Forensic Identification of People from Images and Video

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Abstract—**Forensic Examiners within FBI's Forensic Audio, Video and Image Analysis Unit (FAVIAU) perform person identification from image and video examinations, such as facial comparison, ear comparison, hand comparison, and height determination. The examiners currently perform these tasks without the assistance of automated biometric applications. Due to the high volume of casework that the FAVIAU handles, it is anticipated that automated biometrics can be added to the examination workflow to increase efficiency, as well as provide statistics and rates of probability that can be used in court. This paper will outline the current methods of facial and body comparisons, as well as height determinations, in order to demonstrate to those developing biometric systems the methods and needs of the FBI.**

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. Fingerprint biometric tasks are performed by the Laboratory Division and the Criminal Justice Information Services (CJIS). DNA analyses are performed within the Laboratory Division. Additional biometric tasks, such as voice comparison and identification of people from images, are the responsibility of the Forensic Audio, Video and Image Analysis Unit (FAVIAU), within the Operational Technology Division (OTD). This paper will focus on visual biometrics applied to the image and video evidence submitted to the FAVIAU of the FBI.

FAVIAU image examiners currently perform facial and body comparisons as one-to-one or one-to-few (generally less than 10) verifications, as well as performing height determinations. These identification tasks are done as part of investigations in both criminal and intelligence cases. Often these cases require that FAVIAU image examiners testify in the judicial system as expert witnesses. Part of any successful testimony is the ability to explain the methods that were used to perform the identification. Just as DNA examiners can point to repeating base pair matches to justify an identification, image examiners must be able to point to actual physical features on a face or body to justify their conclusions in court. 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. Likewise, there is a critical need to identify the specific physical characteristics used by biometric systems to rank candidate matches.

Within the FBI, CJIS is undertaking the Next Generation Identification Program (NGI), which will expand the capabilities of the Integrated Automated Fingerprint Identification System (IAFIS) to include facial and other biometrics [1]. The image examiners of the FAVIAU will be the subject matter experts (SME) performing the final facial comparisons, or verifications. Therefore, the goal of this paper is to demonstrate the processes, and observable characteristics, used by the human SME to perform facial and body comparisons in order to 1) provide insight to those developing biometric systems about how these tasks have historically been performed, 2) illustrate what is needed for the results of a biometric system to be accepted in the judicial system and 3) stress the importance of gathering statistical data about the physical characteristics of the human body and the reliability of results generated by biometric systems.

II. Examinations

There are two types of examinations that involve biometrics performed by image examiners within FAVIAU: photographic comparisons and photogrammetry (height determination). In both of these examinations, images depicting the subject, 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 biometric technology.

A. Photographic Comparisons

Photographic comparisons of people are generally one-to-one or one-to few comparisons of persons questioned and known. The overall goal is to determine if the questioned

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individual is the suspect, the 'known individual', to the exclusion of all others. If so, this is called Individualization or Identification in the forensics community. Note: this would be a called a "verification" by the biometrics community. Additionally, the examination may lead to the Exclusion or Elimination of the known individual as being the questioned individual. If an individualization or elimination cannot be made, it is reported that no definitive conclusion is possible. In every case, even when no conclusion is possible, it is common practice to report those features found to be similar and dissimilar that provide the basis for identification or exclusion.

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 a person to be individualized [2]. These specific characteristics include number and location of facial minutiae, such as freckles and blemishes, as well as scars, tattoos, chipped teeth, lip creases, wrinkles, etc. By using these traits, effectively the 'texture' of the face, examiners have been able to differentiate between identical twins in images. Measurements of facial features and facial landmarks [3,4] are compared relatively but not absolutely. Methods that rely solely on measurements of facial features or landmarks [5,6,7] are severely affected by image perspective and are therefore nearly useless in surveillance situations where the position of the head is uncontrolled.

The method of comparison used within FAVIAU follows that of fingerprint examiners, the ACE-V method explored in [2]. This stands for Analyze, Compare, Evaluate, and Verify. In the analysis stage, first the traits of the questioned subject are assessed, including class and individual characteristics. Second, the traits of the known subject are assessed, including class and individual characteristics. Then a comparison of these traits and the images is performed. Similarities and dissimilarities are noted. If there are dissimilarities, the examiner works to understand the nature of the dissimilarity. Often dissimilarities can be readily explained by differences in pose, illumination, expression, or time between the images. Once the comparison is made, the examiner evaluates the similarities and dissimilarities and their significance. For example, the difference in forehead height between individuals in questioned and known images is more significant than a possible difference in skin-tone as the latter can potentially be explained by make-up or tanning.

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 assist in their evaluation of similarities and dissimilarities. The work is then verified; in FAVIAU this involves a peer-review by comparably trained and knowledgeable image examiners.

The conclusions are of 100% certainty in the examiner's opinion that the questioned and known individuals are the same individual, are not the same individual, or could not be identified or excluded. At this time, percentages or probabilities of a match in a facial comparison cannot 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.

Comparison of ears has proved exceptionally useful to image examiners within FAVIAU. Studies have illustrated the differentiation between ears of individuals [8,9] and it is suggested that each ear is unique. Again, the lack of robust statistics is a hindrance to providing a percentage certainty in each case. The pronounced 3D nature of ears makes ear comparisons extremely sensitive to image perspective and therefore ear comparisons are most effective when the images of individuals are of similar perspectives. Another difficulty in ear comparisons is obstruction of the ears, by hair or headwear. Nonetheless, FAVIAU examiners have used ears to assist in the identification and elimination of subjects of comparison.

Hands, fingers, torsos, arms, and other body parts can be compared using similar methods. Hands often feature prominently in images of child pornography, as well as 'trophy shots' from homicides and kidnappings. The comparison of hands involves noting the position, number, and relative pattern of creases on knuckles and palms. The presence and morphology of freckles and scars is of importance, as well as the pattern and density of hair on the back of the hand. Comparisons of arms, legs, torsos, and other body parts also generally rely on the morphology, pattern, and relative spacing of minutiae and hair. It is not uncommon for an examiner to identify a suspect by linking multiple images from either the same crime scene or different ones by repeatedly observing similar features.

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. The results provided by biometric software would be beneficial by reducing the number of suspects and also providing the human examiner with additional evidence to support their opinion. Currently, there is difficulty in that many biometric systems do not provide clear justifications for their numerical results, which could cause confusion in a court of law. For example, one biometric system may yield results showing that two identical images of a person have a match score of 10 while two

different images of the same person may have a match score of 30; these discrepancies must be readily explainable for the technology to be used in the judicial system. A statistical basis for the conclusions would be ideal but at a minimum the results should be explicable and consistent. It is not necessary for a biometric system to illustrate its proprietary algorithm, however it would be beneficial if the reasoning for a match from a specific system had an explainable basis in observable traits.

B. *Photogrammetry*

The objective of photogrammetry is the indirect determination of spatial measurements of objects using photographic images [10]. 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 performed to eliminate suspects or to link multiple crimes, but never as a means to individualize a subject. It is anticipated that gait analysis could be used in conjunction with 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 Interests

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, smoother passage through the judicial system. Consider 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 recent project at the University of Sheffield in the UK (the "Magna database") involved using 2D and 3D images of faces for discriminating the nature of the available cranio-facial landmarks, and derivative measurements, to build statistical models of facial measurements within the sample population [11]. Another project, undertaken at West Virginia University and University of Miami, involved using images of ears to develop 3D ear models and then discriminating between ears [12].

FAVIAU anticipates building on both the facial and ear research projects that we have 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 our 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 the FBI. 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 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 stature. 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 biometrics program at the FBI.

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 to be accepted within a court of law. Likewise, the results should be explainable. Additionally, the statistics of human identification are of prime importance to the forensic community.

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