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UID Enrolment Proof-of-Concept Report

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Introduction

The UID Authority of India conducted a Proof-of-Concept (PoC) study of biometric enrolment from March 2010 to June 2010 in the predominantly rural areas of Andhra Pradesh, Karnataka, and Bihar. The UIDAI also carried out the biometric enrolment of school children in the vicinity of Bangalore. About seventy five thousand people in all were enrolled during the first phase of the PoC study, and sixty thousand of the same people were re-enrolled during the second phase after a gap of three weeks.

Prior to conducting the UIDAI PoC, there was insufficient reliable biometric data available for residents of India that could be used to analyze and reach conclusions relevant to the implementation of the UID program. In addition, outside the state of Andhra Pradesh, there was no significant history of collecting iris images. In the last five years, iris image capture devices have gone through significant technological advances. There was however, limited data available from anywhere in the world regarding the ease of iris capture, as well as the usability of iris images in the case of minors. Therefore, the UIDAI felt it necessary to conduct Proof-of-Concept studies for biometric enrolment in several states, and analyze the data.

This report chronicles these Postludes. The report consists of a narrative of the activities, observations and conclusions based on numerous visits to the enrolment sites, and conclusions inferred through i) the statistical analysis of the processes and ii)by biometric analysis of the data collected during the studies.

In the study, face photos, iris images, and fingerprints of all ten fingers were captured. The ten fingerprints were captured in two different ways: first using a slap device, and then using a single finger device. Rural areas were emphasized in the study for two reasons. One was the uneven quality of fingerprints expected from rural workers whose fingerprints could be worn out by prolonged physical labour. The second was to test the UIDAI's ability to carry out biometric enrolment in locations representative of the majority of India's infrastructure, i.e. in areas with limited access to electrical power, proper lighting, and other support systems.

Objectives

The enrolment PoC was conducted to evaluate technical, operational, and behavioural hypotheses related to both the use of biometric devices and the overall enrolment process itself. It was also conducted to establish a baseline for the quality of biometric data that could be collected in rural India.

Technical objectives

i) Measure the biometric quality that could be achieved in rural Indian conditions

ii) Understand the difficulty challenges in capturing iris images,

iii) Determine suitable ergonomics in the use of the biometric devices, and understand the optimal overall layout of the enrolment station.

Operational objectives

i) Carry out a time and motion study through observation, as well as analysis of process data collected through the client software.

Behavioural objectives

i) Understand how people in rural India would respond to the capture of iris images. This was an important goal, since data on the experience of the public with iris capture devices is limited, compared to studies on fingerprint capture.

ii) Overall response of enrolees to the entire biometric capture process in the PoC needed to be understood

There were also more intangible lessons that would be directly applicable to the actual UID enrolment, since the PoC was designed to mimic UID enrolment. For instance, it was expected that the PoC experience would enable the UID team to tailor biometric enrolment best practices to be more applicable in Indian conditions.

Executive summary of outcome

1. The PoC successfully conducted over 135,000 biometric enrolments. The relative ease of conducting the operation confirmed that biometric enrolment conforming to UID standards of quality and process was indeed possible on a large scale in rural India. The total biometric enrolment time for each individual, on average, was a little over three minutes. Of this, iris enrolment took a little under a minute, and was not perceived to be excessively difficult either by the resident or the enrolling operator. Specifically, many blind people had their iris images captured (For details, see table Page 19)

2. Multiple fingerprint scanners as well as iris capture devices were used in the PoC, and they performed according to expectations. The PoC was dispersed geographically and included many rural, often remote locations across three states. The enrolment was typically conducted with minimal infrastructure and sometimes in extreme weather conditions. Enrolees varied in age all the way from four years to about ninety years of age.

3. Older people took longer to enrol than younger people, and enrolees whose employment involved manual work took longer to enrol than the rest of the PoC population. Older people needed more assistance from operators to capture of their

biometrics. However, the range of enrolment times observed was well within expectations and was not seen as making enrolment impractical.

4. The enrolment variations tested in the process led to the conclusion that the best process was one where the enrolee remained stationary during enrolment and the operator did the positioning of the devices.

5. The enrolment of children in the school showed that children in the age range of four to fifteen could be biometrically enrolled using the same process as that used for adults and with no additional difficulty. The match analysis also showed that their iris images and fingerprints could be deduplicated as accurately as those of adults.

6. The quality of the biometric capture was sensitive to the setup of the enrolment station and the process itself. Most importantly, the enrolment operator's instructions made a significant difference in the efficiency of the biometric capture.

7. The quality check process built into the enrolment software was very important and provided helpful feedback to the operator in capturing high quality images.

8. The biometric matching analysis of 40,000 people showed that the accuracy levels achieved using both iris and ten fingerprints were more than an order of magnitude better compared to using either of the two individually. The multi-modal enrolment was adequate to carry out deduplication on a much larger scale, with reasonable expectations of extending it to all residents of India.

Chronology of planning and execution

It was decided that the PoC would be done in three states: Andhra Pradesh, Karnataka, and Bihar. At least 20,000 sets of biometric data had to be collected in each state. To analyze the accuracy of biometric matching, the same set of biometric samples had to be collected again after a suitable time lag of three weeks. In order to ensure that the 20,000 sets of duplicate data could be collected, the initial enrolment target in each state was 25,000. This would allow for a minority of people not showing up for re-enrolment during the second round.

The regional offices of the UIDAI in conjunction with the technology team worked with the state governments to plan the PoC. In Andhra Pradesh and Karnataka, the Food &Civil Supplies department was designated the nodal agency for the PoC study. In Bihar, the PoC was done in conjunction with enrolment for the NREGS e-Shakti project.

Choice of locations

The following factors were considered while choosing locations for the PoC:

i) The enrolees at the PoC locations had to be representative of the Indian population in biometric quality. This meant that over eighty percent of the PoC locations

were rural, since the majority of India lives in villages. However, the remaining twenty percent of the PoC sites were urban locations close to large cities, in order to have urban areas well represented in the biometric samples collected.

ii) A further consideration was that the rural locations should be at least fifty kilometres away from the large metropolitan areas, such as Bangalore or Hyderabad. This was done since a sampling of closer locations showed that the working population of the villages close to metropolitan areas typically commuted to urban locations for work, and in general, the population was more representative of urban populations.

iii) The goal of the PoC was to collect data representative of India and not necessarily to find difficult-to-use biometrics. Therefore, extremely remote rural areas, often with populations specializing in certain types of work (tea plantation workers, areca nut growers, etc.) were not chosen. This ensured that degradation of biometrics characteristic of such narrow groups was not overrepresented in the sample data collected.

iv) For the three PoCs (apart from the school PoC), the goal was to enrol adults. In Karnataka and Bihar, only residents above 18 years were allowed to enrol. In Andhra Pradesh, adults were encouraged to enrol and very few minors actually enrolled.

The state nodal agencies in collaboration with the UID team and the enrolment agencies accordingly selected a set of locations to conduct the PoC. In Andhra Pradesh and Karnataka, two districts each were chosen for the PoC. In each district, five villages were selected for enrolling people. In Bihar, the villages scheduled for PoC enrolment was decided by the e-Shakti schedule.

The PoC was subsequently conducted in ten villages each in Karnataka and Andhra Pradesh, and in over thirty villages in Bihar. The choice of villages across states met our goal of geographic diversity since the PoC locations were widely dispersed

Within each village, the enrolment location selected was usually the local primary school or other public building (photos below). The enrolment agency brought computers, biometric devices and related equipment. In most areas, one or two power generators were also brought to provide reliable power for lighting and computers. The enrolment was carried out using locally available furniture.

PoC enrolment was also conducted in the Deputy Commissioners' offices in Mysore and Tumkur cities. Finally, PoC enrolment for school children between 4 years and 15 years was conducted in a Bangalore school. In Karnataka, the villages chosen were those with Gram Panchayat offices, i.e., larger villages. In Andhra Pradesh and in Bihar, this was not always so. The following is the list of PoC locations.

Bihar		
Gram Panchayat	**Revenue Villages**	**Block**
Bind	Bind (ward no 4 -14), Bind (Kusar, Bishunpurand& Nirachak)	Bind
Jahana	Jahana, Chatarpur, Rampur, Nirpur, Khalsa, & Nigraian	Bind
Jamsari	Barhog, Jamsari , & Dariapur	Bind
Katrahi	Katrahi , Jakki , Bakra, Makanpur, & Makanpur (Dhullahpur)	Bind
Lodipur	Lodipur, Jaitipur, Gajipur, Ibrahimpur	Bind
Onda	Onda	Asthawan
Tajnipur	Tajnipur, Mahmudabad, Madanchak, Rasalpur, Nauranga, & Rajopur	Bind
Utarthu	Utarthu, Masia, Ahiachak, Muftipur	Bind

Andhra Pradesh		
District	**Mandal**	**Village**
Medak	Tupran	Ghanpur
	Wargal	Wargal
	Wargal	Veluru
	Chegunta	Narsingi
	Patancheru	Ward-11
Krishna	Mylavaram	Velvadam
	Kruthivennu	Lakshmi puram
	Vijayawada Rural	Nidamanuru
	Penamaluru	Poranki
	(Urban)	Vijayawada Urban Ward 9

Karnataka		
District	**Taluk**	**Gram Panchayath or DC Office**
Tumkur	Tumkur	DC Office Staff
	Tumkur	Bellavi
	Gubbi	Chelur
	Madhugiri	Dodderi
	Tiptur	Kibbanahalli
	Sira	Bukkapatna
Mysore	Mysore	DC Office Staff
	Mysore	Varuna

	HD Kote	Hommaragalli
	Nanjangud	Hadinaaru
	Hunsur	Gowdagere
	KR Nagar	Tippuru
Bangalore	School (children PoC)	Poorna Prajna school

Figure 1 Typical PoC Enrolment location

Figure 2 Typical PoC Enrolment room

Biometric devices

Fingerprint scanners and iris capture devices from three different vendors were used in the three PoC states. In Karnataka, the iris devices were from Iris ID (formerly LG Iris) and the fingerprint devices were from Morpho (formerly Sagem). In Bihar, the fingerprint scanner and the iris capture device were both from Crossmatch Technologies. In Andhra Pradesh, the fingerprint scanner and iris capture devices were both from L-1 Identity solutions. In Andhra Pradesh, both a single-eye iris capture device and a two-eye iris capture device were used. The Crossmatch iris devices were binocular type, the L-1 iris devices were hand-held, and the Iris ID iris devices were mounted on tripods, but could also be used as hand-held devices. Using multiple devices added further to the diversity of the PoC process and later enabled us to match images captured using different devices.

Preparation of enrolment agency and software

Enrolment agencies who had already worked with the respective states on previous projects were chosen to implement the PoC by the respective state government agencies. The agencies were 4G ID solutions in Andhra Pradesh, Comat Technologies in Karnataka, and SmarTech Technologies (an arm of Glodyne) in Bihar. In parallel, biometric devices were procured for the PoC. The biometric devices procured were the following: iris capture devices, iris and face capture devices, slap fingerprint scanners, and single finger capture devices.

The enrolment agencies had varying levels of biometric enrolment experience. The UID technology group worked with each agency to ensure adequate training and prescribed the process flow to be followed.

A reference implementation of the enrolment software was created to standardize the process and have a uniform look-and-feel of the application across all three states. However, since the devices used were different in each state, the enrolment software used in each state was a custom version which followed the reference design. The UID technology team worked with each of the three agencies to create the customized software to be used in the corresponding state. There were also variations in the capture process followed, particularly in iris capture, because of the variations in capture devices.

A special feature of the enrolment software was that all biometric images went through a software quality check process. The quality check would indicate a pass or fail based on minimal acceptable quality of the image. If the quality check failed, the image would still be stored, but the operator would be required to recapture the image. The enrolment software entailed the operator to repeat the capture up to four times. The software ensured that the operator was not able to proceed to the next step until the recapture was done.

One important aspect of the enrolment software was the capture of process data along with biometric and demographic data. Thus the number of capture attempts and timestamps captured at numerous points in the capture process were written into an XML file during enrolment. This enabled us to eventually carry out a detailed analysis of the process.

Pre-enrolment field and data preparation

The initial step was to work with the local authorities to find possible enrolment locations and make preparations for getting people to show up. The local authorities typically went house-to-house to inform residents about the date and time they were to enrol. The authorities would also be present at the enrolment centre to ensure that people did show up, resolve any disputes among the enrolees and maintain order. The part played by the local authorities was consequently crucial to the success of the enrolment drive.

The enrolment agency supervisors visited the locations to identify the most suitable building for the enrolment centre, ahead of the start of the PoC. They also arranged for the right furniture among what was available in the building and set up the enrolment stations to meet the PoC needs. One important point was that the table should not be too wide and the heights of the operator, and size of the chairs for the enrolee should accommodate the biometric capture process.

Additionally, it was ensured that there was adequate space for people to wait outside since people crowding around the biometric stations would disturb the process. However, a few chairs were kept nearby for observers since it was felt that each resident observing the process before his or her enrolment would improve the person's ease of enrolment. Posters describing the biometric process (shown in photograph below) were also put up at the door of the enrolment centre to help enrolees familiarize themselves with the process.

In parallel, the demographic data of the residents of the local taluk or mandal was obtained from the food and civil supplies department and loaded into the appropriate laptops. Blank

forms were also kept at the enrolling centres to accommodate people who did not appear in the database, but wished to enrol.

Provisions were made for a bucket of water and towels for residents involved in manual work to clean their hands before enrolment. Also wet and dry clothes were kept at each enrolment station for assisting people with overly dry fingers.

Figure 3 Poster describing biometric capture for residents to observe

Figure 4 Enrolment stations

Figure 5 Enrolment station

Enrolment Process

The basic process and associated workflow enforced by the enrolment software is described below. There were minor variations in each state due to the different devices used and the differences in demographic data collection; these variations are listed subsequently.

1. The enrolee would arrive at the enrolling centre with an identifying card. The first station was a non-biometric station where the demographic information of the enrolee was either collected from the card or retrieved from an existing database. A form populated with the demographic information was then printed (or in some cases, forms were printed ahead of time) and any necessary corrections made. The demographic information collected was name, address, date of birth (or age), and occupation.
   During the second round of enrolment, the tear-off receipt (described in step 6) was used to identify the application number of the applicant.
   Following this the enrolee was sent to an available biometric enrolment station.

2. Using the application number from the application form or first round receipt, the enrolee's demographic record was populated in the enrolment screen. At this point, the operator would check for biometric exceptions (missing fingers or eyes) by asking the enrolee to show his/her hands. If there was an exception, it would be marked in the exception section of the screen, and the information would be stored in the XML file along with the demographic information.

3. Once the above process was completed, the biometric capture would start. The enrolee would first sit down facing the operator and the face photo would be captured by a webcam. The enrolment software would then perform a quality check and crop the image. If the quality check or image cropping failed, the photo would be recaptured up to a maximum of four total attempts. The cropped face photo would be shown on a small frame on the right and it would remain on display during the rest of the biometric capture (see Annexure 1 for screen shots).

   A white non-reflecting background screen was placed behind the enrolee's chair to provide a uniform background for face photo capture, and ensure that the background portion of the photo quality check was met. While capturing face photo, the enrolee was instructed to look straight and keep his or her mouth closed.

   During the second round of enrolment, the face photo from the first round of enrolment would appear on the application screen so that the operator could confirm that the same person whose biometrics had been captured in the first round was being re-enrolled. After confirming that the photo matched the enrolee, the operator would capture a new face photo which would be cropped, and replace the earlier photo on the screen. The photo would be stored along with the other biometrics in the second round database.

4. The iris images of the enrolee were captured with a single-eye or two-eye iris capture device. Based on the results of the quality check, the images would be recaptured for a maximum of four total attempts. While capturing iris image, the enrolee was instructed to look straight into the LEDs, rectangle or other appropriate point (depending on the device), open his or her eyes wide ("look angry or glare") and to not blink.

5. The three slap fingerprint images (4-4-2), i.e. left hand slap, right hand slap, and slap image of the two thumbs, were captured. As above, based on the results of the quality check, the capture would be attempted up to four times. The slap fingerprint capture was done with the enrolee standing. This was to ensure that the person could apply sufficient pressure to be able to get good fingerprints. While capturing fingerprint images, the enrolee was instructed to open their hands, place their fingers flat on the platen in the correct position and press their fingers down firmly.

6. Individual fingerprints of all ten fingers were captured using a single-finger capture device. The individual prints were matched with the corresponding prints from the segmented images of the slap fingerprint captured in step 4. If the fingerprints did not match, step 5 was repeated, while still not exceeding a total of four slap attempts for each type of slap capture. This capture was also done with the enrolee standing.

7. If one or more of the enrolee's fingers or eyes were missing, an exception photograph of the enrolee's face along with both hands opened to show the missing fingers would be captured. This was in order to have a visual record of the missing biometrics.

8. In the first round of enrolment, a tear-off receipt that was printed at the bottom of the application form was given to the enrolee, and the enrolee was asked to bring the tear-off receipt when returning for re-enrolment in the second round.

Figure 6 Damaged finger example

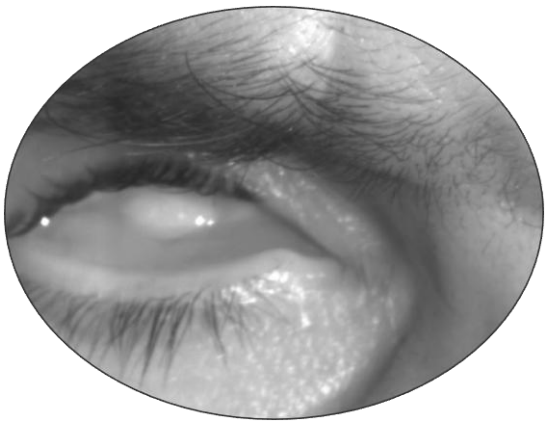


Figure 7 Damaged eye example

Process Variations

1. Identifying document of enrolee: The enrolee would come to the enrolling centre with his or her ration card in the case of Karnataka and Andhra Pradesh. In Bihar, the enrolee was asked to bring his or her job card. Neither of these cards would completely identify the individual since a single ration card listed all members of the family and each job card would list all adult members of the family. So, an additional digit was appended to the ration card or job card number to create an application number identifying the individual.

   Collection of demographic information: In Karnataka, a pre-printed form which had the relevant data for the enrolee was chosen from a stack containing forms for all residents of the village sorted by ration card number. This was handed to the enrolee. In Andhra Pradesh, a form containing the enrolee information was printed at the enrolment site and handed over to the enrolee. In Bihar, the enrolees were asked to fill in the form (if necessary, the enrolment agency employee filled the form for the enrolee) and the data was then entered into the application.

2. For iris capture, there were three variations in the three states:
   In Bihar, a binocular type iris capture device was used. Ideally, the enrolees would be able to hold the iris device to their eyes unassisted, and wait for the iris capture to complete. In practice, the operator sometimes helped hold the device up, particularly in the case of older enrolees.

   In Andhra Pradesh, the operator held the device. The enrolee would stand up and the operator would bring the capture device close to the enrolee's face and then move the device back slowly to capture the iris image. Both single eye devices and dual eye devices were used. Dual eye device were used for about 61.5 percent of the enrolments and the remaining were done used the single eye device.

   In Karnataka, a dual eye device was used and it was mounted on a tripod for a large part of the PoC. The resident would move his or her face slowly towards the device and the device would capture the iris image at the appropriate distance. A small portion of the PoC was done using the iris capture device as a hand-held device, where the operator moved the device towards the enrolee's eyes The PoC done later in the school in Karnataka also used the same dual eye device as a hand held device.

Figure 8: Karnataka- iris camera mounted on a tripod

Enrolment software

The enrolment software had the following screens (Annexure 1)

1. Demographic data and biometric exception capture
2. Face photo capture
3. Dual iris capture
4. Slap fingerprint capture – three slaps to capture all ten fingerprints
5. Capture of ten fingerprints using a single finger device
6. Capture of an exception photograph if necessary

The following are a few noteworthy points related to the enrolment software:

Once the face photo was captured and cropped, it was displayed on a small frame during the capture of all the other biometrics. This would allow the operator to avoid mistakes and avoid combining the biometrics of two different individuals in one enrolment if there was an interruption halfway through the enrolment process.

There were visual biometric quality indicators associated with each image, which the operator could use to quickly gauge image quality (Annexure 1). This was done to avoid the necessity for the operator to interpret quantitative scores.

The enrolment software would save time stamps during each screen transition, i.e. when moving from one of the screens (1 to 5) listed above to any of the other screens. This was used to measure the "process" time associated with the capture of each biometric. The time measured was not directly related to the time spent by the device to capture the image.

In the context of the UID, the time required for enrolment of each person was a very important factor since it directly translated into the resources needed. Therefore, it was important to record the overall "process" time related to the capture of each biometric and not only the device capture time. For instance, the time measured included the time spent by the operator giving instructions related to the biometric capture, the time spent in the enrolee positioning himself or herself for the specific biometric etc.

Thus, the measured times may not be applicable in a different context. In particular, when the enrolee is experienced in the process and if selfenrolment is done, the conclusions reached here would not be valid. Also, the measurement was not designed to measure device efficiency beyond the UID context.

The "process" timestamps and the number of attempts captured by the software allowed us to compute average capture times and the average number of capture attempts per biometric. In conjunction with the age and occupation captured in the demographic screen, we were also able to analyse the average capture time and average number of capture attempts by age and by occupation. This was important since there are several occupations where repeated rubbing and scratching of fingers result in worn out fingerprints.

Finally the software also indicated the number of fingers and eyes for which images could not be captured in each enrolment, because the corresponding finger or eye was missing or damaged. Even in these cases, the remaining biometrics were captured and the enrolment was completed successfully

Re-enrolment Rates

One of the important goals of the PoC was to create known duplicates by having each enrolee come back after three weeks to be re-enrolled. During the planning of the PoC, there was apprehension that a significant number of enrolees would not come back for re-enrolment. This was a source of concern particularly in Karnataka and Andhra Pradesh, where the PoC was not associated with any ongoing government benefits program and was a standalone experiment. Therefore, incentives were provided for enrolees to re-enrol. In Andhra Pradesh, and Bihar, each enrolee was given seventy rupees following re-enrolment. In Karnataka, a small snack was provided both during the first round and during the second round of enrolment. Despite these efforts, the conservative target rate of re-enrolment was set at eighty percent. Therefore twenty-five thousand people in each state were targeted in the first round to generate matched pair of twenty thousand after the second round. Actual re-enrolment rates were very good and the enrolment agencies were able to reach the targets without much difficulty.

The following are the actual re-enrolment rates observed.

Karnataka Re-enrolment Rates

	Taluk	Gram Panchayath	Enrolment numbers	Reenrolment numbers	Percentage reenrol ling
Tumkur	Tumkur	Bellavi	1,976	1,692	86 %
Tumkur	Gobi	Chelur	2,262	1,747	77 %
Tumkur	Madhugiri	Doddery	2,193	1,797	82 %
Tumkur	Tiptur	Kibbanahalli	2,548	2,171	85 %
Tumkur	Sira	Bukkapatna	2,267	1,615	71 %
Mysore	Mysore	Varuna	2,283	2,097	92 %
Mysore	HD Kote	Hommaragalli	2,698	2,510	93 %
Mysore	Nanjangud	Hadinaaru	1,908	1,659	87 %
Mysore	Hunsur	Gowdagere	2,728	2,454	90 %
Mysore	KR Nagar	Tippuru	2,754	2,331	85 %
		Karnataka Total	23,859	20,073	84 %

Andhra Pradesh Re-enrolment Rates

District	Mandal	Village	Enrolment numbers	Reenrolment numbers	Percentage re-enroling
Medak	Tupran	Ghanpur	2000	1819	91 %
	Wargal	Wargal	2435	2123	87 %
	Wargal	Veluru	2095	1978	94 %
	Chegunta	Narsingi	2756	2539	92 %
	Patancheru	Ward-11	2602	1187	46 %
Krishna	Mylavaram	Velvadam	2826	2477	88 %
	Kruthivennu	Lakshmi puram	2481	2169	87 %
	Vijayawada Rural	Nidamanuru	3031	2659	88 %
	Penamaluru	Poranki	3114	2532	81 %
	Vijaywada Urban	Ward 9	2377	1200	50 %
		AP Total	25717	20683	80 %

Observations

The following are the observed average capture times and number of attempts

		Face photo	Iris	Slap Fingerprints (three images)
Adults	Capture times (for all attempts combined)	34 seconds	52 seconds	1 minute 51 seconds
Adults	Number of attempts	1.5	1.9	1.5
Children (4 to 15 years)	Capture times (for all attempts combined)	33 seconds	35 seconds	1 minute 13 seconds
Children (4 to 15 years)	Number of attempts	1.4	3.1	1.4

The important process time averages are as shown below:

Average biometric enrolment time for adults is 3 minutes 17 seconds

Average biometric enrolment time for children (4 to 15 years) is 2 minutes 21 seconds

Capture times analyzed by age, occupation, and gender are listed in Annexure 2

	Percentage of enrolees
One or more fingers missing or otherwise not capturable	1.2 %
Either or both eyes missing or otherwise not capturable	0.5 %
Missing all 10 finger and both eyes	0.01 %

Table: Biometric Exceptions (missing eyes and fingers)

The average time required for capture of face photo, fingerprints of ten fingers and iris image of adults was three minutes and seventeen seconds. Of this, a little over half the time was spent on fingerprint capture. The time for iris capture was a little below one minute, and face photo capture took over half a minute. The iris image capture time varied significantly by age, with people above eighty taking twice as long as people in their twenties. The variation in capture time of fingerprints was lower with the older group taking twenty percent longer than the younger group. One apparent anomaly in fingerprint capture times is that 20 to 30 year old people took longer to have their fingerprint captured than older people. This can possibly be attributed to the fact that they may be engaged in occupations involving heavier physical labour and correspondingly more wear on their fingerprints than their older

counterparts. The average capture time for iris images and fingerprints for children were no worse than that for adults. This included the youngest children who were only four years old.

The enrolment time also showed significant variation by occupation, with the occupations involving physical labour showing longer enrolment times. For example, agricultural labourers took about one-third longer to have their fingerprints captured compared with public and private sector employees and other white collar workers. Similarly, for iris capture, the variation was over thirty percent.

There were many blind people who had their iris captured successfully. This was because even though they were blind, their iris was intact. Similarly, many people with worn fingerprints had their fingerprints successfully captured. The table above shows that the percentage of residents enrolled with one or more missing fingers was only a little over one percent and the percentage of enrolees with one or both eyes missing was less than one percent of the total enrolee population.

The enrolment PoC for children showed that the process of enrolling children in the age range of four to fifteen was not significantly harder than that of enrolling adults.

Process observations

An important conclusion reached was that the best possible way for conducting biometric enrolment was to have the enrolee be stationary and have the operator do the positioning of the device.

It was also clear that the operator instructions to the resident were very important. The best results obtained in terms of quality and efficiency was when the operator spent a few seconds *ahead of* each biometric capture clearly explaining what was required on the part of the enrolee, for example “keep eyes wide open”, “keep fingers flat on the platen and press hard”, etc. This was much more effective than trying to correct the enrolee’s gaze, positioning etc. *during* the capture of the biometric.

The use of quality check software clearly helped in two ways. The first was that there was a clear message that quality of data collected mattered to the UIDAI and that the quality was going to be monitored. The second was that the operator began to recognize good quality images and over time was well versed in collecting high quality images.

The physical layout of the devices and the ability of the operator to reach out and help the enrolee as required were also seen to be important. Therefore the width of the table had to be small enough so that the operator could reach across. The other option was that the enrolee stood next to the operator on the right side for fingerprint capture.

The ambient light was not always sufficient to capture good quality face photographs even during the day. Table lamps or other artificial lighting was often needed.

The mobile USB tethered iris devices used were adequate for capturing good quality images. In addition, fingerprint images from different devices were matched and there were no

compatibility issues in doing the matching. In general, the devices worked as expected. The differences in process were much more significant compared to the differences in devices.

Iris enrolment was eminently possible from the operator's perspective and was also well accepted by the enrolee. In fact, the iris capture took less time than fingerprint capture.

Older people sometimes needed assistance in positioning themselves (see picture below) and often required assistance in pressing their fingers hard enough on the platen to get good fingerprints. Children were able to position themselves correctly and maintain the position long enough for successful capture of all three biometrics.

The PoC was conducted in the summer months of April, May and June in Medak district of Andhra Pradesh and in Nalanda district in Bihar. During a few days when the PoC was in progress, the temperature reached 44 degrees Celsius in Nalanda district. Despite the extreme temperature and the fact that no fans were available, enrolment went on normally.

In conclusion, it is clear that it is possible to collect good quality biometrics in rural India despite existing shortages in infrastructure, and the biometric variations within the rural population. Reasonable processes can be specified to undertake enrolment on a much larger scale

Figure 9: Older resident being assisted with slap fingerprint capture

Figure 10: Eighty six year old resident being assisted with iris capture

Biometric observations

The ultimate goals of biometric enrolment for the UIDAI are two-fold. One is to carry out biometric deduplication for all enrolees in India, and the second is to authenticate the biometrics of an enrolled resident on demand. Therefore, these activities have been the focus of the analysis conducted on the PoC data.

Biometric matchability analysis was done on the PoC data to understand the quality of the data and how well it could be used for deduplication and authentication. The basic tool used to study the results is the ROC (Receiver Operational Curve) which shows how two types of potential errors can be traded off against each other for the given set of data. Two of the ROC curves that were obtained from the analysis are shown in Annexure 3 to show a sample of the analysis and to explain the results. The analysis was done using images of ten fingerprints and two irises. The face biometric was not used for matching.

Terminology

The following terminology is needed to understand the results.

Identification: This is the process where any one person's biometrics is matched with that of *all* the other people in the database. This results in establishing the enrolee's biometrics as either unique or as a likely duplicate of the biometrics of an enrolee who had enrolled earlier.

FPIR: False Positive Identification Rate: This is the likelihood that a person's biometrics is seen as a duplicate (i.e., the biometric deduplication software identifies his biometrics as matching with that of a different person), even though it is not a duplicate in reality.

FNIR: False Negative Identification Rate: This is the likelihood that a person enrols a second time and the deduplication software is unable to identify their biometrics as a duplicate set.

Verification: This is the process where a person's biometrics is compared only with a copy of his or her biometrics that was captured earlier.

FAR: False Accept Rate: This is the likelihood that a person's biometrics is matched against a different person and the biometrics is seen to match, i.e. the person is wrongly seen to be a different person.

FRR: False Reject Rate: This is the likelihood that a person's biometrics does not match against an earlier sample of his or her biometrics and so he or she is not recognized as the same person.

Results

The matching analysis was done on two sets of 20,000 biometrics, for a total of 40,000. However, the number of comparisons was several orders of magnitude more than 40,000, since each set of fingerprints would be matched against every other set of fingerprints in the data set. Similarly, the iris images from each person would be matched against that of every other person in the data set. Therefore, the results are statistically significant and can be extended to larger populations.

We will now compile the data on the accuracy obtained by enrolling with only fingerprints, enrolling with only iris images, and by enrolling with both biometrics. We will do so using the Identification ROC curve shown in Appendix 3. To compare the accuracies in these three cases, we will look at the point where the FPIR (i.e. the possibility that a person is mistaken to be a different person) is 0.0025 %.

Comparing the FNIR numbers achieved, the FNIR using two irises only is 0.5%, that achieved by using ten fingers only is 0.25%, and that achieved by using ten fingers and two irises is 0.01%. The conclusion we can draw is that accuracy achievable using ten fingerprints is twice that of the accuracy achieved using iris images. Even more important, the accuracy achieved by using ten fingerprints and two irises is fifty times better than by using irises alone and twenty five times better than by using fingerprints alone. The accuracy level achieved was 99.99% in this case.

Looking at the verification ROC for children and adults, we can see that the accuracy obtained in matching for children using iris is better than that for adults. Similarly, the accuracy obtained using fingerprints is better for children than for adults..

By doing analysis as shown in the examples above on real data captured under typical Indian conditions in rural India, we can be confident that biometric matching can be used on a wider

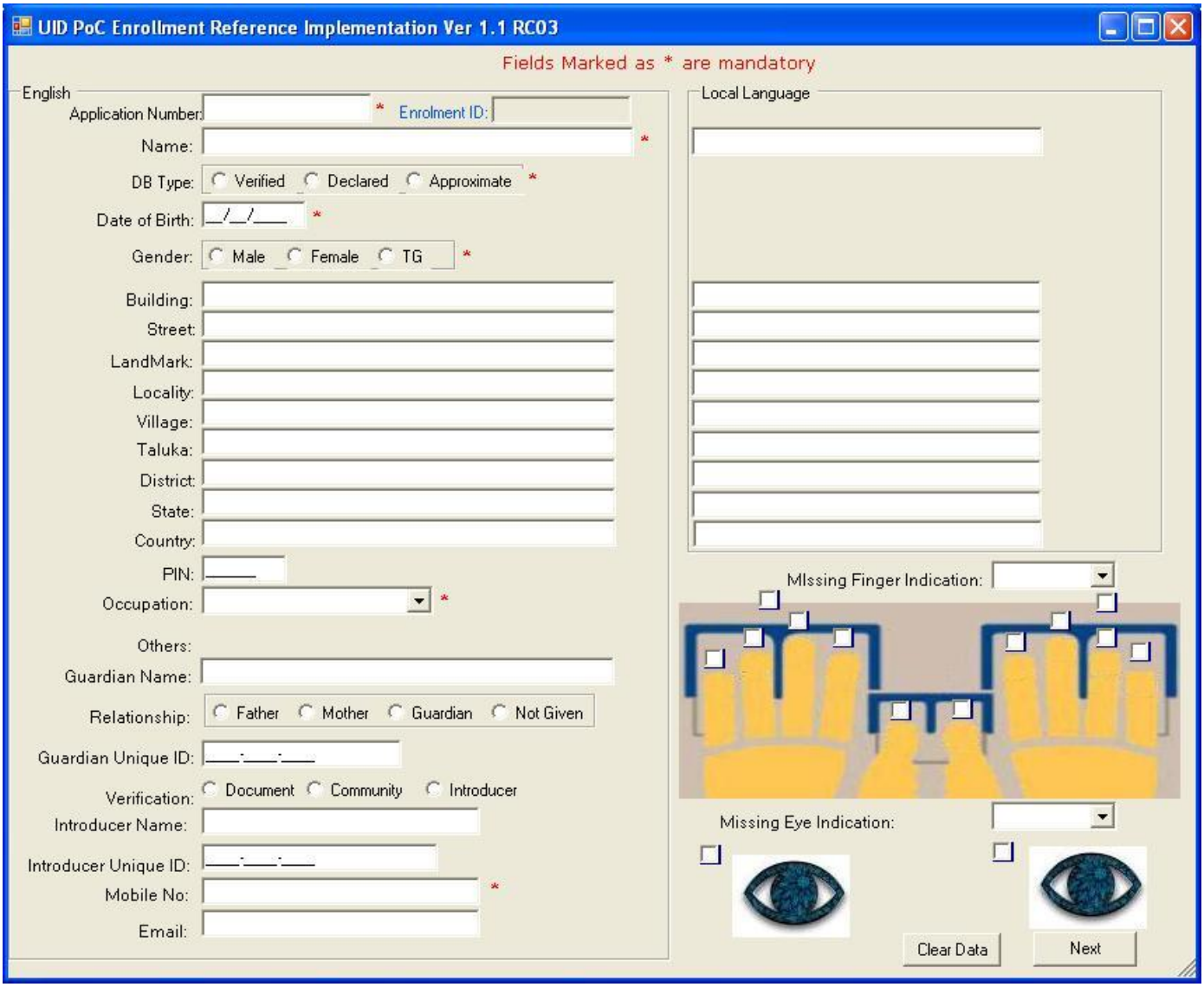
scale to realize the goal of creating unique identities. We have further confirmed that is true as much for children as for adults.

Conclusion

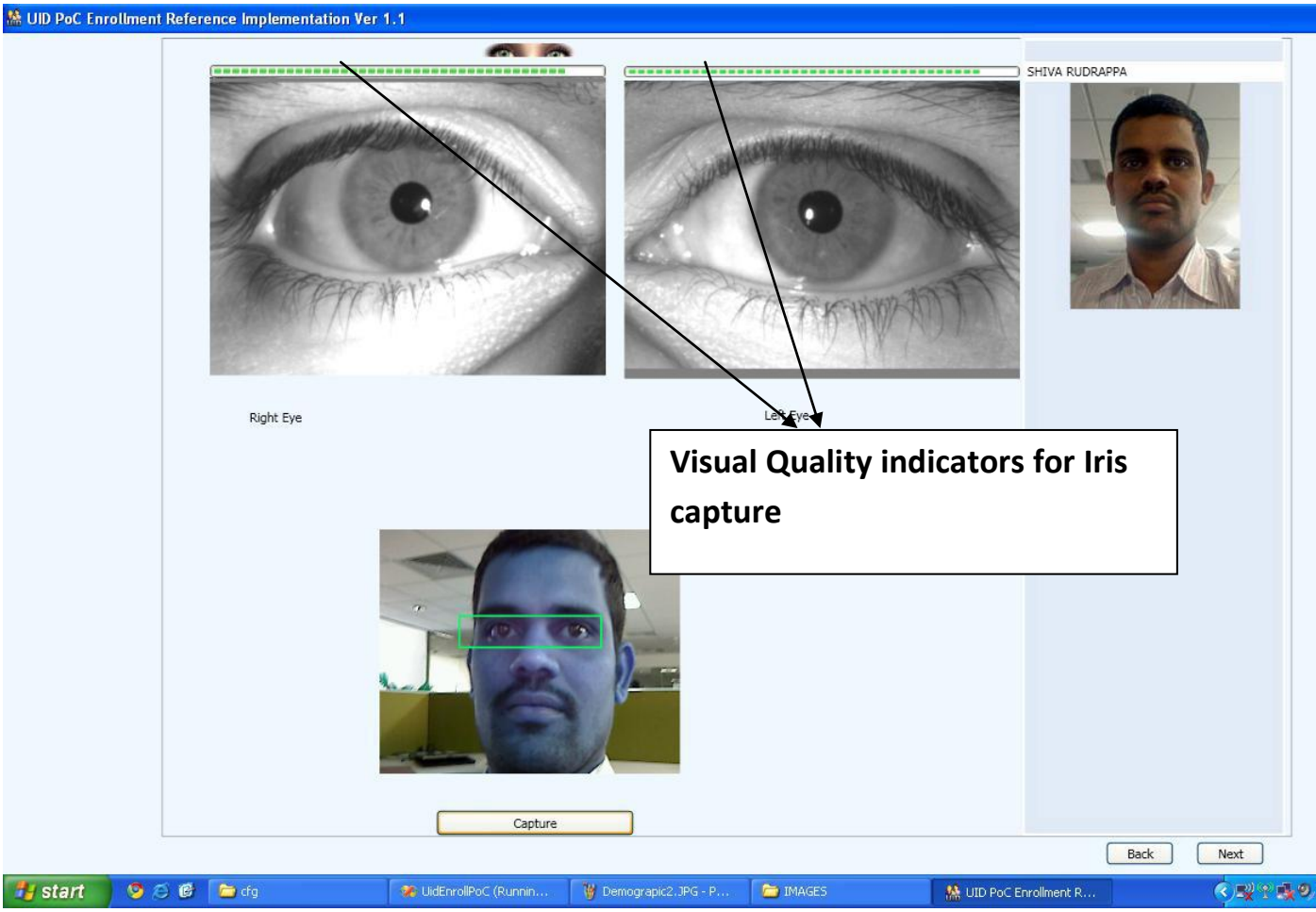
The PoC study was a useful precursor to large scale UID enrolment and has validated our hypotheses regarding biometric enrolment. Iris enrolment was not particularly difficult, and dramatically improved the accuracy levels that could be achieved. The biometric accuracy levels necessary for deduplication of all residents of India are achievable. The time needed for capture of biometrics in typical rural conditions is small enough to support large scale enrolment. In conclusion, the PoC study was a productive part of the ongoing rollout of the UID program.

Annexure 1 - Enrolment application screen shots

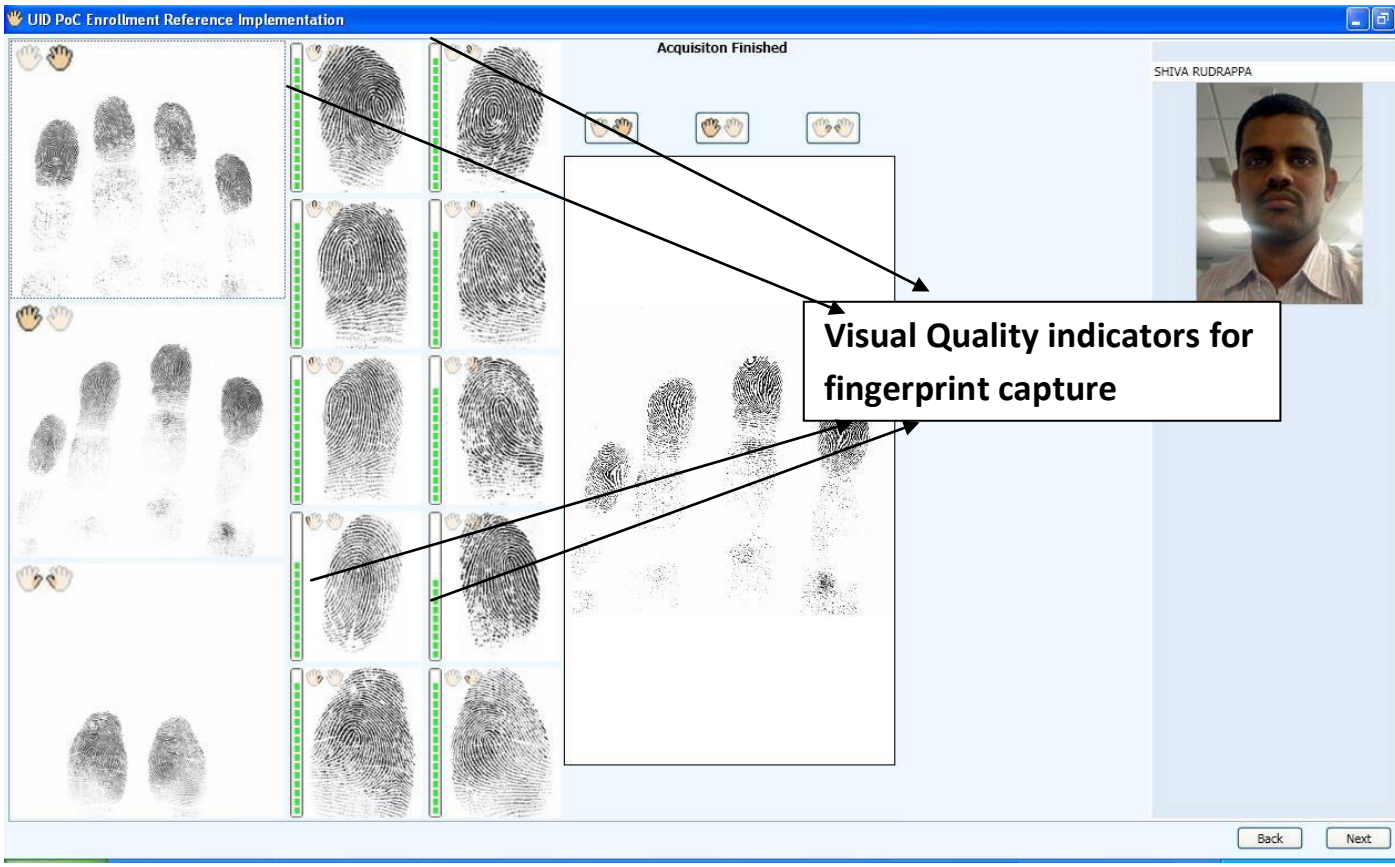
Demographic screen with exception indicators



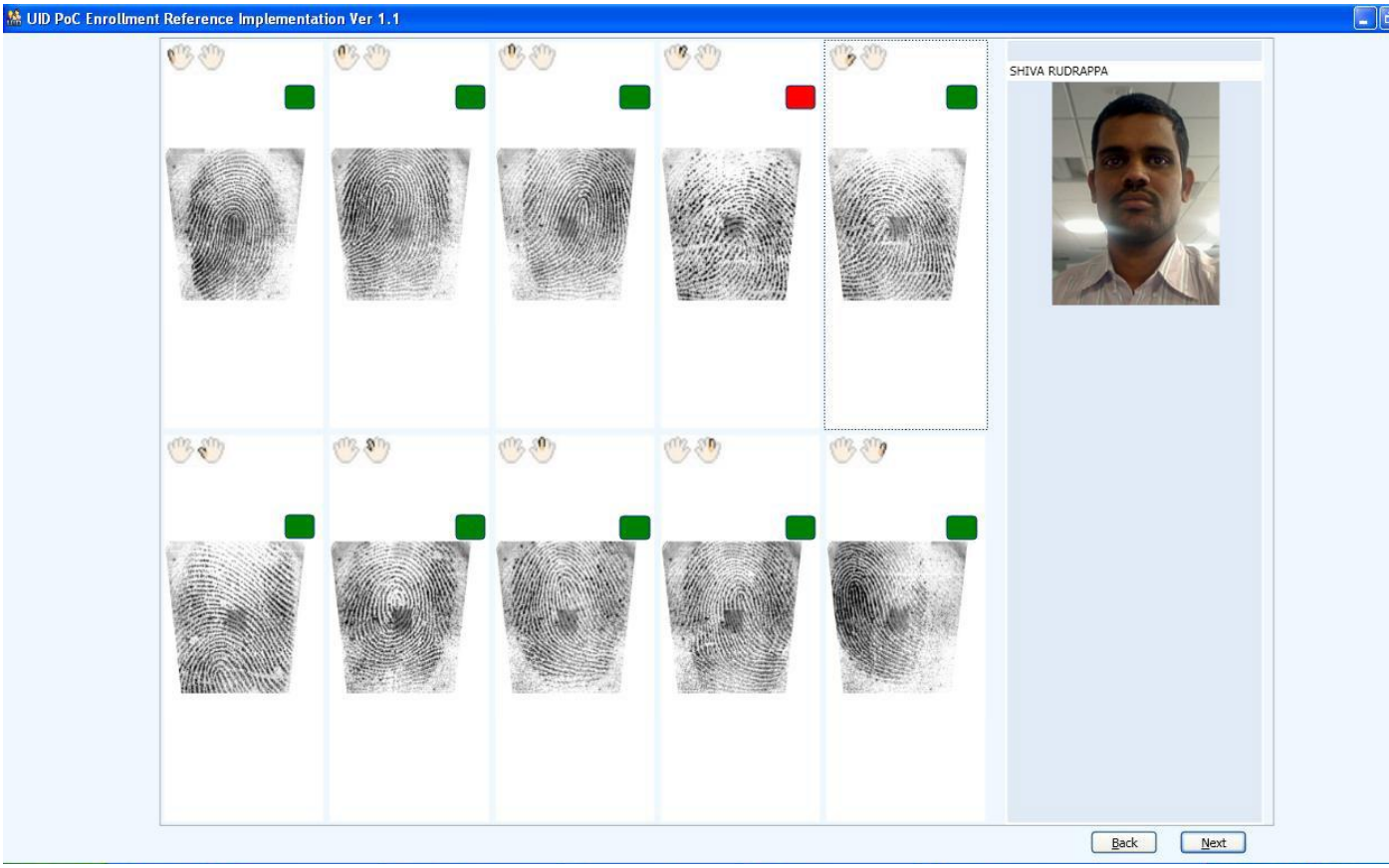
Iris Capture Screen with quality indicators highlighted



Fingerprint Capture Screen with quality indicators highlighted



Single Fingerprint Capture Screen



Annexure 2 – Enrolment times by age and demographics

Age	Under 20	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80	Above 80
Face	0:00:31	0:00:31	0:00:33	0:00:35	0:00:37	0:00:38	0:00:40	0:00:45
Iris	0:00:42	0:00:42	0:00:49	0:00:54	0:00:58	0:01:07	0:01:15	0:01:24
Fingerprint	0:01:45	0:01:52	0:01:43	0:01:45	0:01:53	0:01:56	0:02:08	0:02:14

Enrolment times by age

Occupation	face	iris	slap	Total
Agriculture Labour	0:00:27	0:00:53	0:02:11	0:03:31
Employee	0:00:27	0:00:39	0:01:36	0:02:43
Daily wage earner	0:00:25	0:00:46	0:02:03	0:03:14
Student	0:00:22	0:00:37	0:01:49	0:02:49
House Wife	0:00:27	0:00:59	0:02:04	0:03:29
Coolie	0:00:55	0:00:48	0:01:28	0:03:11
Farmer	0:00:43	0:00:51	0:01:41	0:03:15
Beedi Worker	0:00:21	0:00:44	0:02:57	0:04:02
Artisan	0:00:22	0:00:42	0:03:20	0:04:24
Driver	0:00:33	0:00:39	0:01:52	0:03:04
Other	0:00:27	0:00:44	0:02:16	0:03:27
Retired	0:00:28	0:01:40	0:02:08	0:04:16
Rickshaw Puller	0:00:24	0:00:37	0:01:34	0:02:35

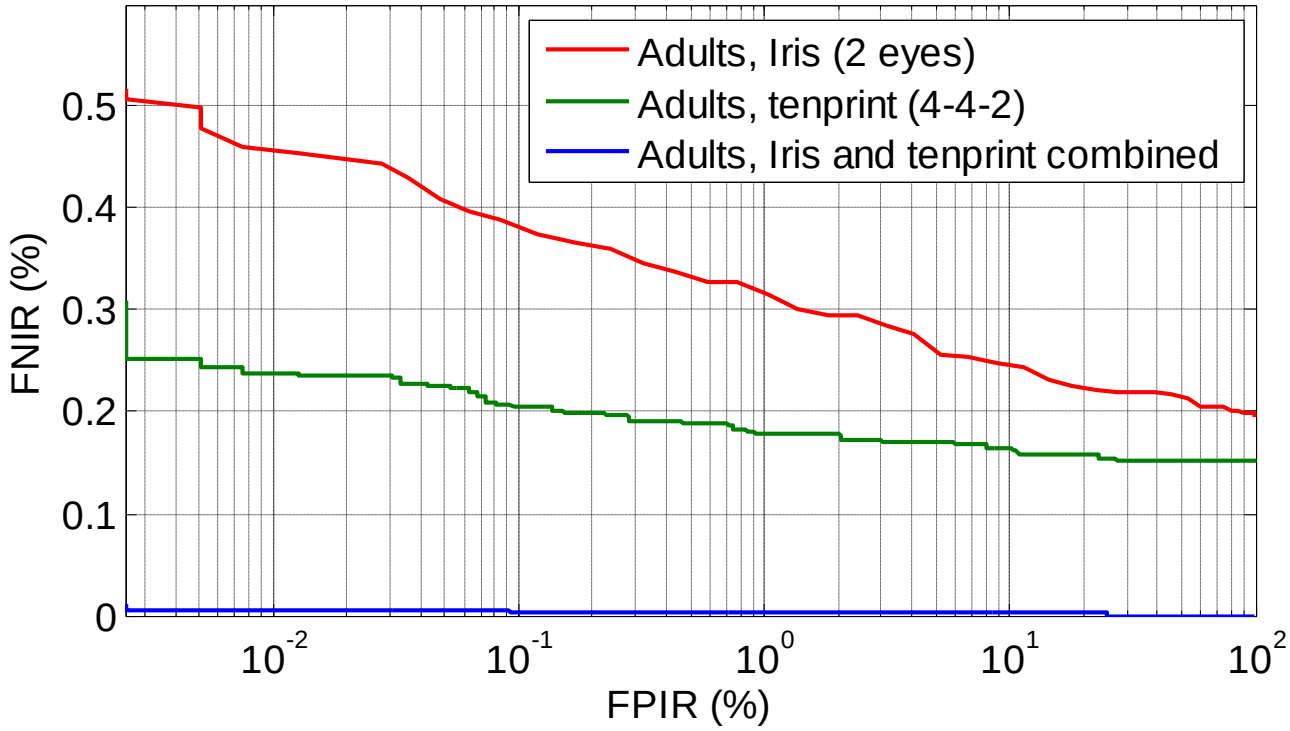
Enrolment times by occupation

	face	iris	slap	total
Male	0:00:30	0:00:48	0:01:50	0:03:08
Female	0:00:27	0:00:56	0:02:09	0:03:32

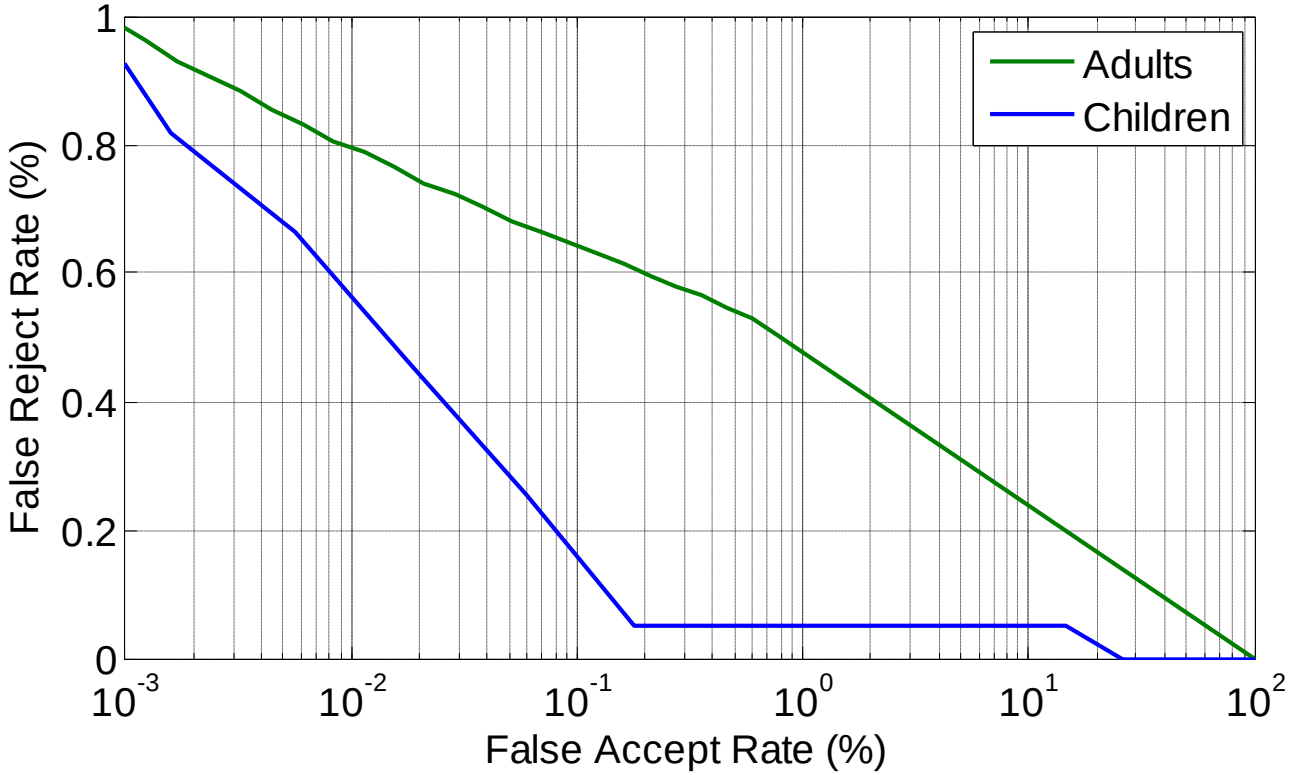
Enrolment times by gender

Annexure 3 – Biometric matching accuracy curves

Identification ROCs(1 in 20,000) for adults



Iris identification ROCs (1:1) for adults and children



Verification ROC for 1,000 children and adults