

Original Article

Design and implementation of biometric child birth registration system for sustainable national development planning

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ABSTRACT

Birth registration is a fundamental right of every child that provides them with the documentary evidence required to secure recognition of legal identity, family relationship, and nationality. Yet, despite the obligation of Nigerian government to register all births, registration levels remain critically low as only 43% of children under the age of 5 years have had their births registered. In the eyes of the law, these unregistered children are nonexistence. More worrisome is the fact that the present system of registration allows a child to be registered many times with different identity resulting in the wrong estimation of the number of the registered children in the country. The interrelationship between birth registration and sustainable national development planning processes is a mutual one that cannot be separated, and therefore an inaccurate and improper birth registration hinders building a vision for the nation and curtails the planning process for overall development. This paper proposes fingerprints biometric based national birth registration system to ensure accurate and proper births estimation for sustainable national development planning in Nigeria using PHP programming language with JavaScript, Minitiae-based Fingerprint Matching Algorithm, and MYSQL database system. The data collection for the system took place in two different primary health centers in Nigeria.

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INTRODUCTION

It is an established fact that accurate birth registration data are the most reliable national population data enabler that helps in identifying geographical, social, economic and gender disparities within national boundaries which aid the national development planning processes.^[1] Though, birth registration and legal identity are central to the concept of national inclusion, they also serve in excluding those not legally entitled to particular rights even when these are widely accepted as human rights. A birth registration is a continuous and permanent recording through an administrative process of the state of the occurrence and characteristics of births in accordance with the legal requirements of a country.^[2] It is a fundamental right of all children and a basic function of all modern governments. It comprises two elements, first, entering of the details of a child's birth and other relevant information such as blood group, genotype, and gender into the official government records. The

second element is the issuing of "birth certificate" to the child's parents or guardians, containing the date and place of birth, and other information such as parents' names and nationality, date of registration, and child's national number.^[3]

Birth registration is a passport to citizenship for registered child, and it incorporates vital data for national statistics to guide governments' formulation of their development policies, such as health, education, and social services.^[4-6] While birth registration is a national policy and a societal matter, it is also inextricably linked to child rights. For example, according to the United Nations General Assembly Resolution 44/25,^[7] Article 7 of the United Nations Convention on the Rights of a Child reads:

"The child shall be registered immediately after birth and shall have the right from birth to a name, the right to acquire a nationality and, as far as possible, the right to know and be cared for by his or her parents."

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The essence of birth registration as a vehicle for sustainable development attainment has been supported by major international development organizations' reports such as the United Nation's Sustainable Development Solution Networks of 2013 which embraces the idea of birth registration and legal identity as a major means of achieving gender equality, economic development through national planning, social inclusion, and human rights for all. Therefore, the interrelationship between birth registration and sustainable national development planning processes is a mutual one that cannot be separated, as inaccurate and improper birth registration hinders building a vision for a nation and curtails the planning processes for overall national development.^[8]

The continuous clamor by different regions in Nigeria for fair and equal distribution of economic resources for national development has stressed the need for proper and transparent national population estimation process. Moreover, the present system allows for individuals to have multiple birth certificates bearing different date/place of birth thereby giving an individual multiple identities. Such multiple identities distort the accuracy of the national population figure and allow for misallocation of national resources while obstructing proper national development planning processes. This work presents a biometric based birth registration system for proper and accurate births estimation for Nigeria sustainable National development planning.

LITERATURE REVIEW

Birth Registration across Countries

Birth registration in Africa originated from colonial administrations era, particularly from the East Africa, when the colonial administrations made it compulsory for non-Africans to register the birth of their children for proper identification and protection.^[9] After securing their independence from the colonial governments, many African countries including Uganda, Kenya, Tanzania, Zambia, and Zimbabwe adopted these colonial instruments to implement national legislation with uniform application. However, it was the United Nations Convention on the Rights of the Child (CRC), the African charter on the Rights and Welfare of the Child (ACRWC) and the advocacy and practical efforts of other child rights organizations, particularly the United Nations International Children's Emergency Fund (UNICEF) that have been responsible for raising awareness of the value and need for universal child registration.^[1]

In Nigeria, the issuance of birth certificate is controlled by the Federal Republic of Nigeria and this is issued under the birth and death (Compulsory Registration) Decree 69 of 1992 constitution of Nigeria. In accordance to Federal Republic of Nigeria Constitution under the section 28(1) "Subject to the provisions of this Part of this Act, the birth of every child born

in Nigeria shall be registered by the registrar of births and deaths for the area in which the child was born by entering in a register kept for that area such particulars concerning the birth as may be (FRN Constitution, 1999), except where a living new-born child is found exposed and no information as to the place of birth is available, the birth shall be registered by the registrar of births and deaths for the area in which the child is found.^[10]

The UNICEF Report (UNICEF Generation Africa 2030) predicts that 136 million births would take place in Nigeria between 2015-2030, representing 19% of the Africa's births and 6% of the world's birth within the said period.^[11] Although, the estimated Nigeria population for 2018 as released in June 2019 by the National Population Commission stands at 198 million. However, 57% unregistered children between the ages of 1 day to 5 years were not accounted for as depicted in Table 1, while millions of the populace possess multiple registration and identities.^[11] The most common barriers responsible for the low rate of birth registration across countries includes: The lack of political will or attention on the part of the government administrative obstacles, the complete absence or inadequacy of legislation, resource constraints, geographical barriers, and socio-cultural factors.^[6] To overcome these barriers to birth registration, several innovative techniques are being adopted in different countries.

In Bangladesh, the rate of registration of children under five increased from 12% in 2006 to 31% in 2011 and 56% in 2021. This improvement was prompted by a range of programmatic actions, from the development of a legislative framework to a national birth registration campaign.^[6] Likewise, national birth registration rates have also improved steadily in Brazil, from 64% in 2000 to 96% in 2021. A birth certificate is the first step towards citizenship in Brazil: It is only with this document that one obtain other important papers or apply for social protection. Legal reforms, including national legislation guaranteeing the right to birth registration, were enacted in 1997 to improve the birth registration by the parents and institutions.

In recent years, the Government of Benin Republic in West Africa has made important advancements in refining her birth registration system which has helped boost birth registration levels from 60% in 2006 to 86% in 2021. In Senegal, the percentage of children under five whose birth is registered grew from 55%-79% between 2005 and 2021. Many different initiatives were introduced by the Senegalese government and its partners during those years, including mass campaigns on the importance of birth registration, the reduction of fees to obtain a birth certificate, and the creation of new registration offices. According to UNICEF,^[11] South Africa has seen a spectacular rise in birth registration within the first year of life, increasing from 24% in 1991 to 50% in 2001, 75% in 2005, 85% in 2012, and 89% in 2021. The government has focused

Table 1: The percentage of children under age five whose births are registered

Registration Status	Name of countries
No Data	Anguilla, Antigua and Barbuda, Bahamas, British Virgin Islands, Brunei Darussalam, China, Dominica, Eritrea, Fiji, Grenada, Holy See, Kuwait, Libya, Malaysia, Mauritius, Micronesia, Niue, Palau, Republic of Korea, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Saudi Arabia, Seychelles, Tokelau, Turks, and Caicos Islands.
1% to 20% of children registered	Chad, Ethiopia, Malawi, Papua New Guinea, Somalia, Zambia
21% to 40% of children registered	Angola, Democratic Republic of Congo, Guinea-Bissau, Liberia, South Sudan, Uganda, United Republic of Tanzania, Yemen
41% to 60% of children registered	Afghanistan, Bangladesh, Equatorial Guinea, Eswatini, Gambia, Lesotho, Mozambique, Nepal, Nigeria (43%), Pakistan, Rwanda, Samoa, Timor-Leste, Tuvalu, Vanuatu, Zimbabwe
61% to 80% of children registered	Burkina Faso, Cambodia, Cameroon, Central African Republic, Cote d'Ivoire, Ghana, Guinea, India, Indonesia, Kenya, Lao People's Democratic Republic, Madagascar, Mauritania, Namibia, Niger, Paraguay, Senegal, Sudan
81% to 100% of children registered	Albania, Algeria, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahrain, Barbados, Belarus, Belgium, Belize, Benin, Bhutan, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Burundi, Cabo Verde, Canada, Chile, Colombia, Comoros, Congo, Cook Islands, Costa Rica, Croatia, Cuba, Cyprus, Denmark, Dominican Republic, Egypt, Estonia, Finland, France, Gabon, Georgia, Germany, Greece, Guyana, Haiti, Honduras, Hungary, Iceland, Iran, Iraq, Ireland, Israel, Italy, Luxembourg, Maldives, San Marino, Sao Tome and Principe, Serbia, Sierra Leone, Singapore, South Africa, South Korea, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Tunisia, Turkiye (Turkey), Ukraine, United Arab Emirates, United Kingdom, United States of America, Uruguay, Uzbekistan, Venezuela, Viet Nam.

its efforts on addressing the needs of rural communities by establishing fixed service centers as well as hospital registration points, mobile units, and multi-purpose community centers.

In the United Republic of Tanzania, the registration of children under five doubled between 1999 and 2010, from 6% to 16%, but the proportion of those with a birth certificate remained unchanged. To address this challenge, the government piloted a new birth registration system in 2012. Assistant registrars were trained at ward levels, in local government offices as well as in hospitals and health clinics, allowing children to be registered at birth or at the same time as immunization, these measures have increased the country's birth registration from 16% in 2010 to 26% in 2021. In Nigeria, the percentage of registered children under the age of 1 year stands at 35% and those under the age of 5 years stands at 43%. The registered children stand at 43% and 42% for male and female children, respectively, as at 2021.^[11] More worrisome is the procedures of the registration in Nigeria that allow multiple registrations of a child, thereby giving multiple identities and inaccurate data for the national development planning purposes.

Several programmatic actions are being introduced by different countries to achieve an efficient and high level birth registration, such as, legislative review to ensure that births registration is free, universal, confidential, and incorporated into the birth and death registry; communication for development efforts that work with community leaders and parliamentarians to promote a broader understanding of the process; deployment of digital technology to obtain timely, accurate and permanent records,

among others. UNICEF^[11] affirms that one (1) among four (4) children under the age of five do not exist officially, and that majority of the unregistered children live in the countries where the functional civil registration is not readily available. Table 1 presents the percentage of children under age five whose births are registered.

The Children's Biometric Studies

The term — Biometrics is derived from the Greek words “bio” (life) and “metrics” (to measure).^[12] Biometric recognition refers to the automated recognition of living individuals based on their biological or behavioral characteristics.^[13,14] Therefore, to avoid an individual from possessing multiple identities, it is essential to use individual characteristics that are robust, unique, universal, and measurable. Scientifically, biometrics adequately meets these requirements. Several efforts have been made to investigate the viability of using different biometric traits for the verification and identification of infants and toddlers (Newborns of 1 day - 2.5 years).^[15,16] Tiwari *et al.*^[17] and Bharadwaj *et al.*^[18] worked on the biometric identification for newborn babies using facial trait (Face) by capturing face images of newborns (0–3 days old). The researchers concluded that it was difficult to capture good quality face images of newborns due to gross head reflexes, and pose expression variations.

Several researchers^[19-22] have worked on the identification of newborns using iris trait (Iris) by studying the viability of using commercial sensors to capture iris images of one and half to eight years (1.5–8 years) old children. They reported a high failure to

enrol (FTE) rate of approximately 57%, although the recognition accuracy for the enrolled subjects was very high (about 99%). Weingaertner *et al.*^[23] investigated the use of palmprints and footprints for identifying newborns (0–2 years old). Manual matching accuracy was reported to be approximately 83% and approximately 67% for palmprints and footprints of newborns.

Lemes *et al.*^[24] used a 1000 ppi commercial sensor to capture palmprint images of 20 newborns (0–2 years old). They reported palmprint recognition accuracy of approximately 95%. Pelgrave *et al.*^[25] and Thompson *et al.*^[26] investigated the use of footprints acquired using traditional ink on paper methods for identification of newborns (0–2 years old) and concluded that footprints cannot be captured reliably. The researchers^[27–29] studied the effect of adolescent growth on the accuracy of fingerprint matching systems and showed that fingerprint growth does not change the accuracy of the already taken fingerprint images at birth as fingerprints form in the womb at 22 weeks and only expand as the child grows. Therefore, a fingerprint of 22 weeks after conception could be used to identify a 50-year-old individual. The Joint Research Centre of the European Commission's technical report (2013) concluded that children can be reliably identified using fingerprints and that the image quality of the fingerprints is a decisive factor in fingerprint recognition.^[30]

STUDY METHODOLOGY

Study Locations

The data for the study were obtained from the Primary Health Centre, Iwaro-Oka, Ondo State; Primary Health Centre, Oke-Ijebu, Akure, Ondo State; Ondo State Specialist Hospital, Akure, Ondo State; Federal Medical Centre, Owo, Ondo State; National Population Commission Office, Akure, Ondo State and National Identity Management Commission, Akure, Ondo State. Visits were made to these places to get first-hand information on how new births are registered; how birth certificates are issued and how the national identity number are obtained.

It was discovered that child registration is manually registered at birth on the health centers' and hospitals' new child registers at the children section, birth certificates are issued on the request of individual at any time without any age restriction or identity verification, and national identity cards are issued after individual registration at the National Identity Management Commission designated centers.

Data Collection

Fingerprint images of 38 new born babies of between one day and 6 months of 15 males and 23 females were captured using the Digital Person U.are.U 4500 Optical Fingerprint Reader at two different locations, Primary Health Centre (PHC), Iwaro-Oka in Akoko area of Ondo State and the Primary Health Centre (PHC), Oke-Ijebu, Akure, Ondo State.

At the Primary Health Centre (PHC), Iwaro-Oka, a total of 240 fingerprint impressions (two index fingers and two thumbs) from 15 babies in the age range [0–6] months were captured. Data were collected over two sessions, in a week apart, and two fingerprint impressions per finger were collected in each session. Likewise, at the Primary Health Centre (PHC), Oke-Ijebu, Akure, a total of 352 fingerprint impressions (two index fingers and two thumbs) from 22 babies in the age range [0–6] months were captured. Data were collected over two sessions, in a week apart, and two fingerprint impressions per finger were collected in each session.

Although, the face images of the babies were also collected during the sessions but they were not used for matching. Instead, they were used for displaying the retrieved subjects from the database so that the child's facial identity can be confirmed. The samples of the subjects' fingerprints collected at the Akure and Iwaro-Oka health centers are presented in Figure 1.

The System Design

The system design defines the architecture, components, interfaces, and data for the system to satisfy specific user requirements. It consists of the input and output processes of the system and the abstract representation of the data flows which is laid down in terms of how the data is inputted into the system, how it is verified, how it is processed and how it is displayed. The system architecture and the data flow diagram are represented in Figures 2 and 3, respectively, containing the components and the relationship between the different components.

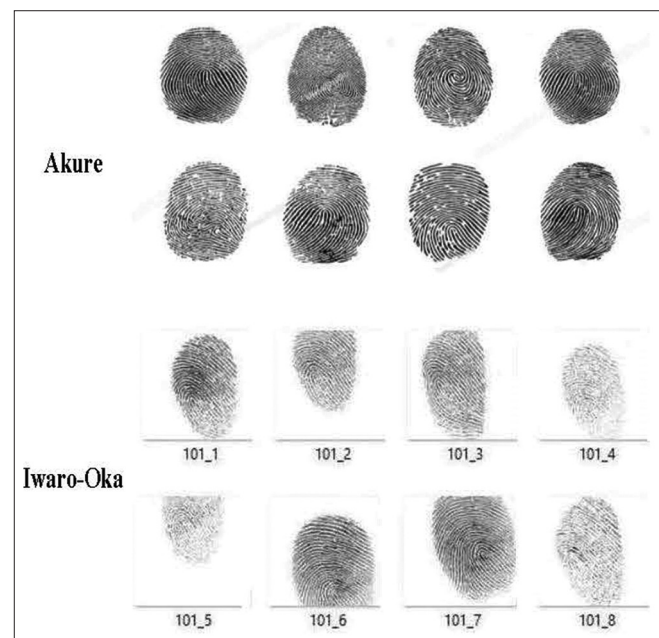


Figure 1: The subjects' fingerprints

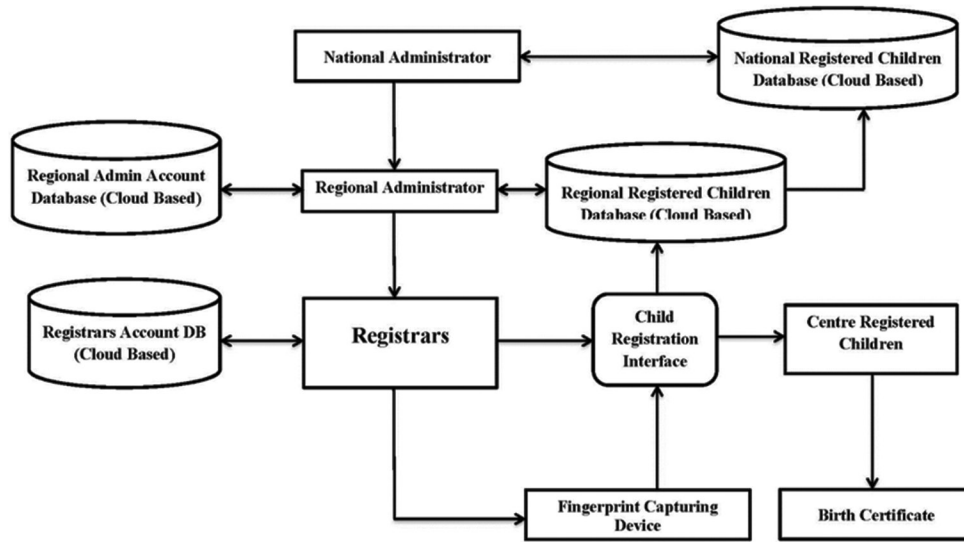


Figure 2: The architecture of the birth registration system

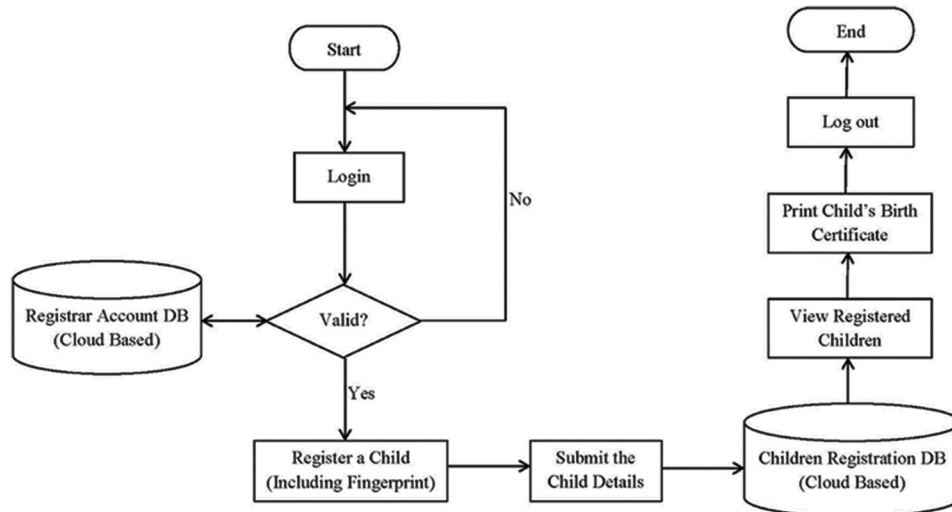


Figure 3: Data flow diagram of a user (registrar) with the system

The system consists of three parts, which are:

- The Frontend (User interface)
- The Database section
- The Backend (Administrative interface).

The frontend (user interface)

The frontend interface for the users (the Registrars) include contain the following features:

- Login page:** This feature allows the user (The Registrars) to login into the system after being registered by the Administrator by entering some registration details (i.e. the email and password) to gain access to the functionalities of the system.
- Dashboard:** On logging in, the User is directed to the dashboard page which serves as the major room that give

the direction to other pages depending on the operation to be performed by the user. The dashboard contains links to other pages of the system which include; profile page, registration page, registered children page, and birth certificate page.

- Profile Page:** This is a page in which all the information of the user is displayed. These data will be fetched from the user table in the database based on what has been provided by the user during registration.
- Register Child Page:** This is a page through which the registrar registers each newly born child at the hospital. The page request for some certain information about the child and his/her parents. Every information provided here are stored in the child registration table provided in the system database.

- v. Registered Children Page: This is a page through which the registrar can view all registered children stored in the system's child registration table. On clicking the page the registered children information are automatically shown in a table.
- vi. Birth certificate page: Registrars are directed to this page immediately he/she clicks the child registration code link provided on the registered children page. This page contains the child birth certificate slip which is presented in a printable form with a government approved seal on the birth certificate slip background.

Database design

The database management system adopted for the system is MySQL database system because of its high security and reliability, high performance, on-demand scalability, and comprehensive transactional support features. The Databases (The Regional Administrators database, the Registrars database, and the Registered Children Database) were created for the system with different tables which include the different Administrators, Registrars, Registered_Child, Child_Certificate tables, among others. The following objectives are considered in the process of designing the databases:

- i. Easy to learn and use.
- ii. Controlled redundancy.
- iii. More information and low cost.

Backend (administrative interface)

The backend of the system is concern with the high administrative operations and maintenance with restricted operational access. The access to the backend of the system is restricted to the National Administrator, Regional Administrators, and the System Administrators. The backend contains the following interfaces:

- i. Login Page: The login page allows the Administrators to input their login details (email addresses and Passwords) that would allow the Administrators to gain access to the dashboard where other features are displayed.
- ii. Dashboard: After login, the Users (Registrars) are directed to the dashboard page which serves as the major room that gives the direction to other pages depending on the operation to be performed by a user. The dashboard contains links to other pages of the system which include; Admin profile page, user registration page, and registered user page.
- iii. Profile Page: This is a page that displays the user's information. These data will be fetched from the user table in the database based of what has been provided by the user during registration.
- iv. Registered User Page: On this page, the administrators are able to view all registered users stored in the system user registration table. Clicking the page, the registered user information is automatically shown in a table.
- v. Register User Page: On this page, the administrators can create account for every user. The page requests for certain

information about the user which includes: First name, lastname, email address, and password. This information are stored in the user registration table at the registrar database within the system.

Fingerprint verification feature

The minutiae based methods of fingerprint matching with an Enhanced Minitiae-based Fingerprint Matching Algorithm^[31] was adopted for the registered children fingerprint verification to prove the biometric correctness of a registered child. The minutiae based fingerprint matching method is known for its high features reliability and robustness resulting from the method's uniqueness, stability, speed of processing, and memory requirements. The fingerprints matching samples are shown in Figure 4 for matched and unmatched fingerprints.

IMPLEMENTATION

System implementation is defined as a realization of technical specifications or algorithm(s) in form of programs, software components or other computer system through computer programming and deployment. It is concerned with the construction of the database, application programs, including the linking of the system's interfaces.

The interface design is concerned with how users add data to the system and how the system present information back to the users. It captures the graphical interface of the system and shows the input design and output design.

Homepage Interface

This interface shows a page where the user or the administrator choose to login. The user is directed to the user login page after clicking on the "Login as User" button and likewise the Administrator is directed to the admin page after clicking on the "Login as Admin" button.

The Login Input Interface

The login input interface of the system is categorized into two:

- i. Administrator Input Interface
- ii. User (Registrar) Input Interface

The administrators and the users interfaces are built with two input fields to accept the Administrator's and the Registrar's login details consisting of their email addresses and the passwords provided during their registration. Theses inputs are vividly validated to ensure that only the correct characters or inputs are accepted by the system.

Child Registration Interface

This is the interface where the newly born child is registered. Some information about the child, such as the child's names, date of birth, place of birth, gender, blood group, genotype, photograph and fingerprint, together with the

parents' information are required for the child's registration. The information are saved in Registered_Child table in the Registered Children Database in the system's database system.

Outputs Interfaces

A quality output is the one which meets the requirements of the end users and presents the information clearly. The processed results are communicated to the users through the output interface. The interface helps displaying the information to the end-users for immediate need. It is the most important and direct source of information to the end-users. An efficient and intelligent output implementation improves the system's relationship with the users for decision-making purposes. There are few output interfaces within the system, such as: Registered Users (Registrars) Registered Children, Birth Certificate, and Database pages.

Registered users page

This page contains the information of the registered users (Registrars) which includes their names, email and location contact addresses, status, date registered, and among others.

However, the first name, last name, email address, unit location, and the registration date of the registered Registrars are display when click of be view by the Administrator. The same method is also used in implementing the registered Administrators page where their information can be viewed by the National Administrator (Super Administrator).

Registered children page

This page contain details of every registered child, the information entails in this page are the child Registration Code, Firstname, Lastname, Date of Birth, Place of Birth, Gender, Blood Group, Genotype, Photograph, and Fingerprint. The child registration code (regcode) serves as a link to each child birth certificate page. Figure 5 shows a sample of the registered children interface.

Birth certificate page

This is a page that allows every registered child to be issued a birth certificate with an approved government logo which serves as the certificate background and government official's signature. The registrar is directed to this page via the child registration code (regcode) link provided on the registered children page.

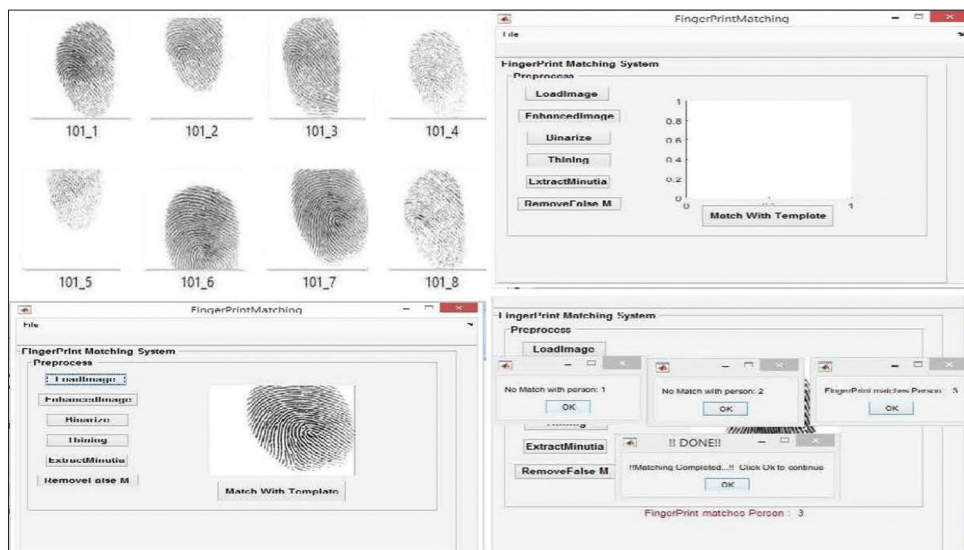


Figure 4: Fingerprint matching verification interface

Registered Children									
Child Regcode	Firstname	Lastname	Date of Birth	Place of Birth	Gender	Blood Group	Genotype	Child Image	Thumbprint
a249419	Ayo	Seyi	2019-04-09	Ondo	Male	O+	AA		
9cf003e	Taiwo	John	2019-01-08	Owo	Male	A+	AS		
64ed628	Deborah	Sekemi	2019-02-21	Idanre	Female	AB	SS		

Figure 5: The sample of registered users' interface

CONCLUSION

Birth registration is the permanent and official recording of a child's birth by a government official which is one of the most important stages in a child's life. It creates the existence of the child under law and provides the foundation for ensuring many of the child's rights. Although birth registration alone does not guarantee that a child will have access to adequate healthcare, right education or be free from abuse or exploitation, its absence leaves a child at significantly greater risk of a range of human rights violations.

This work is developed to provide an effective, efficient, and online accessible interface for the government officials with birth registration responsibility to biometrically register a child at birth using fingerprint method and enabling a centrally managed birth registration database for the country. The XHTML, CSS, JavaScript, and PHP programming language were used for the development of the system while the MYSQL database management was adopted for the system's database.

It is expected that the system when fully deployed by the government agency (National Population Commission) would allow for the central management of the birth registration in the country and eliminate the multiple birth registrations being witness in the country at the moment thereby enabling a more effective national development plans.

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