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Performance improvement using an automation system for recognition of multiple parametric features based on human footprint

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ABSTRACT

Rapid increase in population growth has made the mankind to delve in appropriate identification of individuals through biometrics. Foot Print Recognition System is a new challenging area involved in the Personal recognition that is easy to capture and distinctive. Foot Print has its own dimensions, different in many ways and can be distinguished from one another. The main objective is to provide a novel efficient automated system for Personal Recognition using Foot Print based on structural relations among the features in order to overcome the existing manual method. This system comprises of various statistical computations of various foot print parameters for identifying the factors like Instep-Foot Index, Ball-Foot Index, Heel-Index, Toe- Index etc. The parameters are trained using Neural Network method for the human recognition. The input of this system is the naked footprint and the output gives performance recognition rate. This system is very simple, easy and efficient resulting to time complexity.

Keywords: Human footprint; multiple features; segmentation; cropping; region growing.

INTRODUCTION

Biometrics is mainly used for personal recognition based on the different characteristic of every individual nature of humans. It is broadly classified into two main categories (i) High accuracy-oriented and (ii) Human friendly. High accuracy oriented is for infinite number of people namely finger print and iris, where as the later one refers to a finite number. of people in a group such as co-workers or family. Therefore for a small group identification can be performed efficiently in biometric recognition using Footprint, which is a challenging method now. Palm print, face, retina, voice, signature, keystroke, ear, gait and automatic face recognition (Sukthankar & Stockton, 2001) also plays an methods under specific conclusion (Liu & Silverman, 2001).

There are several other biometric systems existing today, but there is always a need for a new technology and this system will be of apt use for certain special areas of application. This FPRS can be worked in two ways:

1. Static mode: where the user will have to stand and his foot image will be captured by the sensors.
2. Dynamic mode: The walk over mode, where the user can walk without any halt and the sensor will detect the footprint.

In today's world, identity of individuals plays an important role in all fields. It helps to differentiate one person from another. Biometrics can be defined as a stream, which deals with the identification or differentiation of individuals through their physical characteristics or traits. Among the various organs studied in biometrics, footprint is considered to be efficient because it differs from person to person and also spoofing is difficult.

RELATED WORK

Weidong *et al*. (2004) verified the concept of footprint heavy pressure surface pick-up and description. The distribution of footprint heavy pressure surface reflects the behaviour feature and the physiological feature of the human body. It is mentioned that footprint heavy pressure surface pick-up and description is the foundation of footprint biological feature identification.

Sean *et al*. (1996) analyzed the measurement of force distribution beneath the feet. The performance of the postural control system may be helpful in identifying the persons with an increased risk of falling. Foot position and orientation can also be extracted from force distribution without the need for manually tracing footprints.

LIU *et al*. (2006) have proposed measurement system for 3-D foot shapes under different loads. A measurement system for 3-D foot shapes under different loads is described, which can automatically extract foot parameters such as foot length, ball width, heel width, ball girth, toe height, instep height, arch height, ankle height, arch curve and footprint. The information on how the feet shape changes with loads is important for shoe designing, plantar stresses analysis and orthopaedic treatment.

Rong *et al*. (2007) designed toe shaped recognition algorithm based on fuzzy neural networks. The characters of footprint shape, a toe shape description method, based on geometric characteristic values of toe image is proposed. Corner detection is carried out on toe region and the characteristic points which can describe the toe shape are confirmed by the edge of toe image.

Jaeseok *et al*. (2007) proposed a biometric user identification method based on user's gait. They divided obtainable features from user's gait into two categories: (i) walking pattern, and (ii) stepping pattern (dynamic footprints). This paper considers an approach of identifying user with dynamic footprints.

Wei Jia *et al*. (2011) utilize a system to identify the new born babies using the foot image. This is implemented in the hospital maternity ward, where the babies are swapped or changed. Here a coordinate system is defined to align the images, and a region of interest (ROI) is cropped. In recognition stage, four orientation feature-based approaches, ordinal code, BOCV, competitive code, and robust line orientation code, are exploited for recognition. This kind of approach can take high resolution photographs and then can be used for preprocessing and identification with a high accuracy.

Ambeth & Ramakrishnan (2013) has implemented a new approach for FPRS using wavelet and Fuzzy Neural Network. The transformation of the footprint image is done by the wavelet to detect the edge and then according to the statistical distribution disciplinarians of different toe images the membership functions are constructed, keeping the angle and length as parameters. These obtained values are used as single judgement factor. The input to the neural network is given by computing the distance vector between the four model vectors and the comprehensive judgement vector. However, only few features are taken into consideration for this recognition.

PROPOSED WORK

Personal authentication is a critical issue for hospitals, birth centers and other institutions, where multiple births occur and has not been well studied in the past. In this, a novel automated online newborn personal authentication system is proposed, based on footprint recognition. Compared with traditional offline footprint scheme, the proposed automated system can capture digital footprint images with high quality. Besides low quality image, newborn offline footprint has drawbacks. Traditionally footprint images and their parameters are taken manually, thereby it is a difficult task to form the database. This results in loss of time and also lacks in the performance measure.

Figure 1, shows the working module consisting of basically the input image, which is a normal dirty footprint image, which are either scanned or photographed. They are converted into grayscale images i.e., binary images that indicate black (0) and white (1) for showing the image impression. In order to perform morphological operations, regions are marked using the morphological marker. Then the connected components of a particular feature such as a toe are noted and a particular value is found using the 'bwarea.bin' function indicating the area of its presence. This is done by involving the creation of binary files that are required for execution of the morphological operation.

For example, a toe to be noted as an important distinguishing feature, then its length, height, depthness etc. are marked to a fixed level and its area is determined. Each of the above components of the toe is configured and its features are marked and separated. This is preceded by using a support vector machine (SVM) which aids in developing, identifying and differentiating the evolving footprint over time. Here, 4 to 5 features of a selected component are recorded in a small database and trained using supervised neural networks. The network contains more than 1 and less than 3 hidden layers that help in producing a relatively perfect match or mismatch, when executed with proper conditions. This improves the accuracy and also minimizes the execution time. Various griming images are taken for different features and preprocessed generally and the test results given the performance in the identification of an individuals.

The various mathematical factors used during the process includes

$$ballfootindex = \frac{maximumfootwidth}{overallfootwidth} \times 100$$

$$ballheelindex = \frac{maximumfootwidth}{heelwidth} \times 100$$

$$instepfootindex = \frac{minimumfootwidth}{overallfootwidth} \times 100$$

$$heelindex = \frac{heelwidth}{heellength} \times 100$$

$$toeindex = \frac{toewidth}{toelength} \times 100$$

$$toeballindex = \frac{toewidth}{maximumfootwidth} \times 100$$

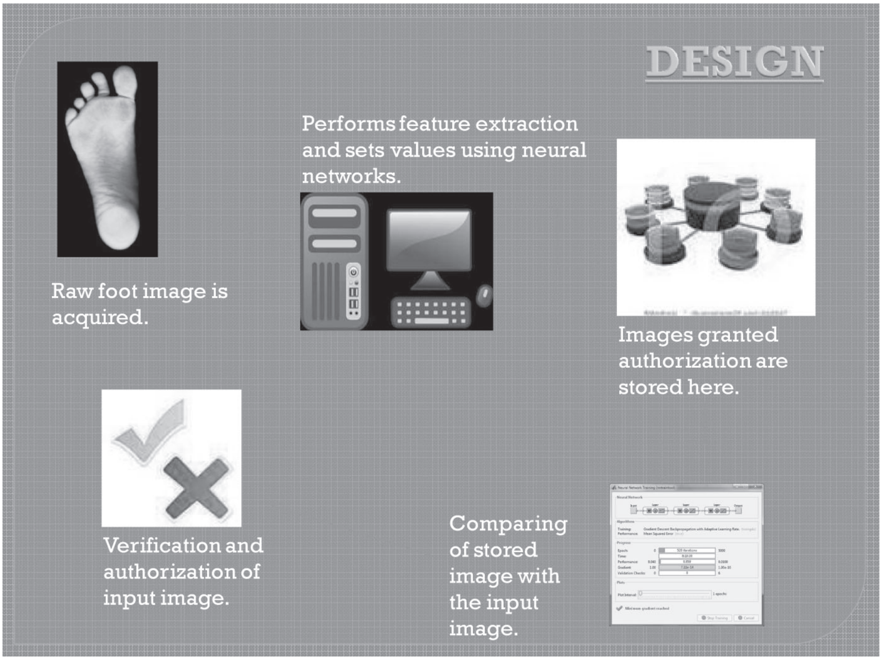

Fig. 1. System structure

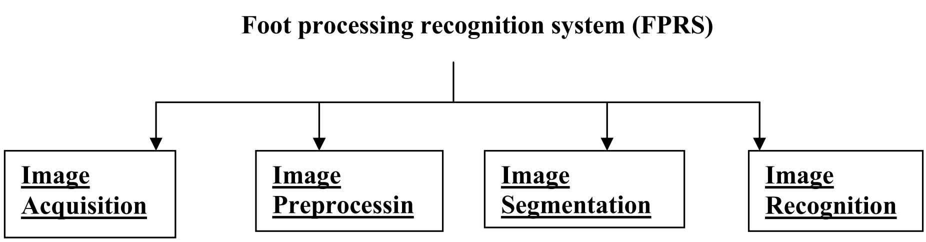

Fig. 2. Module description

The FPRS system shown in Figure 2 constitutes 4 modules namely

Modules:

1. Image Acquisition.
2. Image Preprocessing.
3. Image Segmentation.
4. Image Recognition.

Image acquisition

A raw image file contains processed data obtained from the image sensor of either a digital camera or image scanner. These raw files are not yet processed and therefore not perfect to be printed or edited. Normally, the image is processed, where exact adjustments can be made before it is converted to a “positive” file format such as ‘.jpeg’ for storage, printing, or for further manipulation. The purpose of raw image format is to save with minimum loss of information, data obtained from the sensor, and the conditions surrounding the captured image. In this, a minimum of 50 left and right foot images from various individuals of both genders are obtained. It includes 35 males and 15 females.

Fig. 3. Image acquisition

Figure 3 shows a Canon MG3170 flat-bed scanner for acquiring the image. The foot image is saved using JPEG format in a size range that varies from a minimum of 550 x 190 pixels to 1024 x 768 pixels as per the cropping proportion of execution code.

Fig. 4. Raw foot-image

Figure 4 shows a sample of footprint image obtained from the scanner.

Image preprocessing

Image Preprocessing is the technique of enhancing and improving the quality of data images prior to computational processing. It involves removing low-frequency background noise, equalizing the intensity of the individual particles images, removing shadows and masking portions of images. After this 'Image Filtering' is performed to reduce the noise present in the image. For this 'Gaussian filtering' is used, which are characterized by narrow bandwidths, sharp cutoffs, and low overshoots. First the image is captured and then imported to work for better enhancements using the 'Adobe Photoshop CS5.1 Extended Edition' editor. This stage plays a vital role where changes have been done to RGB range and threshold areas of the image. Due to this, the vibrancy areas of the image are increased to produce a better quality image after the preprocessing stage.

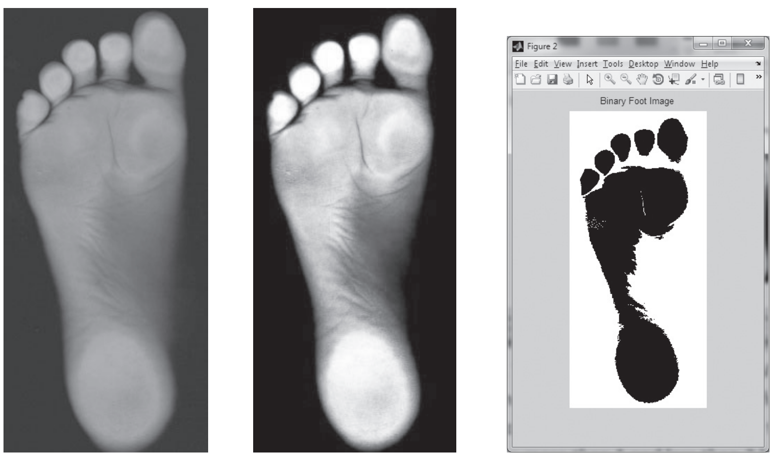

Fig. 5. Steps of image preprocessing process

Figure 5 gives simple example of the working process of the Image Preprocessing.

Image segmentation

Image segmentation is the process of dividing digital image into multiple segments or parts (sets of pixels). The goal is to simplify and change the representation of an image into a more understandable and easier image to analyze. This is used to locate objects and boundaries like lines, curves, etc. in images. Therefore, it is the method of appointing a label to every pixel in an image such that pixels with the same label share certain or similar visual characteristics.The overall segmentation process is explained in the form of algorithms.

Segmentation algorithm of right foot execution:

Step1: get the input image

Step2: convert the input image as gray image

Step3: convert it into binary image based on the given threshold

Step4: find the length of the given image and to create a label matrix 'L'

Strep5: measure a set of properties for each labeled region in the label matrix ' L' as a structure array

Step6: convert the given structure array into a cell array

Step7: then convert the given cell array into a single matrix

Step8: the single matrix for major and minor axis length of the foot image is found.

Pseudocode for the computation of Toe parameters:

Step1: Cray the toe image from the input image using given values

Step2: find the length of the image and create label matrix

Step3: measure the set of properties needed for the given toe image as a structure array

Step4: convert the structure array into a cell array

Step5: convert the given cell array into a single matrix

Step6: the single matrix for the major and minor axis length of the toe image is found.

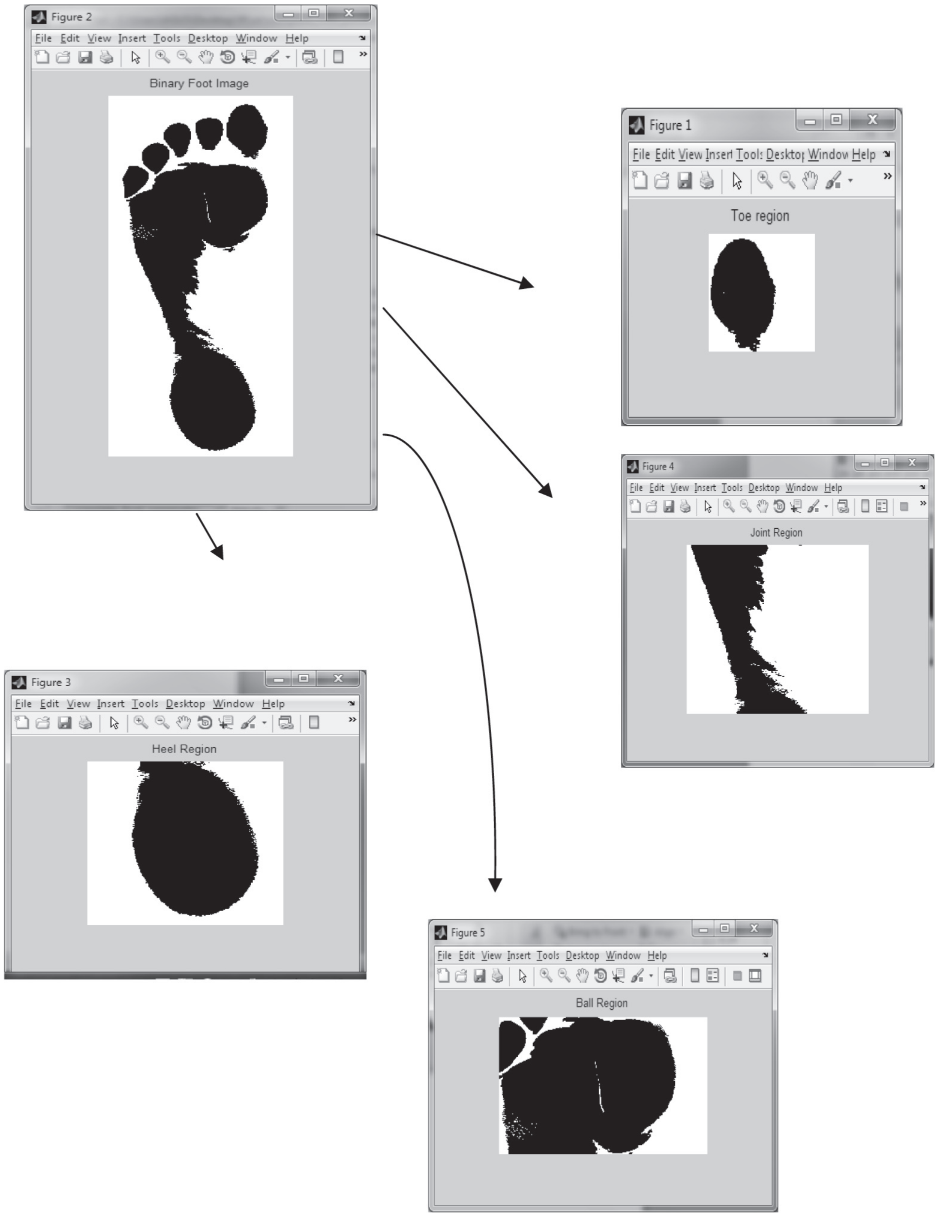

Fig. 6. Process of image segmentation

Figure 6 shows the process of segmentation ouput where the modified and edited foot image is then fed into the execution unit as a required input.

Image recognition

Image Recognition refers to the process where an input image is fed into a recognizing engine and compared with a set of test images. The process needs a minimum of one input image, a database containing a set of authorized images and a test /sample image for comparison. Here recognition method is implied and applied in such a way that it aids in performing and supporting the authentication process. Before the image recognition is initiated, image segmentation must be done.

For this, an automation system is developed which focuses on image segmentation. The output of the system gives the exact value for the various features namely.

a). foot length

b). maximum foot width

c). minimum foot width

d). toe-length

e). toe-width

f). heel-length

g). heel-width

These features are the vital parts of the segmented image of the raw-foot, which are further used to improvise the 6 factors that help in determining the perimeter and area values to be stored in the database.

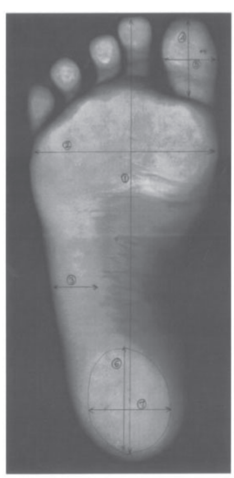

Fig. 7. Measurement of each factor

Figure 7 displays the various measurements of each of the above mentioned factors:

where,

1 -represents the 'footlength'

2 -represents the 'maximumfootwidth'

3 -represents the 'minimumfootwidth'

4 -represents the 'toelength'

5 -represents the 'toewidth'

6 -represents the 'heellength'

7 -represents the 'heelwidth'

1. *Foot length:* This is the maximum distance from the tip of the heel to the tip of the big toe or of another toe, whichever protrudes the farthest.
2. *Maximum foot width:* This indicates the maximum width at the ball, across the heads of first and fifth metatarsal bones of the foot.
3. *Minimum foot width:* Represents the minimum foot width, usually across the arch of the foot.
4. *Toe-length:* The maximum length of the big toe measured from the outermost tip to the ball line.
5. *Toe-width:* The maximum width of the big toe.
6. *Heel-length:* The maximum length of the heel portion along the central line of the footprint. An outline is marked encircling the heel area as observed visually before measuring.
7. *Heel-width:* The maximum width of the heel measured across the encircled area.

Using these features, that include main areas of the foot such as toe, heel, joint, and the ball regions, 6 various factors are developed to obtain the perfect values for the foot parameters. To determine the values of these factors a set of formulas are applied to each factor. They are

1. Ball foot index
2. Ball heel index
3. Instep foot index
4. Heel index
5. Toe index
6. Toe ball index

The basic Formulas used to determine values for the above 6 factors are :

a) ballfootindex = (maximumfootwidth/overallfootwidth)*100

b) ballheelindex = (maximumfootwidth/heelwidth)*100

c) instepfootindex = (minimumfootwidth/overallfootwidth)*100

d) heelindex = (heelwidth/heellength)*100

e) toeindex = (toewidth/toelength)*100

f) toeballindex = (toewidth/maximumfootwidth)*100

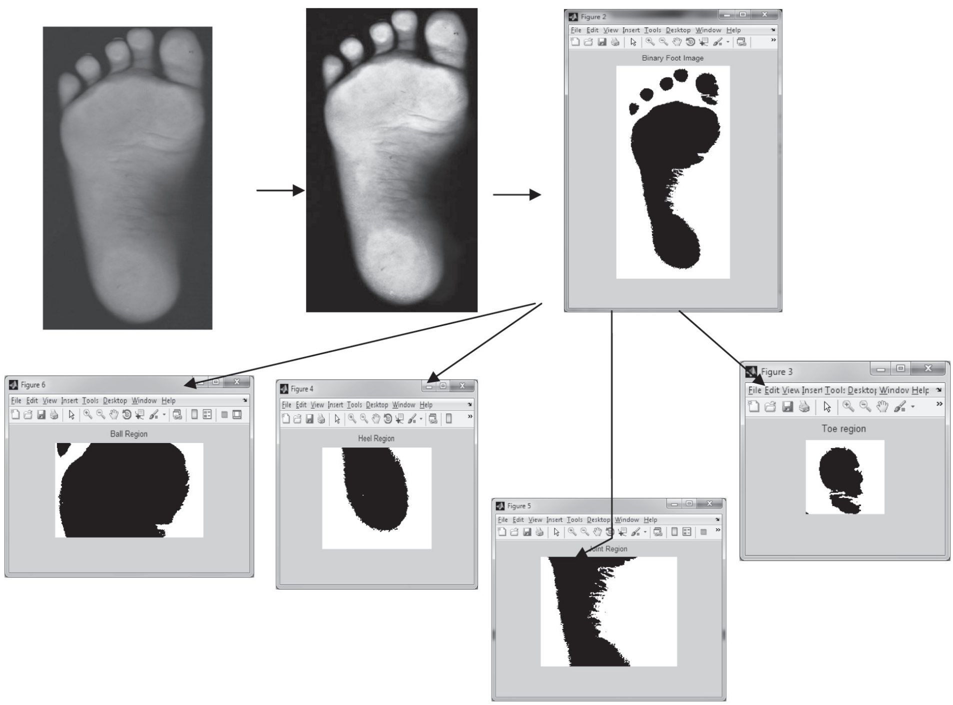

Fig. 8. Basic steps involved in the working process of authentication

Figure 8 gives the sample image used in the process of authentication and its respective process of preprocessing, segmentation and image recognition.

EXPERIMENTAL RESULTS AND ANALYSIS

In our method, simple and an effective image segmentation process is done using the bwarea.bin function present as an in-built function in MATLAB 7.7 software tool.

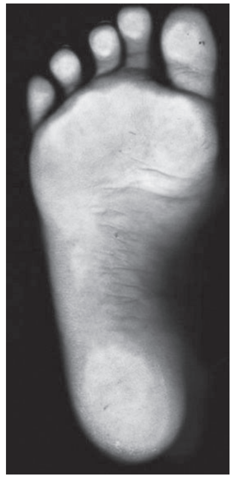

Fig. 9. User1.jpg

Figure 9 shows the image of user1.jpg. This right foot image in the input for the automation system where it generates the value of different features and parametric factors from the image.

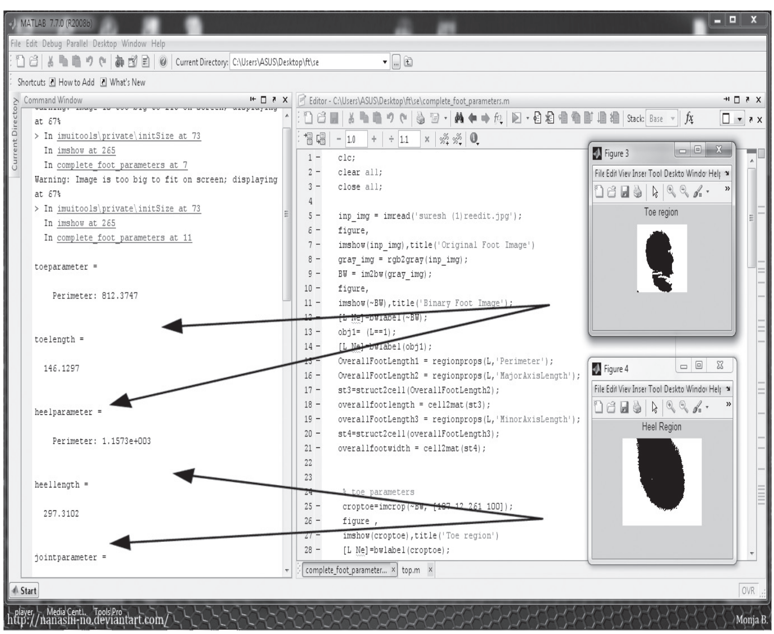

Fig. 10(a). Toe, Heel parameter

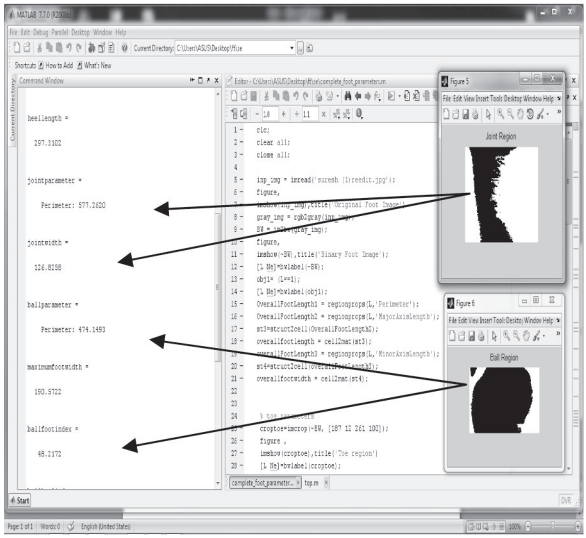

Fig. 10(b). Joint, Ball values

Figure 10 (a) and (b) indicate the screen shots of the system, where the values are:

toeparameter :-Perimeter: 812.3747

toelength = 146.1297

heelparameter:- Perimeter: 1.1573e+003

heellength =297.3102

jointparameter :- Perimeter: 577.2620

jointwidth = 126.8258

ballparameter :- Perimeter: 474.1493

maximumfootwidth =190.5722

ballfootindex =48.2172

ballheelindex = 97.4586

instepfootindex =49.4745

heelindex =65.7702

toeindex =86.7899

toeballindex = 66.5500

The process of image acquisition is performed by obtaining the various right & left images of men & women. The Canon MG3170 flat-bed scanner is the equipment used as the device for capturing the raw foot-image.

The preprocess procedure is followed by enhancing the raw foot-image and followed by image segmentation. The feature extraction technique is done in image segmentation. Table 1 gives the total of 7 factors obtained after segmentation for different individual persons.

Table 1. Find the parameter for Individual persons

Person Name	toe para meter	toe length	heel para meter	heel length	joint para meter	joint width	ball para meter	Max. foot width
User 1	793.7056	192.6477	1.1558e+003	296.0953	546.3087	123.6818	613.9483	188.569
User 2	398.7523	135.4960	651.9483	265.8020	288.7107	72.9110	1.0140e+003	342.6603
User 3	656.3919	136.2125	1.2150e+003	302.0882	0	131.7775	397.1198	109.9474
User 4	703.6224	167.1137	355.3970	101.8243	615.5635	119.0650	569.9066	185.7247
User 5	710.7351	133.3058	1.4440e+003	309.7392	577.0782	128.6147	384.4335	102.5432
User 6	591.3209	142.1974	1.2597e+003	306.6984	510.5513	102.6997	262.6102	89.0127
User 7	422.5685	125.8916	1.3825e+003	256.2231	278.2254	69.5673	218.8528	218.8528
User 8	812.3747	146.1297	1.1573e+003	297.3102	577.2620	126.8258	474.1493	190.5722

Table 2. gives the development of 6 factors resulting from the determination of 7 features.

Table 2. Find the factors for individual person

Person	ball foot index	Ball Heel Index	instep foot index	heel index	toe index	toe ball index
User 1	41.4273	81.0950	51.0849	78.5319	64.2010	65.5895
User 2	94.2930	630.2685	630.2685	20.4541	53.8105	21.2779
User 3	28.9281	47.9586	60.3189	75.8900	96.7441	119.8550
User 4	42.1578	208.9328	20.177	87.2994	71.2479	64.1083
User 5	25.8456	41.2982	62.5829	80.1640	96.4810	125.4249
User 6	24.5443	37.9767	64.6298	76.4229	72.2233	115.3764
User 7	22.3387	33.1183	67.4512	87.7607	55.2597	93.4156
User 8	48.2172	97.4586	49.4745	65.7702	86.7899	66.5500

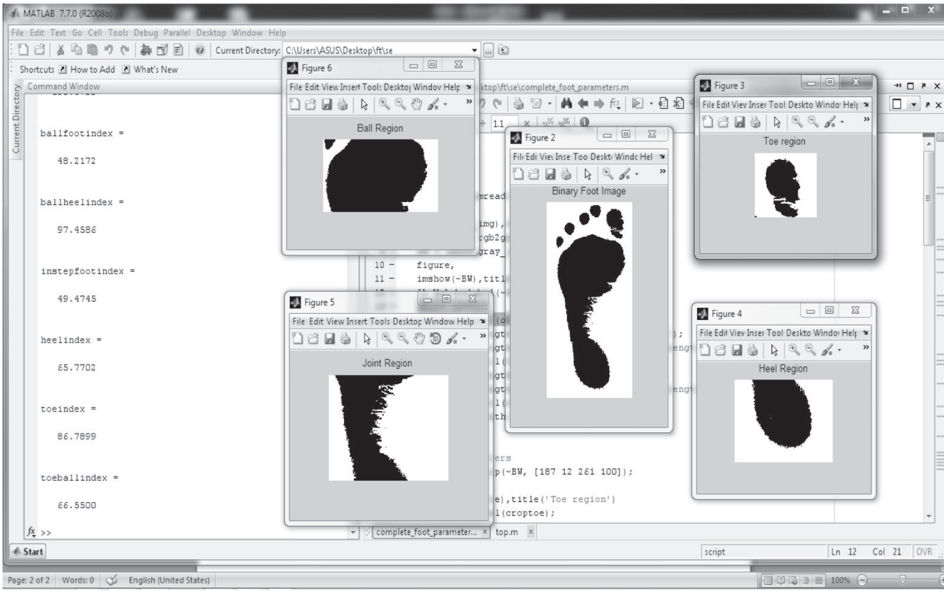

Fig. 11. Other sample parameters

Fig. 12. Toe parameter for different person Fig. 13. Toe length for different person

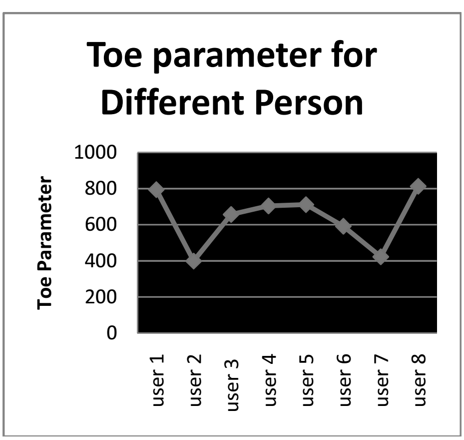

Fig. 12. Toe parameter for different person

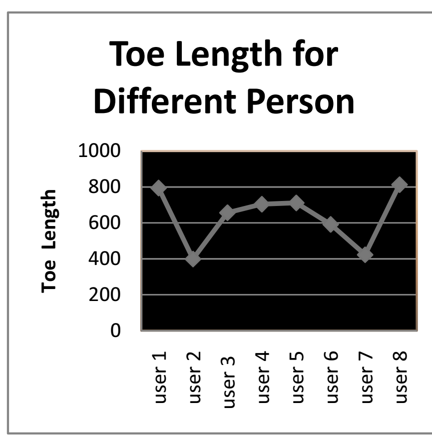

Fig. 13. Toe length for different person

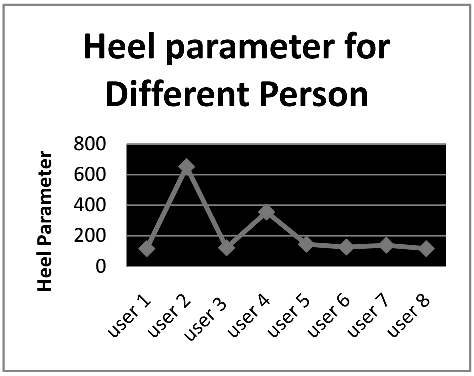

Fig. 14. Heel parameter for different person

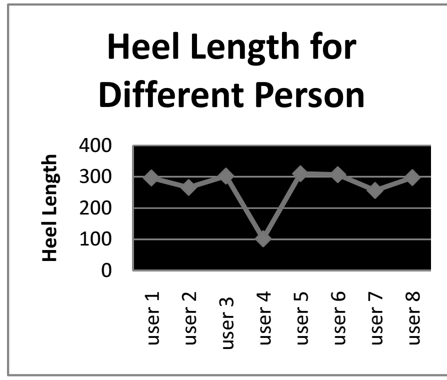

Fig. 15. Heel length for different person

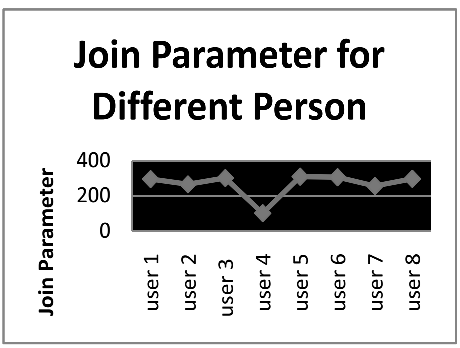

Fig. 16. Joint parameter for different person

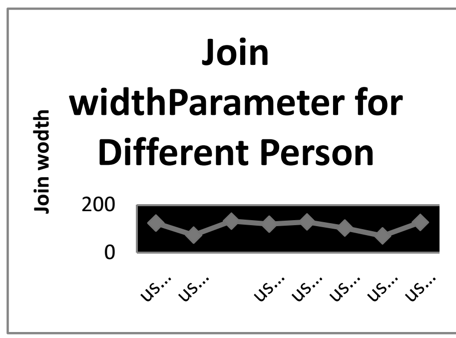

Fig. 17. Joint width parameter for different person

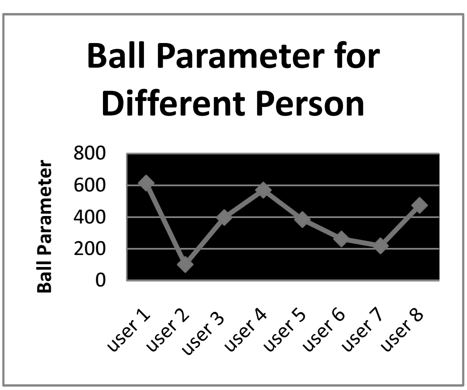

Fig. 18. Ball parameter for different person

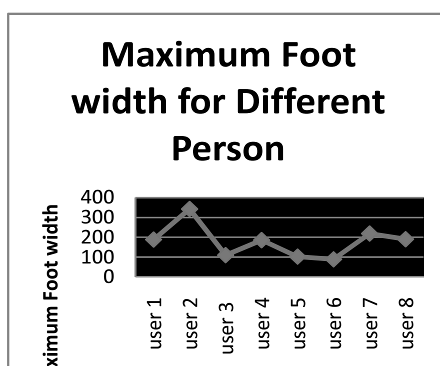

Fig. 19. Maximum foot width for different person

Figure 12-19 gives the 7 parametric feature values of different persons from the automated system which clearly indicates that each feature has different combination of values for different persons.

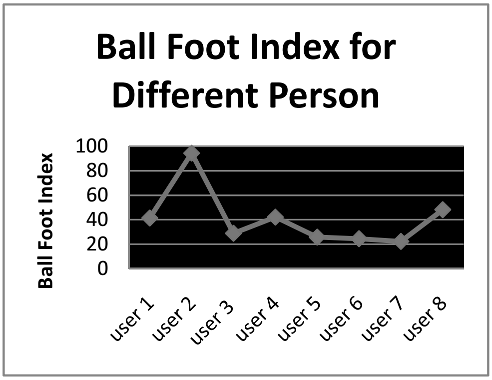

Fig. 20. Ball foot index for different person

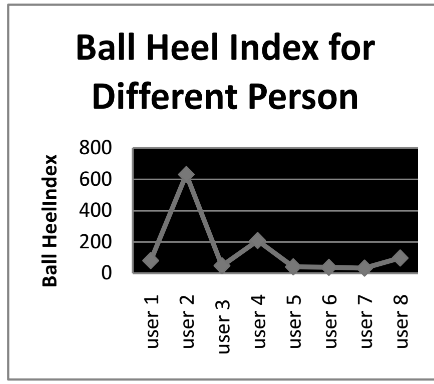

Fig . 21. Ball heel index for different person

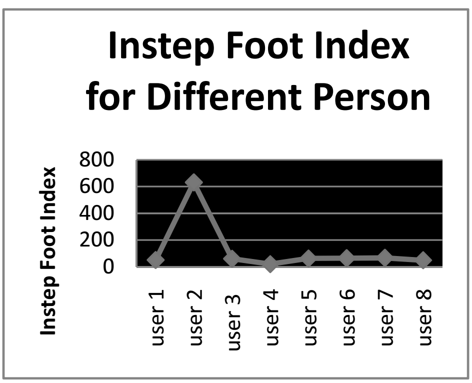

Fig. 22. Instep food index for different person

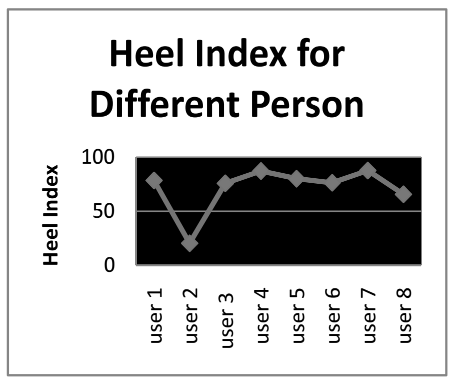

Fig. 23. Heel index for different person

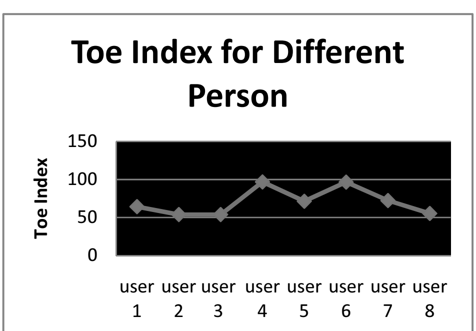

Fig. 24. Toe index for different person

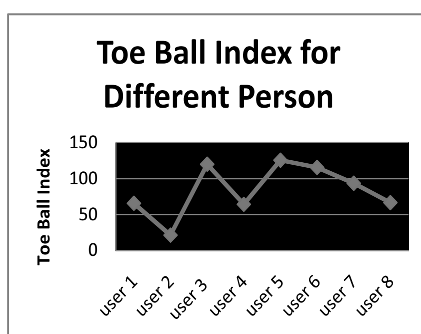

Fig. 25. Toe ball index for different person

Figure 20- 25 depicts the results of the automation system with different factors for different persons. Their results will be benefited to extend further for FPRS in order to increases the performance.

On performing training and testing with the above features and its respective factors, acquired values are fed as input to the recognition process, which involves the presence of a neural network. It performs with 3 levels of different hidden layers. The artificial neural network (ANN), as referred in this project) values are obtained in the form of positive (+ve) & negative (-ve) integer whole number values. The test image with the minimum number of negative (–ve) values are considered as optimal valued FNN results and are used to conclude that the input and the test image are matched and can be authenticated. This process can be framed as the final-decision making step of the recognition process, where it determines the authentication of an image. The results are tabulated in Table 3. and its performance is shown in Table 4.

Table. 3. Find the FNN value for individual persons.

	1 User		2 User		3 User		User 4		5 User		6 User		7 User		8 User	
	P	N	P	N	P	N	P	N	P	N	P	N	P	N	P	N
1 User	5	3	4	4	2	6	3	5	6	2	5	3	5	3	4	4
2 User	4	4	4	4	3	5	3	5	4	4	3	5	4	4	3	5
3 User	2	6	6	2	4	4	3	5	1	7	5	3	5	3	1	7
User 4	4	4	3	5	4	4	4	4	4	4	3	5	6	2	4	4
5 User	2	6	5	3	4	4	3	5	5	3	3	5	3	5	4	4
6 User	4	4	4	4	3	5	3	5	4	4	3	5	5	3	5	3
7 User	4	4	4	4	3	5	3	5	4	4	3	5	5	3	5	3
8 User	2	6	2	6	2	6	4	4	3	5	4	4	4	4	4	4
User 9	2	6	5	3	7	1	5	3	5	3	4	4	4	4	4	4

Table. 4. Find the performances for individual persons

Person	Epoch	Time	performance	Gradient
1 User	206	0.00.06	95 %	3.88
2 User	292	0.00.08	96.6%	0.00
3 User	353	0.00.10	96.7%	0.00
User 4	172	0.00.05	96.3%	1.57 e-13
5 User	131	0.00.04	95.1%	4.06 e-11
6 User	173	0.00.05	96.7%	6.86 e-11
7 User	206	0.00.06	95.5%	3.88 e-11
8 User	292	0.00.09	96.6%	0.00

Performances for Individual persons

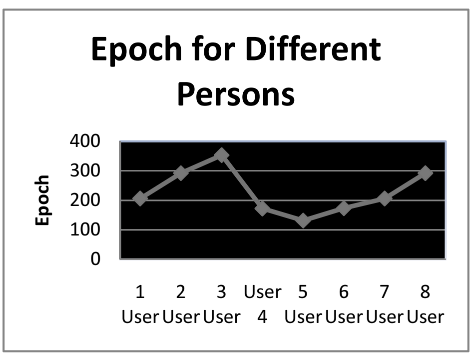

Fig. 26. Epochs for different persons

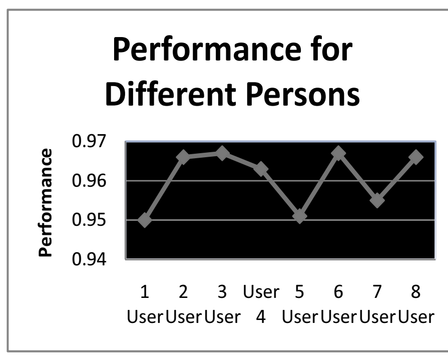

Fig. 27. Performance for different persons

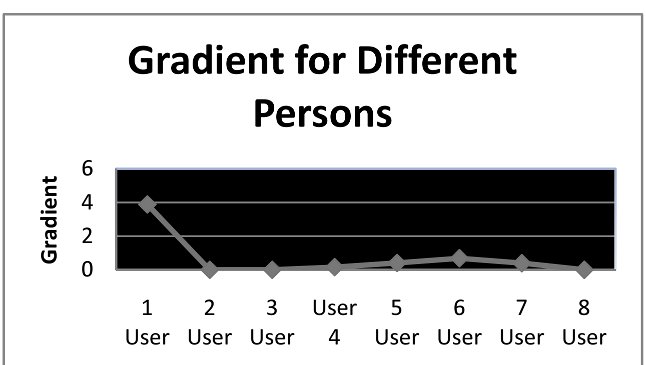

Fig. 28. Gradient for different persons

The accuracy of Recognition of Footprint images here is compared with the other methods for recognition. The following table shows the comparison of accuracy of recognition for wavelet based fuzzy neural network with transform techniques (Ambeth *et al*., 2013).

Table 5. Comparison of accuracy (performance) of the proposed method with other method

Recognition Techniques	Recognition Accuracy (%)	Computation time in ms (Recognition)
DCT (Xiao-Yuan.et.al.,2004)	83.64%	142
FT (Wenxin Li.et.al.,2007)	87.43%	128
Transform Technique(SHT)	92.375%	118
Wavelet Based Fuzzy Neural Network	96.32%	106
Proposed Method	97.43%	102

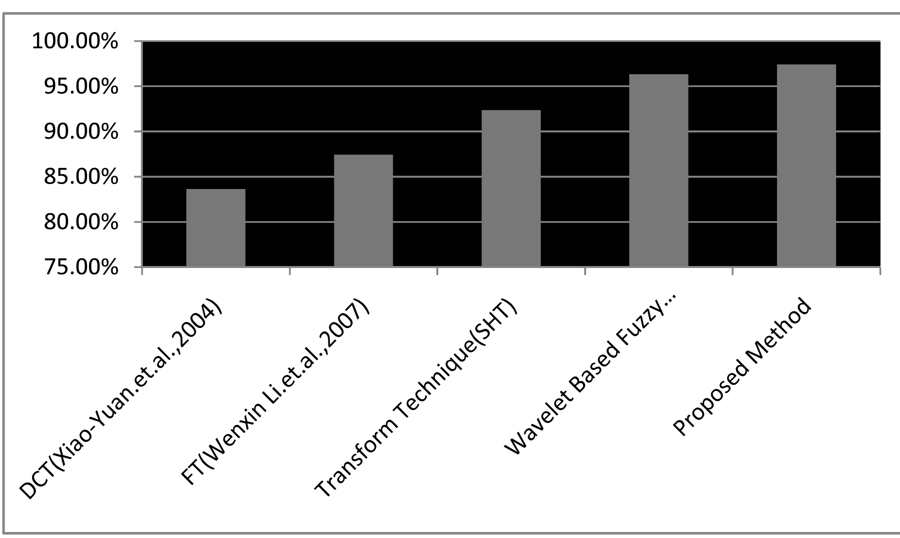

Fig. 29. Comparison of recognition rate between existing and proposed system

The recognition accuracy and computation time are compared and the performance factors are analyzed and proved to be very efficient.

CONCLUSION

We have developed an automation system for the recognition of individual using footprint based on the segmentation features of the foot. This system is superior to the previously separated manual method (Suneel, 1980). In this proposed method,the factors are divided using the statistical formulas and the corresponding values are stored in the database. The calculated set of values representing the factors & features of the foot are applied as input in the neural network and training amongst the images present in the database is done. Accuracy is optimized by including 3 hidden layers in the functioning of training process. This improves the achievement of minimum gradient and also minimum time, to attain the best set of ANN values. A minimum accuracy of 95.6% is obtained using this project's methods of acquiring foot images. This accuracy can be elevated by using most modern techniques of image acquisition and more enhanced images as input. The developed system makes the recognition more robust, even when bad quality as well as unclear image exists. Moreover, it also reduces the time during the recognition thereby increasing the performance of quality.

The future work will further improve the efficiency by combining the output of this automation system with other techniques for an efficient foot print recognition system.

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تحسين الأداء باستخدام نظام آلي للتعرف على ملامح متعددة معطاة من خلال طبعة القدم البشرية

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خلاصة

الزيادة السريعة في النمو السكاني جعلت البشرية تخوض في عملية تحديد مناسبة لهوية الأفراد بواسطة المقاييس الحيوية. نظام التعرف على طبعة القدم هو مجال تحدي جديد مرتبط بالتعرف الشخصي الذي هو سهل الادراك ومميز. طبعة القدم لها أبعاد خاصة بها، تختلف في نواح كثيرة، ويمكن تمييزها من شخص لآخر. الهدف الرئيسي هو توفير نظام آلي جديد ذو كفاءة عالية في التعرف الشخصي باستخدام طبعة القدم بناء على العلاقات الهيكلية بين الملامح من أجل التغلب على الأسلوب اليدوي القائم. ويتألف هذا النظام من حسابات إحصائية عديدة لمعطيات طبعة قدم لتحديد عوامل مثل مؤشر مشط القدم ومؤشر كرة القدم ومؤشر الكعب ومؤشر تو وما الى ذلك. لقد تم تدريب المعطيات باستخدام طريقة الشبكة العصبية للتعرف على البشر. تقتصر مدخلات هذا النظام على طبعة القدم المجردة بينما يعطي المخرج معدل أداء التعرف. هذا النظام بسيط جدا وسهل وفعال ينعكس على مقياس زمن التشغيل.

كلمات مفتاحية: طبعة القدم البشرية؛ ملامح متعددة؛ معالجة اولية؛ تجزئة؛ مرشح جاوس؛ اقتصاص؛ المنطقة المتنامية ؛ التعرف.