Forensic Biometrics from Images and Video at the Federal Bureau of Investigation

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Abstract—**Forensic Examiners within FBI's Forensic Audio, Video and Image Analysis Unit (FAVIAU) perform forensic examinations such as human identification (from image and video) including facial comparison, ear comparison, hand comparison, and height determination. Examinations are performed without the assistance of automated biometric applications. Due to the high volume of casework, it is anticipated that automated biometrics could enhance the examination workflow to increase efficiency, as well as provide statistics and rates of probability that can be presented in court. To develop such biometric systems, FAVIAU funded research projects concerning facial and ear individualization. Further research concerning facial, ear, and hand biometrics are in the preliminary planning stages.**

I. Introduction

THE Federal Bureau of Investigation (FBI) uses a range of biometrics and anthropometrics and the distribution of these services within the FBI is equally widespread. The Divisions within the FBI's Science and Technology Branch primarily use personal metrics in surveillance and investigation of criminal and domestic intelligence cases. The main user of biometrics within the Branch, and the FBI in general, is the Criminal Justice Information Services (CJIS). CJIS houses the National Crime Information Center (NCIC), a searchable database of criminal justice information available to law enforcement agencies nationwide. CJIS is also home to the Integrated Automated Fingerprint Identification System (IAFIS), the world's largest repository of fingerprint data, which also includes photos and biographical data about criminal subjects. Other Units within the Branch are within the Laboratory Division and they use personal metrics, such as fingerprints and DNA, for forensic purposes.

The Forensic Audio, Video and Image Analysis Unit's (FAVIAU) / Operational Technology Division (OTD) / Science and Technology Branch (S&T), mission is to provide leadership and technical support to FBI investigative efforts, including ensuring the operational availability of modern technologies and the application of forensic examination services related to the collection, processing, and exploitation of digital evidence. The mission of the biometrics program of the OTD is to ensure, as soon as operationally feasible, the availability of biometric technologies, and to support development of systems and processes that will allow for the collection, processing, and exploitation of digital biometric evidence. As such, the FAVIAU exploits digital evidence, in the form of images, video, and audio, to analyze personal metrics including face and voice. Forensic examiners within FAVIAU perform voice comparisons, facial comparisons, height determinations, and other side by side image comparisons. This work will focus on visual biometrics, as observed within image and video evidence submitted to the FAVIAU of the FBI.

FAVIAU's Image Examiners are often called into court to testify as expert witnesses. The acceptance of scientific testimony and evidence in Federal court is regulated by several important legal decisions: Daubert v. Merrell Dow Pharmaceuticals, Inc., 113 S.Ct. 2786 (1993), General Electric v. Joiner, 522 U.S. 136 (1997) and Kumho Tire Co. v. Carmichael, 526 U.S. 137 (1999); and Federal Rule of Evidence 702. Factors considered for acceptance in the court include the overall acceptance of the theory and/or technique in the scientific community, the reliability and testability of theories and/or techniques, the existence of controls and standards, and the existence of an error rate of the theory and/or technique. Therefore, the development and evaluation of the statistics of personal individualization and of biometric systems is of prime importance to FAVIAU.

II. Examinations

There are two types of examinations that involve biometrics performed by Image Examiners within FAVIAU: photographic comparisons and photogrammetry. In both of these examinations, images depicting the subject, i.e. the 'questioned individual', are submitted to the FBI for analyses. The source of the images may be a variety of evidential media ranging from surveillance video from a bank to film still images recovered from a suspect's camera to digital still images found on a questioned individual's computer. Currently, in both types of cases, the examinations are performed without the assistance of any type of "automated methods of recognizing individuals based on their physical or behavioral characteristics," (the definition of Biometrics given by [1]).

A. Photographic Comparisons

Photographic comparisons of people are generally one-to-one comparisons of persons questioned and known. The overall goal is to determine if the questioned individual is the suspect, i.e. the 'known individual', to the exclusion of all others. If the questioned individual and the known are

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identical, this is called Individualization or Identification in the forensics community. Note that this would be a called a Verification in the biometrics community; thus we will use the term Individualization to minimize confusion. Additionally, the examination may lead to the Elimination of the known individual as being the questioned individual. If an individualization or elimination can not be made, it is reported that no conclusion is possible. The traits that are used within the photographic comparison fall into two categories: class and individual characteristics. Class characteristics are those that place an individual within a class or group [2]. These general characteristics include hair color, overall facial shape, presence of facial hair, shape of the nose, presence of freckles, etc. Individual characteristics are those that are unique to the individual and/or allow for an individual to be individualized [2]. These specific characteristics include number and location of freckles, scars, tattoos, chipped teeth, lip creases, number and location of wrinkles, etc. Faces, hands, and other body parts can be compared in these examinations. The Image Examiner may or may not enhance the images to facilitate the comparison. If the perspectives of the questioned and known images are similar, the Image Examiner can also scale the image of the known individual to that of the questioned individual by using the interpupilary distance or other fixed features within the image. An overlay of the scaled known image and the questioned image can be made in order to determine if the relative alignment of other facial features is consistent. The Image Examiner can then work back and forth between questioned and known imagery to develop a conclusion. Percentages or probabilities of a match in a facial comparison can not be provided because there is no statistical basis for such quantifications. The lack of statistics concerning the uniqueness of a face means that no error rate can be provided. Therefore, conclusions are reported as an Examiner's expert opinion.

The advantages to adding automated facial, ear, and/or hand biometrics to this process are clear: increased efficiency, as well as a numerical probability of a match (i.e., an error rate) that can be illustrated in court.

B. *Photogrammetry*

The objective of photogrammetry is the indirect determination of spatial measurements of objects using photographic images [3]. In FAVIAU's forensic context, photogrammetry is most often used to determine the height of a questioned individual or to determine the length of a weapon used in the commission of a crime. The determination of a questioned individual's height is generally done by one of two methods: reverse projection or analytical photogrammetry. This work will not go into the details of either process. Instead, it is enough to note that reverse projection photogrammetry involves Image Examiners reconstructing the original scene of the image and then taking an additional image with a known scale (e.g. a height chart) placed into the scene. Analytical photogrammetry at the FBI involves using geometry and perspective analysis to establish the proportions of the scene and thus determine the height of a questioned individual within that scene.

Height determination is commonly done to eliminate suspects or to link multiple crimes, because human heights follow a Gaussian distribution and thus can rarely be used to individualize a person. It is anticipated that gait analysis could be used in conjunction with such photogrammetry to assist in the identification of a questioned individual. Also, determined heights would allow an Examiner to focus on a narrower range of individuals when querying biometric databases.

III. Research

FAVIAU has a strong interest in developing biometric systems to assist forensic investigations, increasing efficiency and productivity. Additionally, the statistics of personal identification are of interest to FAVIAU as such data serve to establish the uniqueness of individuals. For example, it would be beneficial to know what percentage of the population has a certain ear length or specific pattern of knuckle creases. These statistics are surprisingly lacking, even though they could provide the numerical certainty that would allow biometrics, including fingerprints, wider acceptance in the judicial system. Comparable is how the statistics provided by DNA analysis add to its appeal in the legal system. Therefore, FAVIAU has funded biometric research projects that involve both the development of biometric systems and increasing the known statistics of human identification.

A. *Current and Past Research Projects*

A facial research project funded by the FBI's FAVIAU was carried out at the University of Sheffield in the United Kingdom with the assistance of the University of Nottingham, UK (TSWG – T-216E). Over 3000 faces were scanned using digital stereo-photography and 3D laser scanning at the Magna Science Adventure Centre, a science museum in Rotherham, UK. Researchers then measured between facial features, called landmarks, to obtain relational measurements of faces and determine the uniqueness of same. The project involved extensive analyses of anthropometric, cranio-facial data, which has also involved identifying the measurement accuracy of various capture devices (cameras, scanners etc.) and extensive analysis of the reliability and usefulness of various cranio-facial measurements for security applications [4]. The work focused on the discriminatory nature of the available cranio-facial landmarks and derivative measurements, and on building statistical models of facial measurements within the sample population. The large amount of data (called the Magna Database) and research undertaken during this project are currently being made available to academia, industry, and government within the US, UK, and Canada. The sharing of the research will allow the proposed model to be further evaluated both on appearance and measurement accuracy. The sharing of the database will allow further facial measurements and statistics to be developed, as well as additional facial studies to be investigated.

An additional FAVIAU-funded research project, concerning the biometrics of ears, is currently underway at West Virginia University and also involves the University of Miami in Florida (TSWG – T-2356). The project involves the development of a computer program that will automatically identify persons by their ear pattern in a laboratory environment from both still and video images. Images are being taken of the ears of approximately 500 people. The 2D images, obtained from video by a camera that rotates 180 degrees around the subject, are used to develop a 3D model of the ear. Ear patterns are then automatically extracted from the model. Upon completion in early 2008, the product program will include a classification and matching scheme that will permit the user to assess the likelihood that two ears presented for comparison are either the same ear or are different ears.

B. *Future Research Avenues*

FAVIAU anticipates building on both the facial and ear research projects that were previously funded, as well as exploring additional biometrics including hands and gait. Further facial studies would include additional data collection and landmarking, to make the facial measurement statistics more robust and quantifiable. Additionally, future facial studies will include detailed analyses of facial minutiae, or blemishes, such as moles, scars, and freckles. The frequency of facial minutiae has not been assessed but needs to be determined as such statistics would significantly improve the ability to individualize persons to a high probability.

Likewise, additional ear analyses are needed. Instead of databases of hundreds of ears, thousands of ears, or more, need to be captured, studied, tested, and verified. Uncontrolled views of ears, including obstructed views due to objects such as hair or headwear, must also be considered. The ability to develop a three dimensional model of a known ear would allow an Examiner to match the orientation of a questioned ear observed in an uncontrolled video, a common scenario in forensic and intelligence cases, thus allowing for both automated and manual comparisons to be made.

Research studies focusing on the measurements of hands and the patterns of knuckle creases are also of interest to FAVIAU. Hands often feature prominently in images of child pornography, as well as 'trophy shots' from homicides and kidnappings. The development of measurements, and thus statistics, to quantify the uniqueness of hands and determination of the potential uniqueness of knuckle creases are desired.

Additionally, gait analysis is another research avenue of interest to FAVIAU. Video from scenes such as bank robberies and surveillance situations are sometimes captured at frames rates considered to be real time, or close to real time. These higher frame rates thus depict nearly continuous motion of a subject that is walking or running. Images that depict an entire person who is in motion are often unsuitable for facial or ear photographic comparison or biometrics and are also challenges for photogrammetric height analysis, as the stride of the person affects the ability to measure their true height. Therefore, the ability to use gait analyses to individualize persons in motion would greatly increase our forensic capabilities. Combining gait analysis and photogrammetric height analysis would further assist in the individualization of questioned persons.

Lastly, the multi-modal combination of biometrics including face and ear, hand measurements and knuckle patterns, and gait and height is an ultimate goal of the FAVIAU's biometrics efforts.

IV. SUMMARY

The use of automated biometric systems aimed at facial recognition, ear identification, hand identification, gait analysis, and height determination would greatly enhance the efficiency of forensic work performed by the FBI. However, to date, no biometric system performing the aforementioned tasks has been accepted within the judicial system. Biometric systems must continuously be evaluated and verified in order to be accepted within a court of law. Additionally, the statistics of human identification behind these biometrics are of prime importance to FAVIAU and the forensic community.

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