A Survey: Identification of Identical Twins

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Abstract- *The ability of biometric techniques to distinguish between identical twins is a major challenge. The research is literature survey of identification of identical twins using face recognition. This survey pulls together the literature to date in this area, identifies available datasets for research, points out topics of uncertainty and suggests possible future research.*

I. INTRODUCTION

Identical (monozygotic or MZ)twins are the result of the division of a single zygote (a fertilized egg) early in gestation. At the moment after splitting, the two fertilized eggs have identical DNA.MZ twins typically have strongly similar anatomy and facial appearance. Significant differences in appearance between MZ twins can develop due to both behavioral influences and epigenetic influences.

It was long assumed the MZ twins could not be distinguished by DNA matching; e.g., “By definition, identical twins cannot be distinguished based on DNA” . However, in recent years it has become clear that DNA analysis does have the potential to distinguish between MZ twins [5]. A technique called “ultra-deep next-generation sequencing” was used to resolve a paternity test between MZ twins as possible parents . The essential point is that random mutations accumulate over time and can be mapped by the new technique and used to distinguish MZ twins.

At least four reasons contribute to interest in using biometrics to distinguish between MZ twins [4]. One is that MZ twins are rare, even exotic, so that the topic naturally attracts curiosity. A second reason is that the legal system sometimes finds it is necessary to reliably distinguish between MZ twins. A third reason is that distinguishing between MZ twins is seen as a “hardest possible case” for biometrics, and so it becomes a strong argument for the more general validity of a biometric. Lastly, twin births are increasing in frequency [10], so that these issues are becoming more important over time. This paper summarizes the research literature to date on distinguishing between MZ twins using face, fingerprint, iris, speaker ID and handwriting. In the concluding section, we suggest open questions and possible future research topics.

II. LITERATURE OF FACE RECOGNITION

Facial appearance is a composite of skeletal, muscular, and dermal components. The first is genetically driven and the others are determined by genetics but modified by environment and behavior. Depending on the latter factors' differential influence, MZ twins may have relatively different facial appearances. Research reveals that face recognition systems are challenged by identical twins, and performance can degrade when probe and gallery samples are similarly posed and lit. As a mechanism for assessing face recognition algorithms, studying a data set composed of MZ twins, with appropriate structuring of the machine experiment (match, twin match, nonmatch), can help to characterize the marginal and distinctive effect of twin subjects on accuracy, and thus the margin for misclassification of “minimally different” individuals.

Sun *et al*. published the first study on distinguishing between MZ twins using automatic face recognition. They experimented with data from 51 pairs of identical twins and 15 pairs of non-identical twins, acquired at a Beijing Twins Festival. They acquired face, fingerprint and iris data. The twins status was not recorded from the subjects, but was assigned retrospectively “based on observing whether the facial images of a set of twins were very similar or not”.They conclude that the impostor distribution for matches between identical twins is more like a typical genuine distribution than like a typical impostor distribution.

Klare *et al*. explored the ability of several types of local features to distinguish MZ twins. Their experiments used the ND-Twins dataset. This work uses a taxonomy of facial features, in which Level 1 features are global descriptors such as eigenfaces, Level 2 features are coarsely localized or regional features such as SIFT descriptors, and Level 3 features are fine details such as facial marks and scars. Their results highlight the value of facial components and also the intrinsic challenges of identical twin discrimination.

Phillips *et al*. published a study of MZ twins discrimination incorporating data captured at the Twins Days 2009 and 2010 festivals, with data from over 100 sets of twins in each year. This dataset, the ND-Twins dataset, has been used by other researchers . Phillips *et al*. present error rates and performance curves for multiple commercial face matching algorithms, distinguishing between twins under a variety of conditions, including images taken with a year of time lapse, and breakdown by age and gender. Later publications go into additional detail analyzing the accuracy of distinguishing between twins .

Mozaffari and Behravan describe a dataset of twins face images scraped from the web, associated with different twins festivals around the world, including images from 1,902 pairs of twins. Faces were detected with a Viola-Jones algorithm and resized to 256x256. Results of recognition using PCA, LDA and LBP recognition algorithms are given, with comparison to the same algorithms' performance on FERET and AR. Their database appears to be intended for distribution, but there is no information on how to obtain it.

Le *et al*. develop an approach to distinguish between identical twins using features associated with face aging. The idea is that furrows that develop on the sides of the eyes ("crow's feet"), nose and mouth can be distinctive between twins. Their experiments use a Local Fisher Discriminant Analysis algorithm and the ND-Twins dataset . They are able to obtain as high as 96% discrimination between twins, in the case of subjects making a smile expression and not wearing glasses.

Mahalingam and Ricanek experiment with a component-based algorithm for distinguishing between twins, using both the ND-Twins dataset and the CASIA dataset . They report no significant difference in accuracy for distinguishing between male and female twins, and report that discrimination between twins becomes more accurate with increasing age.

Juefei-Xu and Savvides propose a method to identify MZ twins based on an Augmented Linear Discriminant Analysis. Their experiments also use the ND-TWINS dataset . Hu *et al*.investigated the matching of identical twin faces using a data set containing 455 pairs of MZ twins extracted from Internet photos. Interestingly, the twin pairs were extracted from a single photo, which enforces some similarity in imaging conditions. This dataset is used with an experimental protocol where the classification decision is "same person" versus "twin sibling" and training was performed using either supervised or unsupervised approaches. The dataset is available.

Lamba *et al*. consider a generalization of the identical twin problem, namely the task of distinguishing 'look-alikes' such as impersonators (in this context, twins are considered 'biological look-alikes' by the authors). To support the study, the authors created a databasecontaining a balanced set of images of celebrities and either "genuine or intentional" look-alikes. This work included a human discrimination study employing 50 volunteer raters who were asked to distinguish self-matches from look-alike matches under a time constraint. Interestingly, the results from the human study suggested unbalanced performance on data from different genders and origin. This study included baseline automatic face recognition evaluations using seven different matchers. Algorithms trained on a general (non-lookalike) database and evaluated on a look-alike database exhibited performance very close to random. This poor performance motivated a new method for verification using an SVM with phase features extracted from face regions with a neural network. The proposed method performed at a level well above the random performance of the baseline methods.

Zhang *et al*. report on a "talking profile" approach to distinguishing between twins. The idea is to use signatures derived from facial motion analysis in video. They report on experiments with video of 39 pairs of twins speaking. They work with six different types of face motion in a talking profile, and find that it is important to sample multiple types of face motion. They also report on experiments with non-twins datasets.

Srinivas *et al*. report on experiments with a manually annotated set of facial marks to distinguish between twins. They find that "the position of certain facial marks appears to be similar for twins" but that facial marks can still be useful in discriminating between twins.

There is also a substantial literature on how human observers distinguish between MZ twins based on facial appearance. Due to space limits, we do not attempt to discuss this literature here.

III. CONCLUSIONS

Table 1 summarizes the MZ twins datasets that appear to be available to the research community, with a selected reference that uses the dataset, the type of biometric, the number of MZ twins, and an indication of the ground truth of MZ status. One major need to advance research in this area is a large, readily available multi-modal dataset that includes both MZ and fraternal twins. Ideally, the "ground truth" for MZ / fraternal would be established in some formal manner.

Table 1. Summary of available twins datasets.			
ref	**biometric**	**number of twin pairs**	**MZ ground truth**
[44]	face	126 + 120	self-reported
[58]	face, iris, fingerprint	51	assigned by looking at face images
[18]	iris	76	self-reported
[61]	3D face	107	self-reported
[68]	face	455	?(scraped from web)
[42]	face	1902	?(scraped from web)

Distinguishing between MZ twins using face images has received more attention than other biometric modalities. There are two face image datasets that have been used by multiple research groups, ND-Twins-2009-2010and CASIA-Twins .

Avenues for face matching with increased accuracy for MZ twins include the use of facial marks and the use of regions of the face that develop age-related characteristics. In the special case of "mirror identical" twins,asymmetry analysis may be especially advantageous.

There appears to be disagreement in the literature on the degree of similarity between MZ versus fraternal twins' fingerprints. Srihari *et al.* state that "[t]he similarity of fingerprints of MZ twins is the same as the similarity between fingerprints of fraternal twins", even though they and others find that fraternal twins have a much lower similarity in class of ridge pattern than do MZ twins.

Other issues in fingerprint revolve around the lack of any large and standard dataset. All MZ twins studies reviewed involve relatively small numbers of pairs of MZ twins. Thus it is possible that there are some rare cases that simply have not been seen in any of the studies to date. Also, it is not clear that any of the twins fingerprint databases in the works reviewed are currently available to researchers. There is only one instance of two different research groups studying the same dataset , and that is only a partially overlapping dataset.

In some respects, iris recognition has the most unusual results for distinguishing between MZ twins. There is agreement that, with respect to the industry-standard, Daugman-style approach to iris matching, MZ twins' iris codes are as different as those of unrelated persons. This is a stronger statement than can be made about other modalities. At the same time, there is also evidence that human observers can classify pairs of iris images as (a) belonging to twins or (b) belonging to unrelated persons at accuracy far above chance [17, 18].

Several points are worth making about the body of work in distinguishing between twins using speaker identification. All of the studies to date involve relatively small numbers of pairs of MZ twins, less than 50 pairs. Almost no attention has been paid specifically to fraternal twins. The effect of the twins' age on the ability to distinguish between them has not been investigated. The possible gender-based difference in accuracy in distinguishing between twin pairs has been investigated by just one study, with rather surprising results.

There has been relatively little work in using handwriting to distinguish between MZ twins. The more optimistic accuracy estimates reported are likely not from subject-disjoint train and test experiments.

Studies involving MZ twins have been done with other biometric modalities than those discussed above, including ear , gait and 3-D face scans .

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