Texas 3D Face Recognition Database

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***Abstract*—We make available to serious researchers in three dimensional (3D) face recognition and other related areas, the Texas 3D Face Recognition Database at no cost. This database contains 1149 pairs of high resolution, pose normalized, pre-processed, and perfectly aligned color and range images of 118 adult human subjects acquired using a stereo camera. The images are accompanied with information about the subjects' gender, ethnicity, facial expression, and the locations of 25 manually located anthropometric facial fiducial points. Specific partitions of the data for developing and evaluating 3D face recognition algorithms are also included.**

***Keywords*-3D face recognition; database; stereo image analysis; 3D face modeling;**

I. Introduction

Recent advancements in three dimensional (3D) image acquisition technology have spurred interest in developing accompanying 3D image processing and analysis techniques. Three dimensional human face recognition is one such area of interest [1]. It has numerous applications including automated subject identification, security, and human-computer interaction. Three dimensional face recognition technology also has advantages over two dimensional (2D) face recognition technology in that 3D facial images are more robust to facial pose variations and ambient illumination conditions than 2D images.

To promote serious research in 3D face recognition and related scientific disciplines (*e.g.*, facial reconstruction and plastic surgery, 3D facial modeling and graphics), we are pleased to make available to serious researchers in the field, at no cost, the Texas 3D Face Recognition Database. This large database of two 2D and 3D facial models was acquired at the company Advanced Digital Imaging Research (ADIR), LLC (Friendswood, TX), formerly a subsidiary of Iris International, Inc. (Chatsworth, CA), with assistance from research students and faculty from the Laboratory for Image and Video Engineering (LIVE) at The University of Texas at Austin. The project was sponsored by the Advanced Technology Program of the National Institute of Standards and Technology. Information about the database, and instructions to apply for access to it are available on LIVE's web-servers (http://live.ece.utexas.edu/research/texas3dfr/index.htm).

This database is a valuable resource to the 3D face recognition research community. Currently, it is the largest publicly available database of 3D facial images acquired using a stereo imaging system. The database contains 1149 3D models of 118 adult human subjects. The number of images of each subject varies from 1 per subject to 89 per subject. The subjects' ages range from $\sim 22-75$ years. The database includes images of both males and females from the major ethnic groups of Caucasians, Africans, Asians, East Indians, and Hispanics. The faces are in neutral and expressive modes (*e.g.*, Fig. 1 and Fig. 3). The facial expressions present are smiling or talking faces with open/closed mouths and/or closed eyes. The neutral faces are emotionless. All subjects were requested to remove hats and eye-glasses prior to image acquisition.

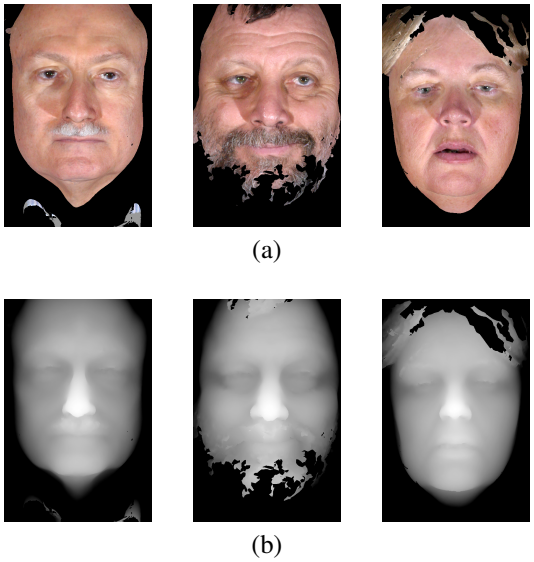

Figure 1. Raw (a) color, and (b) range images of the Texas 3D Face Recognition Database.

II. Acquisition and Normalization

The 3D models in the Texas 3D Face Recognition Database were acquired using an MU-2 stereo imaging system [2] manufactured by 3Q Technologies Ltd. (Atlanta, GA). All subjects were requested to stand at a known distance from the camera system. At the beginning of each acquisition session, and at regular intervals during the

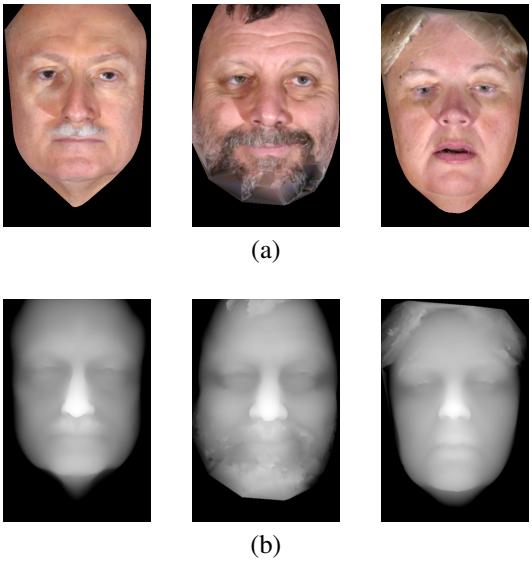

Figure 2. Preprocessed (a) color, and (b) range images of the Texas 3D Face Recognition Database.

session (a session is defined as a set of images acquired on a particular day) the stereo system was calibrated against a target image containing a known pattern of dots on a white background [3]. This ensured that each 3D facial model had the same dimensions as the actual real-world dimensions of the face. The stereo system acquired both the shape and the color images of the face simultaneously. Hence, all pairs of range and color images for a particular acquisition in the Texas 3D Face Recognition Database are perfectly aligned.

The acquired 3D models were successfully transformed to a frontal orientation with the forehead titled back by 10° to the vertical axis. This was achieved by iteratively aligning facial models in arbitrary poses to a template face in a canonical frontal pose using the ICP algorithm [4]. Tilting the forehead of the 3D face back by 10° to the vertical axis ensured that each (x, y) location was associated with a unique z value, and hence the facial surface could be represented as $z = f(x, y)$.

The final representation of each face in the database is a pair of range and color images in the canonical frontal pose that are perfectly aligned to each other (*e.g.*, Fig. 1). The range images were constructed by orthographically projecting the pose normalized 3D models onto a regularly spaced rectangular grid. The corresponding color images were constructed by obtaining the color information at each point in the range image. The tip of the nose of each model is located at the center of the image. The range images are of size 751×501 pixels with a resolution of 0.32 mm along the x, y, and z dimensions. Each z value is represented in an 8 bit format with the highest value of 255 assigned to the tip of the nose and a value of 0 assigned to the background. The color images are similarly of size $751 \times 501 \times 3$ pixels

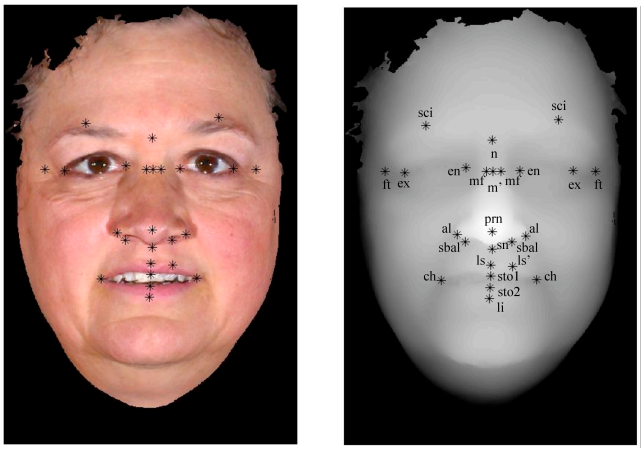

Figure 3. Twenty-five anthropometric fiducial points (a) on a color image, and (b) on a range image.

represented in an uncompressed 8 bit RGB format.

III. Preprocessing

We further preprocessed the raw range and color images to convert them into a form useful for face recognition. We removed small extraneous regions that were not attached to the face region, *e.g.*, shirt collars in the leftmost image in Fig. 1 (a). For this, we detected the face region as the largest connected region of non-zero z values in range images and retained it. All other regions were removed. We eliminated small amounts of impulse noise present in the range images by median filtering them with a square window of size 3×3 pixels. We interpolated the range images using bi-cubic interpolation to remove large holes and finally smoothed them by applying a Gaussian window with $\sigma = 1$ pixel. These steps were also applied to each of the R, G, and B channels of the color images. The preprocessed versions of the raw images shown in Fig. 1 are presented in Fig. 2.

IV. Facial Fiducial Points

We have annotated all 1149 image pairs in the Texas 3D Face Recognition Database with the positions of 25 anthropometric facial fiducial points (Fig. 3). These fiducial points are associated with facial anthropometric proportions [5] that are reported to be variable for human populations [6], [7]. We located the fiducial points manually on the color images by clicking at appropriate locations with a mouse and a computer based graphical user interface (Fig. 4). The locations of the facial fiducial points on the facial range and color images are the same, as the two types of images are perfectly aligned.

V. Data Partitioning

For the purposes of developing, evaluating, and directly comparing the performance of different 3D face recognition

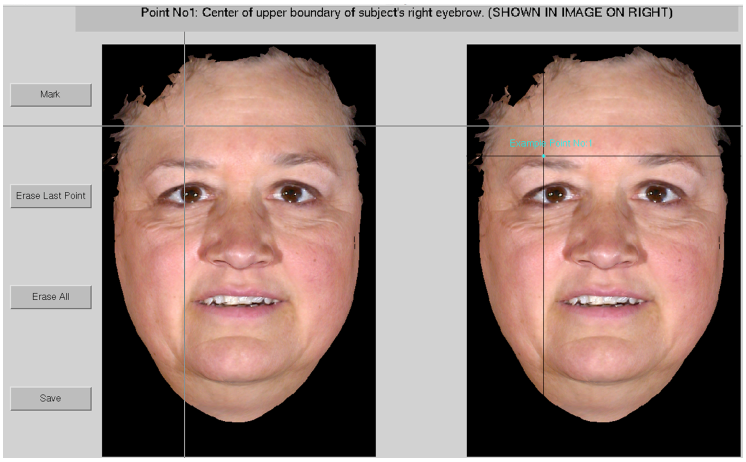

Figure 4. The graphical user interface that was developed for manually locating anthropometric facial fiducial points.

algorithms on a common database, we have partitioned this database into a proposed training data set, a test data set, and a 'remaining' data set (Table I) [6], [7], [8]. The training data set contains a set of randomly selected 360 images of 12 subjects (30 images per subject) in neutral or expressive modes. The test data set includes 768 images of 105 subjects. This test set is further partitioned into a gallery set and a probe set. Consistent with the evaluation protocol of the Face Recognition Grand Challenge (FRGC) 2005 [9], the gallery set contains one range image each of 105 subjects with a neutral facial expression. The probe set contains another set of 663 images of 95 of the gallery subjects with a neutral or an arbitrary facial expression. In the probe set, the number of images of each subject varies from 1 to 55. In accordance with the widely accepted 'closed universe' model for the evaluation of face recognition algorithms [9], every subject in the probe data set is represented in the gallery data set. After partitioning the entire database of 1149 images into the training and test data sets, 21 images of 13 subjects remained, which are included in a 'remaining' data set (Table I).

For 3D face recognition, algorithm development steps including automatic facial fiducial point detection, classifier feature selection, and classifier optimization may be performed using the training and/or the 'remaining' data sets only. Trained classifiers may be evaluated on the independent test data set, which does not overlap with training or the 'remaining' data set.

VI. Availability

The Texas 3-D Face Recognition Database will be made available to researchers on a case-by-case basis. The Texas 3-D Face Recognition Database is intended for research purposes only and may not be used for any commercial purposes. The database of 2D and 3D images will be accompanied with information about the gender, ethnicity,

Partition		No. of Subjects	No. of Images		
			Neutral	Expressive	Total
Training		12	228	132	360
Test	Gallery	105	105	0	105
	Probes	95	480	183	663
Remaining		13	0	21	21

Table I
A SUMMARY OF THE DATA PARTITIONS EMPLOYED FOR DEVELOPING 3D FACE RECOGNITION ALGORITHMS.

facial expression, and the locations of 25 manually detected anthropometric facial fiducial points. Information about the specific data partitions that we have previously employed for developing and evaluating 3D face recognition algorithms [6], [7], [8] will also available. All requests for portions of the Texas 3-D Face Recognition Database must be submitted in electronic email format to Professor Al Bovik, Director of LIVE at: bovik@ece.utexas.edu with the subject line: Request for Use of Texas 3-D Face Recognition Database." Each request from User must be accompanied (via attachment to the email) by a completed, signed, and scanned pdf copy of this Participant Agreement form (http://live.ece.utexas.edu/research/texas3dfr/index.htm). It is expected that access will be granted only to Project Managers and Principal Investigators of senior responsibility. The email request must explain the Users intentions and need for the requested images and data. Upon acceptance, instructions will be given to the User as to how to access the database electronically.

VII. Discussion

The Texas 3D Face Recognition Database will complement the publicly available and widely used FRGC 2005 database [9]. The Texas 3D Face Recognition Database differs from the FRGC 2005 database in a number of respects. First, it is the largest (in terms of the number of

images and subjects) publicly available 3D facial database that has been acquired using a stereo imaging system at a high resolution (0.32 mm) along the x, y, and z dimensions. In comparison, images in the FRGC 2005 database have been acquired using a 3D laser scanning system Minolta Vivid 900/910 series (Konika Minolta Holdings, Inc., Tokyo, Japan), at a lower average resolution of 0.98 mm along the x ad y dimensions, and 0.5 mm along the z dimension [10]. Second, all images in the Texas 3D Face Recognition Database have been acquired at the same scale and are scaled to the true physical dimensions of the captured human faces. The faces in the FRGC, however, have been acquired at differing scales. Third, the pairs of color and range images in the Texas 3D Face Recognition Database are perfectly aligned. In contrast, the color and range images in the FRGC 2005 database were acquired a few seconds apart, and hence are not perfectly aligned [9]. For the same reason, certain pairs of range and color images in the FRGC 2005 database have inconsistent facial expressions [11]. As the acquisition time for the Minolta 3D scanner is greater than 100 ms, certain 3D meshes in the FRGC 2005 database are also reported to be distorted due to the subjects' motion during image acquisition [11].

Images in the FRGC 2005 database also require considerable preprocessing, including hair, clothing, and background elimination, and facial pose and scale normalization. These steps are not required for the Texas 3D Face Recognition Database and hence, it provides a good alternative for researchers focused specifically on developing and evaluating novel algorithms for 3D face recognition, without regard to the initial preprocessing of 3D images. Furthermore, the Texas 3D Face Recognition Database contains adequate variability to model a controlled real world operating environment of co-operative users.

Another compelling and unique feature of the Texas 3D Face Recognition Database is that it provides the positions of a very large number (25) of manually annotated anthropometric facial fiducial points (Fig. 3) for every face in the database. This can be a very valuable resource for researchers developing algorithms for 2D and 3D facial feature detection, face recognition, and facial processing and anthropometry. This information is currently unavailable for any publicly available 2D or 3D face database of comparable size and thus it is no surprise that the currently reported studies of 3D or 2D+3D facial fiducial point detection [12], [13], [14] do not report detection errors relative to any form of 'ground truth data'.

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