Identification from images: Theory and methods.

A thesis submitted by

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Abstract

The use of images for the identification of criminals is becoming more prevalent with the increased use of video surveillance systems. Any anatomical trait that is visible on an image could be used to identify an individual, as long as its usefulness as a biometric indicator is known and can be accurately measured.

The mug shot, which was introduced in 1879 by Alphonse Bertillon was the first photograph used in forensic identification from images and since then the human face has been the focus for identification and recognition. However, the usefulness of the face or any other part of the body that could be measured from an image has not been thoroughly investigated.

Population frequencies of various traits are known. However, many studies which investigate the frequencies of traits, use categorical scales of measurement. Categorical scales of measurement have been used to describe the human face and body for centuries, it is not a new technique. The advantages of using categorical scales to describe various anatomical features is, that it is inexpensive to study and does not require specialised technology. As long as an individual is well trained with sufficient knowledge of the human body, categorical scales are generally accepted as a means of describing human variation. The use of categories for description of the human body is currently accepted for research purposes and cases of skeletal identification. However, the use of categories is questioned when describing an individual from an image.

A possible reason for this could be that in image analyses the traits are often too small to see, they are covered by clothing (such as those of the face by a balaclava) or they are subject to image distortion. Therefore, statements made by an expert witness in court proceedings regarding descriptions of anatomical features using categorical scales from images can often be questioned as it is primarily opinion based evidence.

Morphological analyses which use categories for image analyses have been labelled as ‘unreliable’ for the reasons stated above. Much research has concentrated on using interval scales of measurement on anatomical features seen in images. Using metric measurements of images is an attempt to make image identification more reliable by removing the ‘opinions’ of expert witnesses. The methods which are used currently to take measurements from images are time consuming, tedious, have unacceptable error rates and are often expensive.

Increased use of images for identification that will be used as evidence in court cases lead to the establishment of standards by which scientific evidence can be accepted by courts. These standards require the evidence provided by expert witnesses to be reliable, repeatable, peer reviewed and to have known error rates. The only way to make image-based evidence reliable and repeatable is to use interval scales of measurement and to minimize errors.

This thesis proposes that humans are singular in their overall surface anatomy. Therefore the use of interval scales to measure anatomical features for identification from images is justified as a biometric tool. Various methods have been proposed to take reliable measurements from images and to identify the associated error rates.

In order to accomplish this, several investigations were carried out, where each was concerned with a different issue that was involved with the reliable identification of individuals from images.

The first analysis considered whether or not measurements of the human body can be taken from images with precision, regardless of wearing clothes. Light clothing did not affect accuracy of measurements. Bulky and patterned clothing produced greater inaccuracies, but the overall accuracy rate remained at 96%. It was also found that

anatomists had the ability to locate anthropometric points with greater precision than the specialists in image analysis.

The second analysis considered the development of a method which could be used in forensic identification to establish the similarities or differences between individuals when large numbers of samples are available (n=3982). The method involves searching for duplicate individuals within a large database and once individuals did not match with another on anthropometric measurements, then they are considered ‘singular’. The term singularity was introduced, as it cannot be debated in a court of law, being a method that could be tested compared to ‘uniqueness’ that is universal. Measurements of the human face were examined to evaluate the value of the method in the identification of an individual. Results showed that the probability of finding two individuals with the exact same eight facial measurements is 1 in a trillion. Thus this is comparable with fingerprints.

The third analysis used the method proposed in the second analysis to investigate the value of body measurements as well as measurements of the face in the identification of an individual. Measurements of the body were compared with those of the face to examine, which measurements were better for the identification of an individual. Results showed that measurements of the body are superior to those of the face with a probability of 1 in a quintillion of finding two “duplicate individuals”. This exceeds the probabilities associated with measurements of the face and is comparable with fingerprint and DNA analyses.

The fourth analysis investigated the effect that measurement errors have in analyses of large anthropometric datasets. In order to achieve this, a formula was developed which converted standard metric units to ‘units of TEM’ (technical error of measurement) and incorporated the measurement errors into reported values. Two large

datasets were used, ANSUR (n=3982) and The National Size and Shape Survey of Australia (n =1265). Three examples were used to illustrate the application of the formula: i.e. in forensic investigations, garment construction and study of biological variation. In all examples, using units of TEM was superior to using standard metric units, as it removed inevitable adverse effects that measurement errors have on data.

The final investigation showed that body proportions were not a reliable method for the identification of individuals from images. The error rates associated with the body proportional measurements were equal to the biological variation of individuals.

The information gathered from these five experiments indicates that surface anatomy is sufficient as a biometric tool, which could be applied to identification of individuals from images. Findings in these investigations show that measurements can successfully be taken from images. However, more work needs to be done within the field to reduce error rates.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Teghan Lucas Date

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Manuscripts included in this thesis:

1. Scoleri, T, Lucas, T, Henneberg, M 2014, 'Effect of garments on photoanthropometry of body parts: Application of stature estimation', *Forensic Science International.* Vol. 237, pp. 1-12.

2. Lucas T, Henneberg M 2015a 'Are human faces unique? A metric approach to finding single individuals without duplicates in large samples', *Forensic Science International.* DOI: http://dx.doi.org/10.1016/j.forsciint.2015.09.003

3. Lucas T, Henneberg M 2015b 'Comparing the face to the body, which is better for identification?', *International Journal of Legal Medicine*. DOI: 10.1007/s00414-015-1158-6.

4. Lucas, T, Henneberg M 2015 'Use of units of measurement error in anthropometric comparisons'. Submitted to Journal of Biological and Clinical Anthropology (November 2015).

5. Lucas, T, Kumaratilake, J, Henneberg, M 2015 'Metric identification of the same people from images- how reliable is it?'. Submitted to *Journal of Forensic Sciences* (November 2015).

Conference presentations related to this thesis

Lucas, T, Henneberg, M. 2014 ‘Singularity – the absence of duplication without uniqueness’. 28th Annual conference of the Australasian Society for Human Biology in Glenelg, Adelaide.

Note* the title of the paper that this presentation was based on was later changed to ‘Are human faces unique? A metric approach to finding single individuals without duplicates in large samples’ as suggested by reviewers.

Lucas, T, Henneberg, M. 2015 ‘Comparing the face to the body, which is better for identification?’. 84th Annual meeting of American Association of Physical Anthropologists conference in St. Louis, Missouri.