GAZE TRAJECTORY AS A BIOMETRIC MODALITY

Farzin Deravi and Shivanand P. Guness
School of Engineering and Digital Arts, University of Kent, Canterbury, CT2 7NT, U.K.

Keywords: Biometrics, Gaze tracking.

Abstract: Could everybody be looking at the world in a different way? This paper explores the idea that every individual has a distinctive way of looking at the world and thus it may be possible to identify an individual by how they look at external stimuli. The paper reports on a project to assess the potential for a new biometric modality based on gaze. A gaze tracking system was used to collect gaze information of participants while viewing a series of images for about 5 milliseconds each. The data collected was firstly analysed to select the best suited features using three different algorithms: the Forward Feature Selection, the Backwards Feature Selection and the Branch and Bound Feature Selection algorithms. The performance of the proposed system was then tested with different amounts of data used for classifier training. From the preliminary experimental results obtained, it can be seen that gaze does have some potential as being used as a biometric modality. The experiments carried out were only done on a very small sample; more testing is required to confirm the preliminary findings of this paper.

1 INTRODUCTION

Biometric systems aim to establish the identity of individuals using data obtained from their physical or behavioural characteristics. In recent years there has been an increasing range of systems developed using a wide variety of biometric modalities – including fingerprints, face, voice and gait. In this work we propose the human gaze as a new modality that may also be used to establish identity.

Gaze tracking is the process of continuously measuring the point or direction of gaze of the eyes of an individual. Up to now we are not aware of any studies on the use of gaze as a source of biometric information. In particular, the possibility of using gaze direction as a means for identifying individuals will be explored in this work.

Gaze may be considered a type of behavioural biometrics. Such behavioural modalities are based on acquired behaviour, style, preference, knowledge, motor-skills or strategy used by people while accomplishing different everyday tasks such as driving an automobile, talking on the phone or using a computer (Goudelis, Tefas, & Pitas, 2009; Gutiérrez-García, Ramos-Corchado, & Unger, 2007)

Human Computer Interaction (HCI) is the interaction between the user and devices such as Personal Computers, Smart phones etc. HCI can also be used as a source of biometric information because the interaction of a user and his computer may be quite distinctive if not unique. One attraction for using HCI as a biometric modality is the potential to develop a non-intrusive authentication mechanism (Yampolskiy, 2007).

Gaze may therefore be considered in part as a behavioural biometrics. At the same time it may also have physiological aspects determined by the tissues and muscles that determine its capabilities and limitations. In this respect, it may be likened to text-dependent automatic speaker recognition where a user is asked to read a pre-defined text and the sound generated is analysed and compared with a database to establish his or her identity. In a similar fashion the user of gaze biometrics may be shown a predefined sequence of images and the gaze information is analysed and compared with a database of previously stored gaze data to recognize the individual.

In particular the data generated may be analysed in a similar fashion to Online Signature Verification because the gaze data is very similar to online signature, except for the fact that the gaze data is collected with reference to a screen where the stimulus images are presented and the signature data is obtained on a digitalised pad. A study of HCI-based biometric modalities such as Keystroke and

Deravi F. and Guness S..
GAZE TRAJECTORY AS A BIOMETRIC MODALITY.
DOI: 10.5220/0003275803350341
In *Proceedings of the International Conference on Bio-inspired Systems and Signal Processing* (BIOSIGNALS-2011), pages 335-341
ISBN: 978-989-8425-35-5

Mouse Dynamics may also be helpful in the development of gaze as a biometric modality.

The rest of the paper is organized as follows: In Section 2 a review of some related sources of biometric information is presented. Section 3 describes the design of our proposed system while Section 4 presents the experimental setup and some preliminary test results. Finally Section 5 provides tentative conclusions and suggestions for further work.

2 BACKGROUND

In this section of the dissertation we are looking at traditional behavioural biometrics such as Online Signature Verification and also HCI based biometrics such as Keystroke and Mouse Dynamics. The behavioural aspect of gaze and eye movement is also investigated.

2.1 Biometric Modalities

2.1.1 Online Signature Verification

The study done by Lei et al was to investigate the consistency of the features used for signature verification. The speed, coordinate points and, angles between the speed vector and the X-axis are found to be the most consistent and reliable. The False Accept Rate (FAR), False Reject Rate (FRR) and the Equal Error Rate (EER) are calculated for each feature and this data is used to find the most consistent features (Lei & Govindaraju, 2005). In Chapran et al, the 35 most widely used features used in handwritten signatures. ANOVA (Analysis of Variance) statistic method was used to find the variance of the different features. This enables finding the features that changed when a forged signature was entered. This also helped to find the features which are most suitable for the different types of writing activities such as writing cheques and signing forms (Chapran, Fairhurst, Guest, & Ujam, 2008).

2.1.2 Keystroke Biometrics

Keystroke biometric modality involves collecting data about the typing pattern of the user. There are two different types of keystroke biometrics. The keystroke biometrics can be either static or continuous. In static keystroke biometrics, keystroke biometric is only used during login time whereas with continuous keystroke biometrics; the modality is continuously being monitored. The advantage of continuous keystroke over static is that an imposter user can be detected even if an imposter is substituted for a genuine user after the initial authentication process. The features that can be used are the time between keystrokes, the duration of the keystroke, finger placement and applied pressure on the keys in the paper proposed by Monrose & Rubin (Monrose & Rubin, 2000).

2.1.3 Mouse Dynamics

Mouse Dynamics uses information such as the direction of the movement of the mouse, timing and monitoring when actions such as clicking are performed to authenticate a user. There are two ways in which data is captured for this modality. Data can be collected by the continuous monitor the activities of the user. Another method used is by capturing the mouse interaction in an application such as a game. In a paper proposed by Revett et al, a survey is conducted to investigate mouse movement based biometric authentication systems. Revett et al also proposed a novel graphical authentication system called Mouse Lock. The preliminary result showed that mouse movement or mouse dynamics could be a viable biometric modality. For testing their application with 5 user and they showed that the FAR of the system to be in the range of 2% to 6% and FRR to be in the range of 0% to 7% (Revett, Jahankhani, Magalhães, & Santos, 2008).

2.1.4 Eye Behaviour

In a paper by Adolphs the relationship between the size of the pupils and emotions were investigated. The study was looking at how the size of the pupil of individual is changes while looking at sad faces. Pupil size is well-known to be influenced by stimulus luminance, but it turns out also to be influenced by other factors, including salience and emotional meaning (Adolphs, 2006).

In Harrison et al, the size of the pupil was investigated to see how it changes while viewing the expressions of another person. The study showed that the size of the pupil becomes smaller while viewing sad facial expressions and there is no visible change caused by expressions of happiness, neutral expression or expressions of anger (Harrison, Singer, Rotshtein, Dolan, & Critchley, 2006).

Wang et al used eye tracking and pupil dilation to see if a person is telling the truth. It was observed that the pupils were dilated when deceptive messages were sent and that the dilation was related to the magnitude of the deception (Wang, Spezio, &

Camerer, 2010).

In this study, Castelhano et al (2008) investigated the influence of the gaze of another person on the direction of gaze of an observer. In their experiment the participants were shown a sequence of scene photographs that told a story. Some of the scenes contained an actor fixating an object in the scene. It was observed that the first fixation point of the participants were the face of the actor, the eye then moved to focus on the object the actor was focusing on. Furthermore it was observed that even in the presence of other object in the scene the participants would always focus their gaze on the object the actor is looking at.(Castelhano, Wieth, & Henderson, 2008)

Another study conducted by Castelhano (2009), the influence of task on the movement of the eye is being investigated. The experiments consisted of 20 participants who were asked to view color photographs of natural scenes but under two different instruction sets. The first instruction set was to do a visual search of the image and the second task was to memorization of the image. The results of the experiments show that the fixation points and the gaze duration of the different participants were influenced by the task they were performing. It was also seen that the areas of fixation were different for both tasks but the movement amplitude and the duration of the fixation were not affected (Castelhano, Mack, & Henderson, 2009).

2.2 Tracking Performance

An important consideration is the accuracy with which gaze data can be captured for further analysis. The result in the paper by Chao-Ning et al shows their technique can be used to calculate gaze with an accuracy of 85% to 96% within 2 meters. This was done by calculating the estimated gaze of the system and comparing the result to the coordinate of the dot the user was viewing on the screen. The test was carried out at various distances (Chao-Ning Chan, Oe, & Chern-Sheng Lin, 2007).

3 DESIGN

3.1.1 Overview

The overall system setup is shown in Figure 1. This consists of a display screen where stimulus images are presented and a webcam facing the user to capture their gaze information. Software in the computer attached to the webcam is then used to analyse the images captured by the camera to extract gaze information which is subsequently further processed to extract gaze features. Once the features are extracted, a suitable classifier is used to compare the captured data with previously stored data for this and other users. In this way it is possible to establish error rates for the system and explore its feasibility as a biometric system.

3.1.2 Stimulus

The stimuli used were obtained from an image quality database (Engelke, Maeder, & Zepernick, 2009; Le Callet & Autrusseau, 2005). Five images were chosen from the database. Alternate images of objects or nature and human are displayed to the user. This is done so as to avoid the user's gaze to be influenced by the content of the image and to offer the user a variety of image types. The images are all assumed to be of the same quality and thus the gaze of the user would not be influenced by the quality of the image.

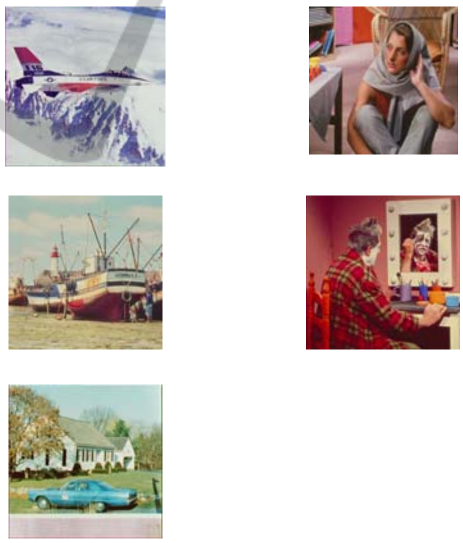

Figure 1: Stimulus images.

3.1.3 Gaze Data

Table 1 describes the structure of the data to be stored for the gaze information that is captured. This data has to contain enough information to enable further processing for biometric feature extractions.

3.1.4 Gaze Capture

Figure 2 show the flow diagram for the enrolment process. User enrolment is the process whereby the

Table 1 : Data structure of the data retrieved from the gaze.

#	Field Name	Description
1	Frame Number	Unique incremental number
2	Time	The time the gaze was captured
3	Interval	The interval time used by the sensor
4	X coordinate of left pupil	The X coordinate of the centre of the left pupil
5	Y coordinate of left pupil	The Y coordinate of the centre of the left pupil
6	Tracking status of left pupil	The tracking status of the left pupil
7	X coordinate of right pupil	The X coordinate of the centre of the right pupil
8	Y coordinate of right pupil	The Y coordinate of the centre of the right pupil
9	Tracking status of right pupil	The tracking status of the right pupil
10	Type of data	The type of the data
11	Size of left pupil	The size of the left pupil
12	Size of right pupil	The size of the right pupil
13	Stimulus	The stimulus being presented to the user
14	X coordinate of gaze point	The X coordinate of the estimated gaze point
15	Y coordinate of gaze point	The Y coordinate of the estimated gaze point
16	Interoccular distance	The distance between the left and right pupil of the user

biometrics of the user is processed and added to the system. The user is presented with a number of images. The images are presented to the user in a full screen and modal mode i.e. the user would not see any other activity on the screen and the application would have the focus the during the gaze capture session so as to prevent the user from getting distracted from other operations on the screen. The gaze data of the user on the images are recorded. Between images the screen is greyed out and the user is asked to fix the location in the middle of the screen. This data is used to calibrate the gaze of the user and also to ensure that the user starts looking at each of the images from the same location. The mapping from the location of the pupil to the centre of the screen is stored as the calibration data and is used to estimate the gaze of the user when the user is looking at screen/images.

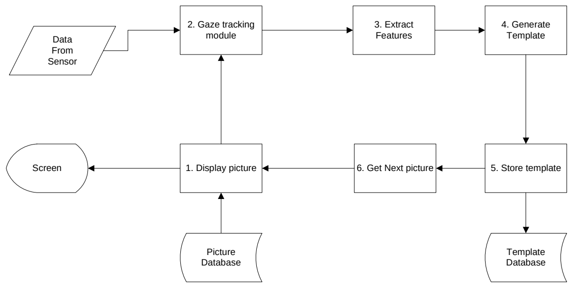

Figure 2: Flow chart of user enrolment.

3.1.5 Gaze Features

Table 2 is a list of features to be extracted from the gaze data:

Table 2: List of features from gaze data.

Data Column#	Feature	Description
2	Duration	The duration the gaze was at the current position
4,5	Left Pupil	The location of the left pupil location
7,8	Right Pupil	The location of the right pupil location
11,12	Size of Pupil	The size of the pupil
14,15	Gaze Point	The calculated gaze point on the screen

The data column number corresponds to the data column in Table 1.

4 EXPERIMENTATION

4.1 Set Up

For the experiment the equipment are placed in a table mounted configuration. The camera is placed in front and in the middle of the screen. The user is placed at a distance of 30-60cm from the screen. The procedure of the test is based on (Duchowski, 2007; Judd, Ehinger, Durand, & Torralba, 2009; Van, Rajashekar, Bovik, & Cormack, 2009).

4.2 Procedure

4.2.1 Initialisation

The purpose of the initialisation phase is to detect and initialise the location of the face, eyes and nose.

The purpose of this phase is to verify if the user is facing the sensor and viewing the scene. Once a face is detected and the eye and pupil centres are detected the calibration phase can begin.

4.2.2 Calibration

For the calibration phase the user is presented with 9 dots on the screen. The dots are shown at one location at a time. The user has to fix their gaze on the dots when they appear. Each dot is displayed to the user for a period of 5 seconds (5000 milliseconds).

4.2.3 Gaze Capture

Once the calibration is complete, the user is shown a set of images. The images used were obtained from a quality image database (Engelke et al., 2009; Le Callet & Autrusseau, 2005) so as to prevent the quality of the images used to influence the data captured. The images are assumed to be of similar quality. The user is shown the images for a period of 5 seconds (5000 milliseconds). For each set of images 2 gaze capture sessions are required. This is because as it is seen in the literature review that the gaze or eye movement is based on the task being carried out (Castelhano et al., 2009).

4.2.4 Rest Period

The rest period is used to rest the gaze of the user by making the user look at the centre of the screen. The rest period is shown between showing the different stimulus images for gaze capture. The duration of the rest period is 3 seconds (3000 milliseconds).

4.3 Results

4.3.1 Performance

For this test the experiment the whole feature list as described in Table 1 : Data structure of the data retrieved from the gaze.Table 1.

4.3.2 Feature Analysis

Figure 4, shows the difference in the performance of the system using features selected using the Forward Feature Selection (FFS), Backwards Feature Selection (BFS) and Branch and Bound (B&B) algorithms. The performance data is compared against the performance using all the features which is used as a control. As it can be seen when selecting 2 to 3 features, the performance did not improved

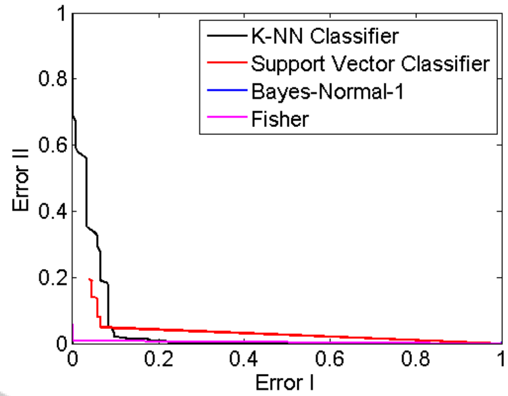

Figure 3: ROC curve with 20% of data as Training data.

Table 3: Results from testing with classifiers.

Classifier	Error Rate (20% training data)	Error Rate (50% training data)	Error Rate (80% training data)
K-Nearest Neighbor Classifier (KNNC)	0.152	0.064	0.030
Support Vector Classifier (SVC)	0.077	0.004	0.010
Normal densities based linear classifier (LDC)	0.077	0.004	0.010
Fisher Minimum Least Square Linear Classifier (FISHERC)	0.005	0.004	0.000

using the features selection algorithms. On selecting 4 features, there was a slight improvement in the performance of the system with the feature selection algorithms. With 5 to 7 features being selected, it can be seen that the features obtained from the feature selection algorithms improved the performance of the system. When 8 features were selected, using the FFS algorithm only a slightly improvement of the performance was noticed and with the BFS and B&B algorithms the performance was equal to the control performance using all the features. The best performance is obtained using the BFS and the B&B algorithms with 7 features selected from Table 2. The features selected are:

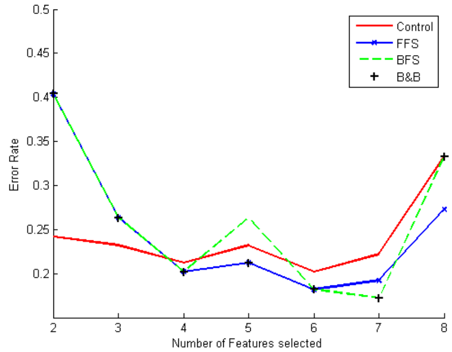

Figure 4: Error rate before and after feature selection.

Table 4: Best Feature selection algorithms and features selected.

Algorithm	1	2	3	4	5	6	7	8	9
BFS	1	2		3	4	5	6		7
B&B	2	4	7		5	1		6	3

5 CONCLUSIONS

This work has relied on techniques developed in the field of behavioural biometric; HCI based biometric modalities and combining results with techniques from gaze tracking, pupillometry and facial feature extraction to create a new biometric modality based on gaze. From the preliminary result obtained, it can be seen that gaze information may have some potential for being used as a biometric modality. The experiments carried out were only done on a very small sample; more testing is required to confirm the preliminary findings of this project.

A gaze-based biometric modality would be both an affordable and nonintrusive way of verifying the user's identity. In addition, a gaze-based biometric modality would also open the way to a number of new application areas. It would be well suited for verification of users which interact with a whole range of devices containing a camera such as smart phones, personal computers etc. Gaze-based biometric systems could also be used as a remote authentication system for web sites or e-commerce sites. Another potential area where such technologies can be used is in liveness detection. In such an approach, liveness detection may be based on the movement of the pupil using as stimulus either the variation of lighting condition or using images.

Future research on this topic should be directed at increasing overall accuracy of the gaze tracking system as well as looking into possibility of developing multimodal biometric system based on other existing biometric modalities such as iris, fingerprint or HCI-based biometric modalities such as keystroke or mouse dynamics.

REFERENCES

Adolphs, R. (2006). A landmark study finds that when we look at sad faces, the size of the pupil we look at influences the size of our own pupil. *Social Cognitive and Affective Neuroscience, 1*(1), 3-4. doi:10.1093/scan/nsl011

Castelhano, M. S., Mack, M. L., & Henderson, J. M. (2009). Viewing task influences eye movement control during active scene perception. *Journal of Vision, 9*(3) doi:10.1167/9.3.6

Castelhano, M. S., Wieth, M., & Henderson, J. M. (2008). I see what you see: Eye movements in real-world scenes are affected by perceived direction of gaze., 251-262. doi:http://dx.doi.org/10.1007/978-3-540-77343-6_16

Chao-Ning Chan, Oe, S., & Chern-Sheng Lin. (2007). Active eye-tracking system by using quad PTZ cameras. *Industrial Electronics Society, 2007. IECON 2007. 33rd Annual Conference of the IEEE,* 2389-2394.

Chapran, J., Fairhurst, M. C., Guest, R. M., & Ujam, C. (2008). Task-related population characteristics in handwriting analysis. *Computer Vision, IET, 2*(2), 75-87.

Duchowski, A. T. (2007). *Eye tracking methodology: Theory and practice*. Secaucus, NJ, USA: Springer-Verlag New York, Inc.

Engelke, U., Maeder, A., & Zepernick, H. -. (2009). Visual attention modelling for subjective image quality databases. *, Rio De Janeiro*

Goudelis, G., Tefas, A., & Pitas, I. (2009). Emerging biometric modalities: A survey. *Journal on Multimodal User Interfaces,* , 1-19. doi:10.1007/s12193-009-0020-x

Gutiérrez-García, J. O., Ramos-Corchado, F. F., & Unger, H. (2007). User authentication via mouse biometrics and the usage of graphic user interfaces: An application approach. *2007 International Conference on Security and Management, SAM'07,* Las Vegas, NV. 76-82.

Harrison, N. A., Singer, T., Rotshtein, P., Dolan, R. J., & Critchley, H. D. (2006). Pupillary contagion: Central mechanisms engaged in sadness processing. *Social Cognitive and Affective Neuroscience, 1*(1), 5-17. doi:10.1093/scan/nsl006

Judd, T., Ehinger, K., Durand, F., & Torralba, A. (2009). Learning to predict where humans look. *IEEE International Conference on Computer Vision (ICCV),*

Le Callet, P., & Autrusseau, F. (2005). Subjective quality assessment IRCCyN/IVC database.

Lei, H., & Govindaraju, V. (2005). A comparative study on the consistency of features in on-line signature verification. *Pattern Recognition Letters, 26*(15), 2483-2489. doi:DOI: 10.1016/j.patrec.2005.05.005

Monrose, F., & Rubin, A. D. (2000). Keystroke dynamics as a biometric for authentication. *Future Generation Computer Systems, 16*(4), 351-359. doi:DOI: 10.1016/S0167-739X(99)00059-X

Revett, K., Jahankhani, H., Magalhães, S. T., & Santos, H. M. D. (2008). A survey of user authentication based on mouse dynamics. In H. Jahankhani, K. Revett & D. Palmer-Brown (Eds.), *Global E-security* (, pp. 210-219) Springer Berlin Heidelberg.

Van, D. L., Rajashekar, U., Bovik, A. C., & Cormack, L. K. (2009). Doves: A database of visual eye movements. *Spatial Vision, 22*(2), 161-177. doi:10.1163/156856809787465636

Wang, J. T., Spezio, M., & Camerer, C. F. (2010). *Pinocchio's pupil: Using eyetracking and pupil dilation to understand truth telling and deception in sender-receiver games*

Yampolskiy, R. V. (2007). Human computer interaction based intrusion detection. *Information Technology, 2007. ITNG '07. Fourth International Conference on*, 837-842.