Facial Recognition and Mobile Based System for Patient Identification/Verification in Medical Emergencies for Developing Economies

Kingsley C. Nwosu, Ph.D., Okey A. Igbonagwam, Ph.D.
Department of Computer Science and Information Systems,
Saint Leo University, Virginia Peninsula, Virginia, USA.

Abstract— **Medical emergencies are part of the common daily lives of people in developing and under-developed economies. Frequently, some of these medical emergencies end up tragically for many people in these countries due to many reasons, one of which depends on the delivery of the medical treatment especially when the patient is uncommunicative or unresponsive. The ability of the attending medical personnel to access a patient's medical history is critical for the quality of the treatment rendered during emergencies. Unfortunately, today many lives are lost in low income economies during medical emergencies due to lack of and inaccessibility of a patient's medical information.**

Keywords—medical emergencies, developing economies, patient identification, facial recognition

I. INTRODUCTION

In spite of the global efforts by healthcare providers to focus on preventive healthcare systems, medical emergencies continue to claim many lives in low income economies due to many reasons including, but not limited to, insufficiencies of qualified medical personnel, unavailability of appropriate medical equipment, cultural barriers, cost, and unreliable delivery systems. Medical emergencies are usually handled in three phases – at point of occurrence, during transportation, and at a health facility. However, as concluded by [1] in their works in Zimbabwe, the fate of an emergency patient depends greatly on what happens during the first phase of the treatment. The issues and problems surrounding the insufficiencies of medical personnel and unavailability of equipment have been amply discussed in [2][3][4][5][6][7][8]. The recent incidents surrounding the Ebola virus and its transmission to the United States have significantly highlighted and elevated the issues concerned with international medical emergencies. The focus of this paper is on the issues contributing to the unreliability of the emergency healthcare delivery process.

Under normal healthcare delivery process, the quality of the services rendered is greatly impacted by the knowledge and/or accessibility of a patient's medical information. Many healthcare delivery accidents and mistreatments (especially the way that the first Ebola patient was initially handled in the US) have happened, in part, due to the absence or inaccessibility of a patient's medical history [9][10][11]. This situation is complicated in a medical emergency situation when a patient is uncommunicative, unresponsive or uneager or unwilling to provide some medical information. What is needed to effectively address this problem is a system that can securely and reliably capture, store, and retrieve a patient's relevant medical information. The reliability depends greatly on how to verify or identify a patient during a medical emergency situation described earlier. Low income economies are notorious with the absence of healthcare infrastructure that facilities storage and access of necessary patients' medical information.

This system is an attempt to design and develop an affordable, reliable system, and platform to facilitate the capture, storage, access, and retrieval of critical patients' medical information for medical emergencies in developing and under-developed economies; and the ease of accessibility of this information globally, when necessary.

II. GENERAL SYSTEM DESCRIPTION

This system comprises a frontend for patient registration or enrollment and patient identification; and a backend for data storage and retrieval (see Fig. 1). The patient registration or enrollment can be done either by the patient's Primary Care Physician (PCP) with the authorization of the patient or by the patient. Only critical medical information necessary

for emergency medical care is captured during the enrollment, including the patient's passport-sized digital image. All textual information is stored in the backend in encrypted form. Only authorized persons who have successfully authenticated biometrically are allowed access via the frontend mobile application.

A. The Frontend Applications

The system's frontend comprises two mobile applications for (1) Patient Enrollment and (2) Patient Identification.

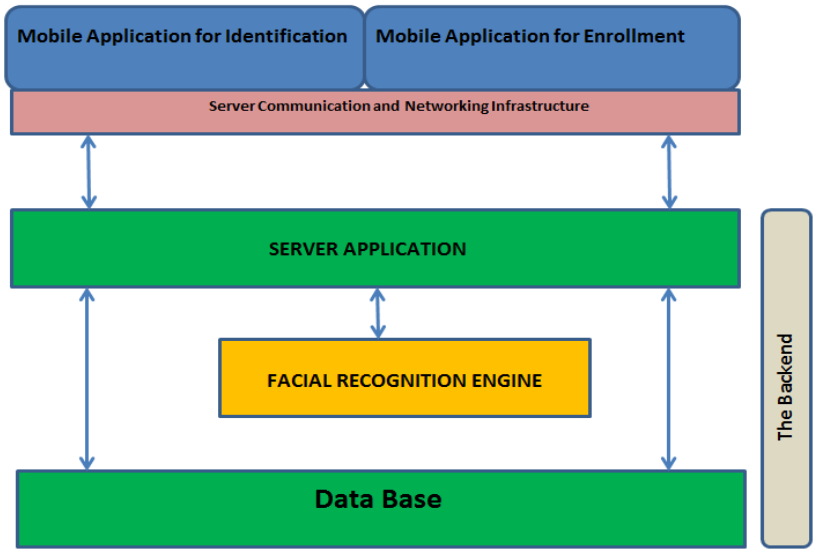

Fig. 1: General conceptual architecture of the system.

1) Patient Enrollment Application (PEA)

The PEA is used to enroll a patient in the system (Fig. 2). The enrollment process involves the capture of critical and necessary emergency medical information including the patient's passport-sized digital photograph. One of the critical emergency medical information is the patient's list of allergies which include, but not limited to: Cockroach Allergy, Drug Allergies, Dust Allergy, Eye Allergies, Food Allergies, Insect Sting Allergies, Latex Allergy, Mold Allergy, Pet Allergies, Rhinitis, Sinusitis, and Skin Allergies. In addition to the allergies, the enrollment process captures some personal information about the patient such as the name, age and gender, which are vital during the identification process. Furthermore, other optional pieces of information can be captured such as the patient's past medical history, past surgical history, social history, family history, and medications. The patient enrollment can be done by either the patient's Primary Care Physician (PCP) with the authorization of the patient or by the patient. Some of the enroller's information are automatically retrieved from the associated mobile phone and stored for security purposes and post enrollment validation. Distinction is made between information obtained via enrollment from a patient or the PCP during storage, retrieval, and display of the information. This is to convey the degree of reliability based on the sources of the information. For security purposes, all textual data that will never be part of the identification criteria are stored in encrypted form.

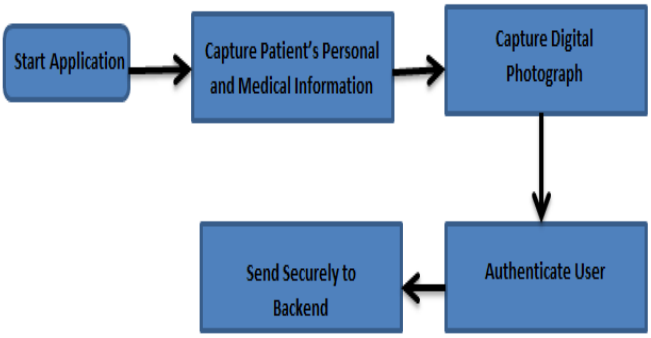

Fig. 2: Patient enrollment flow diagram.

2) ***Patient Identification Application (PIA)***

The other component of the frontend is the Patient Identification Application (Fig. 3) which is used to identify a patient during an emergency situation. In the best case scenario during a medical emergency, the patient's name, age, and gender are known. In that case, a verification operation is performed with the age, name, and gender to retrieve the associated information, if available. In the worst case scenario, neither the name nor age is known. In this case, an identification operation is required as described below (see "***System's Facial Recognition Technique***") using the patient's gender and estimated age. Depending on the result of each matching request, the user can repeatedly modify the patient's age and perform another matching request, as detailed in the matching technique below.

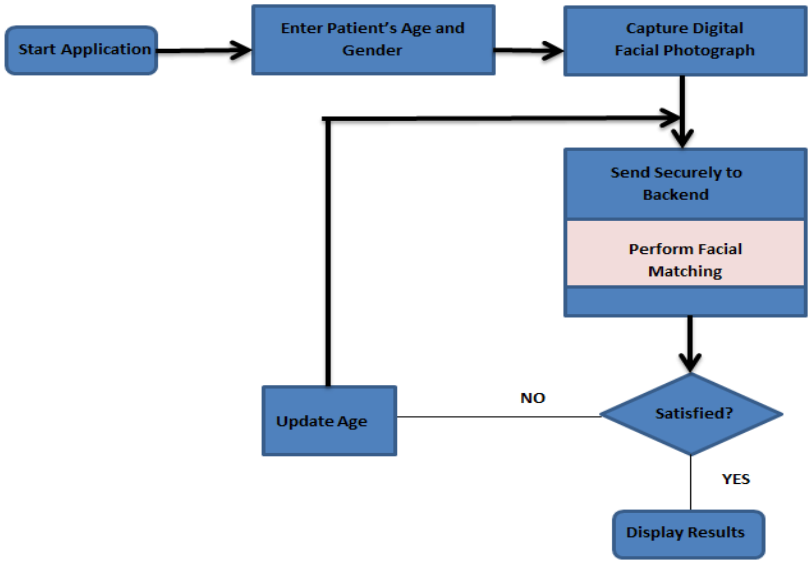

Fig. 3: Patient identification flow diagram.

B. ***The Backend***

The system's backend (Fig. 4) is responsible for performing the facial matching, encryption, decryption, storage, and retrieval. The backend accepts the enrollment data from the frontend application, formats the data by encryption and

facial template extraction, and stores in the database. The enrollment fails if the facial template extraction was unsuccessful. During patient identification, the backend performs the facial matching activity and returns the matching patients' facial images and associated medical information. The frontend controls whether to modify the request and repeat the process.

C. The Facial Recognition Engine

Biometrics verification and identification are the processes of using an individual's measurable physiological or behavioral attributes to either confirm or deny the stated identity of the individual or determine the identity of the individual.

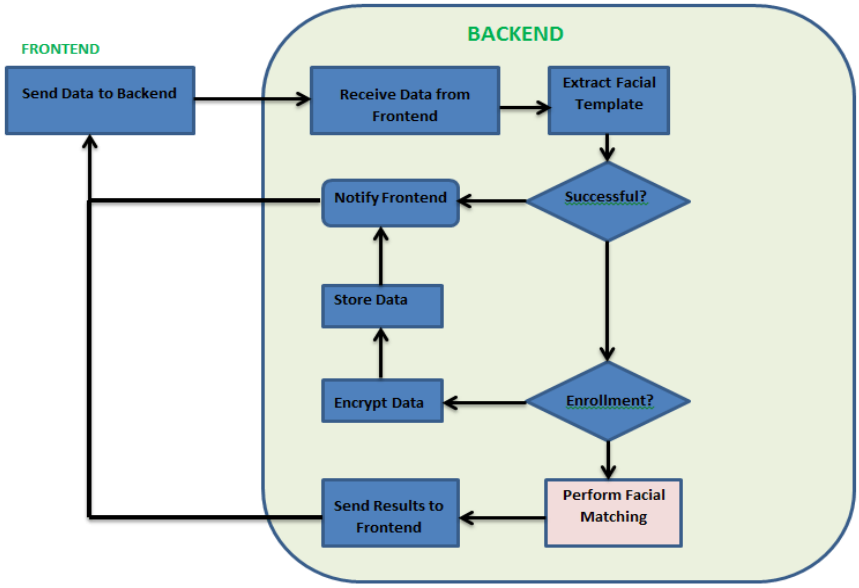

Fig. 4: Backend flow diagram.

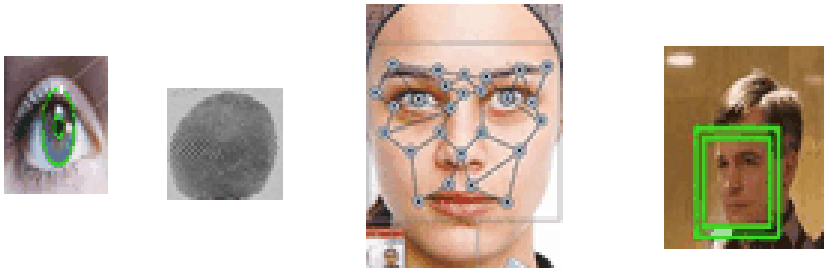

Fig. 5: Examples of Biometrics

The physiological or behavioral attributes of an individual have to do with the measurable characteristics of the individual with respect to the functioning of the body such as fingerprints, face, DNA, Iris, Palm, voice, signature, keystroke dynamics, etc. (Fig. 5.)

Basically, physiological has to do with data derived from the measurement of a part of a person's anatomy; while behavioral has to do with data derived from measurement of an action performed by a person. Verification is the process of determining whether someone or something is, in fact, who or what it is declared to be; while identification is the process of establishing the identity of an individual. Verifying or confirming a person's identity can be accomplished by using something the person knows (password), something the person has (token) or something that's part of the person (biometrics). Collectively, they provide the highest degree of security, however, individually; biometrics has the highest degree of security and reliability.

Why Facial Recognition?

Facial recognition is the least intrusive of all the biometric technologies. Facial recognition systems can surreptitiously take a picture of a person's face when they are present within the defined area. The facial recognition software operates by detecting a face and then measuring the various features of the face. Everyone's face has several, distinguishable characteristics that constitute the facial features. These features include, but not limited to: distance between the eyes, width of the nose, depth of the eye sockets, the shape of the cheekbones, and the length of the jaw line. These features are then measured and aggregated to produce a quantifiable numerical code that is used in facial recognition process. The entire process involves the following steps:

- ***Detection/Capturing*** – An image can be obtained by scanning an existing photograph or using a manually controlled video camera or by a camera automatically detecting a face.
- ***Extraction/Representation*** - Unique data (code) is extracted from the sample and a template is created. This may involve using and comparing serial samples.
- ***Matching*** - The system then decides if the features extracted from the new sample are matching or not.

D. The System's Facial Recognition Technique

The facial matching (recognition) approach used in this system uses a patient's gender, estimated age, and photo image (live or stored) to retrieve a set of patients facial templates that meet a given similarity threshold in comparison with the target patient. The age and similarity parameters can be adjusted during successive iterations of an identification session in order to obtain an optimal result. A similarity value measures the degree of similarity between two facial objects. Therefore, a value of 1.0 indicates a 100% match between two facial objects. The lower the similarity value, the higher the probability that more facial objects will match the target object.

To describe the facial matching technique utilized here, we let:

- a represent the estimated age of a patient and a_z represent the estimated age during the z^{th} iteration of a given identification session.
- g represent the gender of the patient.
- S represent a set of similarity threshold values 0.1 to 1.0 with 0.1 differential, where $S = \{.1,.2,.3,...,1.0\}$ and S_i represents the i^{th} element of S; and S_{sys} represents the system default threshold value.
- $F(a_z,g,j)$ represent the face matching function that compares two face objects and returns a value y where $0 <= y <= 1.0$; j represents any face object from the target database that meets the a_z and g selection criteria.
- H represent the face matching process that uses $F(a_z,g,j)$ and yields a set of facial objects, Ω.
- ${}_zH$ represent the z^{th} iteration within a given identification session where $z >= 0$.
- ${}_zH(all,S_i)$ represent the result of applying S_i threshold value, that is, $F(a_z,g,j) >= S_i$.

- $_zH(max,S_i)$ represent the result of applying S_i threshold value such that there exists $F(a_z,g,j) = max$ and for all $m \neq j$, $F(a_z,g,m) <= max$.

Therefore, for a given t^{th} iteration within an identification session,

$$\Omega = {}_tH(all,S_{sys}) \cup {}_tH(max,S_{sys}) \quad \text{if } t = 0 \qquad (1)$$

$$\Omega = {}_tH(all,S_i) \quad \text{if } t > 0 \qquad (2)$$

Consequently, the associated pseudo code for the z^{th} iteration for an identification session is thus:

PROCEDURE *G(a_z,g,S_i)*

Initialize $_zH(max,S_i)$ to empty

Obtain Ω *for $F(a_z,g,j)$*

For each face template in **Ω**

Compute the similarity value

If similarity value >= S_i then

Add face template ID to $_zH(all,S_i)$

End if

If similarity value > similarity value of $_zH(max,S_i)$ then

Set $_zH(max,S_i)$ to current face ID

End if

End For each

If z == 0 then

Add $_zH(max,S_i)$ to $_zH(all,S_i)$

End if

Return $_zH(all,S_i)$

End PROCEDURE

III. SYSTEM STATUS AND TESTING RESULTS

The frontend of this system has been designed and partially implemented. The PEA and PIE has been prototyped as Java applications for testing and demonstration purposes. The backend has been fully implemented. The test database was populated with one to three thousand facial templates with 1:1 male/female ratio.

Due to the fact that an identification process may be time-intensive because of its **O**(**N**)[1] execution time when matching ***N*** facial templates, it's always a concern in any facial matching system to determine the performance efficiency of the system. Our evaluation environment used a LINUX 32-bit machine with Apache Web Server, MySQL Database Server, (2) 2.4 GHz Processors and 4 GB RAM. The CPU matching time for 1,000 to 3,000 facial templates in the database with

[1] Big O notation is used to describe the performance or complexity of an algorithm. It's mostly used to describe the **worst-case** scenario of an algorithm either in the execution time or space used.

a percentage hit of 30%-50% ranged from 7.5 *milliseconds* to 38.3 *milliseconds*. The total CPU time to retrieve all the applicable facial templates and IDs from the database ranged from 32.0 *milliseconds* to 163.0 *milliseconds.*

This system is still in-progress and we are planning to complete the application development, system integration, and system testing using our Computer Technology Excellence Laboratory (**CTEL**) which is currently under development. Also, we plan to extend this work into the area of Google glass as a platform for automated identification and verification of patients via facial recognition.

IV. CONCLUSIONS

This paper attempts to address the issue of patient identification during a medical emergency when a patient's medical information is inaccessible as a result of the patient's inability to respond to provide the needed pieces of information. The system comprises two frontend mobile applications that are used to enroll and identify a patient based on the patient's facial recognition in conjunction with the gender and tunable age parameters. This system utilizes efficient and effective facial template management and matching technique to determine whether a given patient already exists in the database; and to retrieve the associated medical information. The ability to quickly identify a patient even when the patient is unresponsive enables healthcare providers to access a patient's medical history which is invaluable for quality of care.

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