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Recognizability of computer-generated facial approximations in an automated facial recognition context for potential use in unidentified persons data repositories: Optimally and operationally modeled conditions

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ABSTRACT

Currently in the United States, the remains of thousands of unidentified human decedents are housed in medical, law enforcement, and forensic facilities throughout the country. A number of digital data repositories have been established to curate and disseminate the details of these unidentified decedent cases; some repositories also maintain records of missing persons. Although a cross-reference for *textual* data similarity occurs between the missing persons and unidentified decedent records in some repositories, no repository is currently known to employ an image analysis technology for cross-referencing *image* data. Results suggest that the computer-generated facial approximations used in this research were consistently included in prioritized candidate lists when used in an automated facial recognition context.

Two concurrent studies exploring the specific use-case discussed here were executed. The first employed an *optimally*-conditioned facial image gallery (g = 6159) (i.e., a gallery comprised of highly consistent facial images), a research design intended to establish the ceiling performance of the combined use of the two software programs employed. The second employed a gallery (g = 1816) compiled from a real-world dataset of missing persons' facial images, a research design intended to inform potential *operational* performance when using the highly varied facial images typically comprising public databases. Multiple types of facial approximations (reconstructions) with varying degrees of weight adjustments, age adjustments, or the presence (or absence) of visible eyes, and combinations of these variables, were evaluated. Overall, in the larger, optimally modeled study, 53% of the facial approximations for the t = 159 test subjects examined were matched to his or her corresponding life photo within the top 50 images of a candidate list generated from a blind (unrestricted) search of the highly consistent gallery (g = 6159). In the operationally modeled study, 31% of the test subjects' (t = 16) facial approximations were matched to their corresponding life photos within the top 50 images of a candidate list generated from a blind search of the gallery populated with images from an operational dataset (g = 1816). As anticipated, candidate list inclusion rates improved with the use of demographic filters. No significantly different inclusion rates were observed between the sex or age cohorts examined. Significant differences were, however, observed across population cohorts.

Entities curating missing and unidentified decedent records may benefit from a *paired* implementation of facial recognition technology and computer-generated approximations as part of a comprehensive investigative strategy for the *specific envisioned use-case* discussed in this research.

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1. Introduction

Currently in the United States, the remains of an estimated 10,000–13,000 unidentified human decedents are housed as Jane and John Does in medical examiner offices, law enforcement facilities, and forensic laboratories throughout the country [1–3].

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An additional ~4400 unidentified decedent cases are handled each year by medical examiners and coroners' offices, of which an estimated 25% remain unidentified [1]. In an effort to combat this growing issue, a number of local, state, and federal repositories have been established to house and disseminate the details of these unidentified decedent cases [4]. Reporting to the repositories is, however, largely voluntary and the actual number of unidentified decedents is conceivably as high as 40,000–50,000 [3–6].

Two of the larger national unidentified decedent repositories are the Federal Bureau of Investigation's (FBI) National Crime Information Center (NCIC) Unidentified Persons (UP) File and the U. S. Department of Justice's (DOJ) National Missing and Unidentified Persons System (NamUs) [7,8]. Both repositories maintain databases containing the details of thousands of active unidentified decedent cases (approximately 8000 and 10,000, respectively) [7,8]. In addition to unidentified decedent records, these repositories also maintain missing persons' cases, which are automatically cross-referenced for data similarities with the unidentified decedents' records [9,10]. Facial images, if available, are also included in both the missing and unidentified decedent repositories. The facial images in the missing persons' records are typically provided by relatives, the department of motor vehicles, or local law enforcement agencies. The facial images in the unidentified decedents' records are generally comprised of autopsy photographs, post-mortem reconstructions, and facial approximations (commonly referred to as facial *reconstructions*), the latter typically in the form of 2D composites and photographs of 3D clay models. Although an automated cross-reference for *textual* data (e.g., dates, locations, biological profile details) similarity occurs between the missing persons and unidentified decedent cases within (but not across) each of the above repositories, neither national repository is currently known to employ an *image analysis* technology to cross-reference and report potential image matches.

1.1. Biometrics

Image analysis technologies are a subset of a larger collection of technologies broadly referred to as *biometrics*. Biometrics is the term applied to the automated and semi-automated methods of human identification via discriminative physical and behavioral characteristics [11]. Although the term biometrics refers to a number of highly varied technologies, common operational and evaluation designs exist [11–13]. First, a biometric system is typically established in one of two modes: 1:1 *verification* or 1:N *identification* [12,13]. In the verification mode, an individual's presented identity is either verified or denied by comparing the presented identity against his or her authentic identity stored in a database of known individuals (referred to as a *gallery*). In the identification mode, the goal is to establish the identity of an unknown individual by comparing the individual to the entire corpus of stored identities. The identification task terminates once the image of interest (referred to as a *probe*) has been evaluated against all database identities and a list of the most likely matches is generated. Note that the use of the term "identification" here departs from the conventional use of the term in the law enforcement community where it typically indicates a positively identified individual. Here it simply refers to the name of the task, not necessarily the end result. Second, biometric system modes are further differentiated as operating in either an *open* or a *closed* universe [11–13]. In an open universe, the existence of a probe to gallery correlation is unknown. In contrast, in a closed universe all probes will have at least one corresponding gallery image. Verification operates within a closed universe, while identification applications are more typically open. Finally, a biometric technology may be evaluated in one of three modes: *technology*, *scenario*, and *operational* [14,15]. A technology evaluation is intended to examine and compare the capabilities of one or more technologies under standardized, controlled conditions, and is preferably of repeatable design. A scenario-based evaluation is typically conducted for predictive purposes by examining a particular technology for a specific use-case in a simulated operational context. An operational evaluation is intended to test a specific technology in situ under real-world conditions while utilizing live operational data.

1.2. Facial recognition

Currently, a number of commercial and open source image analysis technologies exist, including technologies developed exclusively for facial recognition. Facial recognition systems employ an array of complex face detection, image normalization, feature extraction, and face matching algorithms to compare a facial image of interest (i.e., a *probe*) against a reference set of images (i.e., a *gallery*) [11–16]. Once a set of gallery (g) images has been established, probe (p) images are imported and compared against the existing gallery. Depending on the operational mode employed, a single potential match (1:1 verification) or multiple potential matches (1:N identification) are produced. Multiple 1:N matches are selected based on user-defined search parameters (e.g., demographic restrictions) and ranked according to software-specific scoring criteria, effectively providing a prioritized list of potential matches. In biometric literature the user-defined parameter and list of potential matches are referred to as a *search filter* and *candidate list*, respectively [11–16]. Once a candidate list is produced, an operator may cease the matching process and accept the presented list or choose a number of iteration avenues to better constrain or expand potential candidates (e.g., resubmit the probe image using alternate search filters). Once a final candidate list is accepted by the operator, human adjudication is necessary to finalize the identification process [12,13].

The question arises as to whether or not the current data cross-referencing functions of missing and unidentified decedent repositories (e.g., NCIC and NamUs) would be enhanced by the incorporation of image analysis technologies. Further, could these technologies match non-photographic images such as computer-generated facial approximations? The purpose of this study was to gather data to inform this specific use-case by testing the recognizability of computer-generated facial approximations in an objective, automated facial recognition environment. Utilizing commercial facial recognition software, this research examined how accurately computer-generated facial approximations are matched with corresponding life photos of the approximated individuals. The research studies reported in this paper were conducted in a closed universe, scenario based, *use-case specific* mode using a commercial facial recognition software and both optimally- and operationally conditioned image galleries.

The results of these studies will contribute preliminary data useful for: (i) evaluating the general utility of computer-generated facial approximations in automated recognition contexts, (ii) examining the potential enhancement of the cross-reference functions of missing and unidentified persons tracking systems, and (iii) stimulating additional research employing innovative approaches and emerging technologies for producing investigative leads in unidentified persons cases.

2. Materials and methods

The data presented in this paper were part of a larger research effort with the specific aims of: (i) validating the computerized facial approximation software, ReFace[1] [17–25] and (ii) investigating potential operational applications for the ReFace software,

[1] ReFace is undergoing validation and is not yet offered publicly. Public release is currently being explored.