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Neural networks for identifying drunk persons using thermal infrared imagery

Georgia Koukiou *, Vassilis Anastassopoulos

University of Patras, Electronics Laboratory, Physics Department, Patras 26500, Greece

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ABSTRACT

Neural networks were tested on infrared images of faces for discriminating intoxicated persons. The images were acquired during controlled alcohol consumption by forty-one persons. Two different experimental approaches were thoroughly investigated. In the first one, each face was examined, location by location, using each time a different neural network, in order to find out those regions that can be used for discriminating a drunk from a sober person. It was found that it was mainly the face forehead that changed thermal behaviour with alcohol consumption. In the second procedure, a single neural structure was trained on the whole face. The discrimination performance of this neural structure was tested on the same face, as well as on unknown faces. The neural networks presented high discrimination performance even on unknown persons, when trained on the forehead of the sober and the drunk person, respectively. Small neural structures presented better generalisation performance.

1. Introduction

Biometric measurements mainly on the face as well as on fingerprints have been extensively employed in security procedures for recognition and identification of persons [1–5]. When images are obtained in the visible spectrum, face recognition [5] procedures are strongly affected by illumination conditions. Images from faces acquired in the thermal infrared spectrum [6–8] contain information related to the temperature of the face, which mainly depends on the physiological condition of the person [9]. The human face (skin) radiates as a perfect black body [9] in a mean temperature around 300 K according to the Wien Law, with emissivity value between 0.98 and 0.99 and maximum at 9.5 μm wavelength. Thus, this region of electromagnetic spectrum (7–13 μm) is the most appropriate for acquiring information from the face. Drunkenness is a challenging physiological condition to be investigated using infrared imagery. This is because arteries and vessels on the face of a drunk person, increase activity with the consumption of alcohol. However, most of the publications in the literature refer only to automotive anti-drunk driving systems, which utilise electrical signals from the heart or brain [10].

Neural networks have been used so far for human faces [11] recognition. They have also been used in infrared biometric procedures using hand images [12], in other pattern recognition tasks where thermal signatures are available [13], as well as in infrared face recognition [14,15]. Especially, the work in Ref. [14] deals with the problem of thermovision applications for biometric people recognition, with main goal of the automation of the recognition process and the exploitation of infrared imaging for realising a biometric system. In Ref. [15], a method with thermal image processing and neural networks was presented for recognition of facial expressions, which was based on the examination of the 2-dimensional temperature distribution on the face.

In Refs. [16,17], two new methods have been presented for identifying drunk persons, based on the change of thermal signature of the faces. In the first method [16], simple pixels on the thermal image of the face of sober and drunk persons are used as features in a drunk identification procedure, while the concept of "drunk feature space" is proposed. Furthermore, in the same work it was shown that the regions of the forehead and the nose change temperature, when a person consumes alcohol. In the second method [17], the drunk identification approach was based on extracting those blood vessels on the face, which exhibit higher activity with alcohol consumption. Anisotropic diffusion and top-hat transformation were applied for this purpose. Anisotropic diffusion is a smoothing operation, which preserves edges and line structures and accordingly enhances blood vessels in the rest tissue. On the other hand, top-hat transformation is a morphological operation, which isolates high-valued shape structures like vessels in a gray scale image.

* Corresponding author. Tel.: +30 2610996147; fax: +30 2610997456.
E-mail address: gkoukiou@upatras.gr (G. Koukiou).

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This paper attempts to offer a way of discriminating sober from drunk persons, using thermal infrared images and neural networks. The present identification method is totally different from the approaches presented in Refs. [16,17]. In this respect, it does not aim at verifying those approaches, but is a totally stand-alone procedure to detect intoxication. At the same time, the conclusions in the present work are consistent with those reported in Refs. [16,17]. According to the literature [7], the rise in the tissue temperature is mainly due to increased blood vessel activity. This fact leads to increased tissue temperature at least close to vessels. While in the work in [17], only the activity of the vessels is examined, but the present paper examines every location on the face. Furthermore, a totally new larger database was built and used. Actually, in this work the utility of the thermal images in identifying drunk persons is assessed by means of a "blind approach", i.e. the neural networks, where simple pixels from the face of the persons are used as input to the networks. Neural networks of the same structure, but of different sizes, are employed to accommodate the training samples. Two different approaches for applying the neural networks were used. In the first one, a different neural network was trained on each location of the face of a specific person (sober and drunk persons' thermal images). The locations of the face in which the networks converge easily are very good candidates for discriminating intoxicated persons. In the second approach, only one neural network is applied on the whole face. In this case, the network is tested with respect to its generalisation ability, i.e. a network that is trained on a specific person to work satisfactorily on other persons' faces as well, discriminating drunk from sober people. This work proves that a small neural structure trained on the forehead of a specific person (sober and drunk) presents a very good generalisation performance and discriminates between sober and drunk, without having been trained on the specific person beforehand.

In the experimental procedure, forty-one persons were involved. They were initially sober and then drank a specific amount of alcohol in a systematic way. The participants were aware about the experimental procedure. Thermal images were obtained from calm and sober persons, as well as from drunk persons having consumed the same quantity of alcohol, while the acquisitions were taken on specific time instances. In this sense, the database created with the 41 persons can be considered adequate, since it is the only one found in the literature providing all this information.

Finally, it is worth mentioning that only intoxicated situation is tested in the experiments, assuming that no other scenario happens; i.e. the people employed were calm and in normal physical and psychological condition, healthy, without psychological stress or any kind of body exercise before the experiment. Moreover, the significant contribution of this work is that, it shows that person intoxication can be detected using the thermal images of the drunk persons only. This is very important, since in real intoxicated person identification procedures, the corresponding sober images are not available. The thermal images of the intoxicated person due to the increased activity of the dense vessel network [7] around the nose and the forehead provide the necessary information for detecting intoxication. The infrared images of the intoxicated person contain personal information and simultaneously give clear evidence to the authorities to proceed to further investigation with other evidence supporting intoxicated situation. Based on this method smart devices could be manufactured which will make alert the people close to an intoxicated person, or inactivate important infrastructure.

The organisation of the paper is as follows. In Section 2, a description is provided regarding the data used and the experimental procedure followed. The training of different neural networks on different face locations is explained in Section 3. The training of a single neural network using the information from the whole face is addressed in Section 4. In Section 5, the performance of a trained neural network on different persons' face is examined. Finally, Section 6 draws the conclusions.

2. Data used and experimental procedure

The infrared images used in this work were acquired by means of the Thermo Vision Micron/A10 Model infrared camera (18 mm, f/1.6) of FLIR Company. The operating wavelengths are from 7.5 to 13.0 μm, which means that the obtained information is in the thermal infrared region corresponding to the maximum of the Wien curve at 9.5 μm for 300 K. Actually, the human skin emits electromagnetic radiation as an almost black body with emissivity value between 0.98 and 0.99 in this exact region of wavelengths [18]. A black body, according to contemporary physics, is a body, which absorbs any incident electromagnetic radiation, while it emits, depending on its temperature, electromagnetic radiation described by the Stefan–Boltzmann law.

In the present experimental procedure, forty-one people were involved, among which 31 males and 10 females. Each person consumed alcohol, four glasses of wine of 120 ml each, in 1 h period (total of 62.4 ml alcohol). In each acquisition, a sequence of 50 frames was acquired from each person with a sampling period of 100 ms between the frames. The first acquisition of 50 frames for each specific person was obtained before alcohol consumption. A second acquisition of 50 frames was obtained 30 min after drinking the fourth glass of wine. Thus, a total of 100 frames (2×50) was acquired for each person in two acquisitions resulting in a data base of 4100 images. The resolution of the infrared images is 128×160 pixels. This resolution corresponds to a pixel size 2×2 mm, taking into consideration the distance of the face from the camera.

The noise in the infrared images has been studied carefully. In our case, noise is regarded the deviation of the pixels from the mean value. These values follow closely the Gaussian distribution $N(0, 1.2)$. Furthermore, the contrast of the thermal images is the better possible. This was achieved by bringing almost the whole dynamic range of the camera (256 gray levels) to incorporate the temperature distribution of the face. The mean value of 50 frames of a specific acquisition is demonstrated in Fig. 1.

The experimental procedure required the availability of the thermal images of an intoxicated person as well as the thermal images of the corresponding sober person, so that comparisons could be carried out. Consequently, the people participating in the experiment have to be conscious about the requirements of the procedure. Researchers working in our department were asked to participate, since only they could be aware about the needs of the experiment. All participants were healthy and well aware of taking

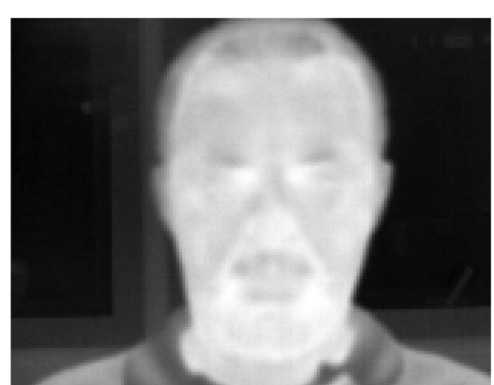

Fig. 1. Mean value of 50 frames of a specific drunk person.