

Project Completion Report

A. Project title: Automatic Personal Identification Biometrics System (APIBS) for Large Scale Applications

B. Project Summary

In this project, a scalable solution of personal identification for large scale applications named Automatic Personal Identification Biometrics System (APIBS) has been developed. For identification, APIBS uses two biometrics; fingerprints and human iris. The system is a software/hardware distributed modular and scalable design specifically designed for large scale applications. It can efficiently handle a database of millions of registered persons. Following are some of the salient features of the developed system.

- It has a Client-Server architecture where server can handle virtually unlimited number of client stations and a database of 10's of Millions of entries. The biometric matching is performed online with the whole database at a time.
- The system is capable of performing the tasks of Enrollment, Identification, Modification and Reporting. In Enrollment, a new subject is enrolled (registered) into the database. 10 fingerprints and two iris scans of each person is acquired and saved into the database with personal information. In Identification, depending on the mode, fingerprint and/or iris images are first acquired and after pre-processing and feature extraction, a biometric code (template) is generated against the image. It is then matched in the central server with all the already enrolled templates from the database. The Modification process is used to modify the data of subjects already enrolled into the system by generating modification requests to the Central office for further processing. By invoking a Reporting request an officer at the client office can view reports regarding server queuing status and results of the identification requests.
- Four modes of identification are supported namely, (i) identification based on iris images only, (ii) identification based on fingerprint images acquired in a controlled environment, (iii) identification based on both fingerprint and Iris images, and finally (iv) identification based on fingerprint images acquired in an uncontrolled environment.
- The Client side is responsible for all user interactions with the system and is implemented in Visual Studio 2008 .Net. The Server application is platform independent as it is implemented in JAVA. In addition to Database Management System (DMS) it also communicates with various clients and performs prioritized queuing of requests and related data sent through web services. The server also controlling the FPGA based matching unit though PCI-Express interface.
- Hardware matching accelerator, is implemented on FPGA (Vertex V LX110T) board. It ensures very fast matching of the query template to all the gallery templates from existing data to identify a person in real time.

The algorithms for fingerprint and iris recognition are specifically designed to be accurate enough to be used in large scale application and implementable on FPGA based hardware accelerators in real time.

The scope of work included algorithm development, code optimization, hardware development, integrated system design and implementation and finally database management & host application development. The project was divided into five phases defined as follows:

- Phase-1: Project Setup, Research and Planning
- Phase-2: Algorithm Finalization, Optimization and Hardware Procurement

- Phase-3: Hardware Development, Software Application Development
- Phase-4: Integration & Prototype Development
- Phase-5: Performance Evaluation, Gap Analysis and Tuning

The first four phases were successfully completed within the prescribed time. However the last deliverable took extra time.

The project was executed by a dedicated development team of experienced and young engineers & researchers either affiliated with Muhammad Ali Jinnah University or hired specifically for the project. The developed team was divided into four sub teams of algorithm development & implementation, software application development, Hardware & system development & the QA team. The development team for the project consisted of total 13 technical resources and 2 supporting staff. The 14 technical members included PD, JPD, 2 team leads, 5 developers, 2 research assistants and 2 internees who were hired off and on in the project. The supporting staff included an accountant and a coordinator.

C. Objectives and achievements

- **Original Project Objectives**

Research Objectives

- To evaluate independently all the recent algorithms for fingerprint and iris recognition on large databases. The algorithms will be selected based on their robustness in practical and non-ideal conditions and their computational efficiency.
- To work on further improvement or development of algorithms wherever required. This includes fine tuning of algorithms and testing against various types of databases.
- To research on the hardware optimization and optimized system design to fulfill high data throughput and fast search requirements of high-end systems with large databases.
- To significantly contribute to the biometric research activities, both within the country and also outside by writing/presenting research papers on different developed algorithms and techniques.
- To validate the performance of algorithms by participating in international fingerprint and iris recognition competitions.

Academic Objectives

- To establish a biometric hardware research lab where students can work, not only, on algorithms but also on hardware implementation/optimizations aspects of biometric system development. This lab will serve as a hub of R&D activities in the field of biometrics system development and will train engineers in this field.
- To enable Masters/PhD students, to work on the applied research in the field of the algorithm development and hardware optimization of biometrics based identification systems.
- To develop a working relationship between MAJU and NADRA or other biometric companies, thus providing an industry academia collaboration model.

Industrial Objectives

- To develop full fledged biometrics based identification systems, capable of fulfilling high-end requirements of large databases and providing reliable performance at high matching rates. Different variants of such system can be made for various user

defined applications, such as, home security application, online bank transfers, etc.

- To contribute to the development of biometric products for small scale, medium scale and large scale applications. Small scale applications include individual company's security applications such as access controls, biometric based attendance records and company's soft data access etc. Medium scale applications are related to larger industries, security agencies, airport staff access etc. Large scale applications include national level biometric records, online bank transactions and ATMs, immigration control at airports and international criminal records.
- To achieve self-sufficiency in the development of biometrics systems and provide in-home solutions to different stake holders in this field, such as, NADRA and other private companies having biometrics products. This will save a lot of financial resources for these organizations.

Human Resource Development Objectives

- To develop a pool of engineers, being trained in design and development of biometric products.

Other Objectives

- The long term objectives will be to help and collaborate with local vendors and companies to compete in the international market of biometrics products, opening new avenues for exports.

• **Objectives Achieved**

Almost all the short term project objectives described above has been achieved up to a great extent. Among the research, industrial and organizational objectives the following benchmarks were achieved.

- An active research group of vision and pattern recognition systems (VisPRS) was established in Muhammad Ali Jinnah University, with primary research focus on biometrics. Rigorous research in different fields of biometrics, including physiological biometrics like fingerprint, iris, palm-print and face recognition and behavioral biometrics like online signature verification have been initiated. The research group currently has more than 15 active members including 1 group supervisor, 2 post PhD researchers, 10 PhD students, 2 Masters thesis students and a number of undergraduate students.
- An in depth research was carried out under this project on the current trends and latest algorithms in the fields of enhancement and recognition algorithms for iris and fingerprint. As a result different variants of new algorithms, both in iris and in fingerprint, were developed especially designed for FPGA implementation.
- As algorithms improvement and tuning is a constant process of research, it has been done throughout the duration of the project and it is still being carried out in the research group under a number of Masters and PhD theses.
- A significant part of the project was dedicated towards the research on the design of efficient system which can deal on one side with large database and other side with the hardware accelerator units. Therefore the design of the system incorporates all the major functionalities which are required in such a large scale system. The prototype is built on a low cost server system and fulfills all the initially set speed requirements. The design of the system including FPGA design is such that speed performance can further be enhanced by using high end server systems.

- The research group has now active contribution in the research in biometrics. Currently 5 PhD students are pursuing their PhD research in biometrics. Three students are working on Face Recognition, one student is working on Fingerprint Enhancement and one student is pursuing his research in Iris localization and enhancement. Two students have completed their Masters thesis in biometrics including one in Palm-print Recognition and one in Iris Encoding and Matching. Moreover, three final year undergraduate projects have also been completed in biometrics fields. The first undergraduate project was titled as, “Implementation of fast iris based identification system on embedded DSP board”, the second project was, “Implementation of fingerprint verification system on embedded platform”, and the final one was, “Fingerprint identification system with fast matcher implemented on Graphics card”.

Following research papers are either accepted or submitted within last two years.

1. Usama I. Bajwa, Imtiaz A. Taj and Zeeshan E. Bhatti, “A Comprehensive Comparative Analysis of Performance of Laplacianfaces and Eigenfaces for Face Recognition”, The Imaging Science Journal, Vol. 59, No.1, pp. 32-40, Feb. 2011.
2. M. Talal Ibrahim, M. A. Khan, K. S. Alimgeer, M. K Khan, Imtiaz A. Taj and L. Guan “Velocity and Pressure-based Partitions of Horizontal and Vertical Trajectories for On-line Signature Verification Pattern Recognition”, Pattern Recognition (Elsevier), Volume 43 Issue 8, pp. 2817-2832, August 2010.
3. Mubeen Ghafoor, Imtiaz A. Taj and Waqas Ahmed “An Improved Contextual Filtering Approach for Fingerprint Enhancement”, submitted to Computer Vision and Image Understanding (Elsevier), Under Review.
4. Mubeen Ghafoor, Imtiaz A. Taj and Waqas Ellahi “2-D STFT Analysis and Contextual Filtering for Fingerprint Enhancement and Distortion Removal”, submitted to Pattern Recognition (Elsevier), Under Review.
5. Duratulain Mirza, Imtiaz A. Taj, Ayesha Khalid, “A Robust Eyelid and Eyelash Removal Method and a Local Binarization based Feature Extraction Technique for Iris Recognition”, Proceedings of 2009 IEEE 13th International Multitopic Conference (INMIC 2009), pp. 311-316.
6. Zeeshan E. Bhatti, Usama I. Bajwa, Imtiaz .A. Taj, Introducing Set of Internal Parameters for Laplacian Faces to Enhance Performance under Varying Conditions, Proceedings of 2009 IEEE 13th International Multitopic Conference (INMIC 2009), pp. 279-283.

- We have also registered in the FVC-Ongoing Fingerprint Verification Competition as a contender. This a premium ongoing competition where the top vendors and research groups related to fingerprint recognition participate. Good results in the competition are recognized worldwide. We are modifying our algorithm according to their requirement to be able to compete in the competition.
- We are also seeking partners in developing and marketing the system and its smaller variants. We also approached NADRA for joint development and deployment. However the response from NADRA was not very forthcoming but it has conveyed to us that once we demonstrate our algorithmic strength in the international competitions like FVC, it will collaborate with us for a National level system.
- A full fledge system was successfully designed and implemented keeping in view the market requirements. In addition to this large scale system, different smaller and medium and variants of the system were also constructed in various student projects which can be beneficial for smaller industry targets.
- As mentioned the development team consisted of 15 members including 9 young engineers who were trained in these fields and all of them are now serving in different

prestigious organizations. Moreover three student projects involving a total of 7 students were carried out and these students also got rigorous training in biometric field.

- **Objectives not Achieved**

As discussed above almost all the short term objectives were met up to the completion of the project. However, the long term objectives are still not achieved and need attention from now onwards. These include collaboration with local vendors, marketing the system and related products through collaboration, and taking part in international competitions to build repute.

D. Technology Transfer/Commercialization Approach

The technology developed during the project will be transferred to various stake holders in the following ways:

- The source code of APIBS software application is available as the final deliverable thus enabling a large community to benefit from the outcomes of the project.
- Comprehensive documentation including user manual, installation guide, developer's kit, etc. has been prepared with the final release of the project to help developers and users of the system.
- Research Publications in reputed international conferences and journals are being published as briefed in Section C: Objectives achieved.
- The technical team developed during the project can be used as technology incubator in the field of biometrics. A number of engineers have been trained in the project who will help to further propagate the skill in the industry in related fields. Moreover a number of seminars and workshops were arranged in the university to disseminate the finding/results of conducted research.

E. Benefits of the Project

- **Outputs of the project and potential beneficiaries**

In this project a scalable high-end solution for personal identification system APIBS was developed. All the main tasks of algorithm development, optimization, and software application design, FPGA based hardware accelerator development and the software application development and then integration with testing has been completed.

By combining two of the most stable and reliable biometrics, i.e. Fingerprint and Iris, and providing so many flexible modes of operation, APIBS is a complete and the most feasible solution in the market to be deployed in numbers in Pakistan. Most of the large-scale systems available in the market are built on software application first and then scaled to large scale application by enhancing computation power using server clusters which make the solution very expensive. The strength of this solution lies in the fact that only one server can be used and most of the computation load is handled by specifically design hardware accelerators implemented on FGPA cards, therefore, not requiring large server clusters, which makes the solution cheaper and compact. APIBS has the capacity to be central part of a variety of present and future commercial applications, including large scale, medium scale and small scale applications. Our project will contribute significantly in all these application areas. Therefore multiple segments of the society

would be the direct customers and beneficiaries of the Project.

Common Industries and Companies

Mid level applications of biometric systems involve personal identification/verification using medium and small databases. Applications like company's logins and check-ins, and authorized access to databases are examples of such applications and are directed towards large and medium strength industries and companies. APIBS provides provision for enrollment and identification therefore it can be used in these applications. The design of the system may be scaled according to requirements.

Local Vendors/Manufacturers of Biometric Products

In our country various biometric vendor companies such as Biometricaxs, AFC Technology and Universal Biometric are dealing in small scale biometric based products, such as fingerprint locks, home security systems, login locks, etc. Most of the products they are marketing are not designed and developed locally but are either only assembled with imported components or fully imported. Since many small scale products can be derived from individual components of our proposed APIBS, this project can help such companies to fully develop, improve and expand the scope of their products.

Foreign customers

APIBS has a lot of potential to attract foreign companies, security agencies etc who are looking for cheap and reliable solutions.

- **Organizational Outcomes**

As explained in the Section C: Objectives Achieved, an active research group VisPRS was established with the help of this project. The in depth research and technological knowhow gained in the project is very helpful in producing a number of future PhDs, Masters theses and undergraduate projects. A team has been developed with expertise in the fields of biometric algorithms and hardware design. Moreover different organizations may benefit from the project as briefed in the previous subsection.

- **National Impacts**

Research and development of biometrics based personal identifications systems is one of the priority areas in current geopolitical scenario, especially for our country's environment. Although, in our country, some groups are doing research on fingerprint verification and identification systems, but mostly they are confined to algorithms development and do not include designing dedicated hardware systems for accelerated identification on large scale databases. Moreover, very few researchers in Pakistan are working in other biometrics based personal identification systems with almost no output.

Although the use of biometrics is increasing in airports, border crossings, company's logins and entrances, etc but even now it is just the tip of the iceberg. Personal identification in financial transaction is a challenge of future and we will need biometrics systems which can match many to many at a time. Therefore, in near future, mass deployment of such high-end biometrics systems will be needed not only for security purposes such as in airports but also for increased online transactions. For this purpose, the development of APIBS may prove to be a milestone because it involves in it different types of products and different biometrics.

Key National benefits of this project are given below:

- The project has and will contribute to the development of biometrics products for small scale, medium scale and large scale applications, providing high accuracy and timing efficiency using very large databases.
- The project is a step towards achieve self sufficiency in the development of biometrics systems and provide in-home solutions to different stakeholders in this field which will save a lot of financial resources for these organizations.
- Biometrics has potential application in future transaction system and required specific changes can be incorporated in the system for use in financial transaction applications of the banks. APIBS can be easily modified to do so.
- R&D Facilities in the form of biometric lab established during this project will help academia to conduct future research and development in biometric areas.

F. Assessment of Project Structure

- **Project Team**

The composition of the development team was exactly as was defined in the project proposal also described in Section B: Project Summary. During the extension period also the composition of the team was exactly according to that defined in change request for extension which was later approved.

The team worked very efficiently in the first 4 phases of the project and the progress was exactly according to the initial plan. This was also highlighted in the progress reports of the corresponding quarters.

- **Collaborations**

The project was entirely carried out by the project development team affiliated with MAJU. No other party was involved in the development phase of the project. However for commercialization of the APIBS and related products we are looking for collaborators and contacts have been established with different companies in this regard as highlighted in section D.

G. Research Approach

Different activities included in the development of APIBS included initial requirement specification and equipment procurement, algorithm development, algorithm optimization, hardware system design, FPGA based matching accelerator design, application development, system integration and finally performance evaluation and testing. During the project it was especially noted that the initially perceived research and development steps were accurate and the project went exactly according to the plan. Rigorous planning preceded every one of these tasks and it was made sure that the resources are properly and sufficiently assigned. All these tasks except the last one were completed and the phase wise deliverables were submitted in time.

H. Assessment of Project Schedule

As discussed earlier the first four phases were completed exactly according to the schedule.

I. Assessment of Project Costs

<p>Despite extended duration, the project has been completed keeping well within the total allocated budget.</p>
<p>J. Additional Project Funding obtained</p> <p>No additional funding was obtained.</p>