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Cogent automatic fingerprint identification system research

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ABSTRACT

Cogent Automatic Fingerprint Identification System (CAFIS) could filtrate and match fingerprints features automatically by computer to search for similar fingerprints, which were identified by specialists finally, in order to providing help for criminal cases. In this paper, the principle, fingerprint identification process and the system workflow of CAFIS were introduced firstly. Then, the five functions modules contain image acquisition, screening, feature matching, scoring and sorting was focused on; and the algorithm of feature matching was introduced briefly. The results of experiment show that the CAFIS has advantages in capacity of database, matching speed, accuracy, etc.

Key words: CAFIS, Fingerprint Identification, feature matching

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INTRODUCTION

Fingerprint identification is a kind of criminal detection technology, which develops quickly with the development of society. It has been practiced for thousands of years from the earliest fingerprint found to the birth of fingerprint technology, and then from manual fingerprint identification technology to automatic fingerprint identification technology. And in recent years, with the development of information technology represented by computer technology since 1960s, people found the new thoughts and methods in study of fingerprint identification. Fingerprint is a Biometrics feature, which is unique and highly stable for individuals. With the introduction of fingerprint experts, the repeat probability of people's fingerprint is almost zero. So, it is the most persuasive method using fingerprint to identify criminals, and it is called the most secure evidence.

At present, there are several famous corporations of AFIS in the word, such as SAGEM, UltraScan, Printrak Motorola, NEC, Biolink, Idenicator, Cogent, etc.

In our country, there are four major famous AFIS: AFIS(researched by Institute of Criminal Science and Technology of bureau of public security in Beijing City and Tsinghai University), PU-AFIS(researched by PKU HIGH-TECH), EGF-AFIS(researched by Etgoldenfinger Co., Ltd), CAFIS(researched by Beijing Hisign Technology Co., Ltd.). This paper researches the AFIS based on CAFIS.

BRIEF INTRODUCTION OF CAIFS

1. Principle of fingerprint identification

Because of the uniqueness, stability and convenience, fingerprint almost has been the pronoun of biological feature identification. Fingerprints are uneven lines on the end of finger, which arranged in regular order and came into being different types of fingerprints. The starting point, end point, bonding point and branch point are called the minutiae of fingerprints. CAFIS just use the minutiae of different fingerprints to identify criminals. Because every person has different fingerprints, and there are distinct different among ten fingerprints of the same person, fingerprints can be used to personal identification.

Fingerprint identification is to sure whether two fingerprints come from the same finger. People have engaged in fingerprints research for many years. D.K.Isneor proposed an algorithm using image matching to identify two fingerprints [1]. AndrewKHrechka proposed another algorithm using structure matching to identify fingerprints [2]. But at present, the most commonly used method is using the minutiae model proposed by FBI, which use the extreme point of crest line and branch point to identify fingerprints. The automatic fingerprint identification will exchange to point patterns, while minutiae are represented by point patterns.

When we collect fingerprints, there are many misty fingerprints because the position of pressing their fingerprints is not all the same, and the point putting fingerprint is different, which will result in be out of shape. How to extract feature and match feature directly is the key of fingerprint identification technology.

2. Process of fingerprint identification

AFIS is much similar with manual identification. But because computer can't justify the right or wrong of every fingerprint, it just can offer a candidacy list according to the similarity. The fingerprint identification process of CAFIS includes mainly five segments: image collection, filtration, feature matching, scoring and sorting. After the process of scoring, every candidacy fingerprint will have a score about similarity. The score is much higher; it is more likely to be. The system will sort these candidacy fingerprints again according to scores. Specialized persons will identify further the top fingerprints, usually the top 50, then, we can get the final result of identification.

The next, this paper will introduce the process of fingerprint identification in case of CAFIS.

FRAMEWORKS OF CAFIS

1. Workflows of CAFIS

The total system workflows of CAFIS are as follows:

(1) Fingerprints collection and then input into system in the client;

(2) Fingerprints in the system are transmitted to AFIS service by COMM service (communication service);

(3) AFIS service search for a comparison service which is idle from TTS1 to TTSn (TTS means comparison service), then TTS will deal with fingerprints query. If the system doesn't install PMA (Hardware Acceleration comparison equipment), then the T11 service (comparison engine) in the next level do the follow-up work, such as filtration, comparison, scoring and so on;

(4) If the system has installed PMA, T11 will send the fingerprint to TFILTER (comparison filtration service) through TFRONT (comparison transit service), TFILTER will filtrate for the first time, the result will be transmitted to TBACK (comparison for the second level) for the second filtration and matching, the result will be scored and sorting;

(5) The system will get a candidacy list after sorting, which will be sent back to the client, and then specialized persons will have the final identification. Please see the Fig. 1 for the concrete workflow.

2. The basic function modules

CAFIS includes mainly five function modules: image collection, filtration, feature matching, scoring and sorting.

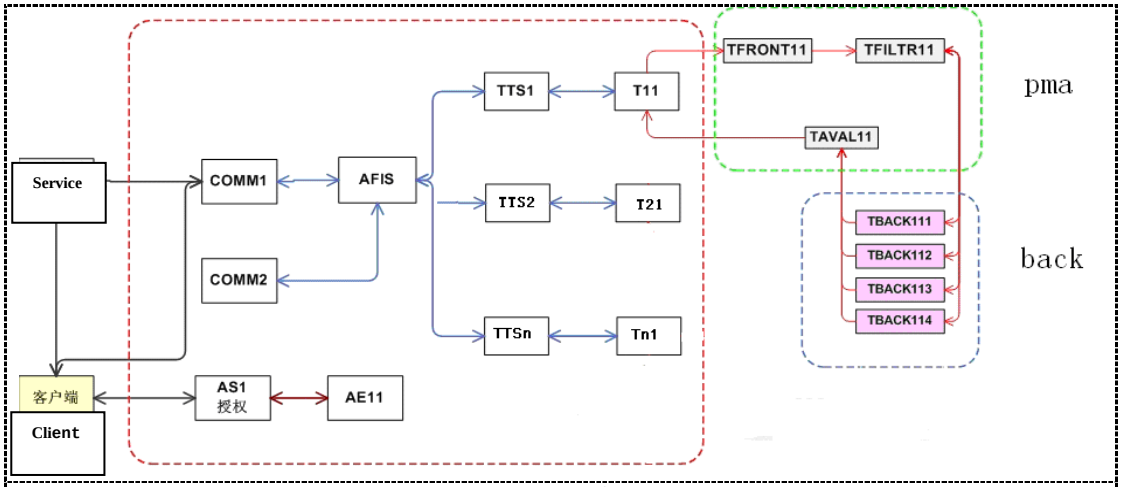


Fig .1: System workflow graph.

2.1 Fingerprint image acquisition

Fingerprint image acquisition is the basic of whole fingerprint management and application. The quality of fingerprint directly affects the classification of fingerprint and the accuracy of exacting centers, triangles and features

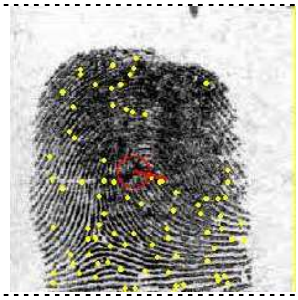
The image acquisition of CAFIS is classified into two kinds: fingerprints pressed on papers and fingerprints at the scene of the crime. There are two methods to collect fingerprints pressed on papers or equipments:

- Traditional style of pressing fingerprints using printing ink, then are input into the system by scanner.
- Fingerprints collection equipments, as present, are HX-R8061U and HX-R8062U. About the collecting of fingerprints at the scene of the crime, specialized persons obtain the fingerprints remained at the scene of the crime by criminal investigation, use a digital camera to take pictures, and then input them into the system. Fingerprints collected in various ways are shown in Fig. 2.

2.2 Filtration of features

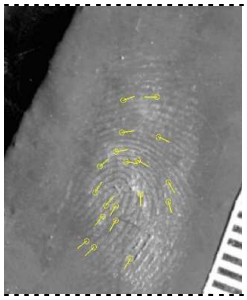
Filtration is a process of comparing the critical feature of fingerprints at the scene of the crime (basing on the position and type of fingerprints, the whorl's direction, the construction of centres and triangles, critical features and scars) with fingerprints pressed on papers or equipments, and then the system will remove those fingerprints which are not in accord with these features.

To take characteristics filtration for an example, it accords the structure of the position and direction of centres and triangles to filtrate fingerprints. Fig. 3 is a fingerprint at the scene of the crime, a whorl, whose upper-centre and left-triangle are estimated, lower-centre and right-triangle are determined. For this fingerprint, its upper-centre, lower-centre, left-triangle and right-triangle form a series of structure relationship. Such as, the direction of the lower-centre relative to the upper-centre, the distance between the lower-centre and the upper-centre, the distance between the left-triangle and the upper-centre, the distance between the right-triangle and the upper-centre, the distance between the left-triangle and the lower-centre, topological relations of them and so on. The next, to illustrate with examples, as shown in Fig. 3, there are two values if we make a line from the upper-centre to the right-triangle, which can be represented by M and N, respectively. It is to say that referring to fingerprint at the scene of the crime，the distance between the upper-centre and the right-triangle of correspondent fingerprint pressed is between M to N. Taking the factor of deformation into account, if the deformation parameter is α, the distance between the upper-centre and the right-triangle should be between $M+M\times\alpha$ and $N-N\times\alpha$.



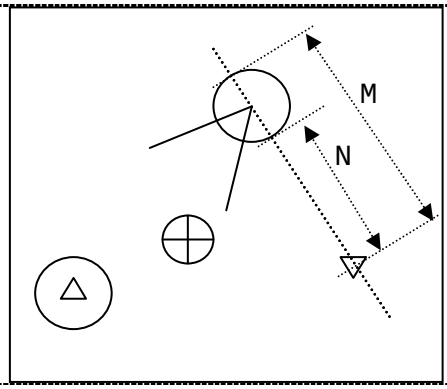
(a) Fingerprint pressed on papers using printing ink

(b) Fingerprint collected with equipments



(c) Fingerprint collected at the scene of the crime with digital cameras

Fig. 2: Fingerprints collected in various ways



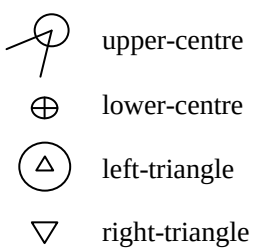


Fig. 3: an example of characteristics structure relation

2.3 Feature matching

The system marks the corresponding minutiae on the fingerprint pressed referring to the minutiae of the fingerprint at the scene of the crime; this is called the "feature matching". It is a complicated process, following it the basic principle: Supposing the feature number of the fingerprint at the scene of the crime is A, he feature number of the fingerprint pressed is B. Firstly, the system finds the corresponding fingerprint pressed basing on the feature of the fingerprint at the scene of the crime, and makes sure the position of every minutiae on the fingerprint pressed, then, all features in this range should be candidate features, supposing the number is N, this process is called "1→N". Next, the system will pick out the most matching feature from N candidate features basing on matching algorithm; this process is called "N →1". Thirdly, the most matching feature is as the basic point, the system will find other features in every direction, at the same time; it will examine and correct the existed features, until it finds out all the corresponding minutiae on the fingerprint pressed, the number is M (or less than M). This process is over.

2.4 Scoring of similar features

The scoring includes bonus point and deduction of points. Bonus point is to affirm the similarity of two fingerprints. Deduction of points is to negate the similarity of two fingerprints, that is, to exclude dissimilar fingerprints. These two processes cooperate. In CAFIS, factors of bonus point and deduction of points are following:

(1) Numbers of similar; (Bonus point)
(2) The particularity and integrity of matching features structure; (Bonus point)
- the particularity: such as adverse features, unusual features and so on;
- the integrity: congruity;

(3) The integral error and coincidence degree of matching; (Deduction of points)
(4) The integral matching coincidence degree. (Deduction of points)

2.5 Sorting of fingerprints

This is the last process of CAFIS. It is to sort fingerprints again according to values. These fingerprints sorting in front will be submitted to special persons to identify further, and then we will get the final matching result.

3 Algorithm of feature matching

3.1 Features orientation

Features orientation is to define the position of centre-triangle on fingerprints pressed basing on fingerprints at the scene of the crime, and to find N similar features at this position. As shown in Fig. 4, the position of "feature A" can be described as follow: the distance from A to the upper-centre is K, the included angle between A and the direction of the upper-centre is D, the distance from A to the left-triangle is T. When the deformation factor is considered, supposing the deformation rate is α, the position of "feature A" should be described as follow: the distance from A to the upper-centre is between K+Kα and K-Kα, the included angle between A and the direction of the upper-centre is between D＋Dα and D-Dα, the distance from A to the left-triangle is between T＋Tα and T-Tα. As shown in Fig. 5, the position of "feature A" should be within the range of shadow.

The next, the system will find candidacy features of the feature on fingerprints pressed. As shown in Fig. 4, there are three features in the corresponding range, that is, three candidacy features. Now, the "feature B" can be directly removed according to the direction of "feature A", because its direction is in the opposite direction. Then, there are only two candidacy features, that is, the N equals to two.

In the same way, we can get the aggregate of matching "feature K": $k => \varphi_{(k)} = k_0、k_1、k_2、k_3、k_4.....$, the value of this aggregate may be null.

3.2 The only matching feature (process of N→1)

Through features orientation, we can find candidacy features of fingerprints at the scene of the crime. For example, in last example, candidacy features of "feature A" are "candidate 1" and "candidate 3". Then, following is to make sure the fittest candidacy feature between "candidate 1" and "candidate 3", this is the process of N→1. The method of choosing one feature from N features is called "part feature structure" matching.

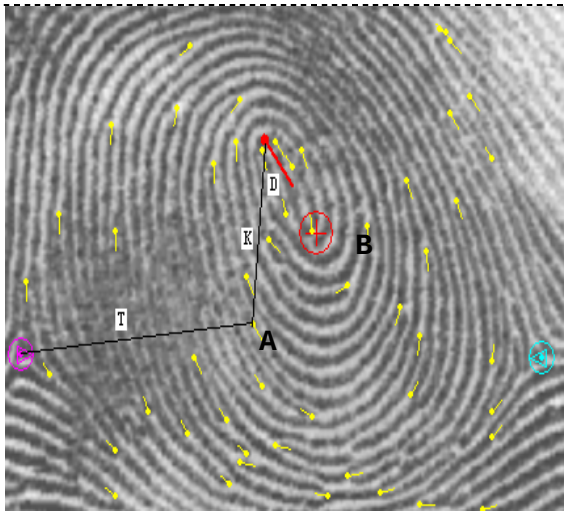


Fig. 4: The relation between "feature A" and centre-triangle

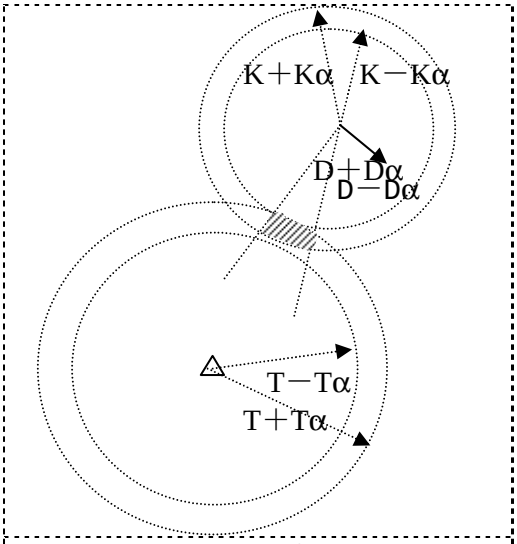


Fig. 5: The relation after addingα.

3.3 Derivative process

In last process, we can get the only corresponding feature of T fingerprints at the scene of crime. Then, these T feature are as the basic point, the system will find other probable corresponding features if we derivate in every direction. Altogether, it will examine and correct the existed features continuously. As shown in Fig. 6, the "feature A" on the fingerprint at the scene of crime is a basic point. Basing on the relation between the "feature A" and "feature B", the system can derivate the corresponding feature of "feature B" is "feature II" or "feature III" on the fingerprint pressed, finally it the corresponding feature fixed is "feature II". The next, the "feature B" can be as another basic point", the "feature C" is as well.

In the description of features orientation above, this paper used some features (centre, triangle, for example). They are called orientation features which can help matching special features quickly. They include: the centre (orientates quickly by using its direction and position), lower-centre, triangle (basing its position to orientate quickly), etc. Orientation features have three main functions: making sure the position of features on fingerprints easily, improving the accuracy of matching, improving the matching speeds.

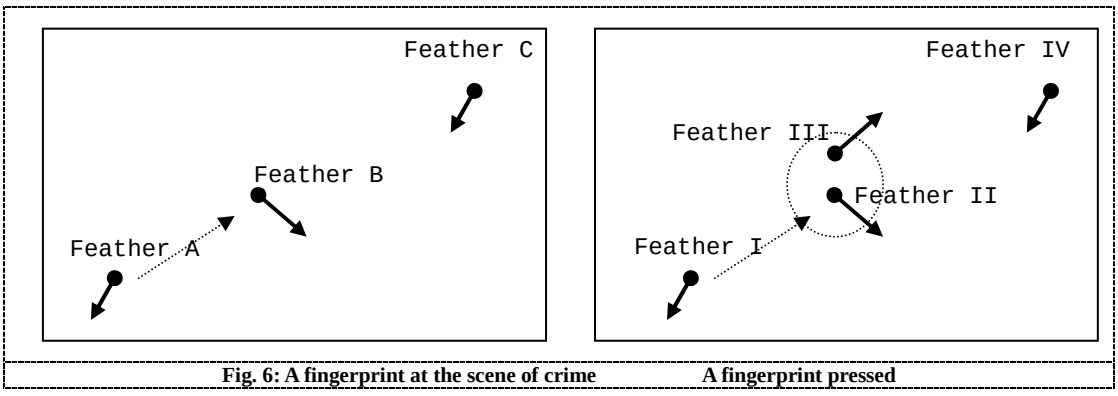


Fig. 6: A fingerprint at the scene of crime **A fingerprint pressed**

4. Advantages

4.1 Big capacity of the database

CAFIS has built a big database in Henan province, which can contain fingerprints of ten million persons. This includes: fingerprints of ten fingers have been 5800 thousands; fingerprints at the scene of crime have been 900 thousands. And with the increasing of data, the capacity of database can be improved continually. At present, it is the biggest database of fingerprints of ten fingers in our country.

4.2 Quick matching speed

At present, the matching speed of CAFIS is 3000 thousand per second, that is, it cans mach 3000 thousand fingerprints in one second. If the database capacity of fingerprints of ten fingers is one million, it needs 100*10/300(about 3.33) seconds to find a fingerprint at the scene of crime.

4.3 High accuracy

After testing, for CAFIS, we found that the accuracy of inquiring the database of fingerprint of ten fingers basing on the database of fingerprint of ten fingers is 99%, the accuracy of inquiring the database of fingerprint of ten fingers basing on the database of fingerprint at the scene of crime is 72%. The artificial inquires has many variable factors; the rate of leaving out must be much lower if we use CAFIS to inquire fingerprints.

4.4 Stable algorithm, extremely low declining rates

A lot of testing data demonstrate that the algorithm of CAFIS is stable and the declining rates are extremely low. When the capacity of CAFIS database is one million persons, we use a fingerprint at the scene of crime to inquire the database of fingerprints pressed, if a fingerprint inquired was second in the candidacy list, then we increase the capacity of CAFIS database to ten million persons, match, score and sort again, the fingerprint inquired was still second in the candidacy list. Thus, it demonstrates the conclusion above.

EXPERIMENTAL RESULTS AND ANALYSIS

To take fourteen thousands seven hundreds and ninety four fingerprints exacted by using CAFIS for an example, fingers distribution of fingerprints exacted are shown in Table 1.

Table 1. Fingers distribution.

Fingers	**Left thumb**	**Right thumb**	**Left forefinger**	**Right forefinger**	**Left middle finger**	**Right middle finger**	**Left ring finger**	**Right ring finger**	**Left little finger**	**Right little finger**
Amount	2,047	2,232	1,527	2,000	1,824	2,125	1,018	1,261	383	377
%	13.84	15.09	10.32	13.52	12.33	14.36	6.88	8.52	2.59	2.55

Then, the system extracts features from fingerprints gathered. The amount and quality of features are shown in Table 2. Features extracted are more, the accuracy is higher. The amount of features extracted is closely related to the quality of fingerprints. If it can get features between ten and twenty, the check rate will be higher.

Table 2. Relation between features and the check.

Features	**Below 10**	**10-20**	**Over 20**
Amount	216	12,557	2,021
Check rate(%)	1.5	84.9	13.6

The next, CAFIS will filtrate, match, score and sort according to features extracted, and then it will get a candidacy list. Special persons will make the final identification with the top 50 candidacy fingerprints. The result is shown in Table 3; check results mainly lie in the top 3 in the candidacy list. Thus it can be seen that the check rate of CAFIS is much higher.

Table 3. Relation between the ranking and the check.

Ranking	**1-3**	**3-10**	**10-20**	**20-50**
Amount	13,423	722	433	216
Check rate(%)	90.7	4.8	3	1.5

CONCLUSION

The features of fingerprints pressed, includes fingerprints types, centres, and directions of centres, upper-centres, lower-centres, left-triangles, right-triangles, minutiae and its direction, can be extracted by CAFIS automatically. But with the poor quality of fingerprints pressed, the system cannot extract these features accurately. CAFIS can classify fingerprints according to the quality of fingerprints pressed, and then fingerprint workers make necessary repair. For fingerprints at the scene of crime, the system can extract features automatically. But they are usually obscure, and effect of extracting is low. Currently, it is not recommended, specialists do this work.

The future research direction of CAIFS is how to pretreat fingerprints with poor qualities, and how to extract their features.

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