METHOD AND SYSTEM FOR IDENTIFYING A PERSON USING THEIR FINGER-JOINT PRINT

Inventors: Lei Zhang, Hong Kong (HK); Lin Zhang, Hong Kong (HK); Hailong Zhu, Hong Kong (HK); David Zhang, Hong Kong (HK); Nan Luo, Hong Kong (HK)

Assignee: The Hong Kong Polytechnic University, Kowloon (HK)

Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 768 days.

Filed: Jan. 15, 2009

Prior Publication Data

Int. Cl.
G06K 9/00 (2006.01)

U.S. Cl. ........ 382/115, 382/195; 382/125; 382/118

Field of Classification Search ................. 382/125, 382/115, 195, 118

See application file for complete search history.

References Cited

U.S. PATENT DOCUMENTS
3,576,537 A 4/1971 Ernst
3,576,538 A 4/1971 Miller
3,581,282 A 5/1971 Altman
4,032,889 A 6/1977 Nassimbene
4,736,203 A 4/1988 Sidlauskas
5,862,246 A * 1/1999 Colbert ................. 382/115
6,097,035 A 8/2000 Belongie et al.

OTHER PUBLICATIONS

ABSTRACT
A method for identifying a person using their finger-joint print including the outer skin around the proximal interphalangeal joint of a finger, the method comprising: capturing (10) an image of the finger-joint print of the person; extracting (12) a region of interest (ROI) based on a local convexity property of the finger-joint print; extracting (13) features representing the orientation of the lines in a finger-joint print image from the ROI using an extended Gabor phase coding scheme and the extracted features are represented in competitive code maps; wherein angular distance between the competitive code maps is compared (14) with a reference set in a database to identify the person.

10 Claims, 7 Drawing Sheets
OTHER PUBLICATIONS


* cited by examiner
Capture image of finger-joint print

Image Acquisition Module on captured image

ROI extraction from recognised image

Features extraction and coding of extracted features from ROI

Matcher using angular distance within a predetermined acceptable range

Registration Database

Competitive Code Maps
Figure 11

FRR and FAR plots

Percentage of False Rates vs Decision Threshold
METHOD AND SYSTEM FOR IDENTIFYING A PERSON USING THEIR FINGER-JOINT PRINT

TECHNICAL FIELD

The invention concerns a method and system for identifying a person using their fingerprint print including the outer skin around the proximal interphalangeal joint of a finger.

BACKGROUND OF THE INVENTION

Personal identification has numerous applications such as physical access control, computer security and law enforcement. Biometric based personal identification is regarded as an effective method for automatically recognizing a person’s identity with a high confidence. Biometrics are physiological or behavioral characteristics used to distinguish between individuals which can serve as a superior solution to this problem. Many systems have been developed based on various biometric characteristics. Biometrics systems have been developed based on different kinds of biometrics, including face, iris, fingerprint, palm-print, voice and signature. Each biometric identifier has its own characteristics and application domains and none of them can supersede all the others under every circumstance. For example, although fingerprint identification has been widely used for many years and works well in most cases, it has its own drawbacks including difficulty to acquire fingerprint features. For some types of people, such as labor workers and the elderly, the inner parts of the hands can be easily abraded that will seriously affect the performance of fingerprint, palmprint, or finger based creases based systems. Iris based systems can achieve extremely high accuracy, however, iris scanners are very expensive. Palm print based systems must have a large size acquisition device. As a result, new kinds of systems based on various biometric identifiers are still developing.

Therefore there is a desire for a biometric method and system that addresses some of the problems identified.

SUMMARY OF THE INVENTION

In a preferred aspect, there is provided a method for identifying a person using their fingerprint print including the outer skin around the proximal interphalangeal joint of a finger, the method comprising:

capturing an image of the fingerprint print of the person;
extracting a region of interest (ROI) image $I_{ROI}$ based on a local convexity property of the fingerprint print;
extracting features representing the orientation of the lines in a fingerprint print image from the ROI image $I_{ROI}$ using an extended Gabor phase coding scheme and the extracted features are represented in competitive code maps;
wherein angular distance between the competitive code maps is compared with a reference set in a database to identify the person.

The method may further comprise defining the initial step of placing the finger onto a triangular block.

The method may further comprise defining a ROI coordinate system to extract the ROI image $I_{ROI}$ by:

cropping a coarse sub-image $I_{coarse}$ from the captured image;

obtaining a corresponding edge image $I_{edge}$ from the coarse sub-image $I_{coarse}$ using a canny edge detector;
coding the corresponding edge image $I_{edge}$ based on a local convexity property to obtain a convexity coding image $I_{convex}$ such that each pixel on the corresponding edge image $I_{edge}$ is assigned a code to represent the local convexity of this pixel;

obtaining a line $X=x_0$ to best classify “-1” and “1” pixels on the convexity image $I_{conv}$ and taking the line $X=x_0$ as the Y-axis of the ROI coordinate system and the line

$$y = \frac{\text{height of } I_{coarse}}{2}$$
as the X-axis.

The formula to obtain $x_0$ may be:

$$x_0 = \text{arg min}_x \left( \frac{\text{sum of } \{+1\} \text{ pixels on the right of } X=x}{\text{sum of } \{+1\} \text{ pixels}} + \frac{\text{sum of } \{-1\} \text{ pixels on the left of } X=x}{\text{sum of } \{-1\} \text{ pixels}} \right)$$

A real part $G_R$ of a neurophysiology-based Gabor filter may be applied to the ROI image $I_{ROI}$ to extract the orientation information of the ROI image $I_{ROI}$.

The orientation information may be represented in a competitive code map defined by:

$$\text{compCode}(x, y) = \text{arg max}_j \{ \text{abs}(I_{ROI}(x, y) * G_R(x, y, \omega, \theta)), j = 0, \ldots, 5 \}$$

where * represents the convolution operation and $G_R$ represents the real part of neurophysiology-based Gabor function $G$. The angular distance $D(P, Q)$ may be defined by the following equation:

$$D(P, Q) = \sum_{x \in x_0} \left( \frac{\sum_{y \in y_0} (P_{x}(x, y) \cap Q_{x}(x, y)) \times G(P_{x}(x, y), Q, (x, y))}{\sum_{y \in y_0} (P_{x}(x, y) \cap Q_{x}(x, y))} \right)$$

where:

$$G(P_{x}(x, y), Q, (x, y)) = \begin{cases} 1, & \text{if } P_{x}(x, y) = 6 \text{ and } Q(x, y) \neq 6 \\ 1, & \text{if } P_{x}(x, y) \neq 6 \text{ and } Q(x, y) = 6 \\ 0, & \text{if } P_{x}(x, y) = Q(x, y) \\ \min(P(x, y) - Q(x, y), Q(x, y) - (P(x, y) - 6)), & \text{if } P(x, y) > Q(x, y) \text{ and } P(x, y) \neq 6 \\ \min(Q(x, y) - P(x, y), P(x, y) - (Q(x, y) - 6)), & \text{if } Q(x, y) < P(x, y) \text{ and } Q(x, y) \neq 6 \end{cases}$$

and $\cap$ denotes an AND operator.

An A* path-finding searching algorithm may be used to provide an approximate optimal solution to match the extracted features stored as competitive code maps.
In a second aspect, there is provided a system for identifying a person using their finger-joint print including the outer skin around the proximal interphalangeal joint of a finger, the method comprising:

an image capture device to capture an image of the finger-joint print of the person;
a first extraction module to extract a region of interest (ROI) image $I_{ROI}$ based on a local convexity property of the finger-joint print;
a second extraction module to extract features representing the orientation of the lines in a finger-joint print image from the ROI image $I_{ROI}$ using an extended Gabor phase coding scheme and the extracted features are represented in competitive code maps;

wherein angular distance between the competitive code maps is compared with a reference set in a database to identify the person.

The system may further comprise a triangular block for placement of the finger.

The present invention is a standalone system that advantageously uses the 2D finger-joint print features for personal identification. Through rigid experiments, this new biometric identifier has the properties of uniqueness and stability, which make it a very good biometric characteristic for personal identification.

The present invention advantageously operates in real-time and achieves a high recognition rate that is comparable to other biometric systems, such as fingerprint recognition system.

The present invention is more user friendly than other kinds of systems, such as fingerprint recognition system. The imaging of the present invention is touchless and unlike fingerprint imaging, no imprint will be left.

The present invention has a small form factor compared to some existing biometric systems, such as a palmprint recognition system. This means it can be easily deployed in many applications.

The present invention is very cost effective and can achieve high performance comparable to other popular biometric systems.

The present invention is more suitable than other biometric systems in some specific applications. For example, compared with the fingerprint or palmprint recognition systems, the present invention is more suitable for labor workers. The inner surface of these workers’ hands may suffer severe abrasion and therefore fingerprint or palmprint recognition systems are unsuitable.

**BRIEF DESCRIPTION OF THE DRAWINGS**

An example of the invention will now be described with reference to the accompanying drawings, in which:

FIG. 1 is a process flow diagram for matching a finger-joint print in accordance with a preferred embodiment of the present invention;

FIG. 2 is a structural diagram of a finger-joint print identification system;

FIG. 3 is a sample image captured by an image capture device of the system of FIG. 2;

FIG. 4 is a coarse sub-image $I_{coarse}$, for the sample image of FIG. 3;

FIG. 5 is an edge image $I_{edge}$, for the coarse sub-image $I_{coarse}$ of FIG. 4;

FIGS. 6(a) and (b) illustrate a convex direction coding scheme;

FIG. 7 is a Region of Interest (ROI) coordinate system for the coarse sub-image $I_{coarse}$ of FIG. 4 where the rectangle indicates the ROI area corresponding to the coarse sub-image $I_{coarse}$ that is to be extracted;

FIG. 8 is a set of examples of the ROI images;

FIG. 9 is a set of images where the top image is a ROI image $I_{ROI}$ and the bottom image is its competitive code map;

FIG. 10 is a chart illustrating the distribution of genuine and imposter distances; and

FIG. 11 is a chart illustrating the False Rejection Rate (FRR) and the False Acceptance Rate (FAR) plots.

**DETAILED DESCRIPTION OF THE DRAWINGS**

Referring to FIG. 1, a personal identification system 18 is provided that is based on a two-dimensional (2D) finger-joint print. The finger-joint print refers to the outer skin around the proximal interphalangeal joint of a finger. The system 18 generally comprises two parts: a finger-joint print image acquisition device 19 to capture the finger-joint print image of a person, and a software module 27 to process the captured image for personal identification.

The process of the software module 27 includes: registering and matching finger-joint print images. When registering a finger-joint print, an image of the finger-joint print is captured 10. The finger-joint print image is acquired 11 and then the Region of Interest (ROI) image $I_{ROI}$ is extracted 12 with an extraction algorithm based on the local convexity property of the finger-joint print. The features representing the orientation of the lines in a finger-joint print image is extracted 13 from the ROI image $I_{ROI}$ based on the extended Gabor phase coding scheme. The extracted features are represented in competitive code maps 92 and stored in a database 15. Another feature is retrieved from the newly acquired image and is searched against images previously stored in the database 15 to obtain angular distances during matching. To determine if there is a match, the angular distances are compared 14. If the angular distance is zero a perfect match is found. However, if the angular distance is within a predetermined acceptable range, then this may also be considered a match.

**Finger-Joint Print Image Acquisition Device**

Referring to FIG. 2, the finger-joint print image acquisition device 19 generally comprises a finger bracket 24, a ring LED light source, a lens, a common CCD camera 22 and a frame grabber 21. The frame grabber 21 is an electronic device that captures individual, digital still frames from the CCD camera 22. To obtain a stable finger-joint print image, a case is provided for the finger bracket 24 to form a semi-closed environment. The finger bracket 24 is used to control the pose of the finger. The device 19 ensures that the pose of the finger does not significantly vary between different capturing sessions in order to simplify the recognition methods. The finger bracket 24 has a triangular block 24 which constrains the angle between the proximal phalanx 26 and the middle phalanx 25 to a certain magnitude.

When capturing an image of the finger-joint, the user is instructed to place their finger flat on the basal block of the finger bracket 23 and to make the middle phalanx 25 and the proximal phalanx 26 close against the two slopes of the triangular block 23. The angle between the middle phalanx 25 and the proximal phalanx 26 is approximately the same as that formed by the two slopes of the triangular block 23. After the image is captured by the CCD camera 22 and frame grabber 21, it is transmitted to the computer 20 for further processing by the software module 27. FIG. 3 shows a sample image 30 acquired by the device 19.
ROI Image Extraction from Finger-Joint Print Images

In the software module 27, an ROI coordinate system is defined that is able to align different finger-joint print images for matching. For reliable feature measurements, an algorithm determines the ROI coordinate system. The ROI images are extracted using the ROI coordinate system. The X-axis of the ROI coordinate system is relatively easily identified while the Y-axis presents some difficulty. The "skin curves" on the two sides of the proximal interphalangeal joint have different convexity properties. The details of the ROI image extraction process are described.

A "coarse" sub-image I_{coarse} 40 is cropped from the original image 30.

Useful pixels only occupy a part of the image acquired that corresponds to the "real" finger. The coarse sub-image I_{coarse} 40 is cropped from the original image 30 for the convenience of subsequent processing. The left and right boundaries of the "coarse" sub-image I_{coarse} 40 are evaluated by experience. The top and bottom boundaries are evaluated according to the boundary of the "real" finger. The boundaries are obtained using a method such as a canny edge detector. The corresponding coarse sub-image I_{coarse} 40 of the sample image 30 is depicted in FIG. 4.

A corresponding edge image I_{edge} 50 is obtained for the coarse sub-image I_{coarse} 40 using a canny edge detector. The corresponding edge image I_{edge} 50 for the coarse sub-image I_{coarse} 40 is depicted in FIG. 5.

The corresponding edge image I_{edge} 50 is convex direction coded based on a local convexity property to obtain a convexity coding image I_{c} illustrated by FIG. 6(b). Each pixel of the corresponding edge image I_{edge} 50 is given a code to represent the local convexity of this pixel. The underlying principle of this coding scheme is as follows. Based on the observation of finger-joint print images, an ideal model for "curves" on a finger-joint print image is abstracted as shown in FIG. 6(a). In this model, a finger-joint print "curve" is either convex leftward (squared points in FIG. 6(a) or convex rightward (circle points in FIG. 6(a)). A pixel on a convex leftward curve is given a code "1"; a pixel on a convex rightward curve is given a code "-1", and the other pixels not on any curves are coded as "0". The present invention regards the edges in I_{edge} as "curves" and this convex direction coding is performed on edge FIG. 6(b) illustrates the coding result for FIG. 6(a).

The algorithm is:

\[ y_{nic} = \frac{\text{height of } I_{edge}}{2} \]

initialize I_{c} with the same size as I_{edge} and assign each pixel a value zero; scan each pixel on I_{edge} from left to right, from top to down:

for the current pixel I_{edge}(i,j):

// j represents the row and column of the current pixel in the image I_{edge}

if I_{edge}(i,j) == 0 // it is a background pixel

ignore it;
else if I_{edge}(i,j) == -1 // it is a bifurcation pixel

ignore it;
else if I_{edge}(i+1,j+1) == -1 and I_{edge}(i+1,j) == -1 // it is a bifurcation pixel

I_{c}(i,j) = 1;
else if I_{edge}(i+1,j+1) == 1 and i < y_{nic} or (I_{edge}(i+1,j) == 1 and i > y_{nic})

I_{c}(i,j) = 1;
else if I_{edge}(i+1,j+1) == 1 and i < y_{nic} or (I_{edge}(i+1,j) == -1 and i > y_{nic})

I_{c}(i,j) = -1;
while \( G_k \) represents the real part of Gabor function \( G \). The competitive code at this pixel is then defined as follows:

\[
\text{compCode}(x, y) = \arg \max_j \{ \text{abs}(I_{ROI}(x, y) \times G_k(x, y, \omega_j, \theta_j)) \}
\]

The algorithm details are:
for each pixel \( I_{ROI}(x, y) \) on the ROI image \( I_{ROI} \):

\[
R_i = \{ \text{compCode}(x, y) \} \times G_k(x, y, \omega_j, \theta_j) \}
\]

if \( \text{std}(R_i) / \max(R_i) - \min(R_i) \) < threshold //this pixel does not have a

1. \( \text{compCode}(x, y) = 6; \)

else

\( \text{compCode}(x, y) = \arg \max_j \{ \text{abs}(R_j) \} \}

The competitive code map 92 is also stored in a matrix form. FIG. 9 shows an example of a ROI image I_{ROI} 91 and its corresponding competitive code map 92 obtained with the algorithm described above.

Matching Competitive Codes
Given two competitive code representation of two fingerprint prints, a matching algorithm determines the degree of similarity between them. Angular distances are employed to compare them. Let P and Q be the two feature matrices (competitive code maps 92) and \( P_{\mathbb{R}} \) and \( Q_{\mathbb{R}} \) be the corresponding masks used for indicating the overlapping areas when one of the features is translated. Angular distance \( D(P, Q) \) is defined by the following equation:

\[
D(P, Q) = \frac{\sum_{x,y} P(x,y) \cap Q(x,y)}{\sum_{x,y} P(x,y) + \sum_{x,y} Q(x,y) - \sum_{x,y} P(x,y) \cap Q(x,y)}
\]

where

\[
\begin{align*}
&\text{if } P(x,y) > Q(x,y) \text{ and } P(x,y) \neq 6, \\
&\text{if } P(x,y) \neq 6 \\
&\text{if } Q(x,y) > P(x,y) \text{ and } Q(x,y) \neq 6 \\
&\text{if } Q(x,y) \neq 6 \\
&\text{if } P(x,y) \neq 6 \\
&\text{if } Q(x,y) \neq 6 \\
&\text{if } P(x,y) \neq 6 \\
&\text{if } Q(x,y) \neq 6
\end{align*}
\]

\( \cap \) denotes an AND operator. Taking into account the possible translations in the extracted sub-image (with respect to the one extracted during the enrolment), multiple matches are performed with one of the features translated in horizontal and vertical directions. The minimum of the resulting matching scores is considered to be the final angular distance.

In the majority of cases, the ROI images cannot be perfectly matched. When comparing the competitive codes, a range of translations is applied to obtain multiple matching distances and the minimal one is regarded as the final angular distance. This means that a minimal distance is searched for within a "translation space". It is very time consuming if this is directly performed over the competitive codes. Therefore a multi-scale matching scheme is used. At first, the pyramidal trees for the two competitive codes are constructed based on a down sampling operation. If the normal coarse-to-fine matching is used, for the majority of cases, it cannot provide an optimal solution. This is because when such a searching makes a bad choice of directions in the coarse-to-fine search, it can never backtrack no matter how large the error becomes at the fine scale levels. An \( \Lambda^* \) (which is a path-finding algorithm fully developed in Artificial Intelligence) like searching algorithm is used which can provide an approximate optimal solution. The \( \Lambda^* \) path-finding searching algorithm provides an approximate optimal solution to match the extracted features stored as competitive code maps 92.

Experiments and Results
In order to evaluate the system 18, rigorous experiments are performed on the specially acquired finger-joint print image database from 165 subjects. All images were acquired using the image capture device 22. The database 15 was populated in the dataset, 125 people are male. In addition, the finger-joint print images were collected at two separate sessions. At each session, the subject was asked to provide six images, each of the left index finger, left middle finger, right index finger and right middle finger. Therefore, each person provided 48 images. The database 15 contains 7920 images from 660 different fingers. The average time interval between the first and second sessions was around 25 days.

To verify accuracy of the system 18, each finger-joint print image is matched with all the other images in the database 15. This resulted in 43,560 genuine and 31,359,240 imposter matching distances respectively. FIG. 10 shows the distribution of genuine and imposter matching distances. FIG. 11 shows the performance of the system, in terms of the FRR (false rejection rate) and the FAR (false acceptance rate) characteristics. The EER (equal error rate) obtained by the system is 1.13%, which is comparable with other hand-based biometrics, such as hand geometry, 3D finger surface and fingerprint.

The system 18 uses a 2D finger-joint print which has abundant line features as a biometric identifier. The system 18 is low cost system for real-time personal identification. The system 18 includes a novel CCD camera based finger-joint print image acquisition device 22 and an associated software processing system 27. A preprocessing algorithm extracts the ROI image I_{ROI} from finger-joint print image for feature extraction. The use of a 2D Gabor filter based competitive coding is extended to represent a finger-joint print image using its texture feature. When matching, a normalized angular distance for the matching measurement is applied. The EER of the system is 1.13% using the current finger-joint print database 15 of 7,920 images from 660 different fingers. Experiments indicate that the system 10 can achieve comparable results with other hand-based biometrics, such as fingerprint, hand geometry or 3D finger surface. The system 18 may be used for personal identification or verification. If other biometrics based systems are not suitable, the system 18 is a viable and cost-effective alternative.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the scope or spirit of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects illustrative and not restrictive.

We claim:

1. A method for identifying a person using their finger-joint print including the outer skin around the proximal interphalangeal joint of a finger, the method comprising:

2. Capturing an image of the finger-joint print of the person;

3. Extracting a region of interest (ROI) image I_{ROI} based on a local convexity property of the finger-joint print;
extracting features representing the orientation of the lines in a finger-joint-print image from the ROI image \( I_{ROI} \) using an extended Gabor phase coding scheme and the extracted features are represented in competitive code maps, wherein angular distance between the competitive code maps is compared with a reference set in a database to identify the person; and defining a ROI coordinate system to extract the ROI image \( I_{ROI} \) by:

cropping a coarse sub-image \( I_{coarse} \) from the captured image;

obtaining a corresponding edge image \( I_{edge} \) from the coarse sub-image \( I_{coarse} \) using a canny edge detector;

coding the corresponding edge image \( I_{edge} \) based on a local convexity property to obtain a convexity coding image \( I_{convex} \) such that each pixel on the corresponding edge image \( I_{edge} \) is assigned a code to represent the local convexity of this pixel;

obtaining a line \( X = x_t \) to best classify "-1" and "1" pixels on the convexity image \( I_{convex} \) and taking the line \( X = x_t \) as the \( Y \)-axis of the ROI coordinate system and the line

\[
y = \frac{\text{height of } I_{coarse}}{2}
\]

as the \( X \)-axis.

2. The method according to claim 1, further comprising the initial step of placing the finger onto a triangular block.

3. The method according to claim 1, wherein the formula to obtain \( x_t \) is:

\[
x_t = \argmax \left( \frac{\text{num of "1" pixels on the right of } X = x}{\text{num of "1" pixels}} + \frac{\text{num of "-1" pixels on the left of } X = x}{\text{num of "-1" pixels}} \right)
\]

4. The method according to claim 1, wherein a real part \( G_R \) of a neurophysiology-based Gabor filter is applied to the ROI image \( I_{ROI} \) to extract the orientation information of the ROI \( I_{edge} \).

5. The method according to claim 4, wherein the orientation information is represented in a competitive code map defined by:

\[
\text{compCode}(x, y) = \argmax_j (abs(G_R(x, y) \ast G_j(x, y, \theta_j)), j = \{0, \ldots, 5\})
\]

where \( \ast \) represents the convolution operation and \( G_R \) represents the real part of neurophysiology-based Gabor function \( G \).

6. The method according to claim 1, wherein the angular distance \( D(P, Q) \) is defined by the following equation:

\[
D(P, Q) = \frac{\sum_{x, y \in P} \sum_{x', y' \in Q} (P(x, y) \land Q(x', y')) \times \text{compCode}(x, y, Q(x', y', \theta_{xy}))}{\sum_{x, y \in P} \sum_{x', y' \in Q} (P(x, y) \land Q(x', y'))}
\]

where \( P(x, y) = 6 \) and \( Q(x, y) = 6 \)

\[
1, \ P(x, y) \neq 6 \text{ and } Q(x, y) = 6
\]

\[
0, \ P(x, y) = Q(x, y)
\]

\[
G(P(x, y), Q(x, y)) = \begin{cases} 
\text{min}(P(x, y) - Q(x, y), Q(x, y) - (P(x, y) - 6)), & \text{if } P(x, y) > Q(x, y) \text{ and } P(x, y) \neq 6 \\
\text{min}(Q(x, y) - P(x, y), Q(x, y) - (Q(x, y) - 6)), & \text{if } P(x, y) < Q(x, y) \text{ and } Q(x, y) \neq 6 
\end{cases}
\]

and \( \land \) denotes an AND operator.

7. The method according to claim 1, wherein an A* path-finding searching algorithm is used to provide an approximate optimal solution to match the extracted features stored as competitive code maps.

8. A system for identifying a person using their finger-joint print including the outer skin around the proximal interphalangeal joint of a finger, the system comprising:

- an image capture device to capture an image of the finger-joint print of the person;
- a first extraction module to extract a region of interest (ROI) image \( I_{ROI} \) based on a local convexity property of the finger-joint print; and
- a second extraction module to extract features representing the orientation of the lines in a finger-joint print image from the ROI image \( I_{ROI} \) using an extended Gabor phase coding scheme and the extracted features are represented in competitive code maps, wherein angular distance between the competitive code maps is compared with a reference set in a database to identify the person, and wherein the first extraction module is configured to define a ROI coordinate system to extract the ROI image \( I_{ROI} \) by:

cropping a coarse sub-image \( I_{coarse} \) from the captured image;

obtaining a corresponding edge image \( I_{edge} \) from the coarse sub-image \( I_{coarse} \) using a canny edge detector;

coding the corresponding edge image \( I_{edge} \) based on a local convexity property to obtain a convexity coding image \( I_{convex} \), such that each pixel on the corresponding edge image \( I_{edge} \) is assigned a code to represent the local convexity of this pixel;

obtaining a line \( X = x_t \) to best classify "-1" and "1" pixels on the convexity image \( I_{convex} \) and taking the line \( X = x_t \) as the \( Y \)-axis of the ROI coordinate system and the line

\[
y = \frac{\text{height of } I_{coarse}}{2}
\]

as the \( X \)-axis.

9. The system according to claim 8, further comprising a triangular block for placement of the finger.

10. A system for identifying a person using their finger-joint print including the outer skin around the proximal interphalangeal joint of a finger, the system comprising:

- an image capturing means for capturing an image of the finger-joint print of the person;
- region extracting means for extracting a region of interest (ROI) image \( I_{ROI} \) based on a local convexity property of the finger-joint print;
feature extracting means for extracting features representing the orientation of the lines in a finger joint print image from the ROI image \( I_{ROI} \) using an extended Gabor phase coding scheme and the extracted features are represented in competitive code maps; comparing means for comparing angular distance between the competitive code maps with a reference set in a database to identify the person; and means for defining a ROI coordinate system to extract the ROI image \( I_{ROI} \) by cropping a coarse sub-image \( I_{course} \) from the captured image, obtaining a corresponding edge image \( I_{edge} \) from the coarse sub-image \( I_{course} \) using a canny edge detector, coding the corresponding edge image \( I_{edge} \) based on a local convexity property to obtain a convexity coding image \( I_{conv} \) such that each pixel on the corresponding edge image \( I_{edge} \) is assigned a code to represent the local convexity of this pixel, obtaining a line \( X - x_0 \) to best classify "-1" and "1" pixels on the convexity image and taking the line \( X - x_0 \) as the Y-axis of the ROI coordinate system and the line

\[
y = \frac{\text{height of } I_{course}}{2}
\]

as the X-axis.