An Affective-Based E-Healthcare System Framework

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Abstract- *This work is focused on developing an affective-based e-healthcare system which is tailored towards children with intellectual disability especially children with autism spectrum disorder (ASD). Inaccessibility of healthcare facilities contributed immensely to the health well-being of the vulnerable and; the challenge of not understanding their emotional status can be stressful on the part of the caregivers/parents. This framework deployed telecommunication services, internet and sensor technology to bridge the gap between the chasm of access to quality healthcare and patients with ASD in rural or underserved areas. The objective of this framework is to develop an emotional-based e-Healthcare model. This was achieved using electrodermal activity and Speech recognizer sensor to gather physiological data from an autistic patient, where an affective system was designed using fuzzy logic to analyze the dataset and classify them into the emotional state of the patient. This framework also includes an intelligent system recommending music therapy, whenever there is an indication that the patient emotional state is mounting towards meltdown that can result in behavioral disorder, an alarm is signaled before the moment a specialist is reached. This affective system is integrated into an e-healthcare system for accessibility purposes. Therefore, an affective-based eHealthcare framework is been developed to serve ASD patients in the urban areas, while the rural dwellers are not left out in the access to quality healthcare services.*

Keywords: *Affective computing, Autism Spectrum Disorder (ASD), Emotions, Electrodermal activity (EDA), E-health.*

I. INTRODUCTION

The e-health technology is rapidly growing with an evidence-based positive effect on the users, enhancing users to be adequately supported, improving behavioral and clinical outcomes as compared to non-users[1]. Researches on e-healthcare have shown how different areas of health has been of a great beneficiary of this technology especially in rehabilitation of chronic illness or diseases, stroke, diabetes weight loss and also habilitation processes for neurological disorder a more effective utilization of personal health records without physically attending a hospital or clinic. E-healthcare breaks the barrier of distance providing access to quality healthcare services irrespective of the geographical location.

Human behaviour and reactions are largely influenced by emotion and physiological situations, which implies that emotion plays a vital role in humans' health. Affective based is curb out from the concept of affective computing, as defined by Picard in 1997, as computing that arises from, relates to, or deliberately influences emotion[2]. The ability of a computer machine to recognize emotions infer an emotional state from observation of emotional expressions and through reasoning about an emotion-generating situation. Children with autism are challenged with the inability to feel or express emotion verbally and are also characterized by impairment in social communication, repetitive behaviour, and delay in speech. This disparity in autism awareness and access to quality health services emphasizes the need for a cohesive autism plan. The true rate of urban and rural autism prevalence across Africa and that begins with educating parents and removing the public stigma of autism [5]. Inadequate access to quality healthcare often results in isolation of these children depriving them of an opportunity of wellness or improvement. According to literature, the prevalence rate of autism is increasing at an alarming rate. In 2014, Centres for Disease Control and Prevention (CDC) in the USA showed that about 1 in 68 children were identified with ASD [3]. Statistics also show that in Nigeria, over 1.2 million citizens are with ASD; children and adults in Nigeria are diagnosed with different forms of Autism [4]. Therefore, integration of affective system into e-healthcare poses a great advantage to people with intellectual disabilities (such as ASD sufferers) in detecting their emotional state and infer back the result as an assistive technology that creates awareness to understand the physiological state of the autistic sufferers. Additionally, the facial expression elicited by the ASD sufferers might not correlate with the physiological feelings experienced emotionally. To this end, peradventure emotion they might exhibit can affect their behaviour in a way, a preventive measure could be taken in preventing some reaction that could be fateful [2].

Lisetti et al., in [8], developed an affective system multimodal architecture for monitoring emotions of humans and their responses by employing different physiological devices that captured both internal and external features and empathetic avatars and algorithms that mapped physiological signals to emotions. Also, a user's emotion (MOUE) that identify emotion satisfied by its sensory observations were developed. The k-Nearest Neighbour Algorithm and Discriminant Function Analysis are employed to map physiological **signals** to emotion. [9] designed affective character-based interfaces that address user emotion for the tele-home healthcare application domain. ProComp+ unit sensors captured subject data while decision-theoretical agent derived subjects' emotion from physiological input, selecting responses for the Empathic Companion. For the physiological interface and Agent control interface, Visual C++, HTML, and JavaScript were deployed respectively. In 2006, [10] developed an auto-monitoring system that categorizes from sets of emotion, the psychological state of the subjects. They estimated emotional state of human subjects by classifying vectors of features extracted from bio-sensors using the Support Vector Machine (SVM) algorithm. Mincheol et al. in [11], used a physiological measurement based approach taken via an emotional mouse with in-built sensors. PPG, GSR, and SKT were used to capture physiological data which was analyzed and mapped with subjective emotional states for emotion recognition with an Inference algorithm designed as emotional background intelligence. The emotional model was designed using rule-based. From the studies [[8], [9], [10]] mentioned above, they developed a physiological system which maps out the emotional state from the physiological signals but poses limitations, as their work cannot deduct prediction, make suggestions or tyro some suitable multi-modal action from that state. To this end, we need to develop a model that can identify the emotional state (Arousal, Valence, and Neutral), and then build the tools and method to tyro some suitable multi-modal action from that state. This paper presents a developed framework of an emotional-based e-healthcare controller model. The system provides effective methods for remote healthcare workers and physicians to join forces with one another over patient cases especially for patients with neurodevelopmental disorder (This paper focuses on children with autism). It also makes provision for real-time monitoring of patients' physiological state, resulting in a lessening of healthcare cost delivery with no diminish in the accessibility of quality healthcare. Therefore, access to quality healthcare with no geographical location barrier is harnessed with the potentials in internet and sensor technology, the bridging distance between the patients and the medical experts with effective monitoring of children with autism's physiological state.

II. PROPOSED MODEL

The user's Emotion Model (UEM) is developed to model the user's emotion via a sensory device. The designed range of UEM is to identify the affective element satisfied by its sensory recorded measurements and feedback the user about his/her state. UEM has the following components: (i) Sensory devices (ii) Arduino Mega Microcontroller (iii) Mobile Application with an interface that output the perceived emotional state to the user and like-wisely allows the autistics parent to decipher the child's psychological states enabling the parent to be acquainted with their ward's affective state.

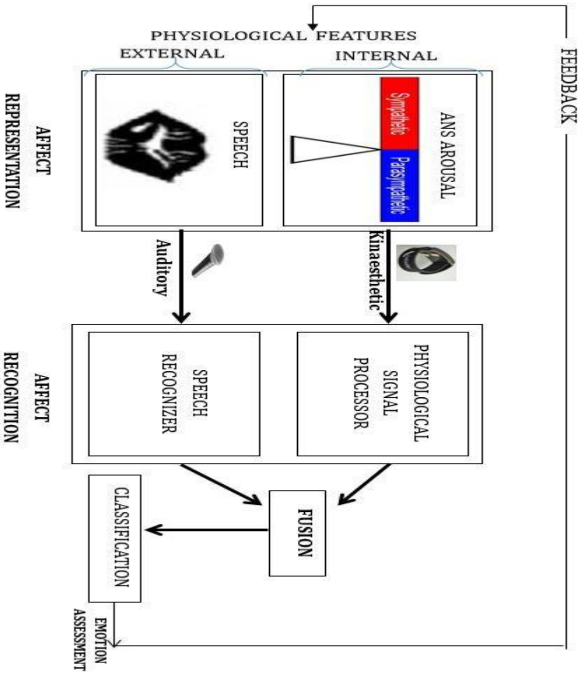

Figure 1: User's Emotion Model

A user expression of emotion linked to physiological features will be taken as input by the UEM. Throughobservation physiological signals are obtained through sensors worn or attached to the user's body where emotions are expressed.Modalities combine are: **K**inesthetic (e.g., obtained through EDA sensor), and **A**uditory (e.g., captured via speech recognizer sensor). The system received input from sensor in a signal-like form for physiological purpose, that describes subjective experience are fused and then classified into a particular arousal or valence emotion. Arousal measures the intensity of emotional states ranging between exciting states to calm state as the arousal value increases. Valence indicates the degree of pleasantness either positive or negative. As a result of bimodal nature of UEM system and its signal processing abilities, user's emotional states are accurately classified using fuzzy logic techniques.

In this framework, fuzzy logic-based affective space modeling was used in the V-A emotion model to process fuzzy variables on emotional expressions. To accurately process the V-A emotion model having the fuzzy variables, FIS system was used for modelling. The following rule was used in this study. The V-A values were processed with fuzzy membership function.

The Mamdani linear output model has the general form:

If $u_1A_1 + u_2A_2 + \ldots\ldots + u_iA_i$ then y (1)

$$y = v_0 + \sum^{m}_{i=1} v_i u_i \quad (2)$$

where u_i ($i = 1, 2, \ldots, n$) is input variables (i.e. dataset from the autistic child) and A_i is a constant parameter, from the fuzzy rule, the output is represented by y. For constant functions, the values of u_i is equal to zero and, hence S = v (constant value). In linear function model, the u_i input are given via FIS editor, where A_i are the given values for the input factors. Through the fuzzy rules, congruentin the interval of the input and output variables are done. If… then rules were used to connect various input factors in other to generate a particular output emotion. Mamdani's model in fuzzy was utilized alongside centroid defuzzificationin other to obtain the degree of emotion.

The weighted average defuzzification of the model is is given by:

$$z = \frac{\sum_{i=1}^{n} w_1 y_1}{\sum_{i=1}^{n} w_1} \quad (3)$$

where the weight wrepresents the overall truth value of the premise of the i -th implication for the input, and is calculated

$$w = \prod^{m}_{i=1} \mu_A(x_i) \quad (4)$$

where fuzzy set A is defined as the membership function μ_A, and $\mu_A(x_i)$ is the degree of membership function x_i in fuzzy set A_i

The rules given below shows the sample of the rules in the knowledge base created. The system will be implemented using if ..., then ..., rules in fuzzy logic,in which the conditional statement will be computed to obtain a desired output, enabling the system to make intelligent decisions.

IF Arousal level is-High and Valence level is Positive, Then Emotional state is High

IF Arousal level is-Low and Valence level is Positive, Then Emotional state is Neutral

IF Arousal level is-High and Valence level is Negative, Then Emotional state is Low

For the output variable emotion, the associated fuzzy sets are of the following degree: arousal (high, medium, low), valence (positive, negative) and neutral.

III. PROPOSED DESIGNS

The proposed system shows the physiological sensors (Electrodermal activity sensor and speech recognizer sensor) embedded on the Arduino Mega microcontroller. The integrated physiological sensors transmit the users' physiological measured sensory data to the receiving device via Bluetooth wireless transmission to the designed application which automatically uploads the signals to the dedicated MATLAB server.

A. Elements of Affective Devices

The elements of affective devices are briefly discussed below:

a) Physiological Sensors

Electrodermal activity sensor: This is a sensor used to measure the alteration in skin electricity conductance ability which happens as a result of reciprocal action between environmental events and an individual's psycho-physiological state. This is also known as Galvanic Skin Response (GSR). Physical, emotional or mental arousals automatically trigger a response in the skin as an indicator of the degree of excitement, relaxation or anxiety which can be called the sympathetic response of the autonomic nervous system, usually called to as "Fight or Flight."

Speech Recognizer Sensor: Speech Recognizer Sensor is used to measure the intensity or pitch signal. The signals are then processed and analyzed to obtain the useful signals in other to identify the emotional state of the user.

b) Arduino Mega Controller

The Arduino board designs use a variety of microprocessors and controllers. The board is equipped with sets of digital and analog output I/O pins that may be interfaced with various expansion boards and other circuits. The microcontroller is programmed using a dialect of features from the programming languages C and it provides an integrated development environment based on the processing language. Arduino mega is of high advantage because of it easy and fast prototyping. Several libraries are provided making the microcontroller program easier.

B. Experimental Design and Procedure

For the research study, the electrodermal activity will be used to capture the sensory data elicited by the child during the therapy session where the interactions between an autistic child and a speech specialized therapists are ongoing. The electrodermal activity sensor will be worn on the ring and index fingers of the child. The interaction will be recorded as part of speech therapy for children with autism, adapting the steps designed based on the Theory of Mind (ToM) [12]. The interaction started with the therapist strategically instigating the child's interest. Once the child's interest are instigated, these series of steps will be attempted.

1. Interest identification: The therapist shows card of objects and learning materials in other to strategically identify the interest of the child. If the child shows interest in the materials, the therapist starts from the point of interest where the child respond positively; otherwise, the therapist go on to the next page on the material or another material without the feedback.
2. Identification and Pronunciation: The therapist engage with the child displaying different object, either the child correctly identify the objects and pronounced it on his own or the therapist help him out in order to develop the speech and communication skills through identifying and pronouncing.
3. Imitation: The child is told to imitate him (therapist) with expressions.
4. Learning colors with music in the background
5. Phonics songs: The therapist plays a song with learning alphabets and words construction in other to calm the restlessness of the child during therapy.

IV. PROPOSED ARCHITECTURE

The main goal of this research is to integrate affective computing into e-healthcare system. This system consists of two modules and a sub-module namely: affective and e-healthcare module, with a recommender sub-module within affective module. The affective module involves integration of physiological sensor for emotion detection into the healthcare system. The sensor includes wearable Electrodermal activity and Speech Recognizer Sensor as discussed in session 3.1 above. The signal extracted from these sensors will be programmed on Arduino Mega Microcontroller by fusing the signals which are sent through Bluetooth to a Mobile application and automatically uploaded to a MATLAB dedicated system. The dedicated MATLAB server is responsible for the analysis of sensory data sent from the receiving devices (Phone or Tablet) through mobile application and classify it, into three emotional states, arousal, valence and neutral state and feedback the user via the mobile application in real. It is also responsible for remote monitoring of all sensory nodes connected to it and if any node is disconnected an emergency message is forward to the users' location, for prompt action to be taken concerning the connectivity. Also, the dedicated system remotely monitors every sensory node connected to the system. This implies that, if any sensor at any location disconnects from the system, an emergency call will be placed through to the patient's home for notification, and so that immediate action can be taken to reconnect back to the dedicated system.

The recommender module is a sub-module within the affective module meant for initiating (Music therapy) a preventive measure against meltdown that will be promptly effected prior to the time the specialist or therapist can be reached. At the instance the feedback is received on the Mobile application, if the emotional state of the child is mounting towards meltdown the buzzer alarms, securing the attention of the parents/caregiver and the specialist, if the child's physiological changes, Pc, mounts towards meltdown threshold, m, which may cause behavior disorder. A response is triggered by the mobile application, which is expressed as:

$$A_r = \begin{cases} 1, & P_c \geq m; \\ 0, & otherwise \end{cases} \quad (5)$$

where physiological changes is P_c, meltdown is m,1 for activation, 0 otherwise; and A_r is Alarm response.

Before when an intervention is effected from the specialist or the therapist a music therapy is activated to help calm the mounting state of the child towards meltdown. Interestingly, [16] literatures as revealed that music stimulates cognitive function since the hemispheres of the brain are used to process music, which allows music therapy to stimulate cognitive function and can help calm negative arousals in children with autism.[17]also agrees that Music therapy can help in the areas of social adaptation, joy, and the quality of parent-child relationships providing insight into understanding of emotional state of an autistics child.

The major objective of this module is to identify a state of emotions in patients and further create awareness when the emotional state tends towards meltdown. Meltdown refers to the state in which a patient displays a behaviour disorder that may be caused by the environmental events or reaction to change of routines that the patient could not explain because of their inability to know or express their emotions verbally. The physiological changes in patients that tend towards this meltdown will be identified by setting a threshold to raise a flag

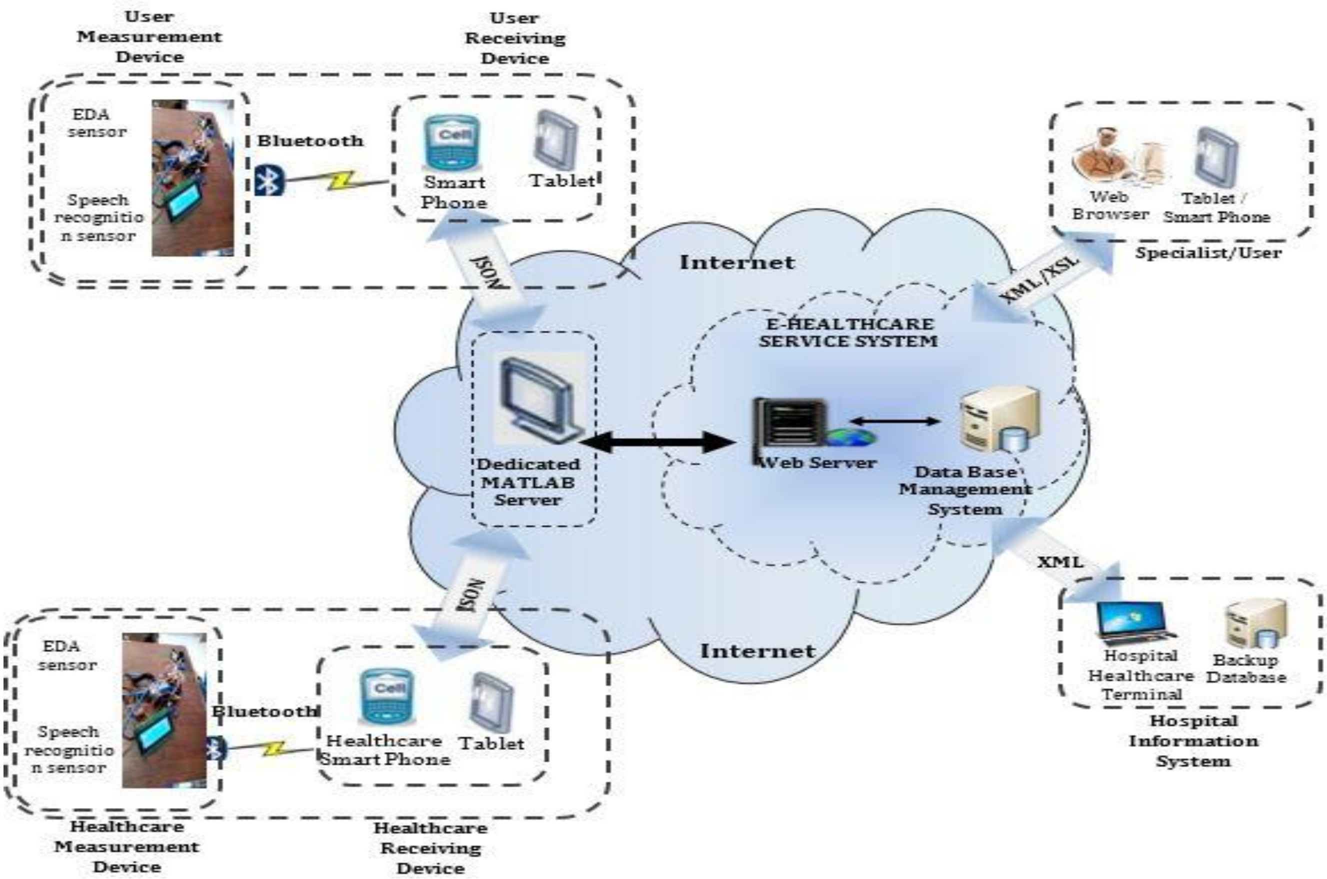

Figure 2: Proposed E-Healthcare System Interoperability Architecture

or alarm when such signals are sensed. In other, for healthcare specialists to remotely surveillance patients connected to health monitoring systems, emergency alarm is generated for immediate intervention through the mobile application.

The e-healthcare module will be designed using service-oriented architecture, which allows the interoperability of healthcare systems. Apart from the provisions to access experts in the field of autism, this module additionally makes room for case review across different health platforms. The e-healthcare module consists of the webserver, communication server and database management server. The web-server delivers the output screens to the web clients and database management systems store patient sensory data, history and records into database repositories.

The web-server specialized to running of a particular software, which serves contents to the World Wide Web and process incoming requests over the hyper-text transfer (HTTP) protocol outputting the screens to the web clients [13], with no additional software needed to be installed on the client computer, saves only a web browser [13]. It hosts the healthcare site and permits communication between the specialist and patients. The server also coordinates the sending of SMS /email to the patient once the appointment is scheduled by the specialist or therapist.

The communication server is responsible for controlling data-exchange with all other systems using extended mark-up language (XML) standards. The XML document will be transformed through an extended style language (XSL) technology. XSL either alters all data or some parts of the data in the actual file utilizing XSLT or opt for the content applying XPath; the outcome of the data can either be HTML or PHP Web page structure according to the individuals' needs. XSLT

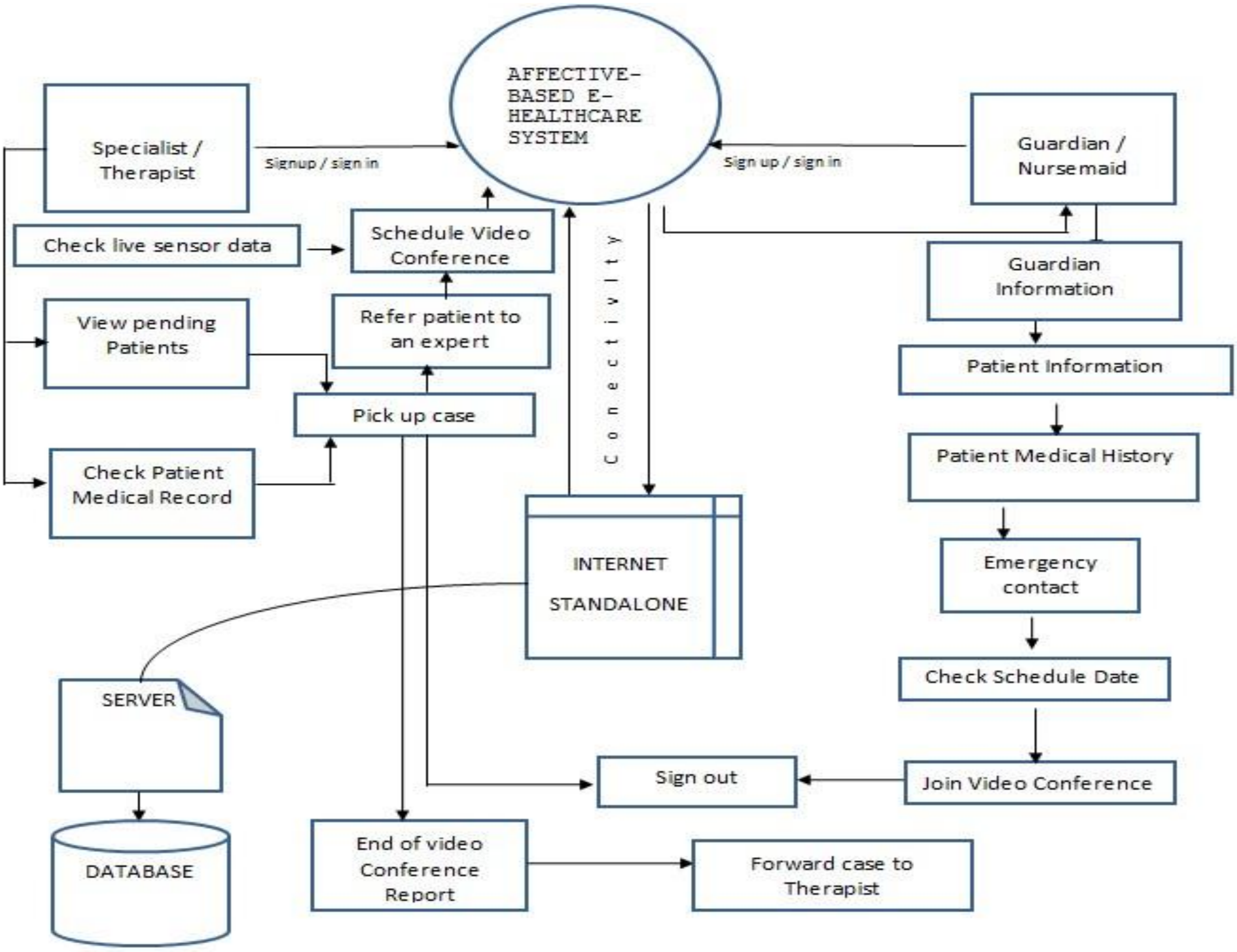

Figure 3 : Proposed Work Flow of Affective-Based E-Healthcare

can also be used to redirect the XML documents into the typical configuration to expedite the data relay.

The relational database management systems (RDBMS) store patient medical records.

The affective modules and the e-healthcare interoperability module will be integrated using JavaScript Object Notation (JSON) Application Programming Interface (API), allowing communication between the affective application and e-healthcare portal. API is a set of functions, routines, and procedures which allows for communication by linking two or more created applications to another application or program through their servers. JSON API module exposes an implementation for data stores and data structures. JSON format will be used concerning this research work which serves as an endpoint for console terminals.

The affective module will be implemented using C programming language to programmed the Arduino Mega Microcontroller to interface the sensors, Java for the Android Mobile version while the web application will be implemented using HTML5, CSS 3 and JavaScript (for frontend) and PHP, MySQL (for backend). The workflow diagram of the proposed system is shown in Figure 3.

V. CHALLENGES AND IMPLEMENTATION

Developing countries are faced with several issues that need to be addressed especially when it comes to adaptation and acceptance of e-healthcare, but top three issues are briefly described in this paper namely, inadequate knowledge in Information and Communication Technologies (ICT); security issues and lack of ICT infrastructure issue which are of paramount to consumers as well as providers.

A. Human factors: Awareness and Skills Acquisition

The modern model of healthcare delivery is inevitable in this technology-driven age. One of the major drawbacks for direct healthcare professionals is acceptance and adoption of newly designed healthcare delivery mode or method, because of the basic skill required to include Information Communication and Technology, Sensor and Web Technologies to operate in the new delivery method. The operability of the newly evolving technologies such as telemedicine, eHealthcare system, patient management system with the ethical issues is greatly dependent on the attitude of the healthcare professional, especially in the developing world.

B. Security and Privacy

The eminence of big data in healthcare requires a high level of security and privacy of patient's records. Securing of patient's records from malicious attacks, unauthorized users are prioritized and a general concern in the world. Due to health information's high level of sensitivity in terms of security and privacy, issues of reliability cannot be over reinforced [14]. Unfortunately, since the regulating bodies often take reactive mode rather than proactive mode [14], it results in lagging of technology.

C. Infrastructure Issues

Infrastructure issues need to be prioritized at the governance level as a derived model for effective use and standardization of information and technology must be implemented. Regulatory framework and national policies alongside ethic and standards should be implemented for the deployment of ICT innovations and solutions, documentation, and maintenance as well as equipping of staffs and highly confidentiality of patient-related data [15]

VI. CONCLUSION

The essence of this research is to develop an affective based e-healthcare system framework that can be used as a prototype to help decipher the emotional state of the children suffering from autism or other neurodevelopmental disorder. Integration of affective computing into health care broadens the applications of sensor technology into the health domain which can be clinic-based or home-based. Therefore, adequate cutting edge research should be more profound in the health sector, in developing countries such as Nigeria, especially in the integration of internet technologies, sensor networks, and ICT as these are the basis or foundation in which an effective e-health is developed. Efficient communication allows professionals to share information and best practices maximizing the benefit for patients and final users. To develop and improve the traditional healthcare delivery in Nigeria, healthcare providers and policymakers need to implement scalability platforms as well as interoperability infrastructure for effective cooperation strategies. It serves as a way to bridge the gap of having to travel to the city for consultation. This system when implemented, will also be of great advantage to patients suffering from chronic diseases such as strokes, diabetes, epileptics seizure, Alzheimer and depression and neurological disorder and also people dwelling in the rural or underserved areas with efficient cost-effectiveness.

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