Pattern Recognition Letters 35 (2014) 101–104

Contents lists available at SciVerse ScienceDirect

Pattern Recognition Letters

journal homepage: www.elsevier.com/locate/patrec

Detection of alcohol intoxication via online handwritten signature verification

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ARTICLE INFO

Article history:
Available online 10 August 2012

Keywords:
Signature verification
Detection of alcohol intoxication
Online handwritten

ABSTRACT

The Internet has recently facilitated various methods of personal authentication based on biometrics. Personal authentication techniques based on human physical features include fingerprint matching, vein matching, facial recognition, speech recognition, and signature recognition. In this study, we investigate the detection of alcohol intoxication on the basis of handwritten signatures. As in the case of previous related studies, we found that the signature attestation rate varies at an individual level according to sex, age, acetaldehyde removal efficiency, and individual constitution.

In this study, we employed 30 people to evaluate the change in a handwritten signature before and after alcoholic intake. First, we measured the signature verification rate using the online signature verification system. The signature verification rate measured using the WACOM Tablet pen before alcohol consumption was 97.0%. Moreover, the size of the characters and the interval between the characters were measured for signatures collected after alcohol consumption. We detected the level of alcohol intoxication on the basis of the total time taken for writing the signature, the average pressure of the brush, the two-dimensional writing speed, and internal angle of stroke turns. The maximum alcohol detection rate of this method was 95.1%, which was achieved when the examinees were tested 35 min after alcohol consumption. The rate of alcohol detection increases with the alcohol density in an examinee's breath.

1. Introduction

Recent developments in the information society have enriched our lives. However, such developments have contributed to the increasing occurrence of technological crime. Therefore, the merits and demerits of such developments must be taken into account. Biometric attestation systems are authentication systems based on human physical features such as fingerprints, speech, facial features, and actions. These systems are based on unique individual features, unlike existing memory attestation systems. In previous authentication systems that handled Internet sales and credit transactions, numerous fraudulent procurements and data falsifications were generated by illegal computer access (Information-technology Promotion Agency). This resulted in considerable losses and leakage of personal information worldwide. We believe that biometric attestation is important to pre-empt such crimes.

However, personal authentication is flawed in that it is dependent on the physical condition of a subject. For example, written signature verification is affected by sleep duration, alcohol content, injuries, and other factors. These factors may affect the pressure, direction, or altitude of signatures. Therefore, verification systems must take such factors into account. Moreover, it has been established that alcohol consumption influences signatures (Hilton, 1969; Asicioglu and Turan, 2003). If an examinee who has consumed alcohol wants his or her signature to be verified, the system may not be able to recognize it. In this study, we achieved a reduction in the error rate of signature verification. Nowadays, online signature verification system has an accuracy of around 98.9% (Chang and Shin, 2008). In our study, we mainly used dynamic positional warping of the x, y coordinates. This signature verification system compares five signatures of same examinee with a test signature. In a previous study, we detected alcohol intoxication from handwritten sentences (Phillips James et al., 2007) on the basis of the differences in words such as "and" and "the." Tests were conducted to determine the factors that affected the signature, such as gender, dominant hand, and age (Liwcki et al., 2007). Our study raises questions about the patch test and psychology because they are influenced by the physical and mental status of a subject, and the sample does not include an error.

2. Intoxicated signature collection and the alcohol detection method

This study was based on online signature verification. A bullet pen was used to measure the direction and pressure of each pen

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http://dx.doi.org/10.1016/j.patrec.2012.07.016

stroke's *x*, *y* coordinates and the total writing time. This study used 100 mL of distilled spirit in the experiment, because the Ministry of Health, Labour and Welfare (The Ministry of Health, Labor and Welfare) recommend a maximum daily alcohol intake of less than 20 g. The 100 mL volume was computed using the following formula:

$$\frac{\text{MA } 20\text{ g}}{\text{ADS } 25\% * \text{DE } 0.8\text{ g}} = 100\text{ mL} \tag{1}$$

where MA is the mass of alcohol, ADS is the alcoholic density, and DE is the density of ethanol. The following checklist was followed when each subject performed the experiment. (1) We asked whether the subject experienced any abnormality in the alcoholic spirit or their body. (2) An alcoholic patch test was performed, which allowed each subject's alcoholic constitution to be determined. Men who experienced difficulty eliminating acetaldehyde could not participate. The number of subjects was 30 people. The subject is targeted at Japanese people in our research.

The experimental methodology is as following

1. Perform an alcohol patch test.
2. Regulate the height of the desk and chair to match each subject's physique.
3. Practice the signature several times using a pen tablet.
4. Record the signature 20 times before alcohol consumption.
5. Drink 100 mL of distilled spirit.
6. Record the signature 10 times at 5, 15, 25, 35, 45 and 55 min after alcohol consumption and record the breath alcohol content of subjects using an alcohol detector.

The first step determined whether any difference could be detected in a subject's signature depending on the quantity of alcohol catabolic enzyme present, where an alcohol patch test was used to judge the alcohol constitution (Teruhiko et al., 2003). The second step investigated experimental error. The third step allowed subjects to adjust to the pen tablet. Subjects practiced writing their signatures with a pen tablet on several occasions. The fourth step asked subjects to write their signatures 20 times on a pen tablet before alcohol consumption. The fifth step required subjects to consume 100 mL of distilled spirit as quickly as possible. The accuracy of the experiment was enhanced when the alcohol was consumed rapidly. The sixth step required subjects to write their signature ten times at 5, 15, 25, 35, 45, and 55 min after alcohol consumption. Each subject's body and breath alcohol concentration were measured using an alcohol detector, SC-102 made by SOCIAC Company was used for the measurement of the breath alcohol content.

Fig. 1 shows part of a subject's signature data before alcohol consumption and 35 min after alcohol consumption. Subjects

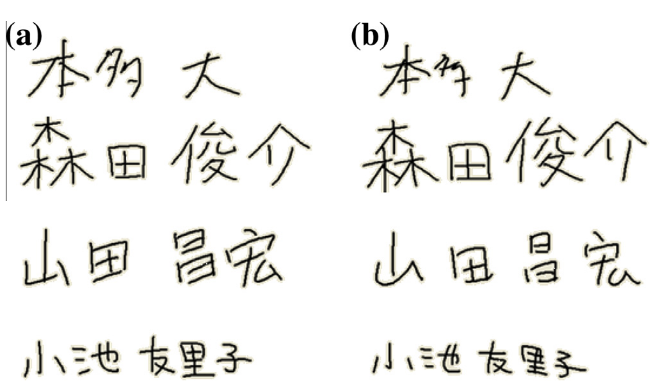

Fig. 1. Examples of Signature (a) before alcohol consumption and (b) 35 min after alcohol consumption.

with a greater tolerance of alcohol exhibited less change. Subject's with less alcohol tolerance showed more changes in each stroke. In some subjects we observed changes in the signature, but not in others. Therefore, we investigated the exact appearance of the signatures.

Five template data that chosen at random from the 1st to the 10th signatures were used. The template data were compared to test data in the signature verification. The data from the 11th to the 20th signatures were verified based on the template data. Similarly, the data after taking alcohol were verified with template data in the signature verification. A signature verification system based on dynamic positional warping (DPW) was used in the experiment (Chang and Shin, 2009). The false acceptance error rates (FAR) and false rejection error rates (FRR) for the system were 5.0% and 4.10%, respectively.

Ten signature data are verified as one group in detecting alcohol verification. The data from the 1st to the 10th signatures before taking alcohol were used as base data. The data from the 11th to the 20th were used as comparison data. The data after taking alcohol were used as comparison data.

The following four comparisons were made before and after alcohol consumption:

1. The mean total time required to write a signature.
2. The mean pen pressure.
3. The velocity of *xy* coordinates.
4. Internal angle of stroke turns.

Mean total time required to write a signature. The first comparison examined the time differential between the test data and the data after alcohol consumption.

$$Total\_Signature\_Time = \sum_{i=0}^{n} (\text{SigEND}_i - \text{SigBEGIN}_i) \tag{2}$$

where SigEND_i is the end time of writing the ith signature, SigBEGIN_i is the start time of writing the ith signature, and n is the number of signatures in a set.

Mean pen pressure. The second comparison examined pen pressure. The pen pressure will be an important factor in our discussion of individual characteristics, because the method used to hold a pen is individual-specific.

$$Pressure = \sum_{i=0}^{n} (\text{PreEND}_i - \text{PreDEGIN}_i) \tag{3}$$

where PreEND_i is the end time of writing with the ith pressure, PreBEGIN_i is the start time of writing with the ith pressure, and n is the number of pressures in a set.

Velocity of xy coordinates. The third comparison examined the velocity of *xy* coordinates.

$$V(t) = \frac{D(P_{xy}(t+1), P_{xy}(t))}{\Delta t} \tag{4}$$

where $P_{xy}(t)$ is *xy* coordinate of time *t* and $D\ (P_{xy}(t{+}1))$is euclidean distance between $P_{xy}(t{+}1)$ and $P_{xy}(t)$.

2.1. Internal angle of stroke turns

First, the center points between initial points are added if the distance between initial points is shorter than the threshold. Second, we define the sequentially near two points (for example a_1, a_2 in Fig. 2 which are three points away from a point (for example A in Fig. 2) as the neighbourhoods of the point. The point angle is calculated by $\angle a_1 A a_2$ for example. Third, the points having point angle which is smaller than 120° are selected as the Feature Points. Fourth, we obtain the points having one of the local minima among