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Technical Note

Automated facial recognition of manually generated clay facial approximations: Potential application in unidentified persons data repositories

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ABSTRACT

This research examined how accurately 2D images (i.e., photographs) of 3D clay facial approximations were matched to corresponding photographs of the approximated individuals using an objective automated facial recognition system. Irrespective of search filter (i.e., blind, sex, or ancestry) or rank class (R_1, R_{10}, R_{25}, and R_{50}) employed, few operationally informative results were observed. In only a single instance of 48 potential match opportunities was a clay approximation matched to a corresponding life photograph within the top 50 images (R_{50}) of a candidate list, even with relatively small gallery sizes created from the application of search filters (e.g., sex or ancestry search restrictions). Increasing the candidate lists to include the top 100 images (R_{100}) resulted in only two additional instances of correct match. Although other untested variables (e.g., approximation method, 2D photographic process, and practitioner skill level) may have impacted the observed results, this study suggests that 2D images of manually generated clay approximations are not readily matched to life photos by automated facial recognition systems. Further investigation is necessary in order to identify the underlying cause(s), if any, of the poor recognition results observed in this study (e.g., potential inferior facial feature detection and extraction). Additional inquiry exploring prospective remedial measures (e.g., stronger feature differentiation) is also warranted, particularly given the prominent use of clay approximations in unidentified persons casework.

1. Introduction

Currently in the United States, the remains of an estimated 10,000–13,000 unidentified human decedents are housed in medical examiner, law enforcement, and forensic facilities throughout the country, with hundreds added to the ranks of the unidentified each year [1–3]. In an effort to combat this growing issue, a number of digital data repositories have been established to curate and disseminate the details of these unidentified decedent cases (e.g., 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)) [4–7]. In addition to case details, some repositories also contain multiple types of facial images (e.g., composites and clay models) approximating the appearance of the unidentified decedents, with 2D images of manually produced clay approximations being the more common (e.g., of the 156 NamUs Virginia UP cases, 59 have facial images, 41 of which are clay approximations, accessed October 22, 2015).

A series of recent publications [8–11] investigated the utility of computerized facial approximations as probe images in automated facial recognition contexts designed to match images of unidentified decedents to photographs of missing persons. The authors report high degrees of match rates and propose that unidentified persons data repositories enhance case resolution potential by populating records with computerized facial approximations, and further, compare the facial approximations to missing persons records (or other relevant databases) via automated facial recognition.

Given that photographs of manually produced clay facial approximations are common in unidentified decedent records repositories, the question arises as to whether or not automated facial recognition systems can utilize this type of image, and even

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more significantly, produce operationally constructive match rates. The purpose of this study is to gather preliminary data to inform this question by examining how accurately photographs of clay facial approximations are matched with corresponding photographs of the approximated individuals using an objective automated facial recognition system (NeoFace® Reveal, NEC Corporation of America, Irving).

2. Materials and methods

The research model employed in this study has been reported [9] and is, therefore, only briefly discussed here for the purpose of pointing out certain methodological differences. Methodological aspects not expressly discussed below were conducted in adherence to the aforementioned research model. In contrast to the methodology detailed in Ref. [9]: (i) one blind and two sex or ancestry filtered searches were conducted, (ii) the probe set consisted of a single 2D image of the manually produced clay approximation of each test subject, and (iii) no modifications or enhancements were made the probe images (e.g., differentiation of facial features via the addition of color, shading, or delineating marks). A gallery search restricted for *both* sex and ancestry would have produced gallery sizes too small for meaningful examination and was precluded from this study.

As an internal control, and to establish a performance baseline for the facial recognition system employed, a uniquely named duplicate of each test subjects' life photograph was tested for recognition against its parent photograph (enrolled in the gallery) in a gallery search against the entirety of the gallery dataset (g = 1816, Table 1). Further, because of the unconventional nature of the probe images used in this study (i.e., photographs of clay models), duplicate photographs of the clay models were similarly tested (i.e, a photo of a clay model tested against its duplicate enrolled in the gallery). This latter internal control was conceived as a means of evaluating the ability of the facial recognition system to process, and match, this unconventional type of facial image probe. The duplicate clay images enrolled into the gallery for the latter internal control test were removed from the gallery prior to commencement of this study.

The complete, unaltered image gallery previously constructed in Ref. [9] was used in this study (Table 1). The image gallery (g = 1816) was compiled from multiple sources and consisted of images for two classifications of individuals, foils (f) and test subjects (t). The foil images (f = 1800) were a subset of a larger operational database of facial images from the NCIC's missing persons repository [7]. See Ref. [9] for subset down-sampling criteria. The foil images were composed of uniquely named images of adult Americans ranging in age from 14 to 85 years old (median 34 years) with representation of both sexes, four ancestral descent groups, and relatively similar representation of three pre-defined age groups. In addition to foil images, the gallery also contained a uniquely named image of each test subject (i.e., the life photos of individuals for whom a 3D clay approximation was sculpted). The test subjects (t = 16) used in this study were adult Americans ranging in confirmed age from 17 to 70 years old with representation of both sexes and three ancestral descent groups. The test subjects were drawn from resolved unidentified persons cases and all identities were confirmed by other means (e.g., DNA comparisons).

Each clay approximation was constructed under blind conditions by one or the other of two experienced FBI artists from 3D replicas of the skulls of the t = 16 test subjects using a three-dimensional (3D) soft tissue facial approximation technique. Published soft tissue depths [12,13] were utilized but not rigorously adhered to if the biological profile or skull morphology suggested deviation. The 3D clay approximations were subsequently photographed (2D images). All clay approximation 2D images were in color, JPG file format, and cropped to a "head and shoulders" composition. The images depicted in Fig. 1 are representative of the test subjects' gallery photos and clay approximation probes employed in this study.

3. Results and discussion

The primary goal of a facial recognition 1:N identification scenario, as modeled in this study, is not that a test subject's corresponding gallery photo is always the first image in a candidate list of potential matches, but rather that a test subject's gallery photo is one of the top *k* images [8]. Given this definition, a correct match in this study indicates that a candidate list contained a test subject's corresponding gallery photo within the top *k* images. The set of top *k* images is referred to here as a *rank class* (R_k) and includes all images that ranked from 1 to *k*, inclusively. The rank classes defined for this study are: (i) R_1; (ii) R_{10}; (iii) R_{25}; and (iv) R_{50}, with R_1 indicating a potential positive identification. As an example, a test subject's approximation is processed and a candidate list is produced indicating the top *k* photo matches for that approximation. If the corresponding gallery photo for the test subject's approximation is in the eighth position in the candidate list, the approximation is considered to have placed in the R_{10} rank class, even though the actual rank is R_8. The above conventions are employed to describe the results observed in this study.

Of the t = 16 life photos used as an internal control to establish a working baseline for the facial recognition system employed in this study, 100% were correctly matched at R_1 to the subjects' corresponding gallery duplicate (i.e., life photo to life photo) in a blind search of g = 1816 images. More importantly, 100% of the duplicate clay approximation probes were also matched at R_1 to their corresponding gallery duplicate (i.e., photo of clay sculpture to photo of clay sculpture), indicating that the facial recognition system successfully processed this unconventional type of probe

Table 1
Gallery demographics.

Ancestry	Test subjects (t)				Foils (f)						
	t	Male	Female	Estimated age[a]	f	Male	Female	14–29	30–49	≥50	Age range
Asian	–	–	–		34	20	14	11	11	12	14–65
Am. Indian	2	2	–	28–52	37	22	15	12	12	13	15–64
African	3	2	1	16–38	390	211	179	123	129	139	14–85
Unknown	–	–	–	–	59	35	24	19	19	21	16–84
Caucasian	11	7	4	15–85	1280	669	611	404	420	455	15–85
Totals	16	11	5		1800	957	843	569	591	640	
Percent		69%	31%			53%	47%	32%	33%	36%	

[a] Estimated age ranges as given in anthropological profile.