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Object Recognition

Given a few training image of the same target object (same object, but may be viewed from different angles or position), the goal of object recognition is to retrieve the same object in other unseen images. It is a difficult problem because the target object in unseen image may appear different from what it appears in the training image, due to the variation of view points, background clutter, ambient illumination, partially occluded by other object or deformation of the object itself. A good object recognition algorithm is supposed to be able to recognize target object given all of the above variations.

► Iris Super-Resolution

Observations from Speech

► Speaker Features

Ocular Biometrics

► Retina Recognition

Odor Biometrics

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Synonyms

Osmology; Scent identification line-ups

Definition

Human odor can be differentiated among individuals and can therefore be seen as a biometric that can be used to identify this person. Dogs have been trained to identify objects held by a specific person for forensic purposes from the beginning of the twentieth century. Advancing technology has made it possible to identify humans based on ► headspace analysis of objects they have handled, opening the route to the use of odor as a biometric.

Introduction

From the early twentieth century, dogs have been used to find and identify humans based on their odor. This has originated from the capacity of dogs to follow the track of a person, either by following the odor the person left directly on the ground that the dog needed to follow quite closely ("tracking"), or by following a broader odor trail that the dogs could follow at some distance ("trailing"). Some dogs were very "track-sure": i.e., they continued to follow the specific person in spite of changes in direction, ground surface, and obstacles, in spite of other people having crossed the path earlier or later. Such dogs could also identify the person that had laid that track. This setup is still followed today in the basic training of bloodhounds all over the world. However, a more formalized manner of working with dogs identifying human odors has also evolved, primarily in Europe.

This formalized methodology is called "scent identification line-up," or "osmology", and is applied as a forensic identification tool in several European countries. Dogs are trained to match the odor of a sample to its counterpart in an array of odors. This can be done in different ways [1, 2]. Generally the dog is given a scent sample from a crime scene that presumably contains the odor of the perpetrator. The odor of the suspect and a number of foils, collected in a standardized manner, are offered to the dog as the array. The dog has to match the crime-scene related odor to that of the suspect in the array, and indicate its choice with a learned response. The methods and materials used to collect human odor differ between countries; the exact protocol for working with the dog differs; quality control measures necessary to validate the correctness of the outcome differ; and the way in which the results are evaluated and used during investigation and trial differ between countries too. In spite of efforts to harmonize these differences, they still exist since there is little scientific evidence to select the "best" way: dogs perform best when tested in the way they were trained, and much depends on how the dogs were selected and trained.

From the little scientific work done using dogs in this field, it became clear that dogs are capable of matching odors collected from different body parts [3, 4]. The series of experiments conducted by Schoon and de Bruin [3], showed that trained police dogs were capable of matching objects (stainless steel tubes) held in the pocket or in the crook of the arm to objects held by hand and vice versa significantly better than chance, but that their performance was a lot better on the comparison they trained often (pocket to hand: 58% correct in a 1 out of 6 comparison) than on a comparison they never trained (crook elbow to hand; hand to crook elbow: 32% correct in a 1 out of 6 comparison). Settle [4] had people scenting objects (pieces of gauze) on numerous body parts and also found dogs could match those that had been handled by the same person significantly better than chance (60% correct in a 1 out of 6 comparison). However, the gauzes they used were stored together per person in a glass jar prior the experiments with the dog, so they may have all reached an equilibrium in this jar. Hepper [5] found that dogs use odor cues that are under genetic control more than those under environmental control. He let dogs match the odor of T shirts of fraternal and identical twins with identical or different diets. When both diet and genes were identical, the dogs could not differentiate between the twins (1 out of 2 comparisons). When the genes were identical but the diets differed, the dogs were able to differentiate between the twins but they took a long time and their choices were not very sure (83.5% correct in a 1 out of 2 comparison). When the genes were different but the diets identical, the dogs performed best and made their choices quickly and surely (89% correct in a 1 out of 2 comparison).

With advancing technology in the second half of the twentieth century, an effort was made to identify the source and composition of the body secretions that made it possible for dogs to actually identify people based on their odor. The human skin can be divided into two layers: the outer layer called the epidermis and the inner layer called the dermis. The dermis layer contains most of the specialized excretory and secretory glands. The dermis layer of the skin contains up to 5 million secretory glands including eccrine, apocrine and sebaceous glands [6]. Bacterial breakdown of apocrine secretions result in a huge number of volatile compounds in armpits [7–9], but for forensic purposes the breakdown of sebaceous gland secretions is more interesting since these products can be found on crime-related objects such as guns, knives, crowbars, gloves etc. Further study showed that trained dogs are capable of matching objects scented by the same person at different times but that their performance was lower [10].

Instrumental Differentiation Body Scent

The individual body odors of humans are determined by several factors that are either stable over time (genetic factors) or vary with environmental or internal conditions. The authors have developed distinguishing terminology for these factors: the "primary odor" of an

Odor Biometrics. Figure 1 Dog searching for a matching odor in a Dutch scent identification line-up (photo courtesy of the Netherlands National Police Agency).

individual contains constituents that come from within and are stable over time regardless of diet or environmental factors; the "secondary odor" contains constituents which also come from within and are present due to diet and environmental factors; and the "tertiary odor" contains constituents which are present because they were applied from the outside (i.e., lotions, soaps, perfumes, etc.) [9]. There is a limited understanding of how the body produces the volatile organic compounds present in human scent. Although the composition of human secretions and fingerprint residues have been evaluated for their chemical composition [6, 7], comparatively little work has been done to determine the volatile organic compounds present in human scent. Knowing the contents of human sweat may not accurately represent the nature of what volatile compounds are present in the headspace above such samples which constitute the scent.

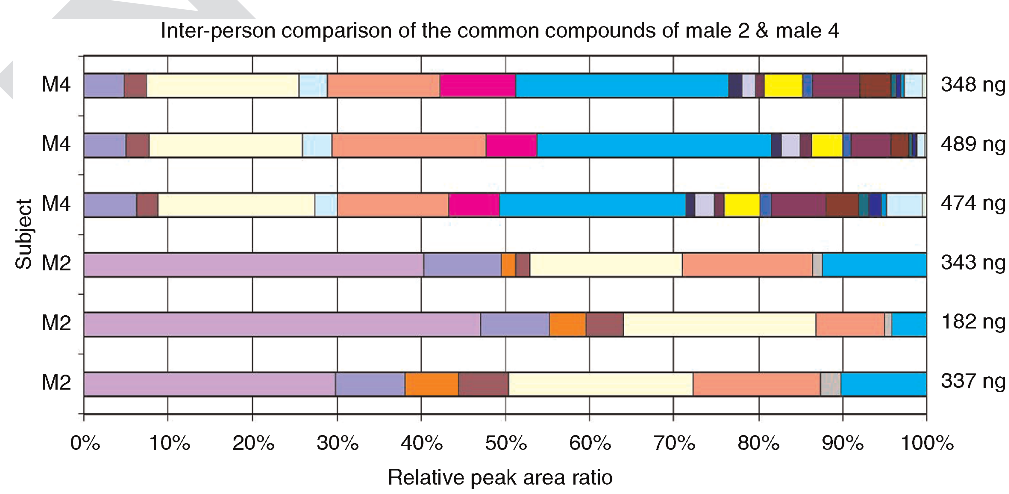
With the use of gas chromatography-mass spectrometry, an increasing number of volatiles were identified in the headspace of objects handled by people [11]. Investigations into the compounds emitted by humans that attract the Yellow Fever mosquito have provided insight into the compounds present in human odor. Samples were collected using glass beads that were rolled between fingers. The beads were then loaded into a GC and cryofocused by liquid nitrogen at the head of the column before analysis with ► GC/MS. The results showed more than 300 observable compounds as components of human skin emanations, including: acids, alcohols, aldehydes, and alkanes. The results also showed qualitative similarities in compounds between the individuals studied, however, quantitative differences were also noted [11].

Until recently, technological limitations have restricted the ability of researchers to identify the chemical components that comprise human scent without altering the sample or to use the information to chemically distinguish between individuals. In addition, it has been difficult to distinguish between primary, secondary, and tertiary odor components in a collected human scent sample. ► Solid phase micro-extraction (SPME) is a simple solvent-free headspace extraction technique which allows for ► volatile organic compounds (VOCs) present in the headspace (gas phase above an item) to be sampled at room temperature. SPME in conjunction with GC/MS has been demonstrated to be a viable route to extract and analyze the VOCs present in the headspace of collected human secretions. In a recent study, the hand odor of 60 subjects were studied (30 males and 30 females) and 63 human compounds extracted, there was a high degree of variability observed with six high frequency compounds, seven medium frequency compounds, and 50 low frequency compounds among the population. The different types of compounds determined to be present in a human hand odor profile included acids, alcohols, aldehydes, alkanes, esters, ketones, and nitrogen containing compounds. It has been demonstrated that nonparametric methods of correlation can be employed to differentiate between VOC patterns from different individuals. In the 60 subject study, it was shown that Spearman Rank Correlation coefficient comparisons of human odor compounds among individuals is a viable method of data handling for the instrumental evaluation of the volatile organic compounds present in collected human scent samples, and that a high degree of distinction is possible among the population studied [12]. Using a match/no-match threshold of 0.9 produces a distinguished ability of 99.7% across the population. Other work also showed that multiple samples taken from the same person showed that these could not be distinguished at the same level. Figure 2 illustrates the variation of the VOC patterns in multiple samples from two different males.

The genetic source of these specific human volatiles has also been investigated. Experimental work with dogs had already indicated a link to the genes of a person, and work with rats and mice had located the genes of the Major Histocompatibility Complex (MHC) as the source of variation. The genetic basis for individualizing body odors has been studied extensively in genetically engineered mice which differ in respect to the genes present in the MHC [13]. MHC exhibits a remarkable genetic diversity with resulting from a variety of characteristics including a level of heterozygosity approaching 100% in natural populations of mice. This high level of heterozygosity seems to be maintained by behavioral factors including mating success and associated with olfactory cues, and chemosensory imprinting. In humans, the MHC is referred to as the HLA, which is a short for human leucocyte antigen. Experiments utilizing trained rats have shown that urine odors of defined HLA-homozygous groups of humans can be distinguished [13]. Individual body scents of mice can be altered by modification of genes within the MHC. Alterations to the individual body scents of mice result in changes in the concentrations of the volatile components found in the urine [14]. Using two-dimensional GC/MS Willse et al. were able to detect differences in the several dozen MHC compounds (including 2,5-dimethylpyrazine and 2-*sec*-butyl-4,5-dihydrothiazole) found in ether-extracted urine from two inbred groups of mice that differed only in MHC genes.

Legal Perspectives on Human Odor for Forensic Purposes

In Europe, scent identification lineups have been used routinely by police forces, for example in Poland and The Netherlands, and the results have been the subject of discussion and different interpretations in court. In Poland Wójcikiewicz [15] summarized a number of court cases where dog evidence was critically reviewed. Generally, the evidence was accepted by Polish courts as "additional evidence," thus allowing the results to be used only if convergent with other evidence; a point



Odor Biometrics. Figure 2 Illustration of the variety in volatile organic compounds as collected by SPME and determined by GC-MS from three samples of two human subjects. Each color is a different VOC.

of view of Wójcikiewicz, given the limited scientific background knowledge at that time. In the Netherlands, scent lineup evidence has been the subject of much debate over the years. A recent case confirmed that results from carefully conducted scent identification lineups can be used as an addition to other evidence [16]. In the absence of the other evidence, a positive result of such a lineup is regarded as insufficient evidence for conviction.

The twenty-first century has brought with it two important case decisions in the United States Court System pertaining to the use of human scent canines in criminal prosecutions. In 2002, the U.S. Court System decided human scent canine associations could be utilized through the introduction of expert witness testimony at trial if the canine teams were shown to be reliable [17]. In 2005, a Kelley hearing in the state of California [18] set a new precedent in the U.S. which allowed human scent identification by canine to be admitted as forensic evidence in court as opposed to being presented as expert witness testimony. The California court ruled that human scent discrimination by canine can be admitted into court as evidence if the person utilizing the technique used the correct scientific procedures, the training and expertise of the dog-handler team is proven to be proficient, and the methods used by the dog handler are reliable.

Summary

The scientific studies to date support the theory that there is sufficient variability in human odor between persons and reproducibility of primary odor compounds from individuals that human odor is a viable biometric that can be used to identify persons. The bulk of the available literature is based on the ability of training dogs to identify objects held by a specific person but advancing technology has recently made it possible to differentiate humans based on headspace analysis of objects they have handled supporting the results seen with dogs. With additional research and development on training and testing protocols with the dogs, and instrumental methods, the future of human odor as an expanded biometric is quite promising. In addition, unlike many other biometrics, human scent can be detected from traces, such as skin rafts, left by a person and can be collected in a noninvasive fashion.

Related Entries

▶ Human Scent and Tracking
▶ Individuality

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Off-Angle or Nonorthogonal Segmentation

► Segmentation of Off-Axis Iris Images

On-Card Matching

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Synonyms

Biometric Match-on-Card, MOC; Work-Sharing On-card Matching

Definition

On-card matching is the process of performing comparison and decision making on an integrated circuit (IC) card or smartcard where the biometric reference data is retained on-card to enhance security and privacy. To perform enrolment, the biometric interface device captures the biometric presentation of the user to create the biometric template. Then, the biometric template and user's information are uploaded to the card's secure storage. To perform on-card matching, the biometric interface device captures the biometric presentation and creates a biometric template. The created biometric template is then uploaded to the card for verification. The verification process shall be executed on-card instead of sending the enrolled template out of the card for verification.

Introduction

The need for enhanced security persists more than ever in a more electronically dependent and interconnected world. The traditional authentication method, such as PIN, is neither secure enough nor convenient for automatic identification system such as border control. Our economic and social activities in today's electronic age are getting more reliant to electronic transactions that transcend geological and physical boundaries. These activities are supported by implicitly trusting the claimed identity – with we trusting that the party we are transacting with is genuine and vice versa. However, conventional password and Personal Identification Number (PIN) commonly used are insecure, requiring the user to change the password or PIN regularly. Biometric technology uses a person's unique and permanent physical or behavioral characteristics to authenticate the identity of a person. Higher level of security can be provided for identity authentication than merely the commonly used PIN, password or token. Some of the popular biometric technologies include fingerprint, face, voice, and iris. All biometric technologies share a common process flow as shown in (Fig. 1) below.

Fig. 1 shows the basic architecture of biometric authentication with a central database. In order to use the biometric system to identify a person, he or she will have to enroll in the system's database. The system has to create and maintain the biometric database in a central PC or server. Even for a biometric door access system (no matter for home use or office use), a small biometric database is stored in the embedded unit. Usually this is not a problem for home use because only the owner or trusted person can have access to the database. But what about the other service providers? If hackers can access some of the confidential database information of big corporations such as Bank of America, LexisNexis, T-Mobile [1] and the security breach affecting more than 200,000 credit card holders [2] who then can the user trust? Since biometric data is permanent and each person has limited amount of choice (a person only has a face and 10 fingers), having the biometric database information stolen is a serious implication to the actual owner. One of the alternatives is to store the biometric template into a smartcard. Smartcard is a plastic card with microprocessor inside to handle the data storage and has processing capability with security features. Hence,