Legacy of Footprints Recognition- A Review

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ABSTRACT
Over the last decade footprint feature extraction has been actively researched for footprint recognition. This paper provides an up-to-date review of major human footprint recognition research. In Earlier sections, we have presented an overview of footprint recognition and its applications. In later sections, literature review of the most recent footprint recognition technique is presented. The most prominent feature extraction and the techniques are also given. Finally, we have summarized all research results discussed.

Keywords
Euclidean distance, Hidden Markov Model, MHE, Matching Algorithm.

1. INTRODUCTION
Many exotic methods are being developed in the field of automated biometric based identification. Various biometric features help in person recognition. Among various methods of person identification, biometric identification such as finger scan or iris scan is the most promising methods now. And palm print, face, retina, voice, signature, keystroke, ear, gait, automatic face recognition [1] are also good methods for specific situations [2].

Likewise, person identification using footprint is also an emerging biometric technique. Also footprint recognition is considered to be a unique method as it has been evidently proved, where it was shown that the feet have characteristics that would form the basis for identification. The uniqueness of barefoot impressions was studied successfully using computer database constructed from inked barefoot prints [3]. The information on footprint morphology is significant as it explains the individuality of each person's footprints [4].Thus, in the aspect of human friendliness footprint based recognition can be a promising method.

Person identification using footprint can be carried out by using any one of the two important features namely static [5] and dynamic [6]. Static feature requires stand-up posture at fixed position every time from the subject, whereas the dynamic feature deals with the walking behavior. The constraint on user posture can be released when dynamic feature is taken into account.

Many Footprint based recognition techniques are being developed in recent years. They make use of several features such as normalized Static footprint [5] based on Euclidean distance, position-based quantization of COP (Center Of Pressure) from shoe-type pressure sensor and HMM[7] ,Modified Haar Energy (MHE)[33].

Footprint either of the bare foot or more commonly as shoeprints provide an opportunity for estimating height as one characteristics helping to identify or eliminate a suspect [8]. In 1902, Macconell [9] recognized that population variation might complicate the relationship between height and foot length ,since he was concerned that his sample of prisoners had an average height 8.4cm less than a sample of 1000 Cambridge of University students. The famous textbook L'Anthropologie [10] provides a number of foot length/height percentages for various populations ranging from 14.9 to 19.1. Foot length relative to height within human races shows no great variation amounting to an average to 15 percent[11].Georges Oliver [12] ,recommended a value of 15.5% where the difference is substantial: the calculated height of an individual with a foot length of 28cm would vary by 6cm.The importance of naked foot marks has been noticed and utilized from very early times. In the famous case of LeDru, the identification of a criminal through footprints was utilised as early as in 1888[13]. Foot prints have also been used in the identification of infants in hospitals[14].According to Rutishauser's[15] study of African children six years of age or youngers specially aimed at estimating height from foot length as the bare footprint ona hard surface. The research reported by Andreson and colleagues [16] however, found that "the relation of the length of the foot of stature showed little change with increasing age".

In fig.1 shows the three main stage of an footprint recognition system are image preprocessing, feature extraction and template matching.

Image preprocessing deals with normalization and image enhancement. In normalization several features are being extracted from the footprint image with respect to position and direction. All these factors can be compensated by the image enhancement algorithms.

Feature extraction is a technique where the footprint features are extracted from the normalized footprint image. The significant features are mainly extracted for accurate identification purpose.

Template matching compares the user template with templates from the database using a matching metric. The matching metric will give a measure of similarity between two footprint templates. It gives a range of values when comparing templates from the same footprint, and another range of values when comparing templates from different footprints. Finally, a decision of high confidence level is made to identify whether the user is an authentic or imposter.

The most prominent algorithms for footprint recognition techniques with features are discussed in following sections. This paper discusses the pros and cons of algorithms

implemented in footprint recognition techniques with features. Footprint image capture and image preprocessing will not be discussed in this paper.

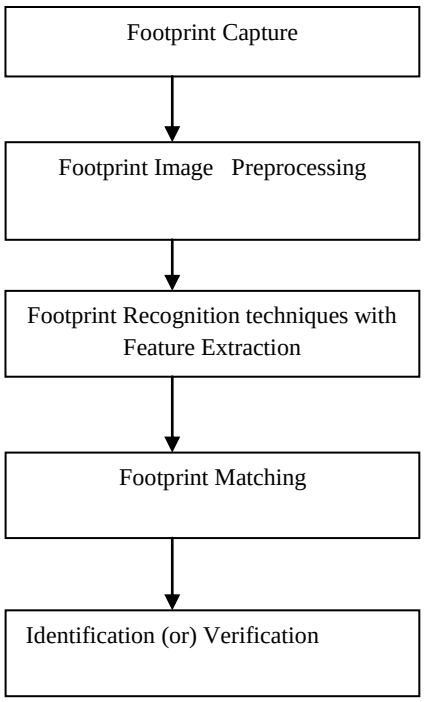

Fig. 1 Stage of footprint recognition algorithm

2. FOOTPRINT RECOGNITION TECHNIQUES

Euclidean distance:

Person identification among 10 men using normalized static footprint. User should make stand-up posture every time [5]. Recognition rate is insufficient for practical uses. Rate of recognition is 85%.

Hidden Markov Model:

Person identification among 5 men using position- based quantization of COP(Center of Pressure) from shoe-type pressure sensor and HMM(Hidden Markov Model). All data were collected in a day. Using shoe-type sensor could be a serious constraint in the view of users. Rate of recognition is 100%[7].

Person identification among 8 men using dynamic footprint from Mat-type pressure sensor. We get quantized COP trajectory and HMM's for two footprints are combined with Levenberg-Marquart learning method for better performance. Rate of recognition is 64%

Recognition rate is not equally distributed and not enough high. All data were collected in a day. Using shoe-type sensor could be a serious constraint in the view of users.

Comprehensive Evaluation Model:

Established to recognize Toe-shape by Neural Networks. Final decision result is based on many factors in the Fuzzy Environment. Comprehensive vector is derived based on singular factors. It becomes a tedious process for large data. Rate of recognition is 92.80%[18].

Matching Algorithm:

Recognition for partially occluded and overlapping objects in composite scenes. The objects are matched against the scene and their position is recovered. Not effectively applicable to rotation, translation and scale invariant cases. Rate of recognition is Successful[17].

Statistical Method:

Fusing the features of recognition extracted from the multiple sensors. A number of problems still remain in fusing when noise is contained in the multiple sensor data. The result is a Higher Recognition rate[19].

SOM(Self-Organizing Map) Algorithm:

Clusters large and complex multi-dimensional data because it is easy to visualize the clustered data and it is time-efficient[20]. Uses an unsupervised learning method for analyzing data without a pre-defined no. of clusters or correlation between data. The result produced is weights of less meaningful or Noisy spots are decreased.

Kohonen's SOM (Self-Organizing Map) Algorithm:

A kind of neural network algorithm used to cluster complex data by mapping multi-dimensional data onto a 2-dimensional space ,and correlating the mapped 2-dimensional data with each other[21]. The drawback is that it is not suitable for small and simple one-dimensional data. It results in Weights of correct regions or meaningful spots are increased.

ART2 Algorithm:

For automatic threshold selection uses the contour shape of the graph created by accumulating distances between all spots of a footprint pattern image[22]. It is difficult to pre-select an initial threshold value because the sizes of feet and strides vary with the species of insects. It gives a good performance in clustering.

Trace Transform Technique:

Trace transform technique builds a new type of data structure from the segmented images, by defining functions based on parallel trace lines [23]. The demerit is that it is a must to do the tracing parallel. It helps in efficiency in distinguishing species of insects to a specified degree.

Neural Network:

The UbiFloorII[24] is a biometric sensor to measure biometric identifier or dynamic footprints. Multilayer perceptron networks is used for identifying individuals based on extracted stepping features. Neural Network consists of three layers : (i)input layer N1 with P1 neurons,

(ii) hidden layer N2 with P2 neurons and (iii) output layer N3 with P3 neurons.

The input vectors converted from the left footprints will be directly the inputs to the neurons of the input layer in our network. The Hidden layer adjusts the weights and baises of the network in order to move the networks closer to the targets.

Principle Component Analysis:

The purpose of PCA training is to obtain several principal components to represent the original stepping features from a high-dimensional measurement space to a low-dimensional eigenspace. PCA training has been employed on vision –based gait recognition approach. Using PCA , template is projected from a matrix to a vector with reduced coefficients. The recognition accuracy with these projected templates is about 90%[26], which is reasonable considering computation loads greatly reduced.

Smoothing Algorithm:

Smoothing algorithm is used to remove noises of different scales of footprint image and protect the outlines of footprint image[25]. A non-idempotent connected operator which can be the criterion for multi-scale filter is defined and an condition to final scale space is decided on the basis of the feature of the footprint image. Subsequently, the connected operator is imposed an increasing property so that not to give rise to artificial edges in filtered images. At last the connected zones of footprint image and their relatios are described and the way of the multi-scale morphological adaptive reconstruction filtering for footprint image is implemented by using maximum tree structure.

Table.1-Footprint recognition Techniques

Name	**Authors**	**Main idea**	**Problems**	**Rate of Recognition**
Euclidean distance	Nakajima,2000	Person identification among 10 men using normalized static footprint.	(i)User should make stand-up posture every time. (ii)Recognition rate is insufficient for practical uses.	85%
Hidden Markov Model	Jung,2003	Person identification among 5 men using position- based quantization of COP(Center of Pressure) from shoe-type pressure sensor and HMM(Hidden Markov Model)	(i)All data were collected in a day (ii)Using shoe-type sensor could be a serious constraint in the view of users.	100%
Comprehensive Evaluation Model	Jang, J.R,1993	Established to recognize Toe-shape by Neural Networks. Final decision result is based on many factors in the Fuzzy Environment.	Comprehensive vector is got based on singular factors. It becomes a tedious process for large data.	92.80%
Matching Algorithm	Jiaqwei Hong and Haim j.Wolfson, 1988	Recognition for partially occluded and overlapping objects in composite scenes.	Not effectively applicable to rotation, translation and scale invariant cases.	Successful

		The objects are matched against the scene and their position is recovered.		
Statistical Method	Kyoko Sudo, Junji Yamato, Akira Tomono,1996	Fusing the features of recognition extracted from the multiple sensors.	A number of problems still remain in fusing when noise is contained in the multiple sensor data.	Higher Recognition rate.
SOM(Self-Organizing Map) Algorithm	M.Chester,1993	Clusters large and complex multi-dimensional data because it is easy to visualize the clustered data and it is time-efficient.	Uses an unsupervised learning method for analyzing data without a pre-defined no. of clusters or correlation between data.	Weights of less meaningful or Noisy spots are decreased.
Kohonen's SOM(Self-Organizing Map) Algorithm	T.Kohonen,2001	A kind of neural network algorithm used to cluster complex data by mapping multi-dimensional data onto a 2-dimensional space ,and correlating the mapped 2-dimensional data with each other.	Not suitable for small and simple one-dimensional data.	Weights of correct regions or meaningful spots are increased.
Hidden Markov Model	Jin-Woo Jung,Zeungnam Bein,Sang-Wan Lee and Tomomasa Sato,2003	Person identification among 8 men using dynamic footprint from Mat-type pressure sensor. We get quantized COP trajectory and HMM's for two footprints are combined with Levenberg-Marquart learning method for better performance.	Recognition rate is not equally distributed and not enough high.	64%

ART2 Alogorithm	B.S.Chin,E.Y.Cha, Y.W.Woo and R.Klette, 2007	For automatic threshold selection uses the contour shape of the graph created by accumulating distances between all spots of a footprint pattern image.	Difficult to pre-select an initial threshold value because the sizes of feet and strides vary with the species of insects.	Good performance in clustering.
Trace Transform Technique	A.Kadyrov and M.Petroue, 2001 & 2004.	To build a new type of data structure from the segmented images, by defining functions based on parallel trace lines.	It is a must to do the tracing parallely.	Distinguish species of insects to a specified degree.
Fuzzy recognition technique	H.Maturino-Lozoya, D.Munoz-Rodriguez, 2000	Uses the theory and method of fuzzy maths for resolving the pattern recognition problems.	Very complicated. can be implemented more efficiently with Neural Networks	92.80%
Neural Network	Jaesoek Yun , Gregory Abowd , Woontack Woo , Jeha Ryu,2007	Recognizes the user with well-trained neural network	Numerous input nodes in the neural network, causing heavy computation loads	92%
Smoothing Algorithm	Shu Yang, Cai-rong Wang, Xue-ying Wang,2007	Removes the noise and protects the outlines of footprint image	Filtered images may have artificial images	Successful
Principle Component Analysis	P. Huang, C. Harris, and M. Nixon, 1999.	Represents the original stepping features	Accuracy percent gets decreased	90%
Best Basis Methods or Wavelet Packets[27],[28] ,[29]	R.Coifman,M.Wickerhauser-1992 and K.Ramchandram, M.Vetterli-1993	Over complete dictionaries	In developing fast algorithms	Successful

Linear Complexity Algorithms [31], [30]	D.L.Donoho,P.B.Stark-1989 and M.Elad ,A.M.Bruckstein-2001	Sparser signal representation	Search for right sparser representation	Not Successful
Singular Value Decomposition (SVD),Pseudo-inverse[32]	M.M.Goodwin,M. Vetterli-1999	Signal representation	Do not yield compact signal representation	Not successful

3. FEATURES OF FOOTPRINT RECOGNITION

Center of Foot Pressure (COP):

COP[24],[7] is used to develop a biometrics personal identification system. Biometrics technology, as a method of personal identification, plays an important role in our daily lives. we calculate the site of COP from the obtained pressure data. Features for identification are extracted from the position and the movement of COP. The center of foot pressure (COP) of humans changes slightly, even when he is motionless. Moreover, their postural stability decreases with aging. While performing a motion, the change of COP becomes larger with aging.

Toe Shape feature:

Toe shape is closely related to the human's eye. So,it is the base to identify person and very important in spying the criminals. There are four geometric shapes of the toe image. They are Triangle, Ellipse, Circular, and Irregular.

Image feature:
The camera takes the image. This research shows that the shapes of pattern spectra differ from men & women. Widely used in aerial defense, outer space exploration, medicine, etc.. Features of footprint image are defined from Angular relation, Length, Region. Fuzzy Neural Network can reflect different toe shapes objectively and correctly. The total automatically recognizable rate arrives at 92.80%[19].

Triple feature:
Used for discriminating paterns of insect footprints for the various species of insects[20],[21]. It is also used for the classification of the insect footprints by using a segment image and its reflection.

Vibration feature:
The vibration signal from the accelerometer is recorded as a voltage level. It determines the acceleration of the footprints of a person[19]. We use 30-dimensional co-efficient of it as the feature vector.

Tactile sensor feature:
Tactile sensor outputs the pressure value on the sensor mat as a gray scale image. A footprint image is obtained by overlapping all frames and taking the maximum value of each pixel. The projection of this image is formed by summing the values for each pixel line from heel to toe. The length of the sequence of values is normalized to 60 pixels [19]. We use this sequence of values **as** a feature vector.

Walking pattern
Walking Pattern can be defined as spatiometral variations variations of gait such as stride length , dynamic range, foot angle and stride and swing phase.Stride length and cadence has been used in various vision-based recognition systems, but not in floor-based systems. Examples of recognition systems based on walking pattern are the UbiFloorI[24] and the UbiFloorII. In these Stride length and stand and swing time can be extracted from the user's gait while walking over the floor.

Stepping floor:
Stepping Floor is used for temporal variations of gait such as GRF[24], static footprint and dynamic footprint. GRF(Ground Reaction Force) is the downward force due to gravity is reflected back onto the body as a reaction when a body is in contact with the ground. Static footprint is the footprint left after a person passes and it can be used to identify individuals through the pressure areas on the soles of their feet. Dynamic footprint can be defined differently according to biometric sensors and available features. It is defined as a COP during stepping heel-strike to toe-off.

Footprint arch:
According to the positions of the footprint arch, footprints are divided into five kinds: High arch footprint is 4.732% , Narrow arch footprint is 1.2613%, Middle arch footprint is 1.2613%, Flat arch footprint is 1.005%, Bulge arch footprint is 0.87% [25].

Table.2-Features of Footprint Recognition

Features	Usage
Center of Foot Pressure (COP)	Used by Biometric personal identification system, using dynamic footprints.
Geometric constraint	Used for straight-forward parallelism. Eliminates the need of breakpoints heuristics.
Toe Shape feature	Toe shape is the base to identify a person and is very important in the work to criminal spy. Closely related to human's age.
Triple feature	Used for discriminating paterns of insect footprints for the various species of insects.
Vibration feature	The vibration signal from the accelerometer is recorded as a voltage level. It determines the acceleration of the footprints of a person.
Tactile sensor feature	Tactile sensor outputs the pressure value on the sensor mat as a gray scale image.
Image feature	The camera takes the image. This research shows that the shapes of pattern spectra differ from men & women. Widely used in aerial defense, outer space exploration, medicine, etc.
Walking Pattern	Used to measure the spatiometral variations of gait such as stride length , dynamic range, foot angle and stride and swing phase.
Stepping Pattern	Used to measure the temporal variations of gait such as GRF, static footprint and dynamic footprint.
Footprint arch	Segments the whole footprint image into five kinds and shows the percentage of space covered by the part.

4. CONCLUSIONS

This paper provides a review of well known researches on footprint recognition. The algorithms used in footprint recognition are categorized into three stages: image pre-processing, feature extraction and template matching. Image pre-processing is the process used to minimize or reduce the noise from original image. In feature extraction process, the features such as pressure, location and weight are extracted from an image and it improves the performance of the footprint recognition and the input image in matching process. By using all these process, it increases the clarity of the image and high matching score can be obtained.

Foot print based authentication bears enough security without drawback of relying on sensitive data demanded by high security applications. Future work includes implementing quality estimation algorithms into a quality based recognition and authentication system to provide an extensive path for research scholars in this area.

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