(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 January 2005 (27.01.2005)

PCT

(10) International Publication Number
WO 2005/008568 A1

(51) International Patent Classification[7]: G06K 9/00

(21) International Application Number: PCT/KR2004/001794

(22) International Filing Date: 19 July 2004 (19.07.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10-2003-0048985 18 July 2003 (18.07.2003) KR

(71) Applicant (*for all designated States except US*): **YONSEI UNIVERSITY** [KR/KR]; Yonsei University, 134, Sinchon-dong, Seodaemun-gu, Seoul 120-749 (KR).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): **KIM, Jai-Hie** [KR/KR]; 614-1201, Booyoung Apt. Eunvit Maeul 6-Danji, Hwajeong 1-dong, Deokyang-gu, Goyang-si, Gyeonggi-do 412-748 (KR).

(74) Agent: **JUNG, Se-Sung**; #208, Hubahuba Bldg., 648, Yoksam-dong, Gangnam-gu, Seoul 135-911 (KR).

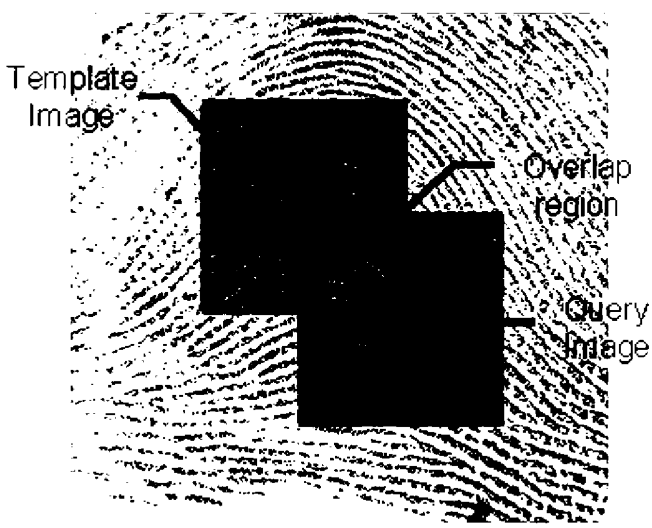
(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** METHOD FOR ACQUIRING A FINGERPRINT IMAGE BY SLIDING AND ROLLING A FINGER



(57) **Abstract:** This invention provides stably capturing strategy of several sequential fingerprint images and their stitching method, which eventually broaden range of enrolling image and prospects for increasing the verification performance of the fingerprint authentication system especially equipped with a small-sized sensor. The whole process consists of 4 parts. First, the fingerprint enrolling procedure captures several sequential images caused by rolling and sliding a finger on a sensor. Second procedure registers several images to make one mosaicked image. It produces a wide region of a fingerprint even with a small-sized sensor. The third compensates for the deformation of the mosaicked image caused by finger's motion on the sensor and the last extracts features from the mosaicked image and stores them into the database.

WO 2005/008568 A1

Description

METHOD FOR ACQUIRING A FINGERPRINT IMAGE BY SLIDING AND ROLLING A FINGER

Technical Field

[1] This invention relates to a fingerprint authentication system with a small sensor. More specifically, the invention relates to a fingerprint enrollment method for acquiring sequential fingerprint images by rolling and sliding a finger on a small sensor, and makes a wide fingerprint image by mosaicking the acquired images.

Background Art

[2] Fingerprint-based verification systems are provided widely because they are convenient to use and relatively superior to other biometrics systems with respect to the price and performance. Especially, a small sensor (e.g., solid-state sensors) has the advantage, such that it can be applied to many appliances (e.g., laptop computers, cellular phones). However, the physical limitation - e.g., size of the sensor - probably results in lack of information about the fingerprint. Therefore the relatively small amount of common region between the template and query impressions results in degraded performance, like a higher rate of false rejects and/or false accepts. An example of the overlapped region between template and query impressions is illustrated in FIG. 1.

[3] To overcome this problem, Fingermatrix, Inc. (US. Pat. No. 4,553,837) invented the device shown FIG. 2 which can acquire a whole fingerprint image. The device illustrated in FIG. 2 rotates a scanner cylindrically around a fingerprint and captures a whole fingerprint image. Cross Match Technologies (US. Pat. No. 6,483,932) invented a rolled fingerprint scanner illustrated in FIG 3. Unlike the device in FIG. 2, instead of rotating the scanner, a rolled fingerprint scanner captures image sequences which are acquired by rolling a finger on a large-sized flat sensor and mosaic them for a whole fingerprint image.

[4] However the device of Cross Match Technologies requires the large senor so the device is mainly used in the specific application like AFIS. In order to acquire a wide fingerprint image with a small sized sensor, some researchers (e.g., A.K Jain, D.J Lee, et al) have studied about the mosaicking method which registers several partial fingerprint images to get a wide fingerprint image. In order to capture a whole fingerprint image, the conventional devices need several appended devices or a large sensor which can cover the whole fingerprint region so the size of the system becomes

bigger and the cost becomes very high too. Also some researchers have tried to get a wide fingerprint image from several partial fingerprint images captured with a small sensor.

Disclosure of Invention

Technical Problem

[5] However the conventional devices collect fingerprint images by dabbing a finger on the sensor so that the collected fingerprint images can be too correlated or uncorrelated. If the images are too correlated, there is no gain in integrating the images into single fingerprint image. Otherwise, it is very difficult to integrating the images.

Technical Solution

[6] The present invention is related to the fingerprint authentication system with a small sensor. The system realized by this invention guides a user to roll his or her finger on the sensor and also slide his/her finger simultaneously, which makes the system obtain a wide area of fingerprint stably even with a small sensor.

[7] In addition, since temporally adjacent images among the acquired images are highly correlated, they can be easily registered. However, accurate registration is unavailable because physical friction when sliding a finger on the sensor can cause the local deformation, which degenerates quality of mosaicked images.

[8] To mosaic the images correctly, first of all, the invention selects several images among the total acquired images based on the quality check algorithm, and then mosaics the images in the temporal order. During the mosaicking process, the invention estimates the global alignment parameters which align two images coarsely by matching the image blocks between two images and finds the corresponding blocks again between two images hierarchically by using the global alignment parameters.

[9] The invention regards the difference between the transformation parameters of each local block and the global transformation parameters as the local deformation and to compensate for the deformation warps two images by 2-pass mesh warping.

[10] Finally, the invention assigns the gray value in the warped image weighted by the coherence of images.

Advantageous Effects

[11] As described above, in accordance with a fingerprint enrollment method, since the system realized by this invention guides a user to roll his or her finger on the sensor and also slide his/her finger simultaneously, there is a merit that the system obtain a wide area of fingerprint stably even with a small sensor. Additionally, since temporally adjacent images among the acquired images are highly correlated, they can be easily

registered.

Description of Drawings

[12] FIG. 1 shows the small common area between a query and template image;

[13] FIG 2. shows the device illustrated in US. Pat. No. 4,553,837;

[14] FIG 3. shows the device illustrated in US. Pat. No. 6,483,932;

[15] FIG. 4 is a block diagram of this invention;

[16] FIG. 5 is a flow chart showing the image mosaicking and feature extraction block in FIG. 4 in detail;

[17] FIG. 6 is a flow chart of the image acquisition part shown in FIG. 5;

[18] FIG. 7 shows that a user rolls and slides his finger horizontally on the sensor;

[19] FIG. 8 are the sequential images captured by the enrollment method shown in FIG. 7;

[20] FIG. 9 is a mosaicked image with the images shown in FIG. 8;

[21] FIG. 10 shows that a user slides his finger vertically on the sensor;

[22] FIG. 11 are the sequential images captured by the enrollment method shown in FIG. 10;

[23] FIG. 12 is a mosaicked image with the images shown in FIG. 11;

[24] FIG. 13 shows that a user rolls and slides his finger in arbitrary direction on the sensor;

[25] FIG. 14 shows the positions of the finger against the sensor enrolled by the method shown in FIG. 13;

[26] FIG. 15 are the sequential images captured by the enrollment method shown in FIG. 13;

[27] FIG. 16 is a mosaicked image with the images shown in FIG. 15;

[28] FIG. 17 is a flow chart which explains the image mosaicking and deformation compensating process for two images;

[29] FIG. 18 shows two enrolled fingerprint images shown in FIG. 17;

[30] FIG. 19 is a coarsely aligned image after being processed in 1020 blocks in FIG. 17;

[31] FIG. 20 is an example image which is divided into several blocks; and

[32] FIG. 21 is a mosaicked image after taking all procedure shown in FIG. 17.

Best Mode

[33] FIG. 1 explains that the common area between a query and template image is so small, because of the small sensor, that the performance can be deteriorated.

[34] FIG. 4 is a general flow chart of this invention. The fingerprint sensor 410 captures

the sequential images enrolled by rolling and sliding a finger on the sensor by a user. A wide mosaicked image is constructed from the captured images and features are extracted from the mosaicked image in the block 420. The extracted features are stored in the database 430.

[35] FIG. 5 shows the detail of the block 420 in FIG. 4. The image acquisition block 510 selects good quality images from the sequential images enrolled by rolling and sliding a finger on the sensor 410 by the user, and guides a user to enroll his fingerprint correctly. The image mosaicking block 520 makes the captured images a wide mosaicked image. When mosaicking the captured images, the deformation of the mosaicked image caused by finger's motion on the sensor is compensated in the process 530. The feature extraction process 540 extracts feature vectors from the mosaicked image and store the feature vectors in the database 430.

[36] FIG. 6 explains the image acquisition block 510 in detail. In the acquisition process, first of all, the system checks the existence of the fingerprint on the fingerprint sensor 410. If the fingerprint exists, the fingerprint image is stored into the temporary buffer. That is, all the images, captured during from putting a finger on the sensor to taking it off the sensor, are stored in the temporary buffer. If the number of the images stored in the buffer is over N, the system doesn't capture any fingerprint image and checks the qualities of the images. If the quality of the images satisfies the system criterion, the system executes the image mosaicking process 520 with these images otherwise the system requires a user to reenroll his or her fingerprint.

[37] FIG. 7 shows an enrollment method according to this invention. A user rolls his or her finger on the sensor and at the same time, slides his or her finger to prevent his or her finger off the sensor. FIG. 8 is the fingerprint images captured sequentially by the enrollment method shown in FIG. 7. Since the captured fingerprint images (See FIG. 8) covers the horizontal region of a finger, if the images are mosaicked like FIG. 9, the system can acquire the wide fingerprint image with a very small sensor.

[38] FIG. 10 shows another enrollment method according to this invention. A user slides his finger vertically on the sensor by a user. FIG. 11 are the fingerprint images captured sequentially by the enrollment method shown in FIG. 10. The captured fingerprint images (See FIG. 11) covers the vertical region of a finger. FIG. 12 is the mosaicked image with the images (See FIG. 11). To acquire the whole fingerprint image, the system guides a user to roll his finger horizontally and slide the finger vertically on the sensor like that in FIG. 13. FIG. 14 shows the position of a finger against the sensor by rolling and sliding a finger in the vertical and horizontal

directions. FIG. 15 is the sequential images captured by the enrollment method shown in FIG. 13. FIG. 15 covers most part of a fingerprint so that the mosaicked image with the sequential images shown in FIG. 16 can represent the whole fingerprint. The enrollment schemes illustrated in FIG. 7, FIG. 10 and FIG. 13 can acquire sequential images which may cover most parts of a fingerprint and the images are highly correlated each other so that it makes the system mosaic the images easily.

[39] FIG. 17 is a flow chart which explains how to make a mosaicked image with the sequential images. For example, in order to stitch two images, first, the each image is normalized with respect to the mean and variance of the intensity value of them to be the same and two images are then aligned coarsely with a global alignment parameter calculated by the normalized cross-correlation between two images. Since, in coarse alignment process, the common area between two images can be calculated roughly, the system tries to align the common area more precisely and compensate for the local deformation in the next steps. In the step 1030, the common area of single image is divided into several blocks and each block is used to find the corresponding block in the common area of the other image hierarchically in the block matching procedure 1040. In the local deformation compensation step 1050, the single image is warped to the other image by 2-pass mesh warping with the corresponding points which are the centers of the corresponding blocks. Finally, the gray value of the common area is assigned with the weighted sum of the gray value from each image according to the quality of each image.

[40] FIG. 11 shows the result images acquired from the procedure illustrated in FIG. 17. FIG. 18 are two example images enrolled by our enrollment scheme. FIG. 19 is the coarsely aligned image after the step 1020. FIG. 20 shows that the common area of the single image is divided into several blocks in the step 1030. FIG. 21 is the final mosaicked image after processing the all steps illustrated in FIG. 17.

Claims

[1] A fingerprint enrollment method for extracting feature vectors from sequential fingerprint images acquired by rolling and sliding a finger on a sensor and storing the extracted feature vectors into a database, comprising the steps of:
a) capturing the sequential fingerprint images acquired by rolling and sliding the finger on the sensor;
b) preprocessing input images and mosaicking the inputted images into a whole fingerprint image;
c) fine tuning for a local deformation caused by a motion of the finger on the sensor; and
d) extracting the feature vectors from a whole fingerprint image mosaicked in the step b) and storing the feature vectors into the database.

[2] The fingerprint enrollment method as claimed in claim 1, wherein the step a) comprises the sub-steps of:
aa) checking the existence of the fingerprint on the sensor;
ab) capturing a fingerprint image with a time interval between an n-th image and an n+1-th image and storing the fingerprint image at a temporary buffer;
ac) checking a quality of fingerprint image stored in the temporary buffer;
ad) requiring a user to reenroll if the quality of each fingerprint image is not good enough.

[3] The fingerprint enrollment method as claimed in claim 2, wherein, in the step a), a required number of fingerprint images is set to N, and the step a) is finished when the number of the acquired fingerprint images equals to N.

[4] The fingerprint enrollment method as claimed in claim 1, wherein, the step b) comprises the sub-steps of:
ba) reducing a noise in the fingerprint image;
bb) enhancing a contrast between valley and ridge;
bc) making a gray scale image a binary image;
bd) thinning ridges whose width becomes single pixel;

[5] The fingerprint enrollment method as claimed in claim 1, wherein the step b) comprises the sub-steps of:
be) estimating transformation parameters to align single image to other globally; and

bf) representing that a common area of single image matches the common area of the other image finely.

[6] The fingerprint enrollment method as claimed in claim 5, wherein the transformation parameter estimation transforms single image globally into the other to maximize a normalized cross-correlation of the common area between two images.

[7] The fingerprint enrollment method as claimed in claim 5, wherein the process making the common area between two images matched finely, comprises the sub-steps of:

i) dividing the common area of single image into several blocks;

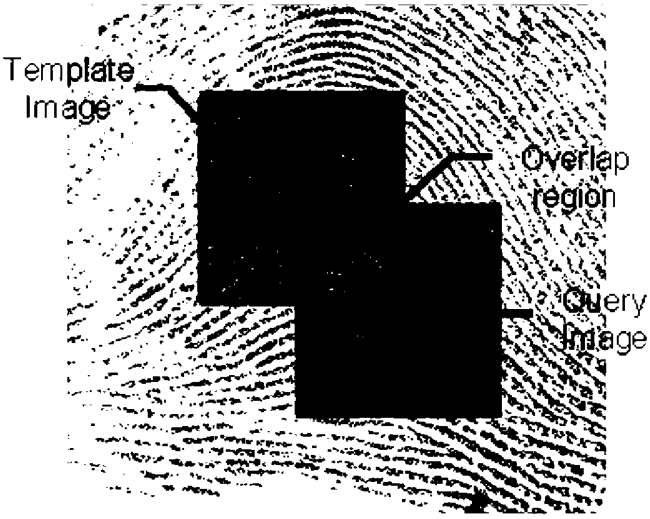
ii) finding corresponding blocks for the blocks of the single image in the other image;

iii) finding optimal transformation parameters for each corresponding block; and

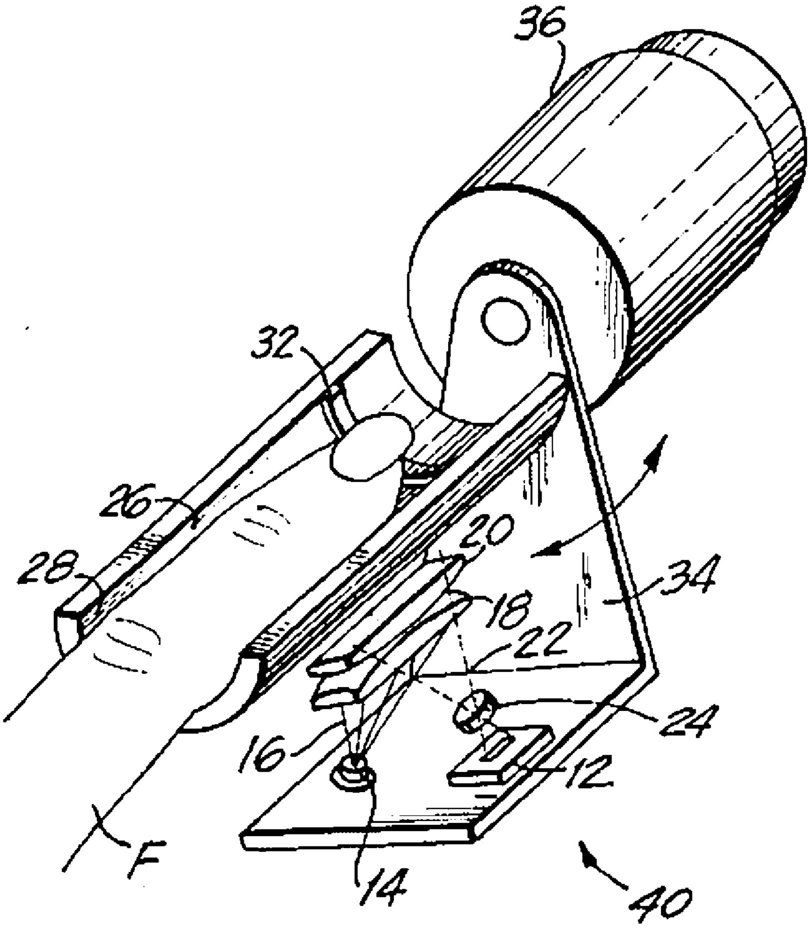
iv) wrapping the common area of the single image to it of the other image, which is implemented when a compensating for the local deformation based on the transformation parameters of each block;

[8] The fingerprint enrollment method as claimed in claim 7, wherein the compensation for the local deformation warps the single image to the other in terms of a control points located a center of corresponding blocks.

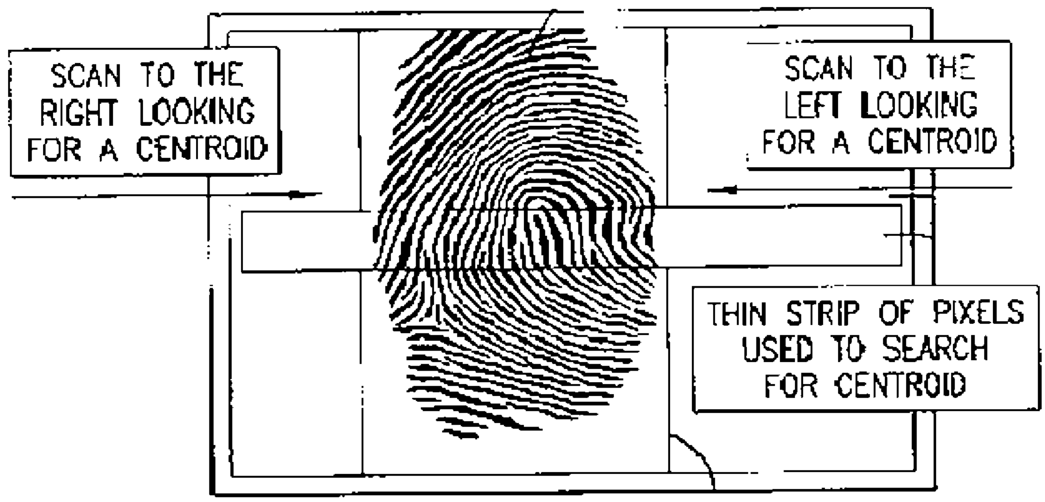
[Fig. 1]


Template Image
Overlap region
Query Image

[Fig. 2]

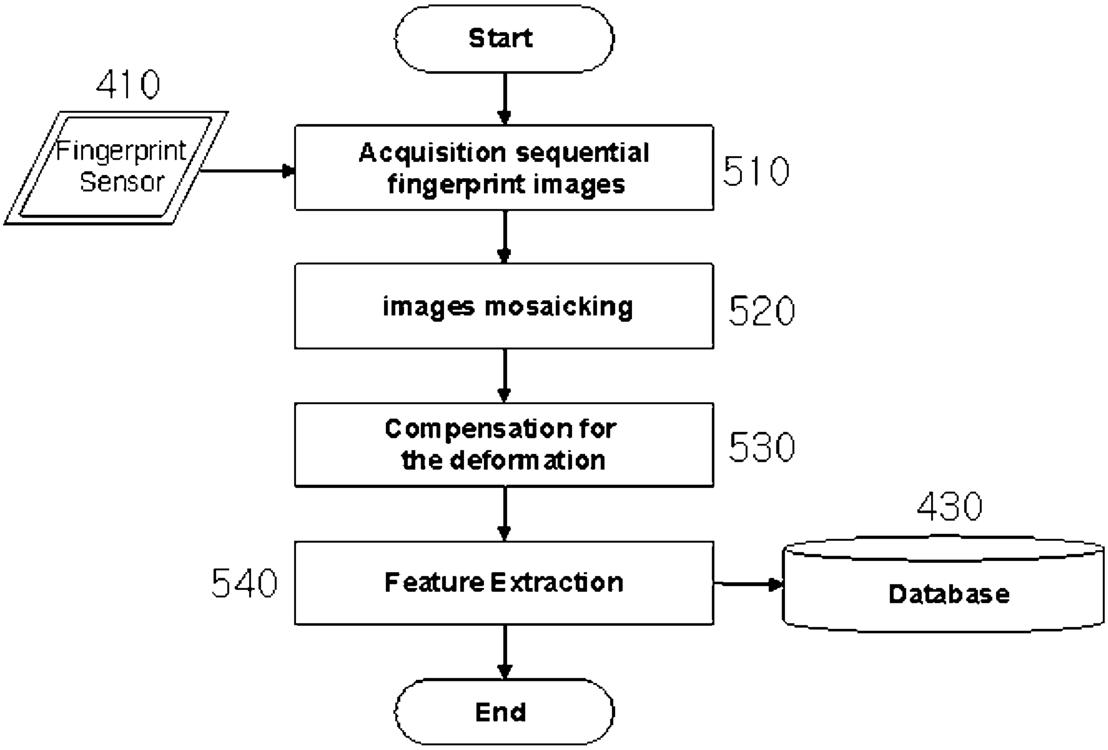

36
32
26
28
20
34
18
22
24
16
12
F
14
40

[Fig. 3]

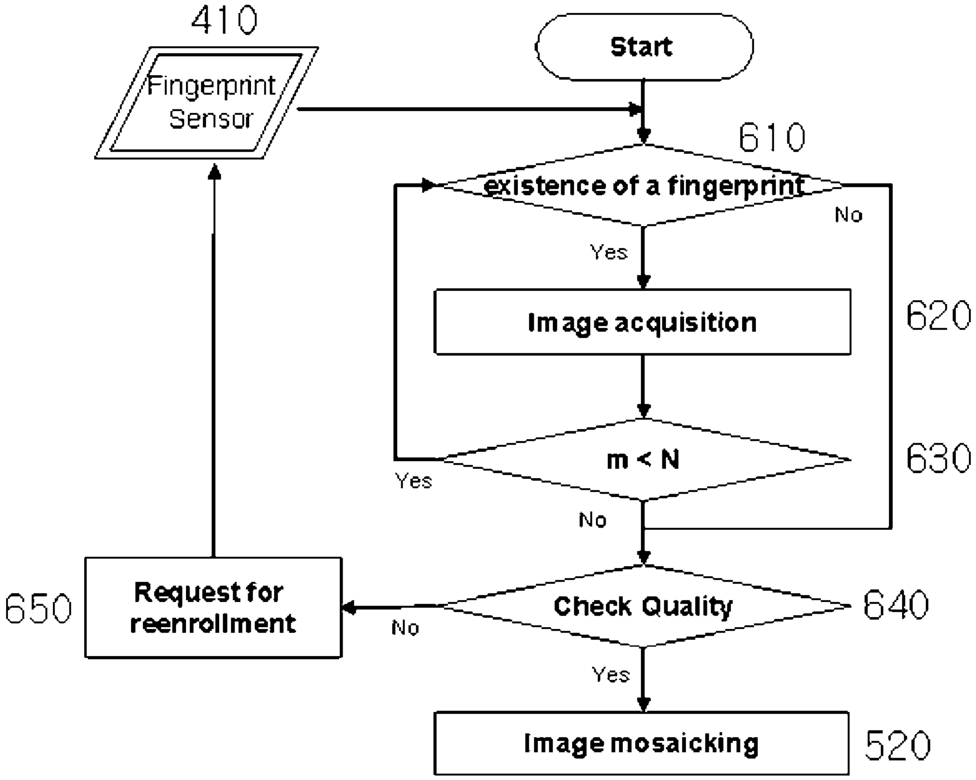


[Fig. 4]

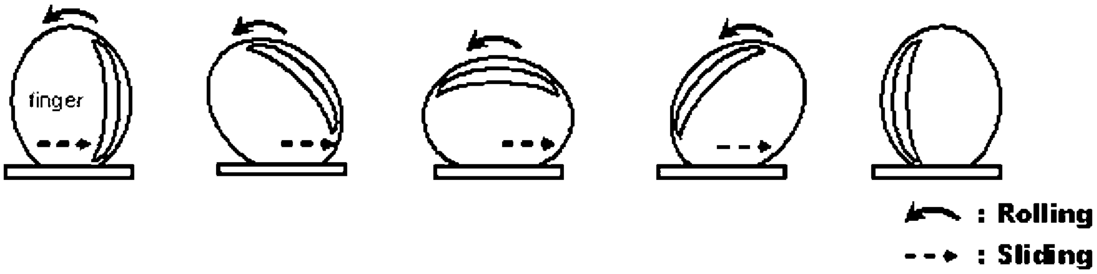
[Fig. 5]



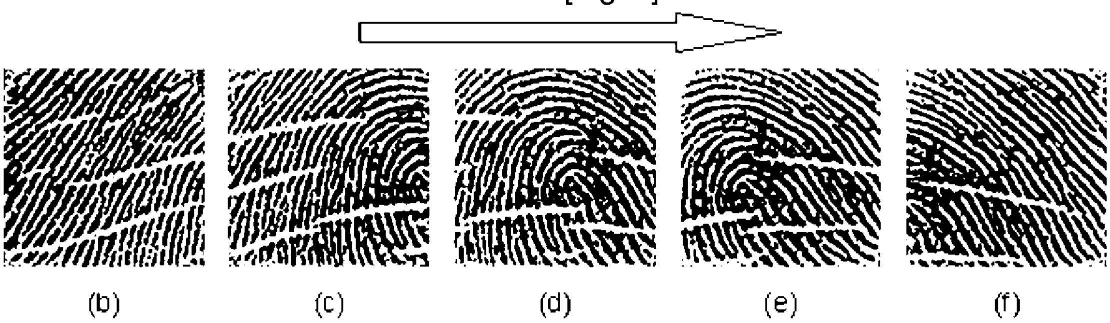
[Fig. 6]



[Fig. 7]



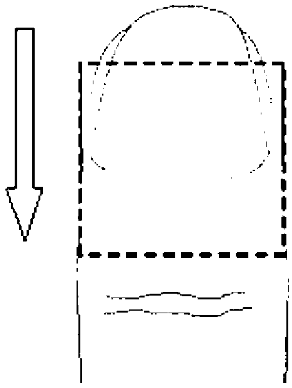
[Fig. 8]



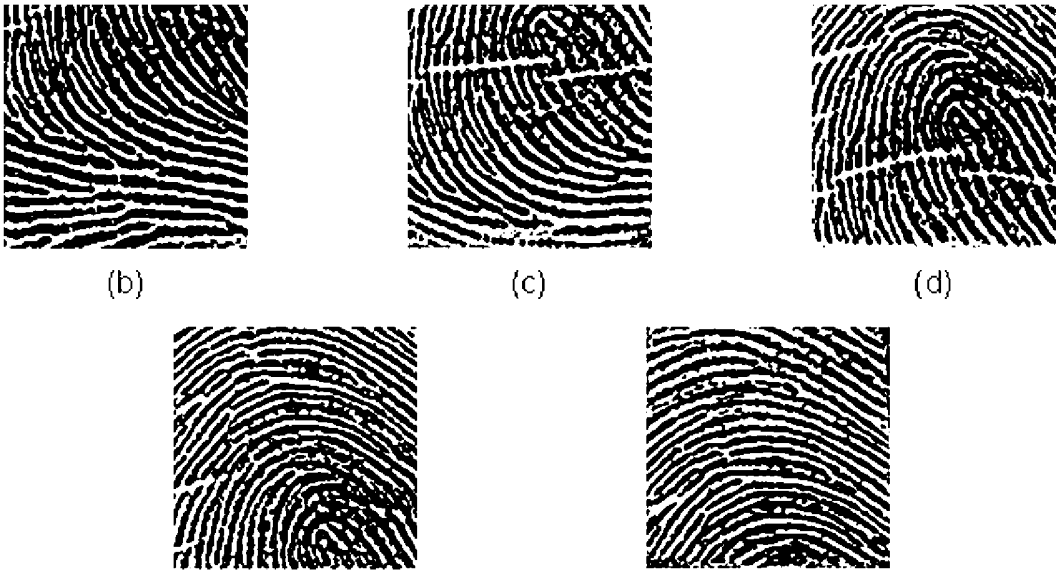
[Fig. 9]

(g) Mosaicked Image

[Fig. 10]



[Fig. 11]



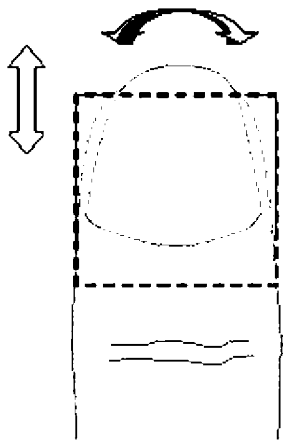
(b) (c) (d)

(e) (f)

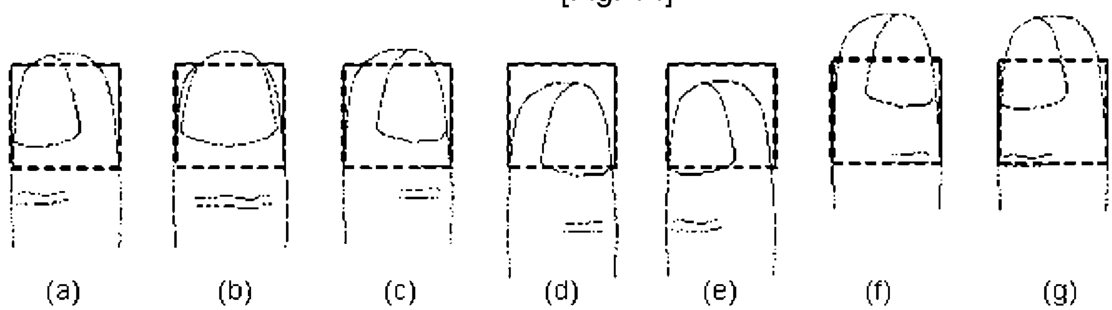
[Fig. 12]

(g) Mosaicked Image

[Fig. 13]



[Fig. 14]

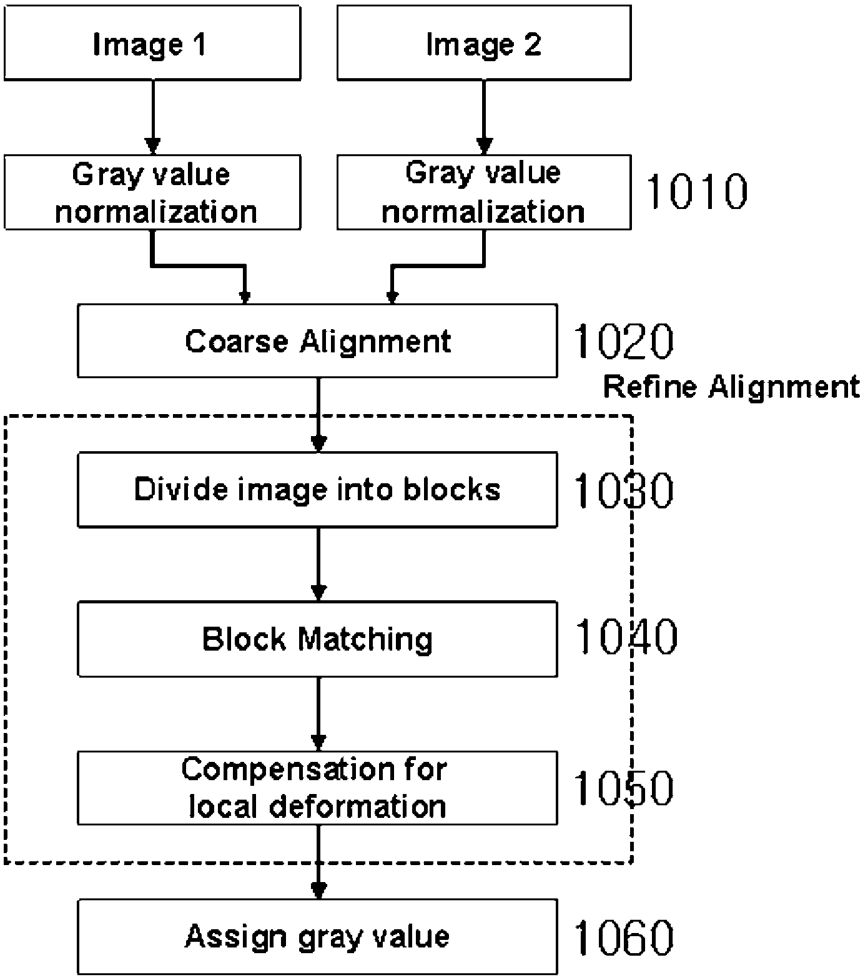


[Fig. 15]

[Fig. 16]

Mosaicked Image

[Fig. 17]



[Fig. 18]

Image 1

Image 2

[Fig. 19]

Coarse alignment Image

[Fig. 20]

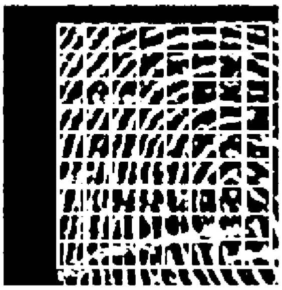


Image Blocks

[Fig. 21]

Mosaicked Image

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2004/001794

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 G06K 9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC G06K 9/00, G03B 29/00, G06T1/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Patents and application For inventions 1975

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search terms used)

KIPASS, FPD, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 2003-0028919 A (shim, jea chang) 11. APR 2003(Family None) * Abstracts & Claims	1-8
Y	JP 10-91769 A (THOMSON CSF) 10. APR 1998(Family None) * Abstracts & Claims	1-8
A	US 5,757,278 A (TOSHIBA CO,LTD) 26. MAY 1998 * Abstracts & Claims	1-8
A	US 5,195,145 A (Identity Technologies CO,LTD) 16. MAR 1993(Family None) * Abstracts & Claims	1-8
A	US 4,537,484 A (IDENTIX CO,LTD) 27. AUG 1985 * Abstracts & Claims	1-8

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 DECEMBER 2004 (06.12.2004)	**06 DECEMBER 2004 (06.12.2004)**

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
920 Dunsan-dong, Seo-gu, Daejeon 302-701,
Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

CHOI, Bong Mook

Telephone No. 82-42-481-5994

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/KR2004/001794

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5,757,278	26. 05. 98	JP 8235361 A	13. 09. 96
US 4,537,484	27. 08. 85	ZA 8500140 A	30. 04. 86
		IL 73990 A	30. 12. 88
		IT 1208498 A	10. 07. 89
		DK 436085 A	26. 09. 85
		GB 2173332 A	08. 10. 86
		FR 2558971 A	02. 08. 85
		WO 8503362 A	01. 08. 85
		SE 8504461 A	26. 09. 85
		SE 453870 A	07. 03. 88
		CH 670752 A	14. 07. 89
		CA 1250774 A	07. 03. 89
		NL 8420320 A	02. 12. 85