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Automated Person Identification System Using Walking Pattern Biometrics

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Abstract— this paper provides a new human identification system based on the walking pattern biometrics of a person. The walking pattern of a person is unique and difficult to replicate by others. So this can be a good automated identification system for any application where person identification is needed, security systems or surveillance. Person to person, walking pattern differences mainly depend on the footstep, body movement and also on the sound of the footsteps. The target of this paper was to provide possible solution of walking pattern recognition system using the computer vision technique with an acceptable accuracy rate.

Index Terms—biometrics, computer visison, footstep, human identification, image procesing, security, walking pattern.

1 Introduction

There are lots of methods to identify human or a person. Some of them are finger print, face recognition, voice recognition, etc. These methods are called as biometrics. Biometrics refers to the identification of humans by their characteristics or traits. "Footstep" a new biometric has been proposed by a group of researches in 1997 [1]. In their research they stated that footstep of a person has a unique property and it is different for different person [1]. So it could be an identity to detect a person. The main benefit of footsteps over the known biometrics is that this is a behavioral fact of human and it is difficult to replicate by others. So using this footstep biometrics we can differentiate the walking pattern form from person to person. Moreover, we will be able to find or to identify a human or a person by their walking pattern.

Footsteps have some potential applications in the smart home environment where footstep sensors are installed to determine the position of a person in a room. It will also recognize human behavior and their interaction. A smart home is designed in such a way that it could communicate with its individual members. However, walking pattern recognition can be a good way to identify the person without noticing or involving them. Moreover, identification system without noticing the object or person is also very important for the security systems. In the other existing biometrics recognition system, there are many flows and can be replicate easily [2,3]. But as the footstep is related to a person's behavior so it will be hard to duplicate [4]. Human identification by footstep biometrics is also a faster way to identify a person because in the other case a person needs to give his identity manually. Like for finger print or iris scan a person needs to press his/her finger or show iris to the scanner. But in footstep recognition, a person not even understands that his identity is being processing. So it is much more automated than the other systems. This identification system can be used in many places like smart home, bank vault, army base etc. Also in the battlefield we can implement this by warless sensor network to track the enemies' movements.

In this paper we present a new way to get data from a person's walking pattern or body movement and propose a system to provide higher accuracy in person identification using this data.

2 METHODOLOGY

The walking pattern information could be collect in different ways. Some of them are describe below,

- The data can be collect from video camera and then by processing the images one can get the pattern of a person's walking style. Study shows that walking movement of a person is different from another person [5-7]. So it could be a good way to capture person's identity by his walking movement.
- Another pattern can also be the walking sound of a person. A study shows that it is possible to identify a person accurately just by hearing their walking sound. And the accuracy rate is about 66%. The study also said that the walking sound also carries gender information. People can recognize gender by the walking sound with more than 77% accuracy [8-10].
- Sensor based system could be another solution for the problem. There are different kinds of sensors to get information of footsteps like pressure sensor. That could be placed in the floor or could be in the person's foot ware. Moreover, Ground Reaction Force (GRF) can give us the accurate data of footsteps [11, 12].
- Another user identification system, known as ubiFloor [12], tracks the user's location with 144 low-cost ON/OFF switch sensors to identify users based on their walking patterns.

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International Journal of Scientific & Engineering Research Volume 6, Issue ƝƼ2Ì×ÛÌÔÉÌÛ-2015
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3 PROPOSED WALKING PATTERN RECOGNITION SYSTEM ARCHITECTURE

We proposed a hybrid approach where we use all three techniques of computer vision mentioned in previous section, as well as Artificial Intelligence. Here a new prototype is designed with the combination of those processes to get a better result. Our main intention is to increase the accuracy rate of pattern recognition as well as to provide a good identification system. It may cost little bit more than the single process but it will definitely increase the accuracy in detection which is essential for any security system.

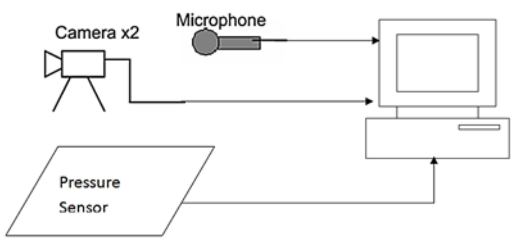

Fig. 1. Implementation Process

The whole system includes Microphone to capture sound of footstep, Camera to capture the movement of the person and pressure sensor or smart floor [5] implemented in the floor to capture the pressure pattern when the person walks. That information will go to a computer and store to a database and will be analyzed by different algorithms and make them a

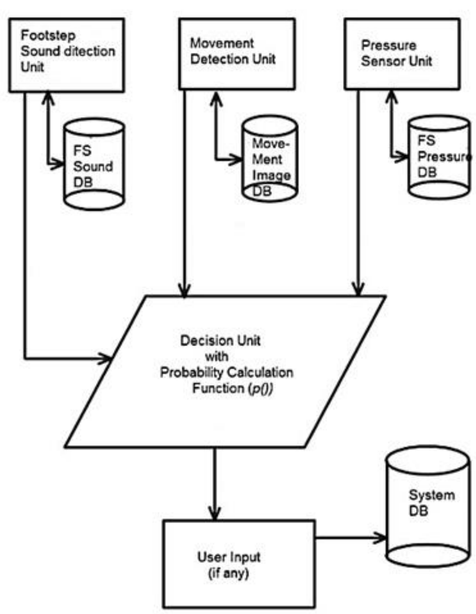

Fig. 2. System Diagram

unique pattern which will tag for a person's information. This will be our training set. By this training set we will identify the unknown person when we get a matched walking pattern from our system.

In this proposed system we use three different model of footstep recognition system. It is a hybrid approach where we use three techniques of computer vision as well as Artificial Intelligence. The whole system consists of four units:

i. Foot Step Sound Detection Unit
ii. Pressure Sensor Unit
iii. Persons Movement Detection Unit
iv. Decision Unit

i. Foot Step Sound Detection Unit: For the sound identification system we use the unique pattern that the footstep sounds form in spectrotemporal domain: spectrotemporal footprint. It is a model of sound processing in the auditory context [13, 14]. The sound of footstep captured by regular microphone. The recorded sounds are filtered with a high-pass filter with cut-of frequency of 125Hz to reduce the recording noise generated by the computer. Then mapped to a high-dimensional modulation representation by an auditory model and then classified by a set of parallel Support Vector Machines (SVM).

ii. Pressure Sensor Unit: For pressure sensor we used the ubiFloor model developed by a group of Korean researchers [12]. The system based on low cost ON/OFF switch sensor.

iii. Persons Movement Detection Unit: In video based recognition captures different movements of a person. So each frame of video is unique posture of the movement. A basic requirement of the system is binary body mask at each frame has been captured, and any webcam in a static background can capture it. From the body masks, the body regions of interest (ROIs) are extracted [15]. A center point in respectto the bodies along the whole movement sequence is taken and scaled to the same dimension using bucolic interpolation. A ROI is scanned column wise to produce the respective vector x ∊ RF, where F is the number of pixels, and, thus, a movement video is represented with a sequence of such vectors [15].

iv. Decision Unit: The previous threeunits compare their corresponding data with their own database sequentially and provide the match results (Person ID) with percentage value. From this value the Decision Unit calculates the probability factor of different match. Then it takes a decision for the match with highest probability and show the result. It also takes input from user (if or if not get a match) to be correct and remember the action to use next time. The probability function is as flows,

$$P_x = \frac{\sum_{u=1}^{3} Pu}{3}$$

Result = Max(P1, P2, P3… Px)

International Journal of Scientific & Engineering Research Volume 6, Issue №2Ì×ÛÌÔÉÌÛ-2015
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Here Px={1,2,3…n} is the resultant person or person's ID. Pu={1…3} is the probability percentage get from three units. The average for each person and take the person with maximum probability as result.Let for example we get the flowing results from different units for a certain case:

Unit 1: P1 60%, P2 10%, P3 30%
Unit 2: P1 40%, P2 20%, P3 30%, P4 10%
Unit 3: P1 70%, P3 30%

So the probability calculation is easy for us now. We can easily said that the probability of being the person P1 is higher than the others.

4 PROPOSED BODY MOVEMENT ANALYSIS

To implement the Person's Body Movement Detection Unit, the video image recognition processis used. The overall structure ofthis unit is implemented to detect the human body parts(e.g. head, leg and arms) and then to combine those body parts to detect the full human. The body parts are combined based on the proper geometric configuration. The performance can be improved greatly if one classifier can be used for detection of human after checking the body parts components are in their proper geometric configuration. To ensure the view invariant human detection for each body part more than one detector has been design and the knowledge of each of those body part detectors are combined finally to increase the robustness of the whole system.
One problem in full human detection is that the system fails to detect the human where body parts are partially occluded. This partial occlusion is accomplished by using an appropriate geometric combination algorithm in designing of the system, so that it detects people even if all of their components are not viewed or detected. In our system we take only the side view of a human body and analysis the movement of different segment of leg (upper leg segment, lower leg segment, foot segment) shows in "Fig. 3". In a walking this three segments change their position relatively with the body. The orientation depends on the body mass, height and many other variables which vary from person to person. For this reason the orientation of the leg segments must be different.

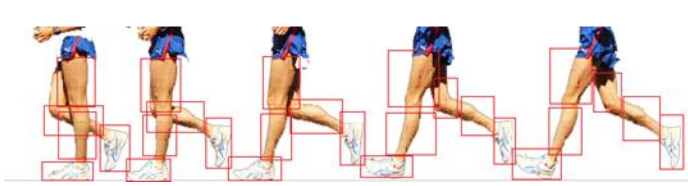


Fig. 3. System Diagram

A. Proof of Our Concept

Our main target is to proof that the segmentation of legs in a walking sequence is different from person to person. For this we consider the legs orientation relative to the body and try to find the mean value of the orientations of the segments. In a walking sequence is accomplished with a strategy called the double pendulum. During forward motion, the leg that leaves the ground swings forward from the hip. This sweep is the first pendulum. Then the leg strikes the ground with the heel and rolls through to the toe in a motion described as an inverted pendulum. The motion of the two legs is coordinated so that one foot or the other is always in contact with the ground.
In "Fig.4" we show rotation of the segments in a walking sequence. From "Fig.4" we can see leg has three segments. One is from hip joint to knee, Knee to ankle and ankle to finger. Each segment has different rotation in every step of a walking Cycle. These rotations are relative to each other.

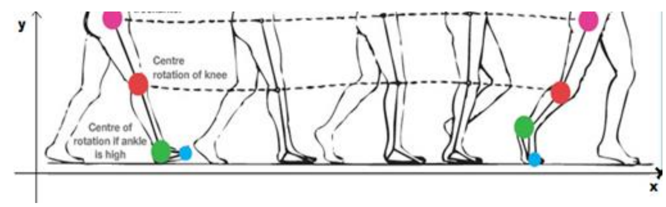


Fig. 4. Leg segment orientation of walking sequence.

We also observed the hip joint follows a sine curve. From this we can get the slope m of each segment. Where,

$$m = \frac{y_1 - y_2}{x_1 - x_2} \quad (1)$$

Then we take the mean and variance of all m for each segment.

$$\bar{m} = \frac{m_1 + m_2 + m_3 + ... + m_n}{n} \quad (2)$$

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2} \quad (3)$$

This orientation is depends on the person's body mass and shape. It also changes on the persons walking behavior. Another difference concerns the movement of the center of mass of the body. In walking the body vaults over the leg on the ground, raising the center of mass to its highest point as the leg passes the vertical, and dropping it to the lowest as the legs are spread apart. We observe the patterns for different subject and different results show for different subject.

International Journal of Scientific & Engineering Research Volume 6, Issue ƝŴ2Ì×ÛÌÔÉÌÛ-2015
ISSN 2229-5518

5 EXPERIMENT AND DATA ANALYSIS

The experiment contains one camera taking video of the walking subject. It capturing only the side view of the subject and also makes sure that all the three segments of subject's leg is properly coming in the frame. We take five frames per walking sequence. The pixel ration of the frames is 150x134. So the image size of five frames together five frames is 150x670 pixel. Then image is put in the graph and measured the slope of each segments for X and Y coordinate. The data was taken for two sequences and then took average as shown in the data of Table 1.

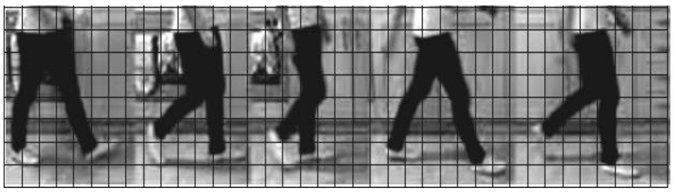


Fig. 5 Slope (m) of three segment of leg in different step of a walking cycle of subject 1.

TABLE 1
SLOPE (M) OF THREE SEGMENT OF LEG IN DIFFERENT STEP OF A WALKING CYCLE OF SUBJECT 1 AND THEIR MEAN AND VARIANCE VALUE.

	segment-1	segment-2	segment-3
step-1 m	0.28	0.33	1.00
step-2 m	0.11	0.17	0.2
step-3 m	0.26	0.47	0.125
step-4 m	0.19	0.33	0.1
step-5 m	0.11	0.27	1
mean(m)	**0.19**	**0.31**	**0.49**
variance(m)	**0.0065**	**0.0119**	**0.2224**

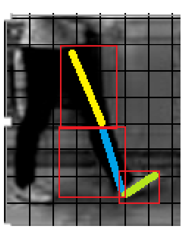


Fig. 6 Segment lines in the graph.

"Fig. 6" shows the slope of different segment of leg. First segment is related to the body, second segment to first and third is to second segment.

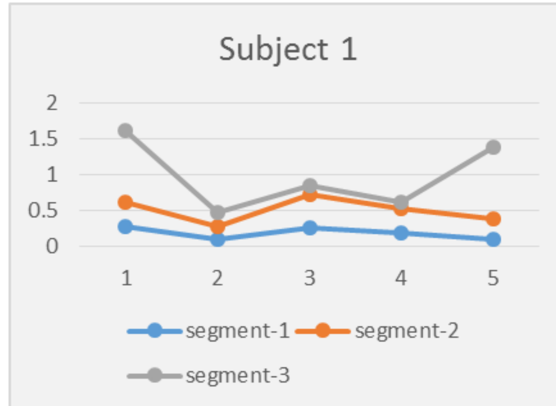
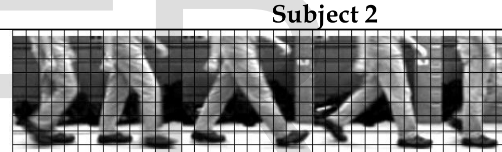


Fig. 7 Chart representation of three segments of leg of subject 1 in a walking cycle.

Our experimental results shows in "Fig. 7", that the mean value and also the variance of different segments are different from one subject to another for their walking sequences. That is detected from the leg segmentation of walking sequences.

Subject 2



	segment-1	segment-2	segment-3
step-1 m	0.28	0.40	0.50
step-2 m	0.4	0.48	0.86
step-3 m	0.04	0.05	0.10
step-4 m	0.36	0.08	0.08
step-5 m	0.2	0.60	0.50
mean(m)	**0.26**	**0.32**	**0.41**
variance(m)	**0.0205**	**0.0602**	**0.1059**

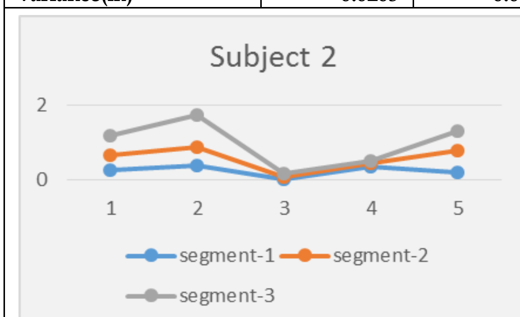


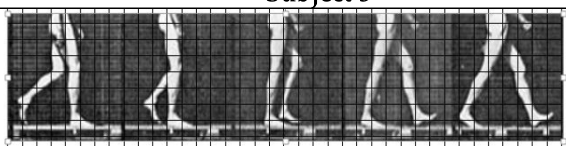
Fig. 8 Slope (m) of three segment of leg in different step of a walking cycle of subject 2 and chart representation.

International Journal of Scientific & Engineering Research Volume 6, Issue ƝƼ2Ì×ÛÌÔÉÌÛ-2015
ISSN 2229-5518

Use of more frames will increase the accuracy. For our proposed system, the leg has to be visible correctly otherwise the coordinate of the segments may not be correct. Moreover, for long or short step for the same person need to be reconciled.

Here we shown some more result for different subjects from Fig. 8 to fig. 9. Each result shows the unique pattern for their walking sequence.

Subject 3



	segment-1	segment-2	segment-3
step-1 m	0.15	0.25	0.60
step-2 m	0.45	0.25	0.75
step-3 m	0.55	0.90	0.88
step-4 m	0.3	0.75	1.11
step-5 m	0.25	0.60	0.40
mean(m)	**0.34**	**0.55**	**0.75**
variance(m)	**0.0255**	**0.0863**	**0.0729**

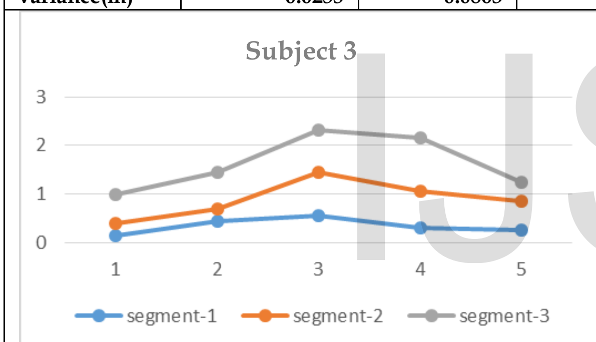


Fig. 9 Slope (m) of three segment of leg in different step of a walking cycle of subject 3 and chart representation.

6 CONCLUSION

Ourpaperpresented a Hybrid model for person identification using only the walking pattern biometrics. We used the combination of three different system units to increase accuracy. Also a new way to get walking pattern data from video image is proposed here. With mathematical analysis we proved that the walking pattern generate by the leg segments is unique and can be used as a person's identity. Also found that this unique information vary for the same parson in different situations. It may represent the person's emotional state.As physical condition can affect his walking style so it could explain the physical state too. That might be another good field for future research.

REFERENCES

[1] [1] Addlesee, M.D., Jones, A., Livesey, F., Samaria, F.: The ORL Active Floor. IEEE Personal Communications. 4 (1997) 235–241

[2] ChasityDeloney, NimaMesgarani, Jonathan Fritz: Person Identification and Gender Recognition from footstep sound using Modulation Analysis. ISR Technical Report 2008-17.

[3] James M. Sabatier, Alexander E. Ekimov, Range limitation for seismic footstep detection. The University of Mississippi. Cattin, C.: Biometric Authentication System Using Human Gait. Swiss Federal Institute of Technology, Zurich. PhD Thesis. (2002)

[4] Rubén Vera Rodríguez, Richard P. Lewis, John S. D. Mason and Nicholas W. D. Evans: Footstep Recognition for a Smart Home Environment. International Journal of Smart Home, Vol. 2, No. 2, Apil, 2008.

[5] Orr, R. J. and Abowd, G. D. "The Smart Floor: AMechanism for Natural User Identification and Tracking". Proceedings of Conference on Human Factors in Computing Systems. 2000, pp. 275-276.

[6] Suutala, J. and Rning, J. "Towards the adaptive identification of walkers: automated feature selection of footsteps using distinction-sensitive LVQ". Proc. International Workshop on Processing Sensory nformation for Proactive Systems. 2004, pp. 61-67.

[7] Middleton, L., Buss, A. A., Bazin, A. I. and Nixon, M. S. "A floor sensor system for gait recognition". Proc. Fourth IEEE Workshop on Automat ic Identification Advanced Technologies. 2005, pp. 171-176.

[8] Footstep Sound using Modulation Analysis. Isr Technlcal Report 2008-17.

[9] Alexander Ekimov and James M. Sabatier: Human detection range by active Doppler and passive ultrasonic methods, National Center for Physical Acoustics. Proc. of SPIE Vol. 6943

[10] T. Chi, P. Ru, and S.A Shamma, "Multiresolution spectrotemporal analysis of complex sounds," Journal of the Acoustical Society of America, 2005

[11] Gao, Y., Brennan, M. J., Mace, B. R. and Muggl eton, J. M. "Person recognition by measuring the ground reaction force due to a footstep". Proc. 9thInternational Conference on Recent Advances in Structural Dynamics. 2006.

[12] Yun, J. S., Lee, S. H., Woo, W. T. and Ryu, J.H. "The User Identification System Using Walking Pattern over the ubiFloor". Proc. International Conference on Control, Automation, and Systems. 2003, pp. 1046-1050.

[13] N. Mesgarani, M. Slaney, S. A. Shamma, "Speech discrimination based on multiscale spectrotemporal features", IEEE International Conference on Acoustic, Speech and Signal Processing, Montreal, Canada, 2004.

[14] T. Chi, P. Ru, and S.A Shamma, "Multiresolution spectrotemporal analysis of complex sounds," Journal of the Acoustical Society of America, 2005.

[15] Bhaskar Chakraborty, Ignasi Rius, Marco Pedersoli, Mikhail Mozerov and Jordi Gonzàlez, "Component-based Human Detection" Institut de Robotica I Informatica Industrial(UPC-CSIC), Edifici U, 08028 Barcelona, Spain.