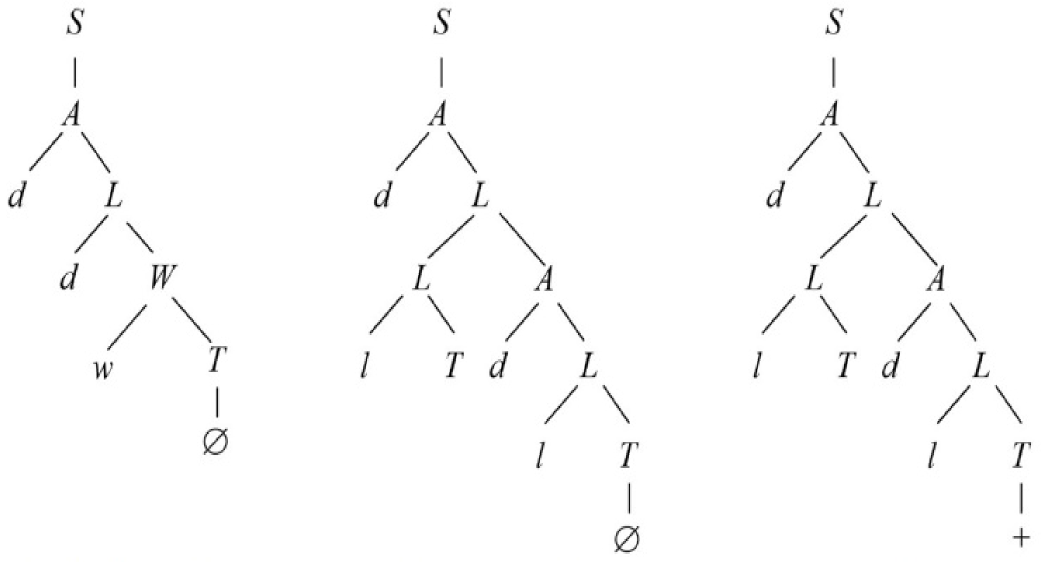
Pattern Type Recognition

classification tree a) right loop, b) left loop, c) tended arch



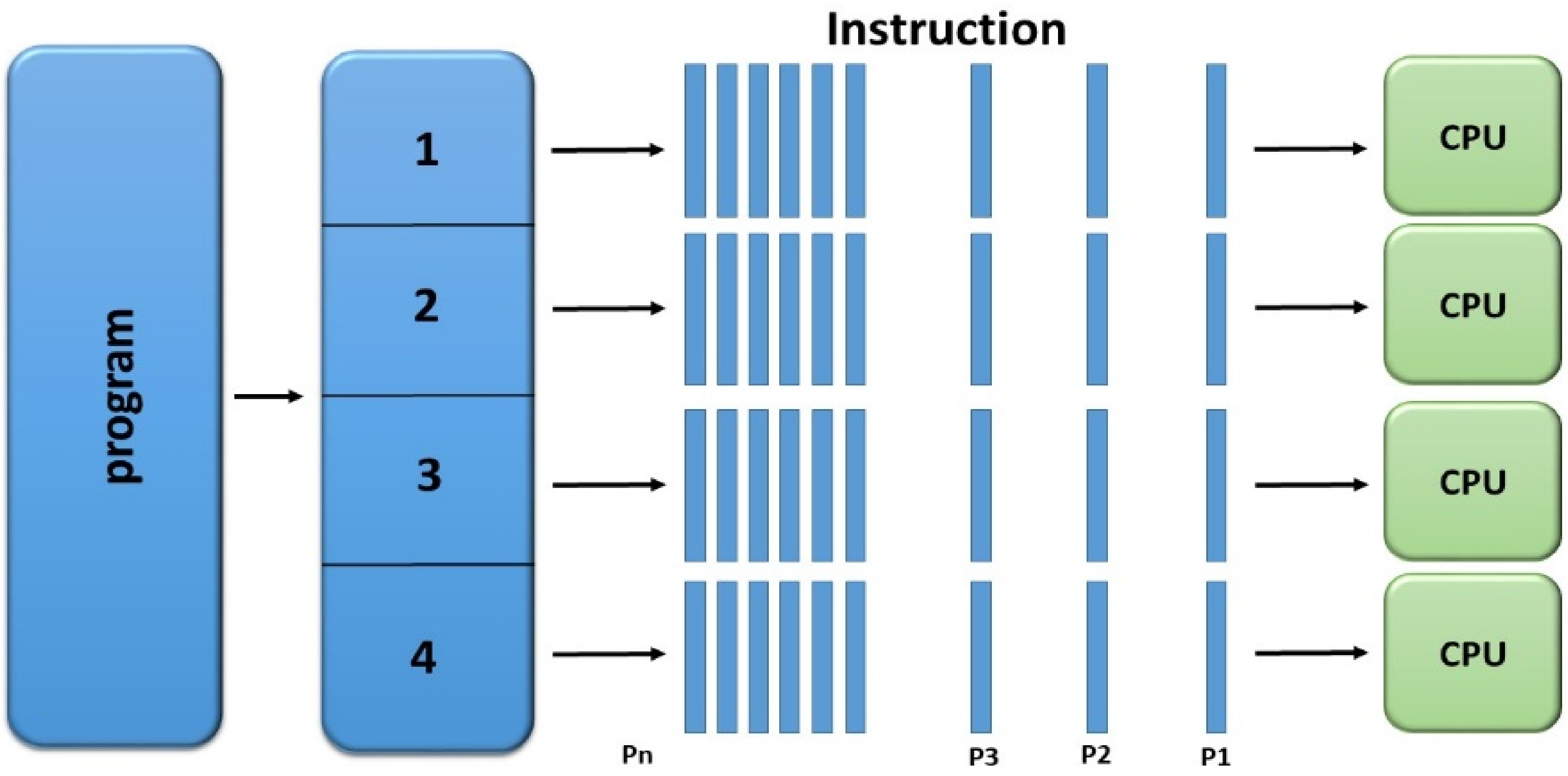
A. Right loop B. Left loop C. Tended arch

classification tree D) simple whorl, E) elongated oval, F) complex …

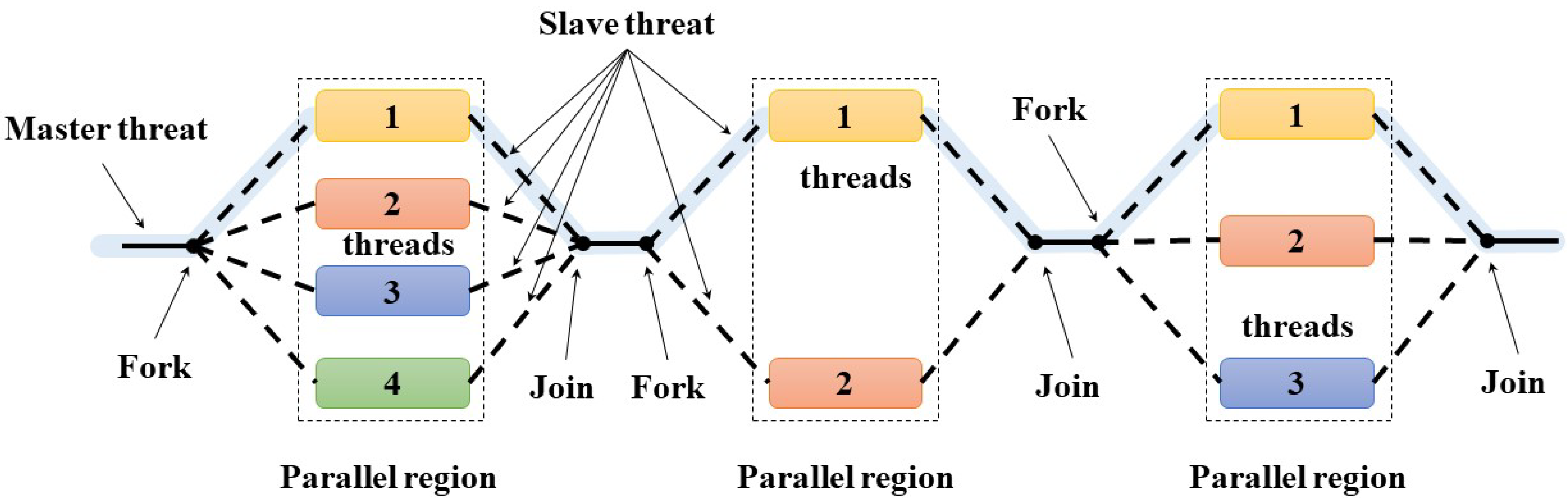


D. Simple whorl E. elongated oval F. complex spinning pattern with clockwise rotation

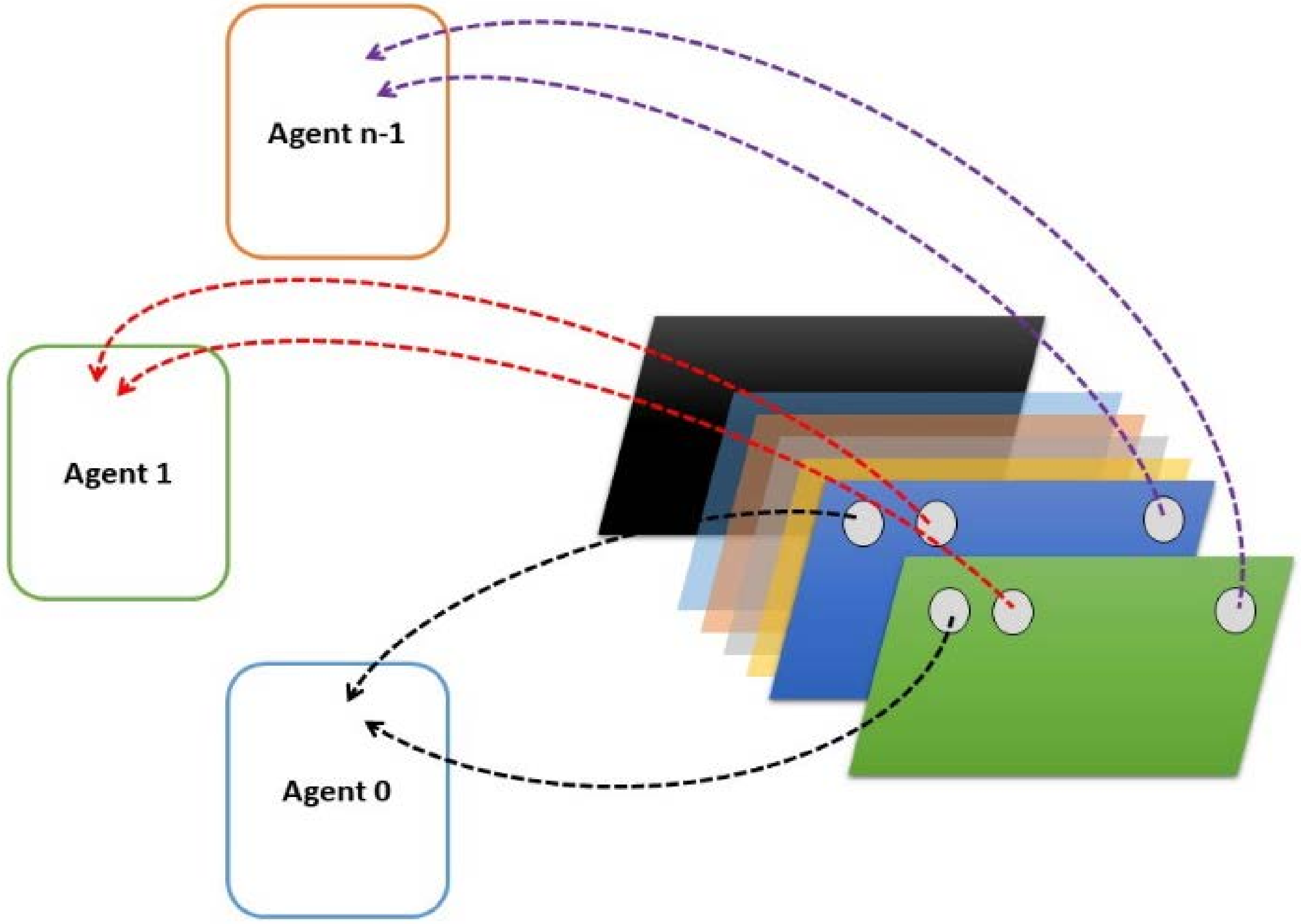
schema parallel problem



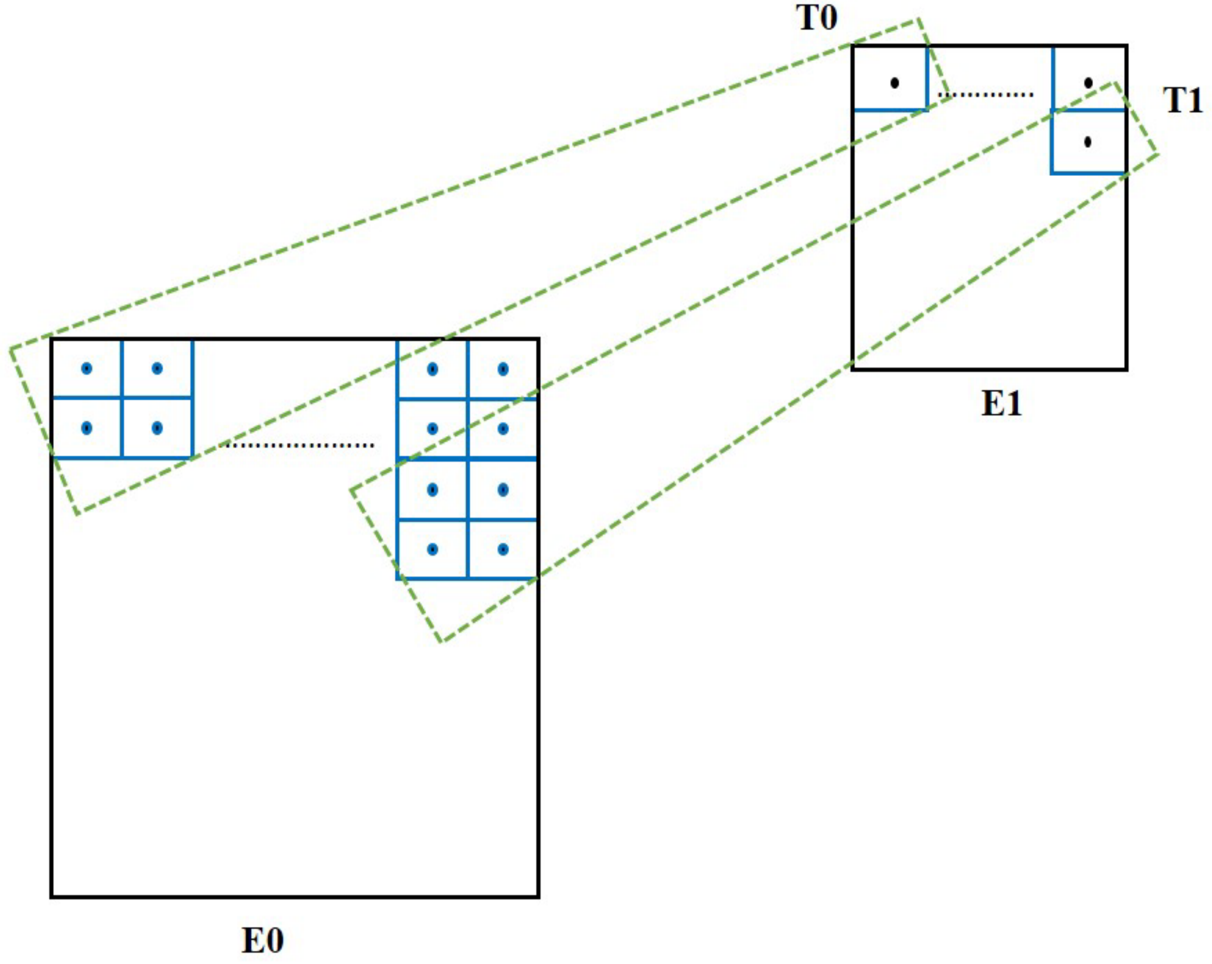
Fork and Join model



Agent schema



Model of item processing in different echelons



Experimental results

- (SPD2010).
- (x_0, y_0, t_0)
- $t = t_0$
- $sqrt\big((x - x_0)^2 + (y - y_0)^2\big) < 10$
- Here, we shall show ground truth labeling used in our training set. According to SPD 2010 competition's instructions, for a ground truth singular point (x_0, y_0, t_0), if a detected singular point (x, y, t) satisfies $t = t_0$ and bias at the same time, the point is considered be truly detected, t is the type of the singular point. We labeled training DB manually. Our labels can be classified into two categories, and thus two sets of labels are generated. One set is the label of cores and the other is the label of deltas.

Testing Dataset and the Evaluation Criteria

1. the evaluation will consider the quantity and type of the detected singular points as well as their distance to the ground truth.
2. For a ground truth singular point (x_0, y_0, t_0), if a detected singular point (x, y, t) satisfies $t = t_0$ and $sqrt\left((x - x_0)^2 + (y - y_0)^2\right) < 10$ at the same time, the point is considered to be truly detected. Otherwise, it is called a miss.
3. The detection rate is defined as the ratio of the truly detected singular points to all ground truth singular points.
4. The miss rate is defined as the ratio of the missed singular points to all ground truth singular points.
5. The false alarm rate is defined as the ratio of the falsely detected singular points to all ground truth singular points.
6. If all singular points are truly detected and there are no spurious singular points in a fingerprint, the fingerprint is considered to be "correctly" detected.

Results

Algorithm	Corrected Detection Rate (%)	Detection Rate (%)		Miss Rate (%)		False Alarm Rate (%)	
		Cores	Deltas	Cores	Deltas	Cores	Deltas
AMF	38	52	60	48	40	56	28
WP	32	42	53	58	47	10	12
SPBC	31	48	45	52	55	32	26
SPOD	35	56	48	44	52	30	35
SP-Net	36	55	52	45	48	26	31
SinNet	48	68	63	32	37	16	15
Proposed Method	69	78	84	22	16	25	5

Conclusion

Summarized the results and results of the research. The appendix contains the source codes of the implemented program in the Visual Studio development environment in C ++. A new approach to feature recognition using an approach combining the cluster method, the petal method, the rotation of the flow map and the selection of the largest value of the curvy shape to select the position of the singularity, as well as a description of the classification of the types of patterns for the fingerprint are proposed. This classification is based on the recognition of features. This recognition consists of flow mapping, curvature generation, tulip analysis. There are three types of features: loop, delta, and whorl. Based on these features, we classified the type of template that has more than six numbers. We also showed trees for a left loop, a right loop, a tented arch, arch, a simple whorl, an elongated oval, and a complex pattern. Classification allows you to divide the fingerprint database into six or more parts that do not overlap in the database, and can speed up the following matching procedure. The results shown seem to be very correct. Method realized in Microsoft Visual Studio 2012 / C ++ Processor Specification (Intel® Core ™ i7-3632QM @ 2.2 GHz Processor). In future work, we plan to optimize singularity recognition if many singularities are found. We also plan to conduct research on how the singularity can be best chosen. The comparative results are better in the most position

list of publications, program registration, patents

Scopus

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- A. N. Alanssari. A Novel Method of Singularity Recognition of Fingerprints // 2019 International Russian Automation Conference (RusAutoCon). Sochi, 2019.
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Vak

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- 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.
- 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.
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- 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.
- 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.
- 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.

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- 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.
- 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 EVM

- Alanssari A. N. Certificate of state registration of program for ЭВМ " Распознавание петель, дельт, завитков изображений отпечатков пальцев " No. 2019660766 from 13.08.2019.

Thank you