India boldly takes biometrics where no country has gone before

by Raj Mashruwala

Earlier this year, the Unique Identification Authority of India (UIDAI) published a drab looking report titled, "*Role of Biometric Technology in Aadhaar Enrolment*"[i]. It appeared like yet-another white paper written by a consultant to satisfy a contractual requirement.

It was anything but that...

In the report, UIDAI announced that it had created the world's largest biometric system:

- 36,000 active enrollment stations;
- 120 million resident multimodal gallery; and
- 1 million identifications per day.

Unlike other programs, it reported its performance: Failure-to-enroll rate of 0.14%, False reject rate (FPIR) of 0.057% and false accept rate (FNIR) of 0.035%. Elsewhere it provided end-to-end cost estimates at US$3 per person for enrollment, processing and delivery of the letter – approximately 1/10 of the cost projected by the pundits.

The biometrics industry paused and pondered. Was it not just over a year ago that UIDAI opened its door for business?

BHAG – Big Hairy Audacious Goal

UIDAI came into existence with bold pronouncements.

- *Provide identity proof to India's 1.2B people, a large number of whom possess no documents whatsoever.*
- *Use biometrics as the basis for identification when 70% of population is involved in manual labor.*
- *Offer real time ubiquitous mobile network based biometric verification service. No card will be issued.*
- *Open door for business in 12-18 months and enroll 600M in 4 years.*

Under a democratic parliament where no single party holds majority.

The project, created on a war footing, went through three phases rapidly before opening its door.

Time Frame	Duration (mo.)	Tasks
Jul – Dec 2009	6	Establish biometric standards Analyze biometric quality in Indian context Decide on biometric modalities to capture
Jan – July 2010	6	Test process on a sample of 75K people Estimate achievable accuracy
Apr – Sep 2010	6	Design, develop and install the system Announce “Open for business”
Oct ’10 – Present	16	Scale and tune the system Enroll 150M with sustainable peak rate of 1M/day

By any yardstick, the achievements are spectacular. It hit biometric quality and quantity in record speed. Its success can be attributed to four primary biometric decisions.

Decision I: Use of two biometric modalities

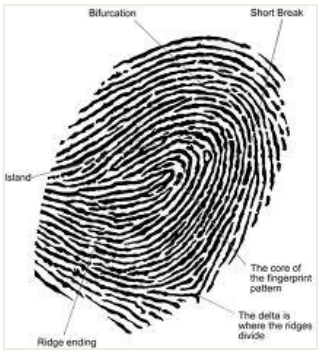
Decision II: Use of multiple parallel ABIS

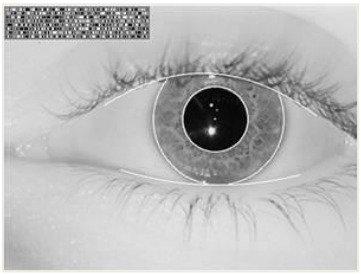
Decision III: Quality Paranoia

Decision IV: Extreme decoupling

I. Two Biometric Modalities

The UID system uses ten fingerprints and two iris images for identification. It will accept a minimum of one fingerprint or iris image for verification. Both modalities are treated equally and identically in the system.





Few have understood the true impact of the iris decision. NIST reports FPIR rate of ten-finger identification to be between 1.5 to 3.5%[ii] on a gallery size of approximately one million. UIDAI reports FPIR rate of 0.057% over a gallery size of 100 million. This is a 50 times accuracy improvement in a 100 times larger database. There is

another way of looking at the impact. UIDAI reports 2.9% of people have biometrically poor quality fingerprints but only 0.23% have biometrically poor quality fingerprints and iris. Since accuracy deteriorates precipitously even with a small number of poor quality images, an overall ten-fold reduction in poor quality enrollments is the root cause for exceptional FPIR and FNIR rates. A third metric would reinforce this point. It is not uncommon in the literature to see estimations of 1 to 5% failure to enroll (FTE) fingerprint rate. UIDAI reports FTE rate of 0.14%, another 10X improvement.

Iris has also helped in "fraud" and unintentional error detection. Reviewing UIDAI results, it appears that 40% of correctly found duplicates had more than one person's biometrics. These duplicates are about 0.2% (or 2,000/day) of the enrollment, a very significant number. They were easier to detect and eliminate because multi-modal gives higher confidence levels for detecting duplicates.

Whichever way performance is measured, iris capture has improved the system 10 to 1000 times[iii]. It is simple to verify the scale of the improvement using a back of the envelope calculation. We know that iris and fingerprint are two completely independent modalities[iv]. If they are combined (i.e., AND operation), the resulting FNIR is the multiplication of the individual FNIRs. For example, if FNIR for FP and iris were 1 in 1,000 (0.1%), the combined FNIR would be 1 in 1,000,000 (0.0001%). Multi-modal systems thus get a much larger flexibility to trade off FPIR and FNIR and arrive at an operating point that is several orders of magnitude better than single mode system.

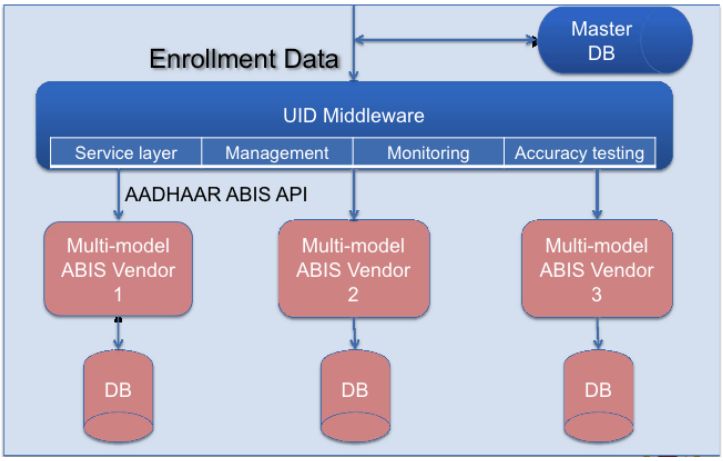
In this author's opinion, the iris decision alone turned the UID system into a roaring biometrics success and averted a potentially catastrophic failure. In hindsight, academics had quantified increased performance of two independent modalities over one modality a long time ago. The UIDAI results should not come as a surprise to them. The author believes that the industry, specifically the buyers and their consultants, were too cautious in the past and waited for someone else to take lead. Then came a newcomer, some would say a naïve UIDAI, and went with the academics' predictions.

Whatever the historical reasons for slow adaptation of multiple modalities, it is truly gratifying to see Indonesia and Mexico, two of the larger developing countries using the same approach in their national ID project. Let us hope others too will follow this now "not so new" approach.

II. Multi-ABIS

An uncommon feature of a UID system is the use of three Automated Biometric Identification Systems (ABIS). While multi-modal identification was clearly discussed in the literature and was on a road map for the FBI's NGI system, the industry was barely trying to get out of clutches of a single proprietary ABIS system. The ability to switch from one ABIS to another was considered a holy grail of interoperability and standardization. UIDAI's decision to use three ABIS initially and allow dynamic replacement of ABIS was received with incredulous stares by the industry.

A schematic shown below indicates the multi-ABIS configuration. In such a model, each ABIS maintains its own version of the entire gallery and is unaware of the existence of the other ABIS. A new enrollment is sent to one or more ABIS for identification. This could be done in parallel so the UID middleware could combine the results or it could be in sequence so the result of one ABIS could be independently verified by the other ABIS.



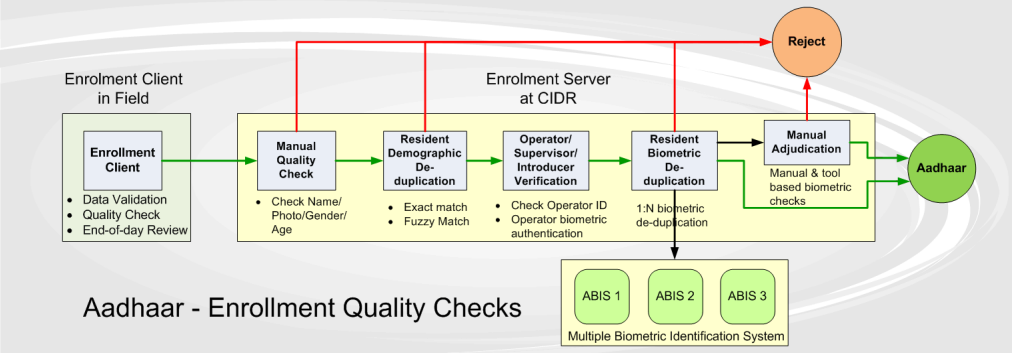
Once in place, which certainly was not an easy task, multiple ABIS provided a number of extremely useful benefits:

1. Continuous improvement and financial incentive: It provided a natural way to maintain competition. UIDAI would reward better performing vendors with more business.
2. Validation. One could test the results of one ABIS against another two. In traditional systems, system testing was a tedious and error prone activity. Now system testing can be nearly automated. Only results that are unusually abnormal need to be checked for manual ground truth. More importantly, these validation tests can be run at any time even in production[v].
3. Improved accuracy. Every "hit" or suspected duplicate can be checked by submitting the same data to other ABIS. False reject rate could be reduced by an order of magnitude. The adjudication process could become semi-automated, resulting in a lesser number of cases to resolve manually.
4. Special handling. Over time, it is possible to understand the strength and weakness of each ABIS. One could be better at handling poor quality FP while other at handling juveniles. The middleware could route the record to the ABIS that is best at handling such cases.
5. Real time calculation of FPIR. Every duplicate detected by any of the ABIS is eventually turned into "ground truth" and can be submitted to other ABIS as a probe. Thus, one can calculate the FPIR rate of the production system using production data, a unique byproduct of the design. The author believes that the use of 4 million probes by UIDAI in the test was generated in this manner.

III. Quality Paranoia

The UID system is almost paranoid about quality. It seems to check quality at every possible point using different and independent algorithms. For example, each ABIS is expected to perform segmentation and quality checks although both were performed during the capture and is available to the ABIS. In the author's opinion, this approach can only help improve quality in a country where

the value of quality is not always appreciated.



IV. Extreme de-coupling

In today's world, the use of standards and open source is a baseline for any good architecture. Open source and standards are necessary but not sufficient for good modular design. UIDAI's approach seemed to again adopt a purist model. It has used standards – the entire stack of ISO biometric data formats including CBEFF. It also uses open source of almost every kind: Linux, MySQL, Apache Hadoop, Rabbit MQ, Drools to name a few. Public APIs exist not only for external components but even for internally developed components. It is common to have APIs for external interfaces such as (a) device interface, called VDM in UIDAI's parlance (b) ABIS API for integration with the three ABIS and (c) Authentication API for authentication client. By completely decoupling biometric sensors, UIDAI was able to use nearly a dozen makes in a completely plug and play manner. Financially, it generated intense price competition. The author estimates that sensor prices fell by 75% in the course of 16 months.

In addition there is more fascinating modularity. For example, the enrollment system is completely separate from the authentication system, although both are to be managed and operated in logically centralized manner. The templates generated by ABIS are not used for authentication. The Authentication system generates its own templates in ISO format.

The quality metrics used during enrollment are available for identification but not relied upon. ABIS are encouraged to compute their own. Similarly segmentation information from the enrollment client is available but ABIS cannot rely on its correctness. The system assumes that a different client might send data in the future.

In biometric design, we have normally observed tight coupling: use of only two types of devices, or only one quality check, which, when cleared, means the data is assumed to be of good quality. UIDAI takes the opposite approach and assumes that each component must be self-reliant.

Conclusions

What lessons can the industry learn?

A. **Innovation:** Innovation implies venturing into areas never tried before. UID's experience clearly validates this. Automated biometric recognition is still a nascent field with less than 20 years of history. Small innovation results in large improvements. The biometric user community ought to put a larger emphasis on innovation.
B. **Adoption:** Now that the system – multi-ABIS, multi-modal, multi-sensor, open source – has been validated in one of the largest biometric system implementations, others should be more forthcoming in its adoption.
C. **Design authority:** ID projects normally hire a SI that helps put together the remaining eco-system. UIDAI did not follow approach. Instead, it created a small team of technologists under its umbrella. This group designed, developed and built the eco-system. The author believes that employees are more likely to embrace new ideas and venture into uncharted territory compared to a hired SI. One can outsource construction, but should not outsource thinking.
D. **UIDAI's Role:** We hope UIDAI takes up its role as the leader in large-scale biometric systems. It needs to mentor others, share the vast experience it is garnering and behave as a biometric industry leader.

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[i] http://uidai.gov.in/images/FrontPageUpdates/role_of_biometric_technology_in_aadhaar_jan21_2012.pdf. Images and schematic of UID system are from various public UIDAI documents.

[ii] NISTIR 7112, Studies of Plain-to-Rolled Fingerprint Matching Using the NIST Algorithmic Test Bed (ATB)

[iii] One should always be careful in comparing measurements from two different systems operated under different conditions. These comparisons should be taken as an indicative sense of magnitude. For example, it is hard to determine if NIST to UIDAI FPIR improvement is 50, 500 or 5,000 times but still safe to conclude that improvement is of several orders of magnitude.

[iv] In case of multiple fingers, there is a higher level of correlation or information overlap among them. The accuracy improvement beyond about 5 fingers is marginal. In case of iris, two iris' have been shown to be non-correlated.

[v] There is a provision for deleting records from the gallery. So after the test, one could simply delete test records.