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Voice activated Home System for the Movement Impaired Aged Persons

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***Abstract*—Smarthome system is one of the major growing industries that change the way people live, and most of these smarthome systems target abled young persons` seeking luxury and sophisticated smarthome platforms; but this design targets the disabled aged. This smarthome system allows the aged to wirelessly control home appliances from a centralized control unit. The developed system is integrated as a single portable unit that allows the user to wirelessly control lights, fans, electronic doors, electronic windows and robotic wheelchair. The system is portable and constructed in a way that it is easy to install, configure, run, and maintain. Here, voice being the primary interface between the aged user and the smarthome, a voice controlled smarthome system is designed, so that the users can perform their domestic tasks by just the use of their voices to speak their command words**

***Index Terms*—Command Words, Home Appliances, Smarthome System, Voice Control, Wireless Communication.**

I. Introduction

Smarthome is a home that uses wireless control systems and information technologies to reduce the need for the disabled aged persons' effort in the utilization of smarthome appliances and services. Voice activated Home system is a smart home system where the different installed integrated smart devices, in the presence of wireless communications network allows the users to wirelessly communicate with the home appliances through voice. These integrated communication systems provide the facility for monitoring and managing the performance of the home, and offer the occupants the support to use home facilities. Some of the today's modern home installed systems are central air conditioner and heating, fire and security alarms, home theater, televisions, lights, doors, windows, etc., and these systems and devices before now existed in total isolation from each other. Due to the rapid advances in wireless communication and information technologies it is now possible to embed various smartness in the home. Smart home therefore provides the facility for message passing of information and commands among these different installed devices and systems. Through this message passing, the smart homes interact intelligently with the aged persons occupying the home to provide comfort and safe living. This home interaction ranges from simple control of home illumination and ambient temperature to control of doors, windows, and navigation of agent based services, through delivery of particular information content based on the inside location and the activities engaged on by the aged occupant of the smart home. Sensors, microcontrollers and Radio Frequency (RF) and Bluetooth Wireless networks are technologies that are required to realize this smart home system. The setup includes either wired or wireless connectivity of the smart sensors and the appliances, to provide control facilities both locally and remotely, and to support special needs of the aged persons. Smart home technology has greatly improved independent living of the disabled aged persons, by increasing the home appliances usability and their service utilization without care-givers.

The remaining parts of this paper is organized as follows: In section II, the related work done by other researchers on voice activated smarthome systems and review of technology will be provided. Section III presents the proposed design, implementation details and tests carried out, while Section IV presents the results and the discussions of the tests system, and Section V is the conclusions and recommendations.

The main objective of this thesis is to design and model a smart home system for the aged persons, who suffer movement disability due to their age. The aged persons will interact with the smart home system using voice as the major means of interaction with this system.

This chapter presents a technical overview of the proposed system. This is a voice-activated smarthome system capable of actuating various home appliances at the convenience of the user. The chapter looks in-depth into the design and implementation of the proposed smart home system. It begins with the modelling of the system, the design - hardware and software - and finally, a prototype implementation for the system.

II. Literature Review

Many project on the application of voice in controlling various home devices have been carried out by many researchers. In [1], the authors proposed an intelligent home navigation system (IHNS) to facilitate the mobility maneuvering of the elderly and the physically challenged persons in their homes. The idea of an automated voice based home navigation system proposed, consist of a wheelchair, navigation module and voice module, and uses a speech recognition module SR-07 and a line follower module for navigation. This IHNS has predefinition for both

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voice commands relating to different rooms, and routes relating to those rooms for the navigation, and also a collision avoidance system was also installed in the project.

In [2], the authors proposed system consisted of a voice controlled wheelchair system, that is built using low cost speech recognition board that utilized HM2007 speech recognition chip and a microcontroller. The chip uses idea of paired-word for issuing a command to the system, so that if words similar to the voice commands are spoken within the vicinity of the voice recognition kit, they are not accidently detected. The system is speaker dependent and also an isolated speech system, to avoid further accidental voice detections.

In [3], the authors developed an intelligent access control system that is based on SPCE061A voice recognition chip, whose supporting software encompassed of the voice training module, the voice recognition module, the voice data processing module and the voice-playing module. The system completes the functions of collecting the voice data, distilling character, special voice recognition and voice playing in terms of initializing the system and the identification training. The central processor of this system is the SPCE061A single chip. The talker confirmation that is relevant to text is realized on the chip, and then homologous order and operation are carried out.

In [4], the authors, developed a system that accepts the usage of clap(s) as the source of input or command to control the lighting system in home in their projects. Their project offers the ability to control the lighting in term of the intensity or brightness with corresponding to the light intensity in a room due to environment. From their project, it has been established that the usage of sound is proved to be one of the ways of controlling the electrical appliance, but the application will be limited to one electrical appliance.

In [5], the authors in their research used HM2007 voice recognition chip in their project that enabled them to use voice to control wheelchair movement. In their project, a wheelchair is modified by equipping it with the motor system that will read the command given by the user to control its speed and movement direction. From their project, it has been established that the usage of voice is capable to be one of the method to control electrical devices. In [5], the authors used voice in their project as a secondary security measure to access a restricted area. The project created a system that required the user to key in a series of password and later verify it with the voice of the user if both are matched, then the door will be unlocked. From their project, voice has been established to have a very potential to be developed as one of the key component of a security related system. The main reason voice is a unique for each and every person, thus, using voice as criteria to access a system will make the system more safety and secure.

In [6], the authors presented a voice controlled smart house system that works with predefined set of voice commands for the defined areas in a house. New commands can be added as required, and a pattern processing technology (such as FIS), is used to process complex patterns such as experienced in speech and vision.

In [7], [8], [9], the authors in their projects on voice activated smartHome system uses either RF or Bluetooth module, and AVR Microcontroller to control heterogeneous home devices. From the literature reviews, the previous systems have not been made to control heterogeneous sensor devices, and so do not require multiple wireless technology module. In this project, the developed system is made more portable, low cost and easy to install and use, by making it a plug and play, and hand-held device.

III. The System Model

Voice sensing and recognition are at the core of this smarthome system, which requires a form of voice processing and analysis, after which the necessary communication to the home appliances for actuation would occur. It is with this in mind that this system was modelled. In this smarthome system, a sort of remote control is needed to operate the system, the system uses voice as the method of control due to the restrictions of the user considered. However, the control of the system comes with the use of voice and an optional manual input, which inputs are processed to be mapped to the appropriate command. After the processing and mapping to appropriate commands, the appliances of the system are controlled via a wireless link within the range of the link used. The Fig1 shows the conceptual model used in designing the system.

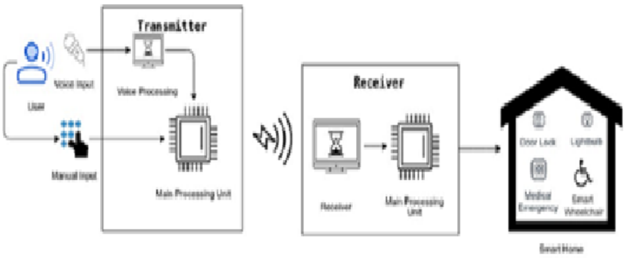

Fig. 1: The Smarthome System Design model

Considering the model in Fig 1, the breakdown of the system model into components would see it divided through the wireless link into two main components as: The Voice-activated subsystem and, the Electrical Control subsystem. Which is synonymous to a Transmitter-Receiver structure as seen in the Fig 1. The transmitting section consists primarily of voice or manual input to the system, and a form of processing where the input is recognized and mapped appropriately to a command, and then sent out wirelessly to the Receiving section. The receiving section consists of a wireless link for the reception of transmitted commands, a processing unit for verifying and acting upon the received commands to activate the selected endpoint. Considering the system model, the system is further designed for its hardware and software constituents.

A. Hardware Design

The system modular design is represented by the architectural block diagram shown in Fig 2, which gives a more detailed interaction of the components of the entire system. The entire smarthome system can be further analyzed separately according to their subsystems, based on this, the diagram has been sectioned into three main modules - The Voice-Activated Subsystem (VAS), the Electrical Control Subsystem (ECS) and Robotic Wheelchair subsystem (RoWS); where the VAS is the

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transmitting unit, while the ECS and the RoWS are the receiving unit.

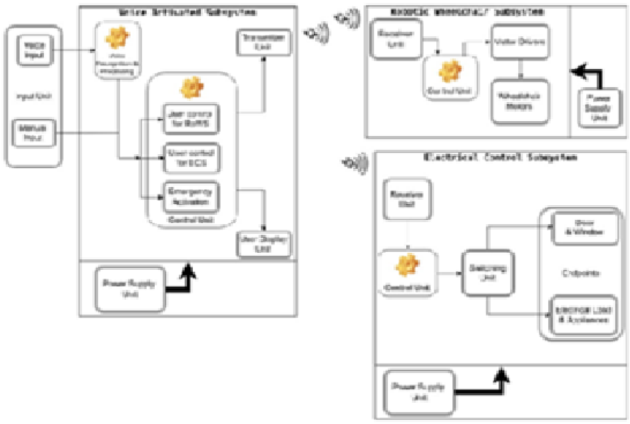

Fig. 2: The Architectural Block Diagram of the Entire System

The Voice-activated subsystem (VAS) comprises the input unit, the control unit, and the transmitter unit as shown in Fig 2. Like the name of the subsystem suggests, the main source of input is through *Voice*, however, there is an alternative manual source of input for robustness. Hence, the input unit consists of two input methods - voice and manual input. This input unit provides commands for controlling the endpoints, the robotic wheelchair or for emergency contact; this is done through voice or the manual input. In the control unit, the processing of the input signals takes place, which is coordinated by a microcontroller.

Here, the voice signals are processed for recognition by a Digital Signal Processor (DSP) and then sent to the microcontroller for transmission. The VAS is responsible for transmitting the processed signals, now in the form of commands, to the ECS or the RoWS.

The Electrical Control Subsystem (ECS) comprises the receiver unit, the control unit, the switching unit, and the endpoints as shown in Fig 2. The receiver unit is responsible for the reception of the transmitted signals from the VCS. The control unit comprises microcontroller at the heart of the subsystem, creating a connection between the received input with the switching unit and coordinating the entire subsystem. It handles endpoint selection through the switching unit by mapping the received command to the appropriate endpoint. The switching unit responds to activation from the control unit. It mainly consists of switching devices responsible for controlling endpoints - home appliances/parts of the house - to the desired state.

The Electrical Control subsystem (ECS) is the controller of the electrical AC and DC endpoints in the smart home. It receives commands from the VCS and responds to the command by acting such as turning on/off an electrical point.

The Robotic Wheelchair Subsystem (RoWS) is similar in structure and operation to the ECS, however, its endpoints are the electric motors of the robotic wheelchair for navigation see figure 5. It responds to the commands of its control unit having received commands from the VAS.

The Robotic Wheelchair subsystem (RoWS) is another receiving subsystem in this smarthome system as illustration is shown in figure 2. It is needed to aid the movement of the user since a disabled user is being considered.

B. The System Software Design

The software design consists of a step-by-step design of the subsystems of the software system architecture shown in the architectural block diagram of Fig 3. Each subsystem is linked only through a physical wireless connection as described in the hardware design, and an illustration of the design flow is seen in Fig 3.

The flow of data goes through the wireless link between the subsystems. The software in the VAS collects and processes the raw voice analogue input as digital data which is sent out to either of the ECS or the RoWS dependent on the active system. The software for the ECS receives input data, processes it and performs a corresponding action that actuates an AC or a DC appliance. Similarly, the software for the RoWS receives input data, processes it and performs a navigation action that corresponding to its input.

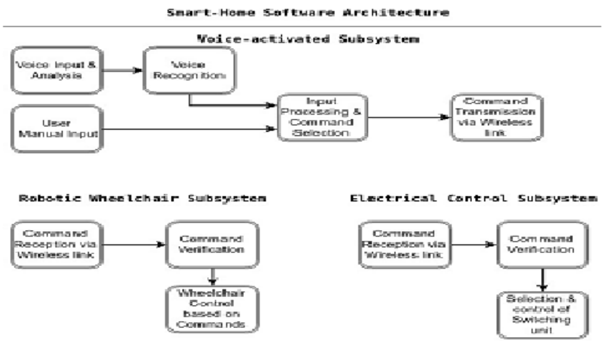

Fig. 3: The software architecture of the smarthome

An effective voice recognition requires the system to detect and allow commands from the specific user designed for. This requires training the VAS adequately to detect only the voice of the user. Hence, the VAS is capable of operating in two modes - the training mode and the normal mode, this is seen in Fig 4.

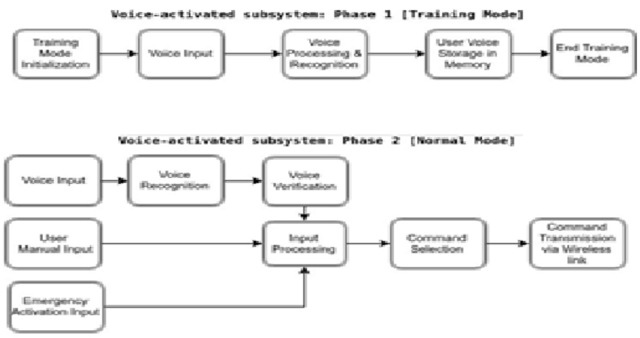

Fig. 4: The software architecture of the VAS

The two modes of the VAS is seen in fig. 4. The training mode of the VAS is necessary for the system to operate as intended. It takes in the analogue voice input from the user, extracts and converts it to digital format to be stored using quantization method, and the digitally processed signals known as command words, are stored, and these command words then form the preset commands of the smarthome system during normal operation.

The normal mode of the VAS operates such that there are reception and verification of the voice signals with the stored voice commands of the user. When the VAS has been trained and is in normal mode, analogue voice input is sent into the VAS and converted to a format that can be verified with the predefined voice input stored during training. Once verification is successful, the commands that map to the predefined voice input are selected to enable the system to perform a particular function.

The control unit of the ECS holds the software for the working of this subsystem. It controls the flow of data into the subsystem and activates any action corresponding to the input received. As seen in figure 4, the ECS processes data through Data Reception, Command Verification, and Command implementation.

The ECS receives incoming data through its wireless link with the VAS. Its control unit manages the flow of data into the subsystem through the device used for communication. On reception, the input data is decoded and is passed to the control unit for verification. Its software verifies the input data from the wireless link and activates a corresponding action. If an invalid data is sent, then no action is performed. Since the control unit interfaces the communication unit with the rest of the circuitry - switching block and the endpoints, it handles all processes and the selection of the endpoint to be activated. Its software directs the flow of data between the interfaced units.

The software for the RoWS works similarly to that of the ECS. The control unit of the RoWS also manages the flow of data into the subsystem and activates any action corresponding to the input received. It also processes data through Data Reception, Command Verification, and Command implementation as seen in the software architecture of the smarthome system shown in figure 3. The RoWS receives incoming data through its wireless link with the VAS. Its control unit manages the flow of data into the subsystem through the device used for communication. On reception, the input data is decoded and is passed to the control unit for verification. Its software verifies the input data from the wireless link and activates a corresponding action for navigating the wheelchair. Since the control unit interfaces the communication unit with the rest of the circuitry - the drive-train for the wheelchair, it coordinates the movement of the wheelchair. Its software directs the flow of data between the interfaced units.

IV. The Smarthome System Prototype Implementation

The smarthome system designed and subsequently implemented is a controllable smarthome system where a control input is used to activated different equipment in the home.

The system hardware and software design processes involving the system architecture with detailed interactions of different sub-peripheral hardware and software components were implemented. The VAS was implemented following the proposed design with the control unit being primarily one that reacts to the voice of the user. The RoWS was implemented with a prototype of a robotic car with voice commands from the VAS controlling the movement adequately. The ECS was implemented to turn on/off endpoints on reception of voice input. The endpoints consisted DC loads such as electrical motors for controlling the opening and closing windows and doors, and AC loads for turning on/off light points, and so on.

The implementation of this prototype is shown in the Fig 5. The voice input, which are converted into digital signals, are sent to the robotic car and the ECS so as to decide whether to trigger an alert, perform an action or otherwise.

Fig. 5: The full smarthome system showing the VAS, ECU and the RoWS

The schematic design for the Smarthome System was carried out using the Schematic designer in the Proteus Software suite as shown in Fig 6.

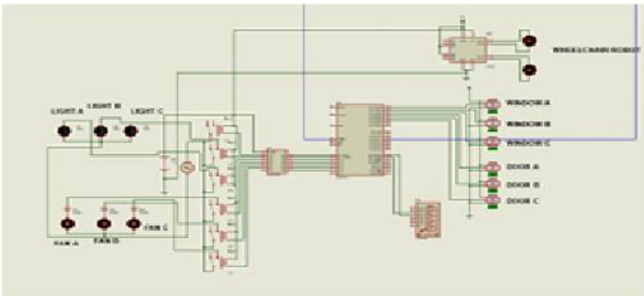

Fig. 6: The schematic design of the Smarthome System

The various experimental tests conducted during the course of executing this research commenced immediately after the voice commands of the aged beneficiaries were encoded into the system through the processes known as system trainings. The summary of various tests conducted are summarized in table I below.

TABLE I: The Summary of the System Tests

TESTING METHODS	TESTING FACTORS	DEVICE RESPONSE	ACCURACY
AMPLITUDE OF VOICE	Normal conversation dB	Device responds 7 out of 10 times	70%
	Whisper dB	Device responds 1 out of 10 times	10%
NUMBER OF WORDS	Minimum 5 words	Device responds accurately 5 out of 5 times	100%
	Maximum words	Device responds accurately 5 out of 10 times	50%
MICROPHONE DISTANCE	Lesser distance 0.25 Meters	Accurate response 90 out of 10 times	100%
	Greater Distance 5 Meters	Accurate response 5 out of 10 times	50%
ENVIRONMENTS	Quite	Accurate response 9 out of 10 times	90%
	Noise	Accurate response 2 out of 10 times	20%
MULTIPLE	Multiple	Device responds	50%

SPEAKERS	speakers	accurately 5 out of 10 times	
	Individual speaker	Device responds accurately 7 out of 10 times	70%
ROOM SIZE	Dead Rooms	Accurate response 8 out of 10 times	80%
	Live Rooms	Accurate response 5 out of 10 times	50%

V. Results and Discussions

A. Results

The result of various experimental tests conducted during the course of achieving the objective of this research and the analysis are based on the interpretations of the results obtained from the tests.

The results portraying the level of system responsiveness and accuracy to the users spoken voice command, which are obtained from both the dead home and live home, and the overall effectiveness results is shown in Fig 7 and the comparison result is shown in Fig 8.

Fig. 7: The System Overall Effectiveness Result.

The overall system effectiveness results on figure 8 demonstrates that all trials in quite or dead home almost achieved zero percentage error, and even at average, dead home still has a very lower percent error. But, when the home environment of test was in a noise or live home, a very higher percentage error occurred because of the surrounding environmental noise thus, the average percentage error for the live home is higher. Hence, it can be seen that the design is much more effective in a quite or dead home with 90% or 80%, while in a noise or live home it is only 20% or 50%, and based on these results it can be deduced that the system works better on a quite or less noisy environment area as depicted on Fig 8.

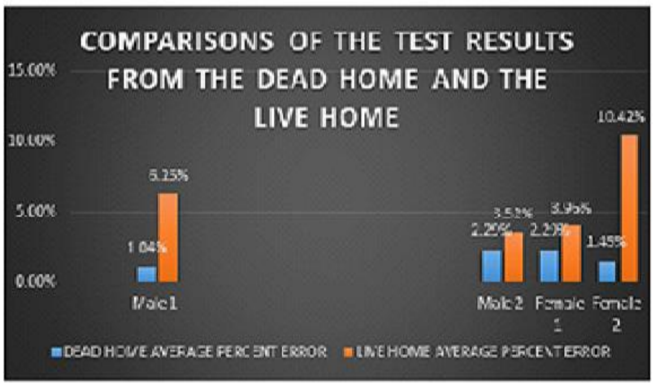

Fig. 8. comparisons of the system performance in a dead home and a live home environment.

The result obtained from calculating the system response time, which is the time that elapsed once the control signal has been activated and the corresponding operation was executed. The time response results for four sets of all five robot wheelchair control commands (20 commands) sent to the smart wheelchair, and the result is represented in Fig 9.

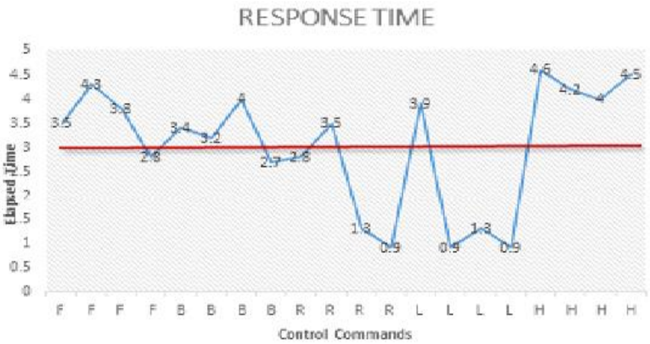

Fig. 9: System Response Time Plot for 20 different commands

The points above the red line in Fig 9 are commands prone to error since they are above the average response time and may not execute as the next command may overwrite the previous command, and this may prove to be inefficient.

Average Response Time = Total Response of All Readings/Number of Trials = 55.1/20

Average System Response Time = 2.76 (seconds).

Finally, the interpretation of various results showed:

1. that from the voice command recognition test results, the effectiveness of the system is affected by the system's environmental noise.
2. that from system performance evaluation test result, due to high system average response time, the system is prone to errors when system user wishes to make quick consecutive changes in navigation.

B. Discussions

The microphone (voice input device) distance sensitivity test results showed that at close distances ranging from 0.5 to 1 meter, the microphone sensor is very much sensitive to voice command and it responded according to the command that is uttered. However, the amplitude of voice command uttered also affected the results of the test here; that was the reason it was possible at some point, to detect some testers' voice commands even at farthest point.

The effects of environment on system level of response and accuracy result showed that the system's response to voice command in a dead home is more accurate in a quiet home environment than in the system's response in a live home.

The overall effectiveness of the results showed that all trials in dead home almost achieved zero percentage error, and even at average, dead home still has a very lower percent error. But, when the home environment of test was in a live home, a very higher percentage error occurred because of the surrounding environmental noise thus, the average percentage error for the live home is larger. Therefore, it can be seen that this design is much more effective in a dead home with 92.93%, while in a live home it is only 75.85%, and based on these results it can be deduced that the system works better on a less noisy environment area as depicted on fig. 8.

Finally, the interpretation of various results showed: that from the voice command recognition test results, the effectiveness of the system is affected by the system's environmental noise; and that from system performance evaluation test result, due to high system average response time, the system is prone to errors when system user wishes to make quick consecutive changes in navigation.

VI. Conclusion

This research was inspired by the difficulties in which the aged persons in Africa who live alone in their home without a helper or care-giver encounter in the course of performing their everyday life activities. One of the biggest need of this group of persons is to continue their daily life activities when they are alone at home without an assisting care-giver. Here in this research, voice recognition based smart home system which can be controlled by the aged person through voice as well as through SMS technology was designed and implemented. The prototype developed enabled the aged persons to control electrical and electromechanical operated devices in a home. The voice recognition chip is used to implement voice recognition while wireless communication was established using RF transceiver modules and Bluetooth transceiver modules because of their efficiency and low power consumption. The system was able to control the smarthome appliances such as: a light bulb, fan, doors, windows, wheelchair, and make emergency calls. The designed voice controlled smart home system, has portability, expandability and easy to installed features.

Based on the objectives of the design, several conclusions can be made. The general conclusion is that the voice-activated control system is possible to be operated in a smart home and could be used to control frequent use functions that aged persons needed in homes. Further development of this system may contribute to homes effective services and homes engagement with technology. The specific conclusions are as follows: The system designed allows the user to turn on & off: lights, and fan through voice recognition; and The system design also allows the user to use voice commands to navigate the motorized wheelchair, open & close doors and windows, and make emergency calls

The system test result shows that the systems function is more successful in a dead room rather than a live room. Also, the results of the tests, showed that the system respond more effectively with a male voice than female voice due to its preciseness.

For this smart home system, the following is recommended to improve its functionality and usability:

1. Use a more functional microphone, so that the system could recognize the command clearly and can function even in noisy environment.
2. Use wireless microphones so that it could be put anywhere.

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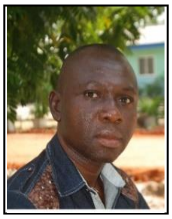

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