APPENDIX 1

DATABASES USED IN THIS THESIS

To evaluate the performance of unimodal and multimodal biometric systems proposed in this thesis work, a collection of biometric samples of iris, retina, ear, fingerprint and palm print images are required. Hence publicly available biometric databases for the above traits are used to create a chimeric multimodal database corresponding to each of the fusion experiment carried out in this work. The salient features of these databases are briefly discussed below.

A 1.1 CASIA iris database

CASIA (Chinese Academy of Sciences’ Institute of Automation) iris image database version 3.0 (CASIA-IrisV3) developed by National Laboratory of pattern recognition, China includes three subsets: CASIA-IrisV3-Interval, Lamp and Twins (http://www.sinobiometrics.com, 2007). CASIA-IrisV3 contains a total of 22,035 iris images from more than 700 subjects. The iris images are 8 bit gray-level JPEG files, collected under near infrared illumination with a resolution of 320 x 280. Almost all the subjects were Chinese and the images were captured with self-developed iris camera.

Most of the images in the Interval database were captured in two sessions in one month interval. It contains 2639 images taken from 249 subjects, captured by circular NIR LED array camera with suitable luminous flux for iris imaging. As these iris images have good clarity, CASIA-Iris-Interval is well-suited for studying the detailed texture features of iris images. A few iris image samples from the three databases are shown in Figure A 1.1.
Both Lamp and Twins datasets were collected using hand-held iris sensor. A lamp was turned on/off close to the subject, to introduce more intra-class variations during image collection. Elastic deformation of iris texture due to pupil expansion and contraction under different illumination conditions can be studied using images of this database. So it is suitable for studying the problems of non-linear iris normalization.

CASIA-IrisV3-Twins contains iris images from 100 pairs of twins, which were collected using IRISPASS-h camera. Some statistics and features of each subset are summarized in Table A 1.1.
Table A 1.1  Statistics of CASIA-IrisV3 database

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>CASIA-IrisV3-Interval</th>
<th>CASIA-IrisV3-Lamp</th>
<th>CASIA-IrisV3-Twins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor</td>
<td>Self-developed</td>
<td>IRISPASS-h</td>
<td>IRISPASS-h</td>
</tr>
<tr>
<td>Environment</td>
<td>Indoor</td>
<td>Indoor with lamp on/off</td>
<td>Outdoor</td>
</tr>
<tr>
<td>Session</td>
<td>Images were captured in two sessions, with at least one month interval</td>
<td>One</td>
<td>One</td>
</tr>
<tr>
<td>No. of subjects</td>
<td>249</td>
<td>411</td>
<td>200</td>
</tr>
<tr>
<td>No. of classes</td>
<td>395</td>
<td>819</td>
<td>400</td>
</tr>
<tr>
<td>No. of images</td>
<td>2639</td>
<td>16213</td>
<td>3183</td>
</tr>
<tr>
<td>Resolution</td>
<td>320*280</td>
<td>640*480</td>
<td>640*480</td>
</tr>
<tr>
<td>Features</td>
<td>Good image quality with extremely clear iris texture details</td>
<td>Nonlinear deformation due to variations of visible illumination</td>
<td>The first publicly available twins’ iris image dataset</td>
</tr>
<tr>
<td>Total</td>
<td>22,035 iris images from more than 700 subjects and 1500 eyes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A 1.2  DRIVE retina database

The images of the Digital Retinal Images for Vessel Extraction (DRIVE) database were obtained from a diabetic retinopathy screening program in The Netherlands (Hoover et al 2000). The screening population consisted of 400 diabetic subjects between 25-90 years of age. From this, 40 images have been randomly selected for DRIVE database, of which 33 did not show any sign of diabetic retinopathy and 7 showed signs of mild early diabetic retinopathy. Each image is a JPEG compressed color photo in TIFF format. The images were acquired using a Canon CR5 non-mydriatic 3CCD camera with a 45 degree field of view (FOV). Each image was captured using 8 bits per color plane at 768 x 584 pixels. The FOV of each image is circular with a diameter of approximately 540 pixels. The images have been
cropped around the FOV and for each image, a mask image is provided that delineates the FOV. There are two classes (vessel and background), and only pixels inside the field of view are taken into account. The set of 40 images have been divided into training and test sets, both containing 20 images. DRIVE database that consists of 20 images that have been hand-labeled twice. One of these labeling is used as gold standard. The other labeling is referred to as the human observer method. Performance is given as accuracy and kappa values (a measure for observer agreement, where the two observers are the gold standard and the segmentation method).

A 1.3  STARE database

The database contains 397 images captured with uneven illumination (http://www.ces.clemson.edu/~ahoover/stare). During the capture of images, the amount of light falling on different parts of the retina varies depending on the direction of the illuminating flash. This direction is not known and varies from image to image. This uneven illumination prevents absolute interpretation of the intensities in the image. Of the 397 images, 43 images have missing or incomplete annotations and the remaining 354 images with annotations were divided according to the following four categories: familiar, unfamiliar, partially familiar and normal images. Some of the sample retina images are shown in Figure A 1.2. There are 38 normal images in this database which are used in this thesis for analysis.

![Figure A 1.2  A sample of retina images](image-url)
A 1.4 VARIA retina database

VARPA Retinal Images for Authentication (VARIA) database includes 233 retina images collected from 139 individuals (http://www.varpa.es/varia.html). The images have been acquired with a TopCon non-mydriatic camera NW-100 model and are optic disc centered with a resolution of 768 x 584.

A 1.5 USTB ear database

University of Science and Technology Beijing (USTB) provides a collection of four different ear image databases taken under various capturing scenarios and is given below (//www.ustb.edu.cn/resb/en/index.htm):

Image database - I

The right ear of 60 volunteers is photographed with digital camera where three different images were obtained from every one of the 60 volunteers. They are normal frontal image, image with trivial angle rotation and image under different lighting conditions. Each of the images has 256 gray scales with rotation and shearing imposed on it, but without illumination compensation. Some images of the database are shown in the Figure A 1.3, in which three images in series belong to a single person.
Image database - II

These images were taken under standard conditions from 77 persons. Four images of right ear of each person were captured, where two images are with angle variation, one with illumination variation and the last one is the profile image. The subject’s head in right hand view is photographed by CCD camera under illumination and angle variations. The distance between the subject and camera is fixed as 2 meters. Each image is a 24-bit true color image with a resolution of 300 x 400 pixels. The first and fourth images are profile images with different lighting conditions. The second and third images have the same illumination conditions as the first, while they are separately rotated by +30° and -30° respectively with reference to the first one. Some images of the database are shown in the Figure A 1.4, in which four images in series belong to a single person.

Figure A 1.4 Examples of ear database - II
**Image database - III**

These images refer to the right side profile images taken from 79 volunteers who are photographed with color CCD camera under the white background and constant lighting. The angle when CCD camera is perpendicular to ear is noted as 0° and called as profile side. The distance between camera and subject is 1.5 meters. The resolution of the image is 768 x 576 and is 24-bit true color. Under normal conditions, the subject rotates from 0° to 60° approximately in steps of 5° towards the right side. At each angle, the ear is photographed twice and thus a total of 22 images were captured (some images shown in Figure A 1.5). Similarly the subject turns left up to 45° and 18 images were collected. Also 144 ear images having partial occlusion (some images shown in Figure A 1.6) were collected from 24 subjects with 6 images per subject under three conditions: partly occlusion (disturbance from some hair), trivial occlusion (little hair) and regular occlusion (natural occlusion).

![Figure A 1.5 Examples of ear database - III](image-url)
Figure A.6  Ear images with partial occlusion

Image database - IV

A camera system consisting of 17 CCD cameras are distributed in a circle with radius being 1 meter and the subject is placed in the center. The cameras are separated by 15° interval and are bilaterally symmetrical. There were 500 volunteers and they were required to look at eye level, look upwards, look downwards, look right and look left in order to capture ear images at multiple poses. The database contains both grayscale images and color images of 500 volunteers and the resolution of image is 500 x 400.

A.1.6  CASIA palm print database

CASIA palm print database contains 5,502 palm print images captured from 312 subjects (http://www.sinobiometrics.com, 2007). For each subject, palm print images from both left and right palms were collected. The palm print images are 8 bit gray level JPEG files and the samples were collected in one session only. There are no pegs in the capturing device to restrict the postures and positions of palms. The device supplies an evenly distributed illumination and captures palm print images using a CMOS camera fixed on the top of the device. A database is constructed for the experimentation by taking 100 subjects with 5 samples per user. The biometric data captured from every user is compared with that of all other users leading to one genuine score and 99 impostor scores for each distinct input. Six typical palm print images in the database are shown in Figure A.1.7.
A 1.7 FVC2002 fingerprint database

Fingerprint Verification competition (FVC) 2002 provides four databases (DB1, DB2, DB3 and DB4) created by using different fingerprint sensors listed below (http://bias.csr.unibo.it/fvc2002):

- DB1: optical sensor "TouchView II" by Identix
- DB2: optical sensor "FX2000" by Biometrika
- DB3: capacitive sensor "100 SC" by Precise Biometrics
- DB4: synthetic fingerprint generation

Figure A 1.8 shows a sample image for each of the 4 databases.
Each database contains images of 110 fingers with 8 samples per finger forming totally 880 fingerprint images. The acquired images are represented with 256 gray levels in TIF format. Image size varies depending on the database type and the orientation of fingerprint is approximately in the range [-15°, +15°] with respect to the vertical orientation. Table A 1.2 lists the image details of the 4 databases.

**Table A 1.2  Image details of FVC2002 fingerprint database**

<table>
<thead>
<tr>
<th>Database</th>
<th>Sensor Type</th>
<th>Image Size</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>DB1</td>
<td>Optical sensor</td>
<td>388x374 (142 Kpixels)</td>
<td>500 dpi</td>
</tr>
<tr>
<td>DB2</td>
<td>Optical sensor</td>
<td>296x560 (162 Kpixels)</td>
<td>569 dpi</td>
</tr>
<tr>
<td>DB3</td>
<td>Capacitive sensor</td>
<td>300x300 (88 Kpixels)</td>
<td>500 dpi</td>
</tr>
<tr>
<td>DB4</td>
<td>SFinGe v2.51</td>
<td>288x384 (108 Kpixels)</td>
<td>about 500 dpi</td>
</tr>
</tbody>
</table>