UNIVERSITY OF PORT HARCOURT

EMBEDDED SYSTEMS:

THE GAME-CHANGER IN MODERN INDUSTRIALIZATION

An Inaugural Lecture

By

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ORDER OF PROCEEDINGS

2.45 pm: Guests are seated

3.00 pm: Academic Procession begins

The Procession shall enter the CBN Centre of Excellence Auditorium, University Park, and the Congregation shall stand as the Procession enters the hall in the following order:

Academic Officer

Professors Faculties/School

Deans, School of Graduate Studies

Provost, College of Health Sciences

Lecturer

University Librarian

Registrar

Deputy Vice-Chancellor- Research and Development

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Vice-Chancellor

After the Vice-Chancellor has ascended the dais, the Congregation shall remain standing for the University of Port Harcourt Anthem.
The Congregation shall thereafter resume their seats.

THE VICE CHANCELLOR'S OPENING REMARKS
The Registrar shall rise, cap, and invite the Vice-Chancellor to make his opening remarks and introduce the Lecturer.
The Lecturer shall remain standing during the Introduction.

THE INAUGURAL LECTURE

The Lecturer shall step on the rostrum, cap and deliver his Inaugural Lecture. After the lecture, he shall step towards the Vice Chancellor, cap and deliver a copy of the Inaugural Lecture to the Vice Chancellor and resume his seat. The Vice Chancellor shall present the document to the Registrar.

CLOSING

The Registrar shall rise, cap and invite the Vice Chancellor to make his Closing Remarks.

The Vice Chancellor's Closing Remarks.

The Vice-Chancellor shall then rise, cap and make his Closing Remarks. The Congregation shall rise for the University of Port Harcourt Anthem and remain standing as the Academic [Honour] Procession retreats in the following order:

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Registrar

University Librarian

Lecturer

Provost, College of Health Sciences

Dean, School of Graduate Studies

Deans of Faculties/School

Professors

Academic Officer

DEDICATION

This inaugural Lecture is first and foremost dedicated to God the Father, God the Son and God the Holy Spirit; and secondly, to my one and only iconic wife **Mrs. Bliss C. Omijeh** and my lovely five Children: **David, Delight, Divine, Destiny and Dominion**.

ACKNOWLEDGMENTS

I am what I am today because the **"I AM THAT I AM"** saved me through His dear Son, **JESUS CHRIST**; and brought "Men and Women" as Destiny **Helpers** on my way - Omijeh

First and foremost, I would like to thank our digital 9th Vice Chancellor of the University of Port Harcourt, **Professor Owunari Abraham Georgewill** for granting me the approval to present this inaugural lecture to you all. He has been a destiny helper to me in many ways. Through his leadership, I became; and was announced as **the first Professor of the new order at the University of Port Harcourt on December 10, 2021**. His contributions to my career growth ever since are immeasurable. Indeed, he is an amiable leader with exceptional qualities and unwavering passion to see the younger ones grow.

I extend my profound gratitude to all the principal officers: **Professor Clifford Ofurum** (Deputy Vice Chancellor, Administration), **Prof. Kingsley Owete** (Deputy Vice Chancellor. Academics), **Prof. Iyeopu Siminialayi** (Deputy Vice Chancellor, Research & Development), **Dr. Gloria Chindah** (Registrar), **Dr. Godspower W.Obah** (Bursar) and **Prof. Helen Emasealu** (University Librarian). **May God bless them all.**

Please permit me to appreciate the former Vice Chancellors of this great citadel of learning whom I worked directly with, for their various supports and impacts on my career. First on the list is **Prof. Don Baridam** (6th VC). He employed me as a staff of this great university on May 22, 2006. Let me sincerely appreciate **Prof. Joseph A. Ajienka** (7th VC) who appointed me as the pioneer Coordinator of the Department of Electronic and Computer Engineering in 2013; and approved my proposal for the establishment of the Centre for Information and Telecommunication Engineering (CITE) in 2014; and thereafter, appointed Prof. Monima Briggs (my boss and mentor) as the pioneer Director of the Centre. Furthermore, I want to heartily thank **Prof. Ndowa E.S. Lale** (8th VC) who appointed me the acting Head of the Electronic Engineering Department in 2016; and also, appointed me as Acting Director of CITE in 2018. Finally, on the list, my heartfelt gratitude goes to **Prof. Stephen A. Okodudu** (Fmr . Ag. VC) who God used greatly in removing the stumbling blocks and obstacles from my path to the rank of a professor. **May GOD bless and reward them all.**

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Finally, let me specially appreciate my one and only iconic wife **Mrs. Bliss C. Omijeh** and my lovely five Children: **David, Delight, Divine, Destiny and Dominion**.

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1.0 INTRODUCTION

As I was growing up at about age 8, I would wake up at midnight and stay hours seeing myself as an Engineer; designing aircraft, automobiles, and Unmanned Aerial Vehicles (UAVs or Drones); trying to demystify technologies behind what looks like mysterious inventions. Most of the things I imagined then, the theories were what I was taught later in physics, years after. Although it was a dream then but today, it is a reality. Therefore, standing before you today, is a Professor of Electronic and Communication (Telecommunication) Engineering, **Professor Bourdillon Odianonsen Omijeh.**

My career passion focuses on the design, development and implementation of electronic and embedded systems-based communication technologies. This includes everything from traditional telecommunication networks to modern wireless and satellite communications which encompasses a broad range of technologies and methodologies to ensure efficient and reliable transmission of information from one end to another.

Generally speaking, Communication means the transfer of information (signal, voice, data, video, or pictures) from one point to another or from one person to another especially within a short distance. If the transfer is over a long or remote distance, it is called "Telecommunication". The prefix "Tele"- means far or remote distance. Therefore, a "Communication Engineer" who designs and implement electronic-based systems for the transfer of information over a long distance is also called a "Telecommunication Engineer". However, where a more robust design is needed for optimized real time processing and automation, a microcontroller-based "Embedded System" is integrated.

Vice Chancellor Sir, dear colleagues and distinguished ladies and gentlemen, someone said and I quote **"Anybody can give an inaugural speech but only Professors deliver inaugural Lectures"**

Therefore, I, **Professor Bourdillon O. Omijeh** will be delivering the …. inaugural lecture, first of its kind, in the field of Electronic and Communication Engineering in the University of Port Harcourt; and the title of my Inaugural lecture is "**Embedded Systems : The Game Changer in Modern Industrialization.**

1.1 Background to the Inaugural Lecture

Industrialization has undergone a series of transformative phases, from mechanization in the First Industrial Revolution to automation and digitalization in the modern era. Today, **embedded systems** stand at the heart of this transformation, enabling industries to achieve unprecedented levels of efficiency, precision, and automation as a game-changer. See Fig. 1

1.2 Aim of the Inaugural Lecture

The aim of my inaugural lecture is to present "Embedded Systems" as the game-changer in modern industrialization; and to showcase my embedded systems-related research breakthroughs and their institutional impacts in terms of industry - collaborations, community impacts, global visibility, grants and infrastructural development to the University of Port Harcourt.

"True research in the Fourth Industrial Revolution (4IR) era goes beyond publications—it's about securing grants, , filing patents, launching startups and fostering collaborations that turn innovations into real-world impact." -Omijeh-

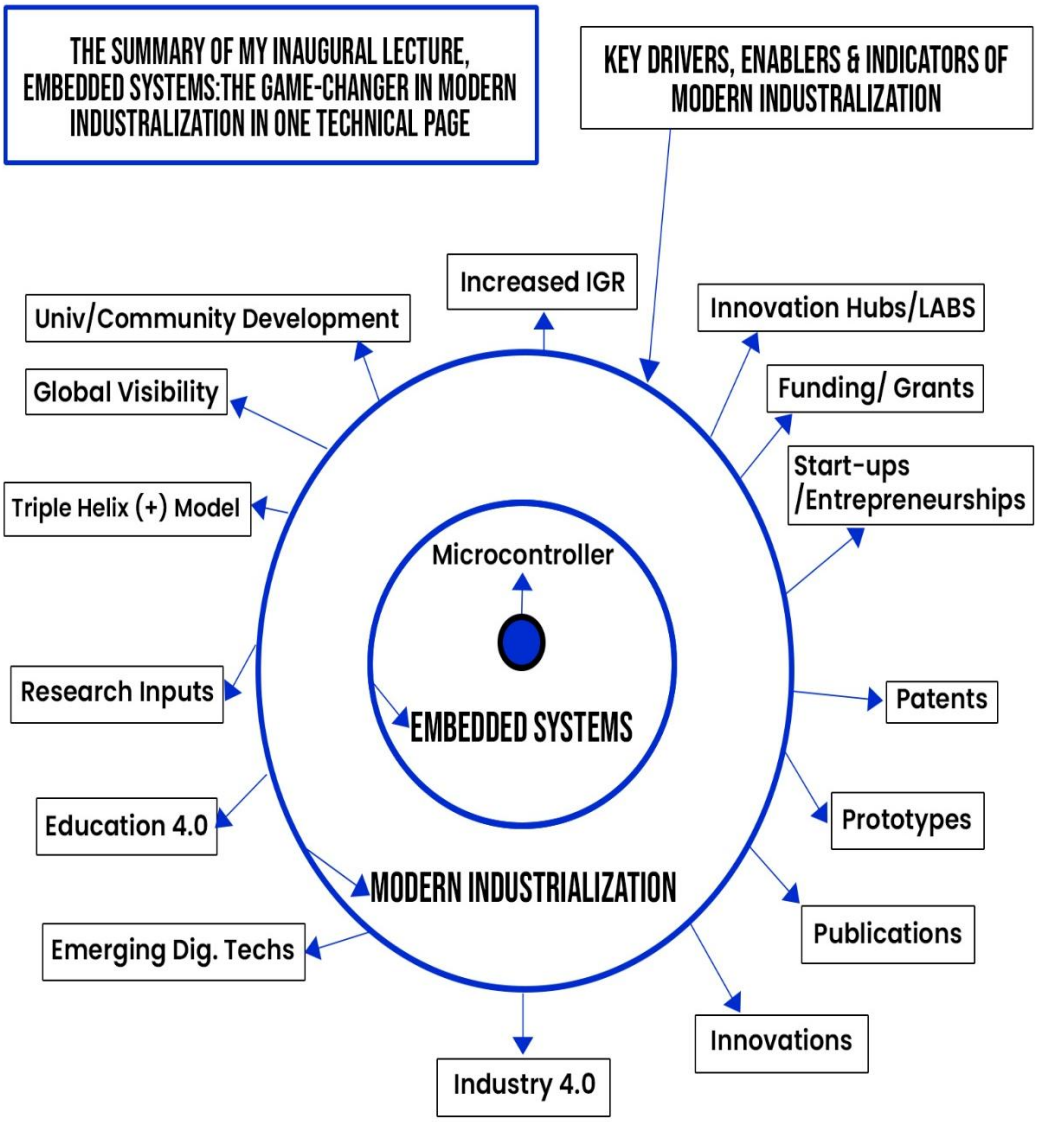

Fig 1 : Embedded Systems : The **Game-Changer** in Modern Industrialization

2.0 Embedded Systems

An **embedded system** is a specialized computing unit designed to perform dedicated tasks within a larger system. Unlike traditional computers, embedded systems are optimized for real-time operation, low power consumption, and seamless integration with hardware components. These systems are now integrated to smart factories, robotics, process automation, and industrial Internet of Things (IIoT), making them the backbone of Industry 4.0 and the game changer in modern industrialization ((Lee & Seshia, 2020)

For Short:

i. An embedded system is like a tiny brain inside devices that focus on one job and do it well! .
ii. An embedded system is like a tiny specialist—it does one specific job well and doesn't get distracted by anything else!

A Calculator in a Supermarket: It's not a full computer, but it's smart enough to add, subtract, and calculate totals. It does just one job—helping with transactions—that's an

embedded system at work!

A Traffic Light: It doesn't need a full computer—just a small system programmed to turn lights red, yellow, or green at the right times. That's an embedded system at work!

A Remote Control: You press a button, and your TV responds. The tiny system inside the remote is only built for sending signals—not for running apps like a smartphone. That's an embedded system at work!

An ATM Machine: You insert your card, enter your PIN, and get cash. That is embedded system at Work!

A Car's Airbag System: It doesn't run on a full laptop, but a small embedded system instantly detects a crash and deploys the airbags.

2.1 Key Features of Embedded Systems

Embedded Systems are distinct from general-purpose computers. Below are the key features:

i. **Dedicated Functionality:** Embedded systems are designed for a specific task or function. Unlike general-purpose computers, they do not support multiple applications. Examples include automotive engine control units (ECUs), pacemakers, and washing machines.

ii. **Real-Time Operation:** Embedded systems operate in **real-time**, meaning they must respond quickly to inputs. They are used in critical applications like airbag deployment, medical monitoring, and industrial automation.

iii. **Low Power Consumption:** Embedded Systems are optimized for energy efficiency, especially in battery-powered devices. They are very useful in applications like Internet of Things (IoT) devices, wearables, and remote sensors.

iv. **Small Size and Lightweight Design:** Embedded Systems are designed to fit into compact devices. They use microcontrollers (MCUs) or microprocessors (MPUs) with built-in memory and peripherals.

v. **High Reliability and Stability:** Embedded systems are designed to work continuously and reliably, often in harsh conditions as required in industrial automation, medical devices, and aerospace systems.

vi. **Minimal User Interface:** Most embedded systems do not have complex user interfaces. Some use LED indicators, buttons, touchscreens, or small LCDs. In IoT and smart systems, they may communicate with a smartphone app or cloud server.

vii. **Hardware and Software Integration:** Embedded systems combine hardware (microcontrollers, sensors, actuators) and software (firmware, RTOS, drivers).Firmware is pre-installed and optimized for the hardware.

viii. **Connectivity and Communication:** Many modern embedded systems support wired and wireless communication protocols, such as: Wired**:** UART, SPI, I2C, CAN bus, Ethernet Wireless: Wi-Fi, Bluetooth, Zigbee, LoRa, NFC. It enables IoT and automation in industrial and consumer applications.

ix. **Low Cost and Mass Production:** Embedded Systems are designed for cost efficiency, making them affordable for mass production. They are used in high-volume consumer electronics, automotive systems, and industrial applications.

x. **Security and Safety:** Embedded systems in critical applications must be secure and resistant to hacking. Safety-critical systems (e.g., medical devices, avionics, automotive) follow strict safety standards.

These unique characteristics make them ideal for automotive, healthcare, industrial automation, consumer electronics, and IoT. The tiny brain of Embedded System is the microcontrollers.

2.2 Microcontroller

A **microcontroller** (**MC**, **UC**, or **µC**) or **microcontroller unit** (**MCU**) is a small computer on a single integrated circuit. It contains one or more processors along with memory and programmable input/output peripherals. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general-purpose applications consisting of various discrete chips.

2.3 Modern Industrialization

Modern industrialization refers to the advanced stage of industrial development characterized by the use of emerging digital technologies, automation, and large-scale production processes. It involves the shift from traditional manual labor and simple machinery to highly efficient, mechanized, and computerized systems ((Xu et al,2018).

2.4 Key features of modern industrialization

i. **Automation and Robotics** – The use of AI, robots, and smart machines to enhance production efficiency.
ii. **Additive Manufacturing** – Technologies like 3D printing, CNC machining, and precision engineering.
iii. **Mass Production** – Large-scale manufacturing of goods using assembly lines and sophisticated logistics.
iv. **Digitalization** – Integration of the Internet of Things (IoT), cloud computing, and smart factories.
v. **Renewable Energy & Sustainability** – Emphasis on green energy sources like solar and wind to reduce environmental impact.
vi. **Global Supply Chains** – Interconnected production networks spanning multiple countries.

Modern industrialization is often linked to **Industry 4.0**, which emphasizes smart factories, data-driven decision-making, and cyber-physical systems.

Keywords and terms associated with Modern Industrialization include: Innovation, Emerging Digital Technologies, Sustainable Development Goals, Industry 4.0, Education 4.0, Start-ups, Entrepreneurship, Embedded Systems, Triple Helix - based Research and Collaborations.

2.5 Industry 4.0

Industry 4.0 or The Fourth Industrial Revolution (4IR) is a neologism describing the rapid technological advancement in the 21st century which affects the overall process of Invention, Innovation and diffusion of technology to achieve the Global Sustainable Development GOALS (SDGs) (Bai et al, 2020). The overall aim of modern Industrialization is full system automation and optimization which is the key function of Embedded Systems(Bai et al, 2020).

2.6 Industrial Revolution

The **Industrial Revolution** refers to the series of technological, economic, and social transformations that drastically changed production methods, industries, and societies over time. The First Industrial Revolution was based on mechanization and steam engines; the second on the use of electricity energy and mass production; and the third

on electronics and information technologies, resulting in a high level of automation in manufacturing((Lou et al, 2019)). Industry 4.0 takes the automation of manufacturing processes to a higher level with smart autonomous systems capable of self-cognition, self-optimization, and self-customization (Fourth Industrial Revolution , 2016).

The roots of industrialization can be traced back to the late 18th century in **Britain**, where economic, political, and scientific advancements created an environment suitable for industrial growth. Prior to this period, societies relied on manual labor and agrarian economies, with most production taking place in small workshops or homes. However, as demand for goods increased, new methods of manufacturing became necessary(Mokyr, 1990)

1st **Industrial Revolution** (1760–1840): marked the shift from agrarian economies to factory-based systems, primarily powered by steam engines and mechanized textile production. Key innovations such as James Watt's steam engine, spinning jenny, and mechanized looms revolutionized industries by increasing efficiency and output. This period also saw rapid urbanization, as people moved from rural areas to industrial cities in search of work (Ashton, 1997)

2nd Industrial Revolution: Expansion and Growth of Mass Production (mid-19th century)

By the mid-19th century, industrialization spread beyond Britain to Europe, North America, and other parts of the world. The Second Industrial Revolution (late 19th to early 20th century) was characterized by advancements in electricity, steel production, and assembly line manufacturing. The widespread use of electric power significantly improved industrial efficiency, allowing factories to operate at higher speeds and lower costs. Henry Ford's assembly line (1913) revolutionized mass production, making automobiles and consumer goods more affordable. This period also saw rapid developments in communication and transportation, with the invention of the telephone, telegraph, railroads, and automobiles further connecting economies (Chandler, 1990)

3rd Industrial Revolution: The Digital and Automation Era (Mid-20th century)

The Third Industrial Revolution (mid-20th century) introduced computers, electronics, and automation, shifting industries from mechanical systems to digital technology. The introduction of programmable logic controllers (PLCs), microprocessors, and industrial robotics revolutionized manufacturing, improving precision, flexibility, and efficiency. Automation reduced reliance on human labor, while advancements in computing allowed for better data processing and management (Freeman & louca, 2001)

4th Industrial Revolution: The Rise of Smart and Connected Industries

Currently, the world is experiencing the Fourth Industrial Revolution (Industry 4.0), which is driven by Artificial Intelligence (AI), the Internet of Things (IoT), big data, embedded systems, and cloud computing. Factories are becoming more intelligent, automated, and interconnected, enabling real-time data analysis, predictive maintenance, and smart decision-making. Technologies such as 3D printing, blockchain, and cyber-physical systems are further shaping industrial landscapes, creating more adaptive, efficient, and sustainable manufacturing processes (David &Kim, 2018). See fig.2

2.7 Opportunities of Industry 4.0

Industry 4.0 provides the following key opportunities as itemized below :

i. Economic gains, such as increased revenues because of lower transaction and transportation costs.
ii. More reliable and consistent productivity and output and better quality products Shift to mass customization with an increased role for SMEs
iii. Enabling innovation across many applications, with a much larger economic impact on growth
iv. Energy-efficient and environmentally sustainable production and systems
v. Effective use of human and material resources
vi. Increased food security and safety
vii. Improvements in the health and safety of workers
viii. Changes in education and training systems
ix. More open innovation systems
x. Changes in the organization of work, with more remote, flexible and on-demand work becoming a standard

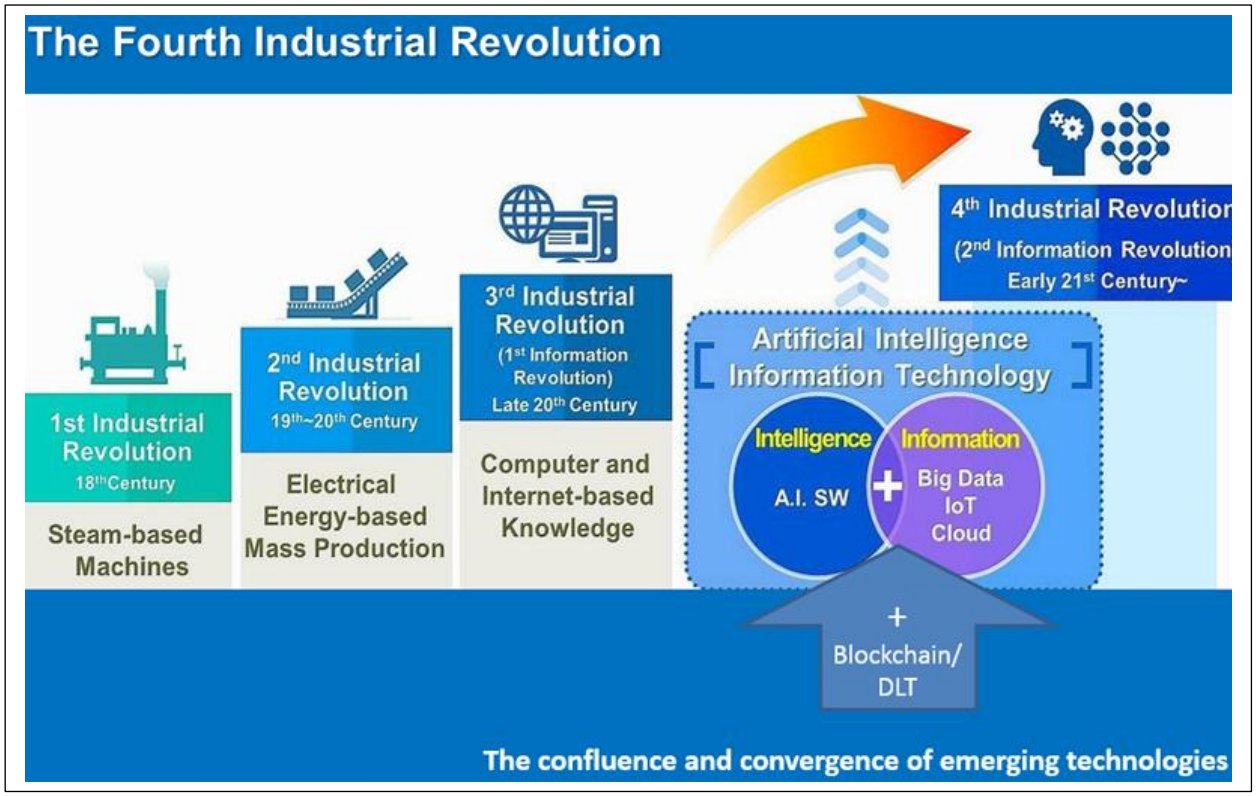

Fig 2: Industrial revolution over time

2.8 Emerging Digital Technologies Driving

Industry 4.0 is driven by the following emerging digital technologies: AI, Generative AI, Machine Learning, Data Analytics, Internet of Things, Cloud computing, Quantum computing, edge computing, Robotics, Virtual /Augmented Realities, 3D printing, personalized Medicine, Neuromorphic Computing, Green Energy Technologies, Metaverse, Block Chain, wearable Heath monitors, Extended reality (XR), voice activated tech, Space Tourism, Digital Twin, Internet of Things, Nano Technology, 5G etc.

a. Artificial Intelligence (AI)

Artificial Intelligence (AI) is the development of computer systems that can perform tasks that typically require human intelligence. These tasks include understanding language, recognizing patterns, solving problems, and making decisions. AI relies on algorithms and large amounts of data to learn and improve over time. It is used in various applications, from virtual assistants and self-driving cars to medical diagnosis and financial forecasting. By automating processes and enhancing efficiency, AI is transforming industries, but it also raises ethical concerns about bias, privacy, and the impact on jobs.AI uses technologies like machine learning, deep learning, and natural language processing to improve and make decisions based on data.

b. Internet of Things (IoT)

he Internet of Things (IoT) is a system where everyday objects are connected to the internet, allowing them to collect, send, and receive data. These devices use sensors and software to interact with their surroundings and automate tasks. For example, a smart home system can adjust the temperature based on occupancy, while wearable health monitors track vital signs in real time. Businesses use IoT for predictive maintenance, optimizing operations, and enhancing security. Although IoT increases efficiency and convenience, it also raises concerns about data privacy and cybersecurity. (Weber, 2010).

c. Machine Learning (ML)

Machine Learning (ML) is a branch of artificial intelligence that enables computers to learn from data and improve their performance without being explicitly programmed. It uses algorithms to identify patterns, make predictions, and automate decision-making. Instead of following predefined rules, ML models analyze large datasets to recognize trends and refine their accuracy over time. It is widely used in recommendation systems, fraud detection, medical diagnosis, self-driving cars, and natural language processing. While ML enhances efficiency and innovation, challenges like data bias, interpretability, and ethical concerns must be addressed.

d. 5G Networks

5G is the fifth generation of wireless network technology, designed to provide faster speeds, lower latency, and greater connectivity compared to previous generations. It enables real-time communication, supporting innovations like smart cities, autonomous vehicles, and the Internet of Things (IoT). With speeds up to 100 times faster than 4G, 5G allows seamless streaming, cloud gaming, and enhanced virtual and augmented reality experiences. Its low latency ensures near-instant data transfer, making remote surgery and industrial automation more reliable. Despite its benefits, 5G requires extensive infrastructure upgrades and raises concerns about security and privacy(Andrews et al., 2014).

e. Edge Computing

Edge computing is a technology that processes data closer to its source rather than relying on a centralized cloud. By handling computations at the "edge" of the network—such as on local devices, sensors, or edge servers—this approach reduces latency, improves response times, and lowers bandwidth usage. It is especially useful for applications requiring real-time processing, such as autonomous vehicles, industrial automation, and IoT devices. Edge computing enhances security by keeping sensitive data closer to its origin, reducing the risk of breaches. However, it also presents challenges in managing distributed infrastructure and ensuring seamless integration with cloud services.

f. Blockchain

Blockchain technology is a decentralized digital ledger that records transactions across multiple computers securely and transparently. Each transaction is grouped into a "block," linked to the previous one, forming a "chain." This structure ensures that data is immutable, meaning once recorded, it cannot be altered or deleted without consensus from the network. Blockchain is widely used in cryptocurrencies like Bitcoin, but its applications extend to supply chain management, digital identity verification, and smart contracts. By eliminating intermediaries and enhancing security, blockchain improves transparency and trust, though challenges like scalability and energy consumption remain concerns.

g. Spatial Computing

Spatial computing is a technology that enables digital and physical environments to interact seamlessly, allowing computers to perceive and respond to the real world. It combines artificial intelligence, augmented reality (AR), virtual reality (VR), Internet of Things (IoT), and advanced sensors to create immersive experiences. By understanding spatial relationships, it enables applications like gesture-based interactions, holographic displays, and real-time 3D mapping. Spatial computing is used in industries such as healthcare, gaming, architecture, and manufacturing, enhancing productivity and user experiences. While it offers groundbreaking possibilities, challenges like data processing, privacy, and hardware limitations must be addressed.

h. Smart Spaces

Smart spaces are physical environments enhanced by technology to improve efficiency, automation, and user experiences. These spaces integrate IoT, artificial intelligence, sensors, and connectivity to collect and analyze data in real time, enabling intelligent decision-making. Examples include smart homes that adjust lighting and temperature automatically, smart offices that optimize energy use and productivity, and smart cities that improve traffic flow and public safety. By creating responsive and adaptive environments, smart spaces enhance convenience, sustainability, and security. However, challenges such as data privacy, cybersecurity, and infrastructure costs must be carefully managed (Kitchin, 2014).

i. Homomorphic Encryption

Homomorphic encryption is an advanced cryptographic technique that allows computations to be performed on encrypted data without decrypting it. This ensures that sensitive information remains secure while still being processed. The results of these computations remain encrypted and can only be revealed when decrypted by an authorized user. This encryption method is particularly useful in privacy-sensitive applications like cloud computing, secure data sharing, and confidential machine learning. It enables organizations to process and analyze encrypted data without exposing it to potential threats. However, homomorphic encryption is computationally intensive and requires significant processing power, making efficiency a key challenge for widespread adoption (**Omijeh** & Agughalum, 2020)

j. Metaverse

The **Metaverse** is a virtual, interconnected digital world where people can interact, work, play, and socialize using immersive technologies like virtual reality (VR), augmented reality (AR), and blockchain. It creates a shared, persistent, and interactive environment where users can have digital identities, own virtual assets, and participate

in real-time activities. Businesses, entertainment, education, and even healthcare are integrating into the metaverse, offering virtual offices, concerts, training programs, and medical consultations. Blockchain enables decentralized ownership through NFTs and cryptocurrencies, allowing users to buy and sell digital goods. While the metaverse promises limitless possibilities, challenges such as privacy, security, and digital inequality must be addressed for broader adoption.

k. 3D Printing and Additive Manufacturing

3D printing and additive manufacturing are technologies that build objects layer by layer from digital models, rather than using traditional subtractive methods like cutting or molding. This process allows for high precision, customization, and efficient material usage. 3D printing is widely used in industries such as healthcare for prosthetics, aerospace for lightweight components, and construction for building homes. Additive manufacturing enables rapid prototyping, reducing production time and costs. While it offers flexibility and innovation, challenges include material limitations, high initial costs, and scalability for mass production

l. Smart Homes and Cities

Smart homes and smart cities use advanced technology to enhance efficiency, convenience, and sustainability in living spaces and urban environments. A smart home integrates IoT devices, artificial intelligence, and automation to control lighting, security, climate, and appliances. Homeowners can manage these systems remotely using smartphones or voice assistants, improving energy efficiency and security while providing a seamless living experience.

A **smart city** extends this concept on a larger scale, using sensors, data analytics, and connectivity to optimize urban infrastructure. Smart traffic management reduces congestion, intelligent waste systems improve sanitation, and smart grids enhance energy distribution. These innovations create sustainable, livable environments but also raise concerns about data privacy, cybersecurity, and infrastructure costs

m. Robotics and Automation

Robotics and automation involve the use of machines and technology to perform tasks with minimal human intervention. Robotics focuses on designing, building, and programming intelligent machines, while automation refers to systems that operate with little or no human input, improving efficiency and accuracy. In industries like manufacturing, robots assemble products with precision, while automated systems streamline processes in warehouses and logistics. In healthcare, robotic surgery enhances precision, and automation speeds up medical diagnostics. Robotics also plays a role in agriculture, military applications, and space exploration. While these technologies increase productivity and safety, they also raise concerns about job displacement, ethical considerations, and cybersecurity risks

2.9 Embedded Systems-based modern Devices and Telecommunication Applications

Embedded Systems are commonly used in the design of modern devices like Smartwatches, Fitness Trackers, Home Automation Systems, Medical Devices (e.g., pacemakers, insulin pumps), Automotive Systems (e.g., engine control units, infotainment systems), Industrial Robots, Air Conditioning Systems, Digital Cameras, Drones, Traffic Light Control Systems, Security Systems (e.g., surveillance cameras,

access control), GPS Navigation Devices, Electronic Voting Machines, Wearable Health Monitors, Point-of-sale (POS) Systems, Barcode Scanners, Digital Thermometers, Automatic Doors, Satellite Communication Systems, ATM Machines, Digital Audio Players, Home Theatre Systems, Video Game Consoles, Electronic Cash Registers, Smart Refrigerators, Elevator Control Systems, Solar Power Inverters, Industrial Control Systems (e.g.,PLCs), Electronic Locks, Fire Alarm Systems, Traffic Monitoring Systems, Electronic Toll Collection Systems, Aircraft Flight Control Systems, Railway Signalling Systems, Embedded Systems in Spacecraft, Microwave Ovens, Electronic Scale, Robot Vacuum Cleaners, Wireless Sensor Networks, Pacemakers, Blood Glucose Monitors, Hearing Aids, Electronic Pet Collars, Wearable Activity Trackers, Electronic Pet Feeders, Electronic Musical Instruments, Digital Thermostats, Electronic Speed Controllers , Gas and Water Meters, Electronic Toys.

Even in telecommunications, embedded systems are integrated as hardware and software components that perform specific functions within larger telecommunication systems. Some applications include but not limited to:

Mobile Phones: Mobile phones are an essential part of our daily lives. Embedded systems play a pivotal role in enhancing the smartphone technology and network connectivity.

Routers and Switches: Routers and switches are vital components of modern telecommunication networks. Embedded systems within these devices ensure efficient internet connectivity, traffic management, and network security.

Wireless Base Stations: Wireless base stations are the backbone of modern telecommunication networks. Embedded Systems facilitate signal transmission, network coverage expansion, and load balancing.

Satellite Communications: Satellite communications have revolutionized global communication and data transmission. Embedded systems play a critical role in various aspects of satellite communication, including signal processing, geolocation services, and weather monitoring.

Optical Transport Networks (OTN): Optical Transport Networks (OTN) are crucial for high-speed data transmission in modern telecommunication networks. Embedded systems play a significant role in the performance of OTN, ensuring network resiliency and efficient bandwidth utilization.

Network Servers: Network servers are essential components of telecommunication networks. They provide data storage and management, centralized control of network resources, and traffic prioritization. Embedded systems play a crucial role in the functioning and performance of network servers.

Internet of Things (IoT) Devices: The Internet of Things (IoT) has transformed the way we interact with our surroundings. Embedded systems play a vital role in the development and operation of IoT devices.

Voice over Internet Protocol (VoIP) Systems: Voice over Internet Protocol (VoIP) systems have revolutionized the way we communicate. Embedded systems play a significant role in the performance and functionality of VoIP systems, enabling cost-effective communication, unified communications, and quality of service (QoS) management.

2.10 Why Embedded Systems have become the game changer in modern industrialization :

i. Automation and Additive Manufacturing

Embedded systems power industrial automation, replacing manual processes with robotics and AI-driven machines. For example, n car manufacturing, embedded microcontrollers manage robotic arms for precision welding and assembly.

ii. Real-Time Monitoring and Predictive Maintenance

Embedded sensors collect data in real time, allowing industries to detect failures before they happen, reducing downtime. For example, Smart factories use embedded IoT sensors in machines to predict wear and tear, scheduling maintenance before breakdowns occur.

iii. Energy Efficiency & Cost Reduction

Embedded systems optimize energy usage, leading to lower costs and sustainability. For example, Smart HVAC (Heating, Ventilation, and Air Conditioning) systems in industrial plants adjust energy use based on real-time demand, reducing electricity consumption.

iv. Industrial IoT (IIoT) and Smart Connectivity

Embedded systems enable machine-to-machine (M2M) communication, integrating IIoT to streamline operations. For example, a smart warehouse uses embedded RFID (Radio Frequency Identification) tags to track inventory automatically.

v. Enhanced Security & Cyber Protection

With industrial systems connected to the internet, embedded security mechanisms prevent cyberattacks and unauthorized access. For example, Industrial control systems (ICS) use embedded firewalls and encryption to protect critical infrastructure from hacking.

vi. Robotics and AI Integration

Modern factories leverage AI-driven embedded systems for intelligent automation, reducing human intervention and improving accuracy. For example, Autonomous **robots** in warehouses sort, pick, and deliver items with minimal human assistance.

vii. Scalability and Adaptability

Industries can scale operations easily with embedded solutions that support modular upgrades. For example, in agriculture, embedded drones with AI capabilities monitor crop health, improving yield and reducing manual labor.

The evolution of industrialization has continuously reshaped economies, improved production efficiency, and enhanced the quality of life worldwide. Each phase of the Industrial Revolution has introduced new technologies that have driven economic growth and innovation. As industries move toward fully automated and AI-driven **systems**, embedded systems remain at the heart of transformation as the game changer.

3.0: MY CAREER JOURNEY AND CONTRIBUTIONS TO KNOWLEDGE

My Vice Chancellor Sir, distinguished colleagues, ladies and gentlemen, please permit me with all sense of humility to show case some of my notable contributions to knowledge in research, teaching and community development. For easy of presentation, I have broken them into three (3) categories, as follow:

i. Embedded Systems -based Devices Developed
ii. Telecommunication Models developed for Teaching and Industrial Applications.
iii. Current Research and Industry-Collaborations Attracted.

3.1 Embedded Systems-based Devices Developed

This section contains some of my research breakthroughs in the field of real-time automated control and communication technologies driven by embedded systems. It contains some embedded systems-based projects, prototypes and solutions developed to solve environmental, domestic and industrial problems. The methodology used in most of them involves: design analysis, algorithm development, modeling, simulations, fabrications, software and hardware integration. The impacts of these innovative devices have gone beyond journal publications. They have attracted and fostered fruitful collaborations, donations, grants and capacity building for students both in the University and neighboring communities. These research breakthroughs have also facilitated some notable infrastructural developments, internally generated revenue, increase in global visibility and ranking of the University.

3.1.1 Computer -based Controlled Devices using Embedded Systems

Omijeh (2008) designed a wireless controlled switch that is actuated by a personal computer. With this device, we could wirelessly control different home appliances (Fans, TVs, Electric Bulbs, Stereos etc.) by putting ON/OFF the switches without manual assistance. This Computer Controlled Switch (CCS) is not only more reliable, safer and quicker but has a LOCK-UP function which prevents an unauthorized or accidental switching; and also, had a Time Scheduler (TS) for programming our appliances to work according to our schedules. This embedded system design contained both hardware and software parts. The interface provides a wireless link between the computer parallel port and the load switch. The signal from the parallel port was first encoded and then transmitted; the transmitted signal was received at the load end through a receiver and was then decoded. The software part was developed using C++ and Visual Basic. The test results showed good response time and performance to design specifications. This developed embedded systems-based computer controlled switch had over 97% reliability after test; making it an improved Computer controlled switch for domestic and industrial electric load control and automation. See Fig 3-5.

Institutional Impacts: This innovative device was well captured in the UNIPORT magazine, October, 2008-January, 2009 edition as **"Electronics Engineer invents computerized Electrical control Switch"** pp5. It was also exhibited to the public during the 24th Convocation Ceremony of the University of Port Harcourt. In fact, this device became a high point in the event as observers and visitors were thrilled by the exhibition.

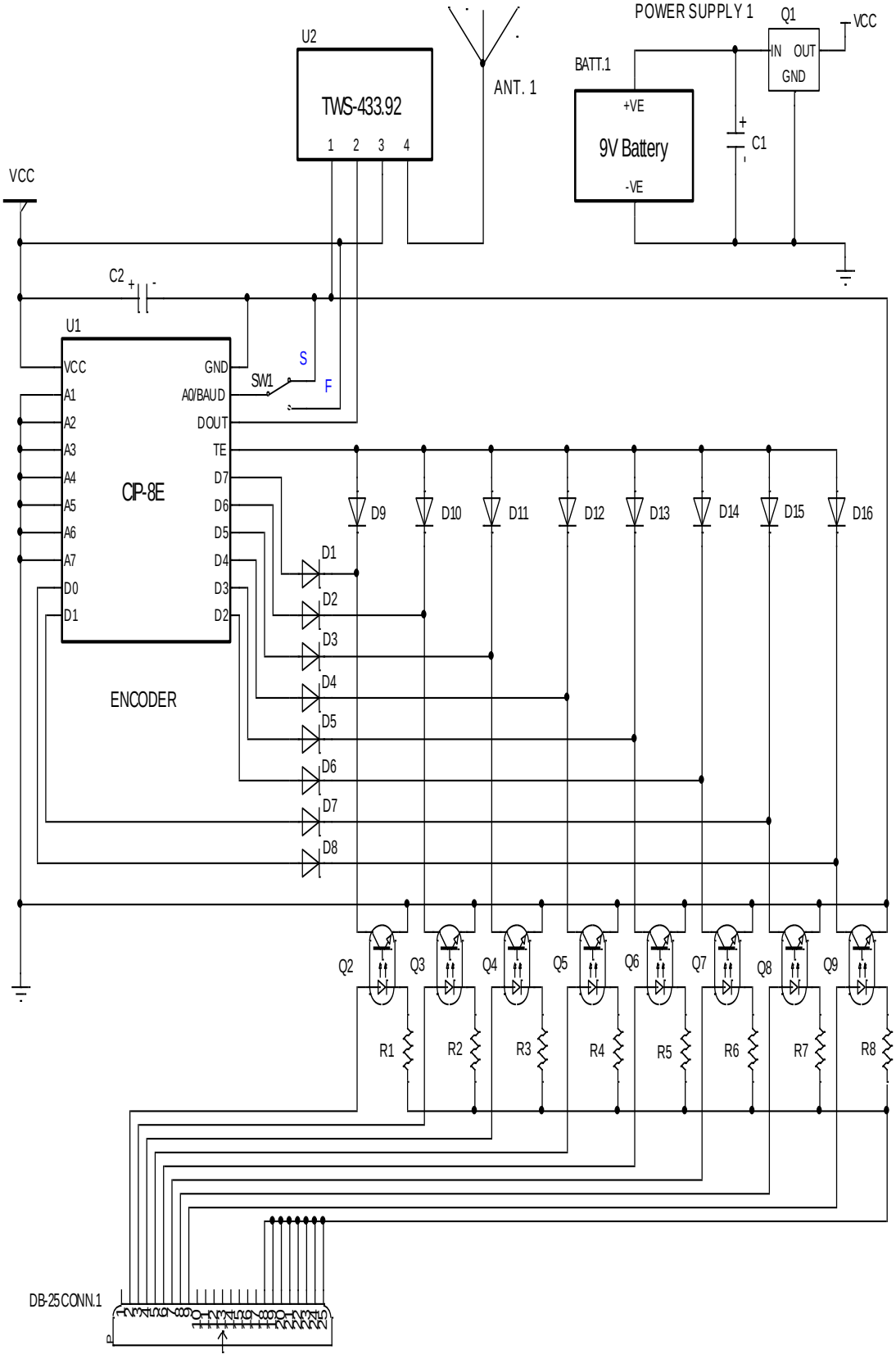

Fig 3: Embedded Systems Design for Computer Controlled Switch (CCS)
(Source: Omijeh, 2008)

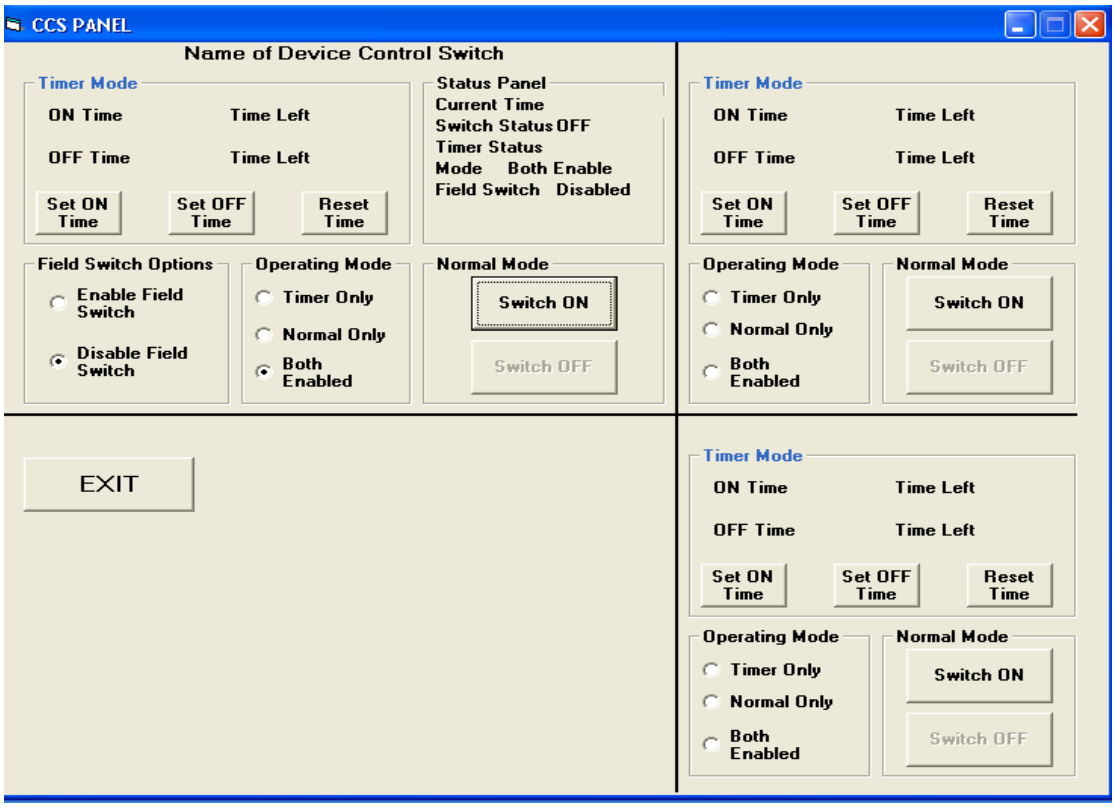

Fig.4: The Graphical User Interface of the developed CCS Software

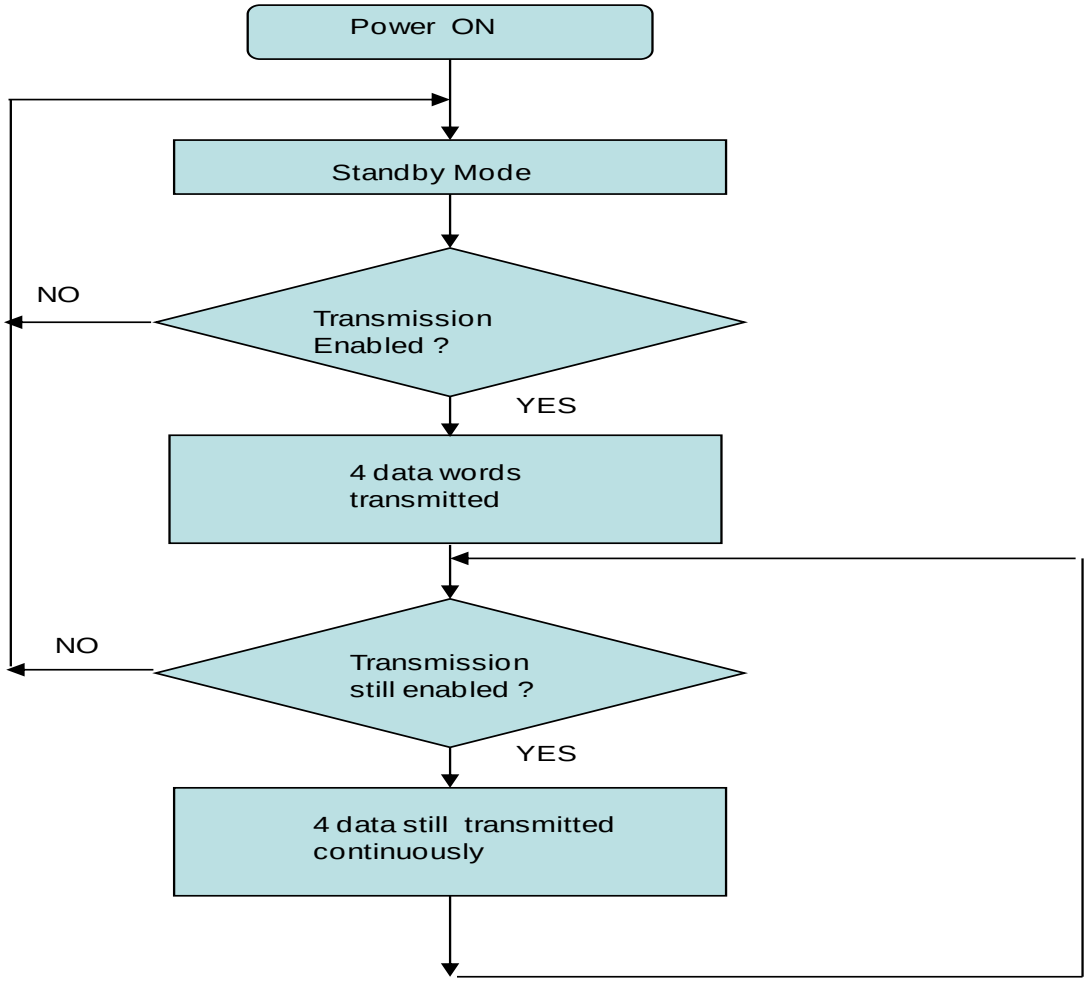

Fig 5: Flow Chart of the Developed CCS Software Algorithm

3.1.2 **GSM-based Controlled Devices for Home Automation**

Omijeh (2016) designed an **RF/GSM-based automatic Switch control for home appliances with SMS feedback** . With this device, we could control our home appliances over very long distances by turning ON and OFF the switches where the appliances are plugged through GSM Networks. This work is very effective with the functionality of radio frequency and SMS protocol, which allows an individual to control any particular appliance using Radio Frequency (RF) and GSM Technology with a feature that enables the user to receive feedback message showing whether the sent command was successful or not (Omijeh 2016). To achieve this, the design methodology used involved 7 stages including a programmed microcontroller (AT mega 32) , the heart of the Embedded System Design. The advantage of this design over the Computer controlled Switch was the ability to control devices over a very long distance with SMS feedback mechanism. This was a major contribution to knowledge. Fig 6 shows the block diagram design approach.

Oluwasegun and **Omijeh (2024)** improved on the GSM-based automatic switch control by including voice activation and internet of things. The aim of the work was to successfully develop an energy monitoring solution capable of delivering Real-time information on the energy consumed by operating home appliances within the home, thus being able to detect load values beyond to identify power theft in home from anywhere in the world. It features a remote power monitoring intelligence with the use of an android web application configured to remotely control the relay circuits via the WI-FI enabled ESP32 microcontrollers. The PZEM-004T and the SRD-05VDC relay circuit were employed to design load consumption monitoring and switching circuit interfaced with separate 32-bit micro-controllers to form separate nodes referred to as smart sockets. The work also covered the use of IoT communication protocols over an electronic power system metering device to monitor AC loads being sourced from two smart sockets.

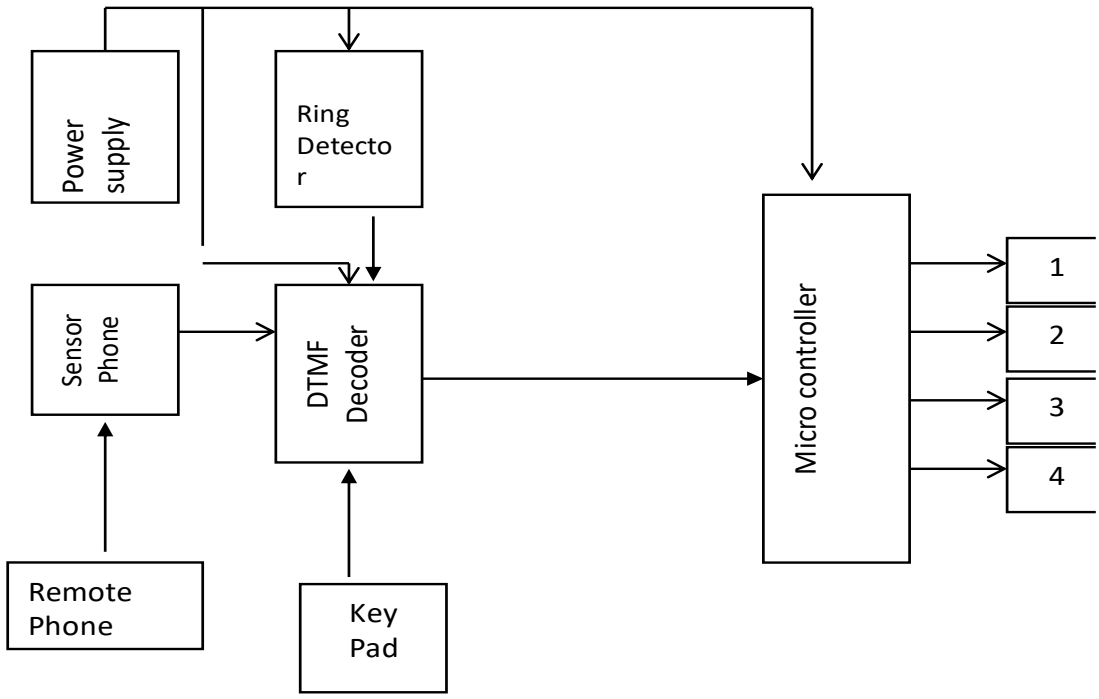

Fig.6: Embedded Systems Design block diagram of the GSM-based Controlled System (GbCS)

3.1.3 GSM/Embedded Systems- based Security Systems

Ehikhamenle and **Omijeh** (2016) designed a GSM-based Solution to detect intruders (unauthorized visitors) ;and sends SMS notification to the authorized user as feedbacks. The AT89C52 microcontroller was programmed to control the other components, a SIM900-GSM module that communicates between the home owner phone and the PIR sensor (motion sensor). The interfacing between the GSM module and the microcontroller was achieved using an IC called MAX232 (this IC converts TTL voltage level (+5V) to RS232 voltage level (plus minus 7.5V) vice versa) and the microcontroller was programmed using assembly language. A major contribution to knowledge in this work was the ability of the developed device to overcome false alarm from inanimate objects. This problem of false alarm was dealt with by using a passive infrared sensor(PIR) which respond only to infrared emitted from the human body and animals. Several tests were carried out and the programmed microcontroller responded to the information sent by the PIR sensor; and in the occurrence of intrusion, sent an SMS alert message to the home owner as well sounding an alarm to alert the neighbors using a buzzer.

Ukata and **Omijeh** (2020) improved on this work by integrating CCTV cameras with some image processing algorithms to detect pixel changes and movements on the cameras' view. This algorithm helps to monitor the direction where movement is spotted, predict intrusion and trigger an alarm through the Arduino controlled hardware based on the outcome of the prediction.

3.1.4 GSM-based Digital Display Embedded Systems

Omijeh et al (2020) designed a GSM-based dot matrix LED display for business adverts, Church Publicities, Stock Exchanges etc . This GSM-based ES provides the facility of real-time message displaying platform where user can change the message content that is to be displayed according to his/her will. A mobile Phone is used to send the message to the GSM based LED display and the microcontroller does all processing of displaying the message content on the LED display in scrolling pattern. The flash memory of the SIM is cleared after reading the update message to make space available for next message. The display is obtained on a 8x6 Light Emitting Diode (LED) dot matrix display, arranged on a vero board. The GSM modem is connected, through MAX 232 Integrated Circuit (MAX 32 IC), to the AT89C51 microcontroller. The messages that are stored in the Electrically Erasable Programmable Read Only Memory (EEPROM) is then displayed on the LED dot matrix display. This hardware uses regulated 5V, 500mA power supply. A three-terminal LM7805 is employed for regulation of the voltage. A bridge type full-wave rectifier is used to rectify the AC output of the secondary of 220/12V step down transformer. The system was tested to 98 % accuracy. The key innovation of this developed device is the ability to do real - time messaging and electronic display.

3.1.5 GSM -based Robotic Devices Designed and Implemented.

This section contains some GSM/based robotic products developed by me and my team . These innovative breakthroughs have attracted commendations from some industry players, opening up further opportunities for upscaling , rebranding and upgrading products for real life implementation and commercialization.

a. Design Analysis of a GSM/RF-Based Remote Controlled Robotic Car

Omijeh et al (2014) designed an microcontroller-based embedded System used to control a robotic car remotely via GSM/RF. This is done in such a way that to control the robot, the user makes a phone call to the phone attached to the robot which automatically answers the call. During the phone call, the user can control the robotic car with the keys on the phone. The robotic car can be controlled from any where no matter the distance without interference as long as the robotic car can be seen by the user. The design methodology involves four stages, namely: power supply unit, the input unit, the control unit and the output unit. The performance evaluation of the designed work after series of tests was very satisfactory. . Interestingly, the fabrication of this prototype was done using local materials. See plate 1-2.

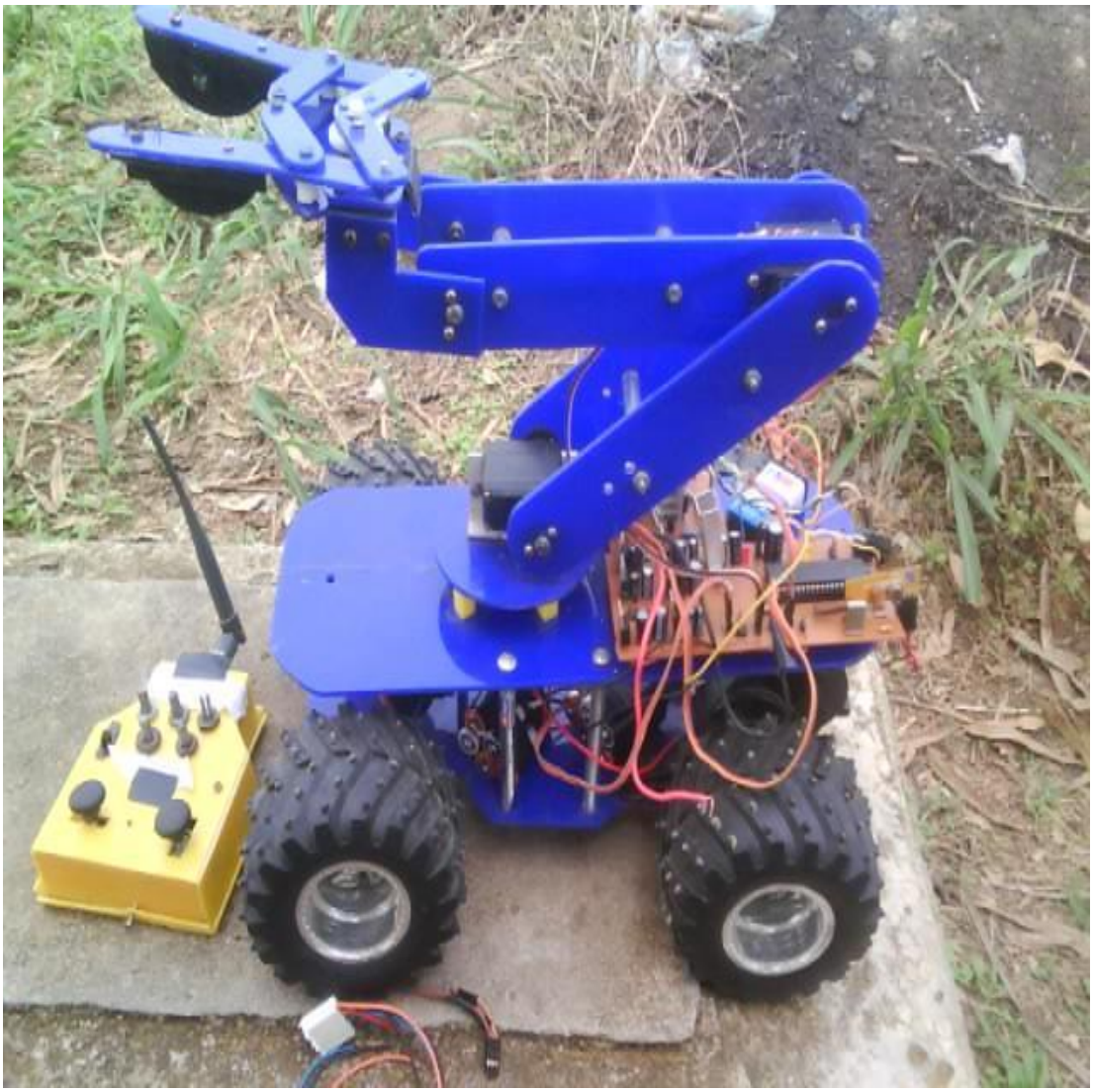

Plate 1: GSM/RF-based Controlled Robotic Car

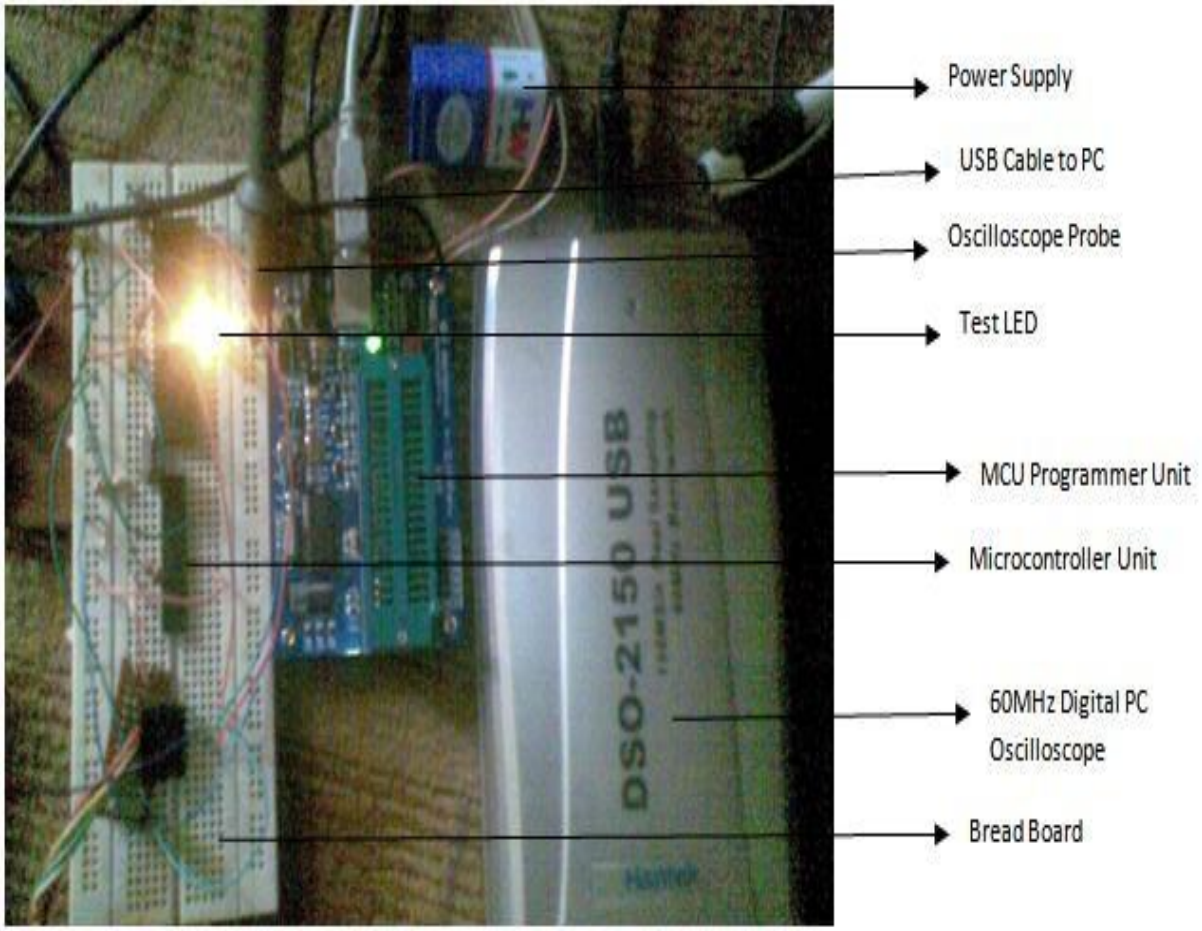

Plate 2: Embedded System Design of the GSM/RF Controlled Robotic Car

b. A quadcopter (UAV) with payload for pipeline inspection and surveillance

The design and implementation of a sustainable and flexible embedded system for an Unmanned Aerial Vehicle (UAV) capable of carrying out inspection in real-time on a pipeline facility and performing surveillance actions using a quadcopter design profile was achieved. The design analysis of this project was carried out in two stages (Hardware and Software), with each stage subdivided further into smaller stages (Requirements, alternatives, decision criteria, decision, and implementation details). To safely fly the quadcopter, various tests were carried out on the individual components and the quadcopter at whole to ensure everything is functioning properly before flight. Two test stages were carried out on the quadcopter, these tests are Unit tests and Flight tests. After concluding the preflight and post flight tests, results were gotten and tables were created. The result obtained in the study showed that the system was capable of attaining autonomous flight at a height of 20 meters and a range of 30 feet.(**Omijeh** et al, 2015)

Robotic Applications developed by Prof. Omijeh and the Catch Them Young team

I worked with my research team to develop the following robotic prototypes which were also exhibited during the **Catch Them Young (CTY)** Digital Initiatives (2nd & 3rd Editions) in 2023 and 2024 respectively at CITE-UPH. Plates 3-7.

Plate 3: AI-Home Robotic Project inspected by the VC (CTY, 2024)

Plate 4: AI & Robotic Prototypes (CTY, 2022)

c. Remote-Controlled Robot Car via Bluetooth Using Smartphone

This is a robot car that is controlled via a smartphone's Bluetooth connection, allowing users to maneuver it remotely. **Applications**: It is useful for surveillance, entertainment, and educational purposes, such as teaching programming and robotics, as well as exploring or inspecting areas remotely in a controlled manner (Omijeh et al, 2015) www.thetidenewsonline.com

Plate 5: Obstacle Avoidance Robotic Car (CTY 2023)

d. Obstacle Avoidance Robot Car

A robotic car equipped with sensors to autonomously detect and avoid obstacles, allowing it to navigate without human intervention. **Applications**: Commonly used in robotics education, automated warehouse systems, and for exploration in uncertain environments like disaster response, where autonomous navigation is beneficial (Catch Them Young , 2023) www.thetidenewsonline.com .Plate 5

e. Hand-Gesture Controlled Robotic Arm Using Computer Vision

This robotic arm interprets hand gestures through computer vision to perform corresponding movements, allowing contact-free control. **Applications**: Useful in environments where touchless control is advantageous, such as hazardous material handling, precision task in laboratories, rehabilitation, and as an interactive educational tool in robotics (Catch Them Young, 2024)www.thetidenewsonline.com. Plate 6

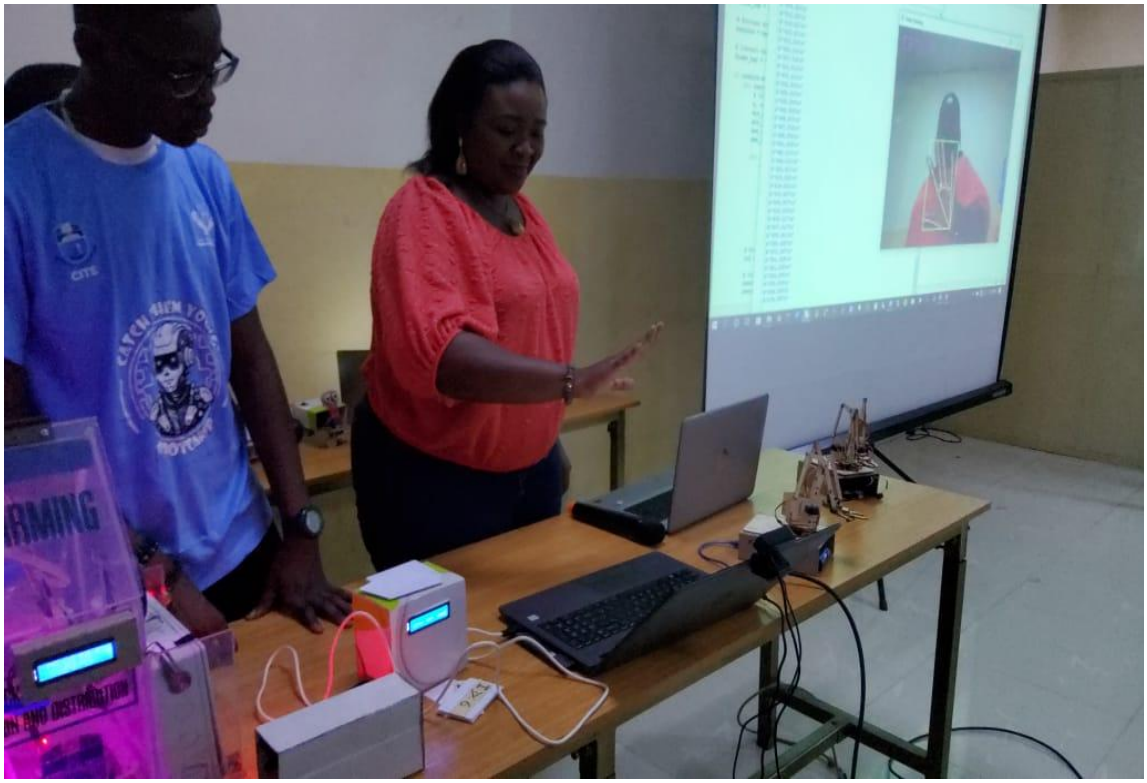

Plate 6: Hand Gesture Robotic Arm using Computer Vision (CTY, 2024)

f. Line Following Robot Car

This is a robotic car programmed to follow a path marked by a line, typically using infrared or optical sensors for accurate path tracking. **Applications**: Used in automated transport systems, assembly line tasks, and educational settings to demonstrate automation and sensor-based navigation (Catch Them Young, 2024) www.thetidenewsonline.com .Plate 7.

Plate 7 : Robotic Prototypes controlled via Bluetooth & GSM (CTY, 2024)

3.1.6 IoT-based Embedded Systems

a. Intelligent hybrid garbage monitoring and alert system

Omijeh et al (2020) developed a Hybrid IoT based Garbage Monitoring system for waste management. This system is designed to aid Municipal Corporation to monitor the status of waste bins by sending notification via a mobile application, a phone all, and also a text message (SMS) containing the status of the waste bin to the respective authorities for the effective disposal of garbage. This system consists of ultrasonic sensor interfaced with various other components such as the Arduino Uno microcontroller and GSM module. Most components are all placed rear compartment of the waste bin constructed, while others are attached to different sections of the waste bin. The ultrasonic sensor is fixed into a plastic container and fitted on the interior side of the lead. By the implementation of this system, garbage collectors would not have to check the status of waste bins manually but will be duly notified when each bin full, hence it eliminates the need for excessive man power, cost and consumption of fuel and ultimately waste of time.

b. Biometric Access Facial Recognition Control System

Omijeh & Udom (2019) designed a facial recognition system and simulated it using Matlab/ Simulink. Its implementation is in a biometric access system. The designed algorithm incorporates two known facial recognition algorithms, the Principal Component Analysis (PCA), and the Local Binary Pattern (LBP) for improved performance in security and biometrics access system. The LBP is used to quickly extract image-coding attributes, while the PCA reduces the facial measurement for quicker measurement and improved processing, which also improved the rate by 90% . The ORL data base in the data base which is in the public facial database for simulation was used as a reference database in the matlab programme for the simulation. This

design can be used in a security biometric access system to restrict some access of criminally minded person to a faculty/event.

c. Enhanced Cloud Computing Security using Application-based Multifactor Authentication

Orimadike and **Omijeh** (2022) developed and implemented an enhanced cloud computing security using an application-based multi-factor authentication system. It evaluates a system in terms of simplicity and performance against an intruder action in a cloud environment. In the first stage of authentication, the system uses the knowledge(password) factor of authentication to perform an authentication process and in the second stage, it requests for a possession (OTP) factor generated from the multifactor authentication app to complete a successful login session. The system randomly performs an IPs in order to grant the user access or deny access. However, if in an event of full disclosure of login credential to an intruder through phishing attack or shoulder surfing or whatsoever means of compromise of the user login credentials; the system alerts the user of suspicious activities, who in turn revokes the intruder's access to the system. We evaluate the system through concerted reviews by a number of client users; the results were impressive as it shows high user learnability, ease of adaptation and huge confidence in the security the system offers.

d. Lidar-based AI model for detection, classification and tracking of vehicular obstacles for intelligent autonomous vehicles

Omijeh & Mbachu (2023) developed Lidar-based AI model for detection classification and tracking of vehicular obstacles for intelligent autonomous vehicles .This work provides an efficient A.I model based on deep learning for obstacles detection, classification, and tracking using about 1617 LiDAR point cloud data scans acquired from a highway driving scene using an Ouster sensor. Using segmentation and clustering algorithms, the presented approach recovers spatial information from the laser point cloud. The task was completed using a trained PointSeg network, which had a greater average class performance figure of 83.75% when compared to that of the well-known Squeezeseg network – 74.43%.

3.1.7 Intelligence-based Medical Software Applications

This section contains some of my intelligence-based Medical Software Solutions developed through interdisciplinary collaborative research work

a. Virtual Dissection Intelligent Software App for Human Anatomy

Omijeh et al (2023) developed an innovative and intelligent Virtual Dissection Applications. The virtual dissection system of human anatomy provides students with a more interactive and engaging experience, allowing them to explore the human body. By using the virtual systems students can visualize complex and atomical structures and understand their functions more easily. The health risk involved with using formalin to preserve cadavers and the scarcity of cadavers has been a major difficulty for the study of human anatomy. Students have also expressed de-satisfaction with the challenges they encounter when converting the 2D illustration from anatomy textbook into 3D modules. This collaborative research CITE and Department of Anatomy (Prof. Omijeh and Dr, Mrs. Ibeauchi as supervisors) involves the development of a virtual reality web application utilizing blender as the primary tool. Blender's materials and

texture capability enhance the visual realism of the anatomical modules. Approximate textures were applied to stimulate different tissue types, allowing users to distinguish between organs, muscles, bones and other structures. The virtual dissection application is designed as a web design solution, ensuring accessibility across multiple platforms and devices. It leverages web technologies such as HTML, CSS, Bootstraps and JavaScript to deliver a seamless and responsive user experience. These research work has provided student with a virtual reality dissection web application that gives assess to the regional section of virtual cadavers that can be rotated, magnified and labelled. The rendered modules were able to achieve a Jaccard index of 0.93 and a dice coefficient of 0.94. It also achieved a remarkable average processing time of 15s and a high user rating of 4.5

b. Improved drug verification system for National Agency for Food and Drug Administration and Control (NAFDAC)

Raheem & **Omijeh** (2021) developed an improved drug verification system for NAFDAC. This work was geared towards the authentication of pharmaceutical products; to mitigate the increasing number of counterfeit drugs in the country and to also verify expired drugs as well. The technology employed was the Quick Response Code technology: a 2-dimensional matrix barcode which like ancestor, the barcode could be scan directly into machine code with a higher response time, and more data storage space, depending on the version of code used. The study proposes a system where every pharmaceutical product producer could generate Quick Response Code for their products, to make important product data such as; Manufacturer Name, Product Name, Production Date, and Expiry Date. The system does not only generate Quick Response Code for manufacturers it also grants consumers the ability to verify products with their phones by scanning the Quik Response Code with the aid of an Application Programming Interface (API) which enables smartphone cameras to access the Quick Response libraries necessary for code scanning. The system is software based; utilizing web application and a database technology for which the product Quik Response Code are generated and stored respectively. Please see plate 8.

c. Design and implementation of an intelligent based remote health monitoring system using wireless sensor network

Uwho & **Omijeh** (2023) developed an intelligent remote health monitoring system with wireless sensor network . For the human population, health coverage is a critical requirement. The Internet of Things (IoT) concepts have become increasingly popular as technology advanced, allowing doctors to link existing medical resources and provide patients with intelligent, reliable, and efficient medical service, As a result, using the WEMOS DI module as medium of communication to monitor pulse rate and temperature is an extremely important mechanism developed with the sole purpose of preventing untimely death from heart attacks and high body temperatures, that could lead to a variety of aliments in the body such as malaria, headaches, ulcers and other illnesses that can be dangerous to human health. Using the patient's personal physiological data, temperature and pulse rates are determined. The sensors collect viral signs from the patient and send them to a database on the internet via the wireless module. An email is sent to the doctor when the patient's body vital measurements surpass the specified threshold, signifying an emergency incident, An Android application on the patient's phone allows the patient to report on his or her health status and to alert the doctor in the case of any emergency, as well as allowing the doctor to track the patient's the doctor in the case of any emergency, as well as allowing the doctor to track the patient's location. The patient's information can be viewed on the

web page via a data network link, providing the doctor remote access to the patient's physiological records and reports, This technology will go far towards reducing unforeseeable scenarios that regularly endanger the lives of thousands of people around the world due to inadequate medical care in emergency situations.

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Dated **28 OCTOBER, 2021** *in respect of* **LITERARY WORK**

Titled **IMPROVED DRUG VERIFICATION SYSTEM FOR NATIONAL AGENCY FOR FOOD AND DRUG ADMINISTRATION AND CONTROL**

whose author is **BILIQIS OLUWAFUNMILAYO RAHEEEM, OMIJEH BOURDILLON**

Given this **21** *day of* **June** **2021**

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For: Director General

NIGERIAN COPYRIGHT COMMISSION

Plate 8: Improved Drug Verification System for NAFDAC (Copyright)

3.1.8 Embedded Systems Model developed for Energy Metering

a. Intelligent Power Theft Detection System

Omijeh et al (2012) developed an Intelligent Power theft detection system (IPTDS) with instantaneous SMS alert to mitigate the problem of " energy tampering and bypass" causing huge revenue loss to power utility companies. The embedded system hardware was designed to specification and then converted into an expert system. The set up contains an Intelligent Statistical Meter(ISM) placed at the transformer end or on Electric High Pole. It communicates with the various consumer' meters linked with it through RF and GSM technologies. It monitors and continuously sums up the total energy consumption measurements from various consumers' meters in a designated region; and sets it as a reference value. Whenever this reference value is exceeded, an unmetered (illegal) load or power theft is detected. An SMS alert is triggered and sent to the Utility Company for necessary action. The algorithm for the power theft detection was developed, modeled and simulated in MATLAB/SIMULINK environment. Results obtained a very satisfactory(Omijeh et al, 2012). This work is recommended to PHCN to help reduce power theft and revenue loss. See Fig 6-8.

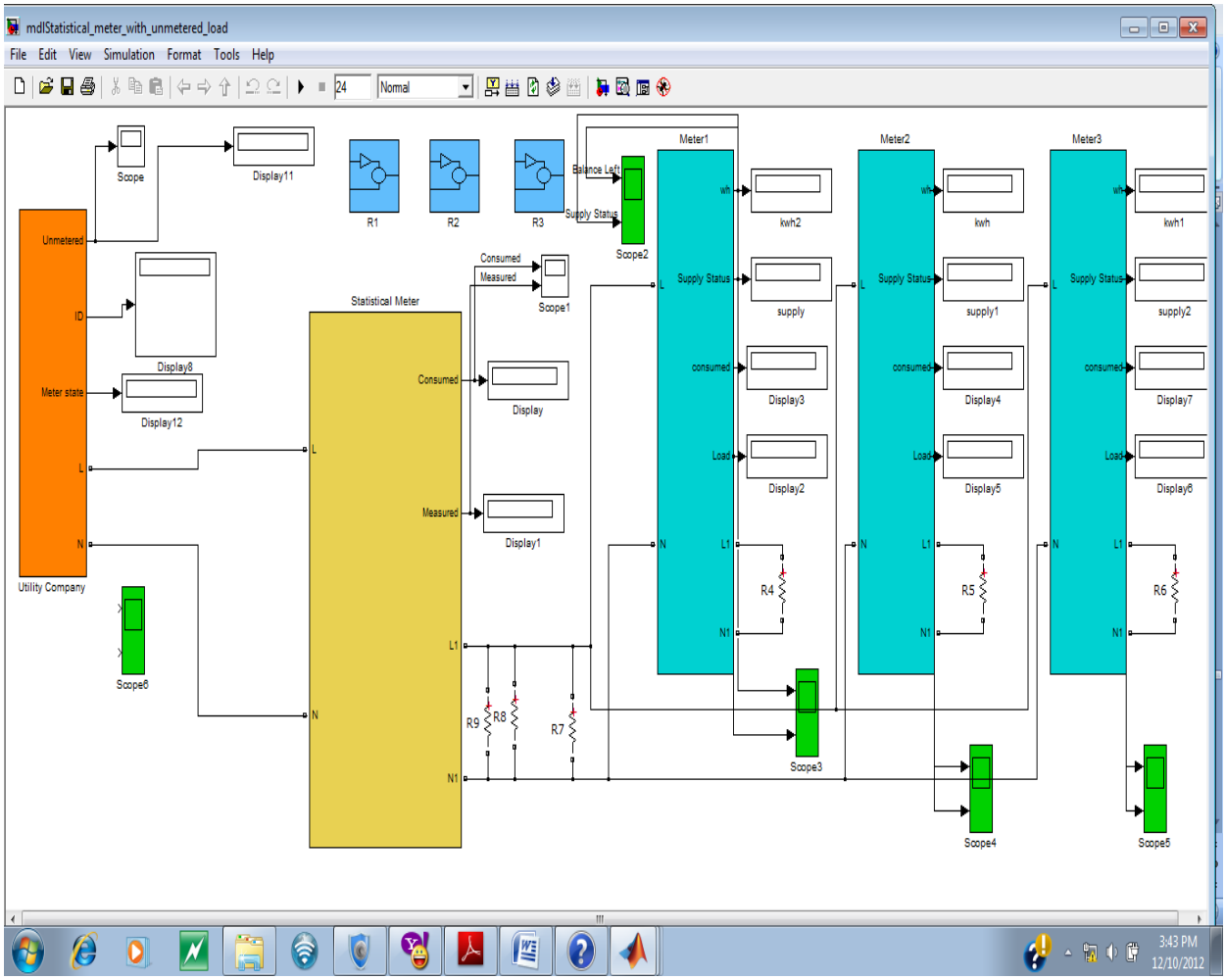

Fig 7: Power Theft Detection Model (Source: Omijeh et al, 2012)

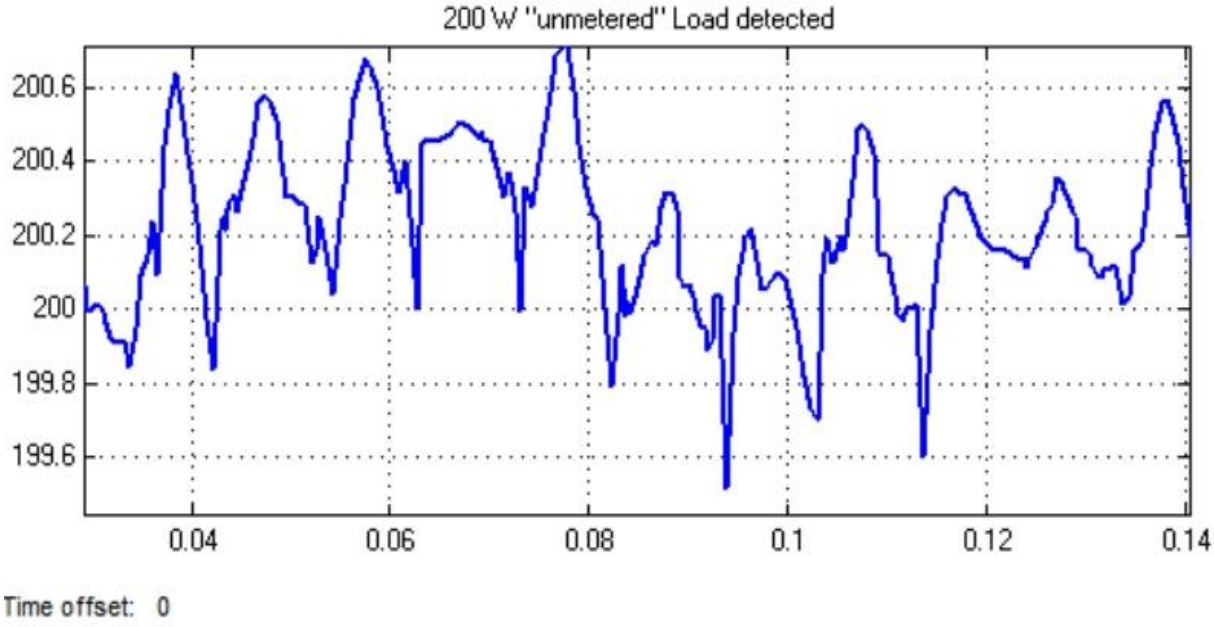

Fig. 8: 200 W "unmetered" Detected

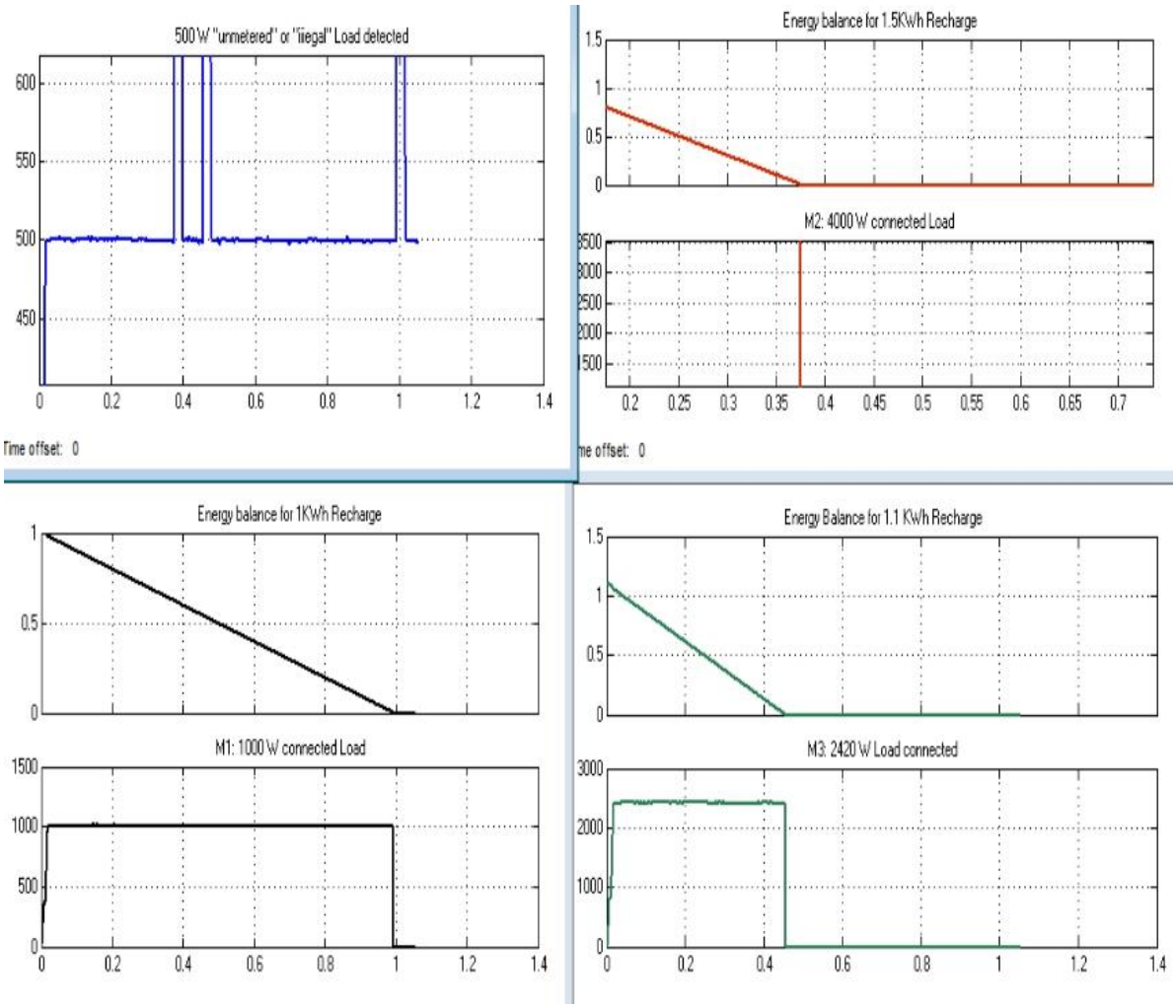

Fig 9: 500W Unmetered load detected With different Recharge Schedules(Source: Omijeh et al, 2012)

b. SMS -Based Protocol for Prepaid Energy Meter

Omijeh et al 2012 develop an SMS protocol enable wireless recharge scheme for prepaid meters. With this work, consumers at the comfort of their homes, without stress or waste of energy or time, can recharge/activate their meters via SMS without the use of keypad by sending a 12-digit Pin number via SMS to the utility company. Fig 9.

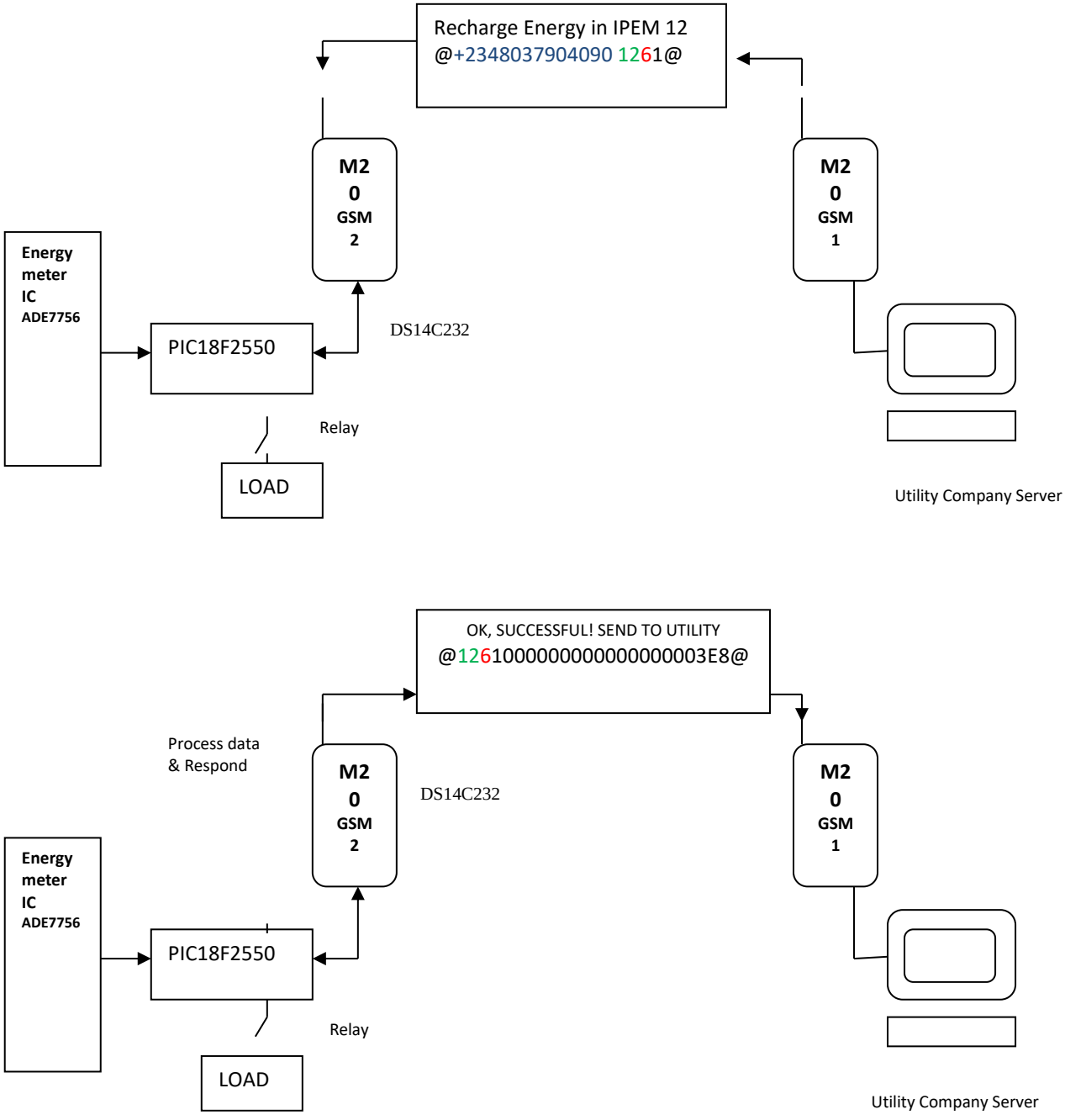

Fig 9: SMS -based protocol for Prepaid Energy Meter (Source: Omijeh et al, 2012)

4.0 TELECOMMUNICATIONS MODELS DEVELOPED FOR TEACHING AND INDUSTRIAL APPLICATIONS

a. Channel Noise Reduction Model for Effective Communication

Omijeh & Vurebel (2015) designed an innovative Channel Noise Reduction Model for effective Communication. The work is based on simulation of noise behavior in communications channel by varying the input parameters (Message Signal Amplitude, Noise Power, Input Power of Channel and Signal to Noise Ratio(SNR)); and the output: signal (strength and noise amplification) and measurements taken. The ODE3 (Bogacki-Shampine) solver with fixed step was used to model simple sine wave function for the message signal and Bandlimited White Noise as the source. The signals were passed through the Additive White Gaussian Noise Channel and the parameters varied. The output signal was connected to a display block and scope for proper measurement. Again, Gaussian filter was introduced at the output of the channel for noise filtration and reduction; and a gain block added to improve the signal output. Transitional delay was also added to smooth out the final signal output. The results obtained from the measurement confirm that introducing the Gaussian filter offers significant improvement in signal strength over communication channel. This innovative model is helpful in telecommunication education and research.

b. OFDM-Based Digital Video Broadcasting (DVB) over Different Wireless Communication Channels.

Omijeh & Agoye (2015) developed a computer model to simulate and evaluate a Digital video broadcasting (DVB) over different wireless communication channels. The system is based on the Quadrature Amplitude Modulation (QAM) and Orthogonal Frequency Division Multiplexing (OFDM) technology, which allows DVB system to explore the spectrum frequencies in a better way, saving spectrum. This model is very useful for educational purpose to analyses the construction of DVB-T system with the aim of investigating the Bit Error Rate (BER) performance of the OFDM based DVB-T 2k mode using different modulation schemes in different transmission channels.

c. Performance Analysis of the WCDMA End-To-End Physical Layer

Omijeh & Udoh (2015) developed an expert system for analyzing and simulating an IMT-2000 WCDMA system. The data is transmitted in a frame by frame basis through a time varying channel. The transmitted signal is corrupted by Multiple access interference which is generated in a structured way rather than treating it as Additive White Gaussian Noise (AWGN). The signal is further corrupted by AWGN and Rayleigh fading at the front end of the receiver. Simple rake diversity combining is employed at the receiver. The bit error rate was investigated at the downlink for different channel conditions. Performance improvement due to error correction coding scheme was observed. The simulator developed was discovered to be an invaluable tool for investigating the design and implementation of WCDMA system

d. A Computer-Based Comparative Performance Analysis of QPSK and 4-QAM Schemes in fading Channels

Omijeh & Sukubo (2015) developed an expert system where QPSK and 4-QAM schemes were compared in Rayleigh and Rician fading environment. Comparison was also made to find out the BER performance differences of each scheme in the fading channels by applying SNR/BER as key performance indicator. With a design modeled in Simulink for this purpose, various instances of simulations were ran and the resulting values of SNR/BER over different time period were recorded for QPSK and 4QAM in the fading channels. By ensuring proper signal alignment and comparing the experimental product of SNR and BER with the theoretical expression SNR x BER = 1, the data set and results obtained were considered reliable. Findings show that 4QAM is generally a better modulation scheme but, is preferable in Rayleigh fading channel at the cost of transmission stability. It was also established that QPSK is an ideal choice in Rician environment than it is in Rayleigh fading environment.

e. Bluetooth-Based Ad-Hoc Network For Voice Transmission Over LAN

Omijeh & Munonye (2015) developed a computer-based model for analyzing Bluetooth-based Ad-hoc Network for voice transmission over Local Area Network . The aim is to analyze the performance of Bluetooth technology when applied to communication between Bluetooth-enabled devices such as smart phones and personal computers connected over Local Area Network (LAN) in order to communicate with other users or devices which are out of the immediate Bluetooth range. The methodology employed includes the use of the following communication blocks : CPM Modulator Baseband , M-FSK Modulator Baseband block, General CRC Generator block, M-FSK Demodulator block, CRC Syndrome Detector block from the Matlab/Simulink Library. The State flow charts were used to implement the transmitter and Receiver Controller respectively. Results obtained after simulation proved satisfactory. The use of Bluetooth in voice and data transmission could produce high data and audio rates while not producing a corresponding rise in error rates. Error rates was found to be in the order of < 0.01.

f. Computer-Based Comparative Analysis of BPSK Versus other PSK Modulation Models;

Omijeh & Adabanya (2015) developed a model for analyzing BPSK technique along-side other MPSK techniques over an AWGN channel paying specific attention to the Bit Error Rates(BER), number of errors and number of samples generated by the MATLAB simulation. The MATLAB simulation results show the BPSK method proves to be a better technique where distance and error generation are top factors to be considered. This model is an excellent tool for telecommunication education.

g. Comparative Study of Bit Error Rate of Different M-ary Modulation Techniques in AWGN Channel

Omijeh & Eyo (2016) developed a model to investigate various digital modulation schemes and their effect on bit error rate (BER); and to ascertain which has the lowest bit error rate. Further analysis includes: to compare bit error rates of various digital modulation schemes using the M-ary modulation technique, analyse the effect of varying signal energy per bit to Noise ratio (Eb/No) on the error rate of various digital modulation schemes, analyse graphically the relationship between Eb/No and BER,

analyse graphically the relationship between BER and M-ary number. A model-based design methodology was employed in the research using MATLAB/SIMULINK. The comparison between different M-ary (M-PAM, M-PSK, and M-QAM) (M = 2, 4, 8, 16, 32, and 64) modulation schemes in normal AWGN channel was done. By analysing the graphical illustration of Eb/No vs BER of these MPSK schemes it was strongly observed that increase in the value of M causes a correspondent increase in the error rate. Therefore, as the error rate increases with increasing M; lower level should be used for long distance communication and vice versa. High level modulation techniques are always preferred for high data rate **(Omijeh &** Agoye ,2015)

h. BER Performance Analysis of M-QAM OFDM over a Multipath Rayleigh Channel with AWGN

Omijeh & Chira (2016) developed a computer-based model for the bit error rate performance analysis of OFDM on M-QAM modulation over a multipath Rayleigh Channel. The model design and simulation was done using Simulink. The results obtained showed that for lower values of Eb/No between 5 - 15db, the BER decreases as the M-ary number increases for the same Eb/No value. However for Eb/No greater than 15db, it was observed that the BER increases as the M-ary number increases for the same Eb/No value.

i. Comparative Analysis of Performance Reed-Solomon Code on the Bit Error Rate (BER) of MIMO GMSK and MIMO MSK in a Noisy Multipath Rayleigh Fading Channel

Omijeh & Eyo (2016) develop a model for the comparative analysis of the performance of Reed-Solomon code on BER of MIMO-GMSK and MIMO-MSK in a noisy multipath Rayleigh fading channel. A Model-based design methodology was employed in this research using Matlab/Simulink; it involved the design and simulation of a MIMO-GMSK and MIMO-MSK digital Modulation system with Reed-Solomon forward error correction method. The results obtained show that the Bit Error Rate (BER) increases as the error correction capability of the RS code decreases for the same ν value. It was also observed that a lower code word symbol RS code is more effective in correcting bit error and produces lower BER in MIMO-GMSK than MIMO-MSK in a noisy multipath Rayleigh channel. The BER decreases as the code word symbol increases for different ν values in the MIMO-MSK system. However, the RS code performed better in correcting bit errors resulting from the effect of a noisy multipath Rayleigh fading channel in the MIMO-GMSK system than in the MIMO-MSK system.

5. 0: CURRENT RESEARCH AND INDUSTRY-COLLABORATIONS ATTRACTED

Modern industrialization is evolving through advanced technologies that enhance efficiency, automation, and sustainability. This transformation is driven by Industry 4.0, which integrates smart systems, artificial intelligence, the Internet of Things (IoT), and robotics into industrial processes. Embedded systems play a crucial role in this shift, providing real-time control, data processing, and automation that optimize manufacturing, logistics, and infrastructure management. These embedded technologies enable industries to operate with greater precision, lower energy

consumption, and improved resource management, aligning with sustainable development principles.

Research serves as the foundation for innovation in Industry 4.0, enabling the development of new materials, intelligent algorithms, and eco-friendly industrial solutions. Scientific advancements in automation, machine learning, and cyber-physical systems drive the efficiency and adaptability of modern industries. The integration of research-driven insights into industrial practices fosters technological breakthroughs that promote economic growth while addressing environmental and social challenges.

The connection between these technological advancements and the Sustainable Development Goals (SDGs) is evident in multiple areas. Industry 4.0 and embedded systems contribute to sustainable production by reducing waste, optimizing energy use, and minimizing industrial emissions. Research and innovation accelerate the development of renewable energy, circular economy models, and climate-resilient infrastructure, supporting SDG targets related to clean energy, responsible consumption, and environmental sustainability. Furthermore, the shift toward digitalized, data-driven industries creates new economic opportunities, improving employment prospects and promoting inclusive growth in line with SDG objectives.

As industrialization continues to advance, the synergy between embedded systems, research, and Industry 4.0 will remain critical in shaping a more sustainable and technologically empowered future. These elements collectively drive innovation, economic resilience, and environmental responsibility, ensuring that industrial progress aligns with global development goals

5.1 Education 4.0 and Sustainable Development Goals

Education 4.0 is a response to the digital transformation of Industry 4.0, integrating **technology-driven, personalized, and competency-based learning** to equip students with the skills needed in the modern workforce. Fig 10

Education has continuously evolved, adapting to societal transformations, technological advancements, and economic demands. In ancient times, learning was informal, often passed through oral traditions and apprenticeships. Knowledge was preserved by scholars, religious leaders, and elders, with access limited to the privileged few. As civilizations progressed, structured education systems emerged, emphasizing literacy, philosophy, and mathematics, laying the foundation for formal schooling.

Fig 10: Educational Revolution over time

With the onset of industrialization, education shifted towards mass schooling, designed to equip students with skills suited for factory-based economies. The curriculum became standardized, focusing on discipline, memorization, and uniformity to prepare individuals for repetitive tasks in industrial settings. As economies evolved, so did education, incorporating more analytical thinking, problem-solving, and creativity. The rise of computers and digital media transformed traditional learning methods, integrating multimedia, online resources, and interactive content into classrooms.

Today, education is undergoing another revolution with the integration of artificial intelligence, virtual reality, and personalized learning models. The shift towards Education 4.0 aligns with Industry 4.0, where learning is dynamic, technology-driven, and tailored to individual needs. Smart classrooms, online platforms, and data-driven education systems are making learning more flexible and accessible. The focus is now on lifelong learning, adaptability, and interdisciplinary skills to keep pace with rapid technological changes.

This evolution reflects humanity's continuous effort to refine how knowledge is acquired and applied. From oral traditions to AI-driven learning, education remains the foundation of progress, constantly reshaping itself to meet the needs of society.

5.2 Sustainable Development Goals (SDGs)

The integration of Education 4.0 and Industry 4.0 plays a transformative role in advancing the Sustainable Development Goals (SDGs) by fostering innovation, inclusivity, and sustainability. Education 4.0, characterized by personalized learning, digital technologies, and skills-oriented approaches, equips individuals with the competencies required in an era of automation and artificial intelligence. Industry 4.0, driven by smart manufacturing, IoT, big data, and robotics, enhances productivity while promoting sustainable industrial practices . See Fig.11.

Together, these advancements contribute to global development by ensuring access to quality education, creating new economic opportunities, and reducing inequalities. Digital learning platforms break traditional barriers, making education more accessible and inclusive, particularly in underserved regions. The workforce is better prepared for the demands of a rapidly evolving job market, reducing unemployment and fostering economic growth. Smart industries improve efficiency while minimizing environmental impact through sustainable production practices, energy optimization, and waste reduction.

As societies transition into a more technology-driven world, the collaboration between Education 4.0 and Industry 4.0 accelerates progress toward a future where knowledge, innovation, and sustainability converge. By aligning education and industrial development with the principles of the SDGs, these advancements create a foundation for a smarter, more equitable, and resilient global economy.

Fig.12: Sustainable Development Goals

How Education 4.0 and Industry 4.0 Support the SDGs

a. **Quality Education (SDG 4)**

- **Personalized and digital learning** makes education more **accessible and inclusive**, reducing inequalities in learning opportunities.
- AI-driven **adaptive learning platforms** enhance education delivery, improving **literacy and digital skills**.
- Virtual and augmented reality (VR/AR) provide **immersive learning experiences**, making technical education more engaging.

b. **Decent Work and Economic Growth (SDG 8)**

- Industry 4.0 creates **high-tech job opportunities** while Education 4.0 ensures that the workforce acquires **future-ready skills**.
- **Lifelong learning programs** help workers adapt to **automation and AI-driven industries**.
- Digital transformation reduces **hazardous jobs**, ensuring **safer workplaces** through robotic automation.

c. **Industry, Innovation, and Infrastructure (SDG 9)**

- Smart manufacturing, IoT, and AI improve **industrial efficiency and reduce waste**.
- Research and development (R&D) in **4IR technologies** drive innovation in **green technology, transportation, and smart cities**.
- Collaboration between **universities, industries, and governments (Triple Helix Model)** accelerates sustainable industrial growth.

d. **Reduced Inequality (SDG 10)**

- Online and **remote learning technologies** ensure education reaches marginalized communities.
- AI-powered **language translation tools** support **global accessibility in education and communication**.
- Industry 4.0 enables **remote work and flexible employment**, promoting inclusivity in the workforce.

e. Sustainable Cities and Communities (SDG 11)

- Smart city initiatives use **IoT, AI, and big data** for efficient **urban planning, transportation, and waste management**.
- Education 4.0 promotes knowledge about **sustainable urban development**.
- Industry 4.0 enhances **energy efficiency in infrastructure and transportation systems**.

f. Climate Action (SDG 13)

- AI-driven **climate monitoring systems** analyze environmental patterns and predict disasters.
- **Smart energy management systems** optimize industrial resource usage, reducing carbon footprints.
- Education 4.0 raises awareness of **environmental sustainability** and promotes green skills.

g. Responsible Consumption and Production (SDG 12)

- **Circular economy models** reduce industrial waste through AI-powered supply chain optimization.
- Sustainable manufacturing processes minimize **resource depletion and environmental harm**.
- Education 4.0 integrates **eco-conscious learning** to promote sustainable practices among future generations.

Education 4.0 and Industry 4.0 are critical enablers of sustainable development, driving innovation, economic growth, and environmental sustainability. When integrated effectively, they support the UN's SDGs by providing quality education, fostering inclusive economic opportunities, and promoting sustainable industrialization. However, achieving these goals requires policy innovation, infrastructure development, and a commitment to equitable digital transformation.

5.3 Research Outputs in 4IR Era

This section contains few of my research outputs in the 4IR era.

a. AI- Adaptive Home and Industrial Automation.

Oluwasegun & **Omijeh (2024)** designed and implemented an **adaptive AI Powered Voice Automation System for home and industrial use.** This intelligent lighting system uses AI to adjust lighting conditions automatically based on user behavior, time of day, occupancy, and ambient lighting. The system learns from daily routines and preferences to provide a personalized lighting experience. It integrated sensors to detect movement, light levels, and even contextual data like weather forecasts adapting the

lighting accordingly without manual input (Oluwasegun and Omijeh , 2024). This developed embedded system hardware has the following applications and features :

a. **Energy Efficiency**: By adjusting brightness based on occupancy and natural light levels, the system can reduce energy waste, lowering utility bills and environmental impact.
b. **Enhanced Comfort**: It adapts to routines, providing soft lighting in the morning and dimmed, calming lighting in the evening, creating an atmosphere aligned with users' preferences.
c. **Home Security**: The system can simulate presence by turning lights on and off when the house is unoccupied, adding a layer of security.
d. **Assistance for Individuals with Disabilities**: This hands-free, intuitive system is ideal for individuals with limited mobility, making lighting control effortless.
e. **Sleep Optimization**: By dimming lights gradually toward bedtime and minimizing blue light exposure, the system promotes a healthier sleep environment.

b. AI Enhanced Smart Greenhouse for Agriculture

An embedded system- based Smart Green House(SGH) was developed for agricultural purposes. The greenhouse system utilizes sensors and automated controls to manage soil moisture, light, temperature, and humidity for optimal plant growth. Which makes it beneficial for precision agriculture, allowing efficient resource management, reducing labor costs, and enhancing crop yields in controlled-environment farming setups (Orimadike et al, 2024).. We also developed an IoT Weather station valuable in agriculture, environmental research, urban planning, and personal or community weather monitoring, offering accessible and continuous weather insights. This a connected weather monitoring system that records and transmits environmental data, such as temperature, humidity, and air pressure, to the cloud for real-time access.

EXHIBITION AT TETFUND NATIONAL FAIR -November 17-21, 2024

These two products from CITE- Uniport were selected from over 3000 submissions made after serious screening exercise by ETTFUND. The two products were:

i. Ai Adaptive home Automation System for maximum Management of Energy usage.
ii. Ai Enhanced Smart Green House for Agriculture

The Vice Chancellor was ably represented by Prof. Iyeopu Siminiliaye, DVC R & D at the opening ceremony, Nov 18 with Prof. Omijeh and his team on ground for the exhibition. More partnerships now in progress as a result of the presentations. Plate 9.

Plate 9: Exhibition at TETFUND National Career Fair

c. 5G Resource Management Model for Telecom Operators

Aji et al(2014) in their work, Dynamic Frequency Reuse for Enhance 5G Spectrum Management developed a model to evaluate the efficiency of a dynamic frequency reuse scheme in enhancing spectral efficiency, throughput, and network load management within 5G networks. Leveraging frequency reuse 7 over frequency reuse 3 on dynamic spectrum sharing of 5G, it unveils a transformative pathway towards scalability and adaptability in telecommunications infrastructures. Integration of machine learning algorithms for dynamic frequency reuse adjustments and a web-based simulator platform for performance assessment further enhance network efficiency and user experience **(Omijeh** & Ogah**.,** 201**5)** . Results showed that the proposed method consistently outperformed the traditional radio frequency reuse and fixed fractional frequency reuse (FFR) techniques, achieving spectral efficiencies ranging from 12 to 16.5 bps/Hz. Furthermore, significant improvements in throughput were observed, with the dynamic frequency reuse method achieving a throughput of 1.17 Mbps, surpassing traditional method and static FFR configurations. Network load management is highlighted as a critical aspect, with the proposed technique demonstrating the highest increase in network load of 135 Mbps with 70 users, effectively mitigating congestion under high-density scenarios (**Omijeh** & Biebuma, 2013; **Omijeh** & Okowa, 2018; **Omije**h & Iroegbu, 2018; **Omijeh** et al, 2020**)**

Institutional Impact

This research work is fully funded by the Nigerian Communications Commission (NCC) through a professorial chair endowment in UPH being occupied by Prof. B. O. Omijeh . Plate 10.

Plate 10: **NCC Team visits VC-UPH, 2022**

d. Development and Implementation of Blockchain Solution to Enable Data Security at University of Port Harcourt

Institutions globally, seek for a solution that intelligently manages the security of data without tampering or mutilations. To compete globally, it has become necessary for the educational sector in Nigeria to build a software solution to end the challenges of fake results, transcripts and certificates and the time it takes to verify their authenticity. In this work , Omijeh et al (2023) developed and implemented a blockchain solution that would enforce the required security for the Centre for Information and Telecommunication Engineering, University of Port Harcourt (CITE, Uniport), Nigeria. The various services that comprise the building of a decentralized blockchain network, the network consensus algorithm and block explorer application as a unit was put together using JavaScript and its associate libraries. The blockchain data structure was developed with the ability of proof of work, the mining of new blocks, the creation of transactions, the validation of the chain, retrieving the data and other functionalities when demanded. The developed Block Chain was tested for ten API (Application Programming Interface) servers and the result shows that the blocks and transactions created were broadcasted throughout the entire network. The blockchain explorer application was also implemented with a lot of features. It allows user to query the blockchain for specific blocks, results, transcript or certificate.

5.4 Bourdigital Pedagogical Model

(Omijeh, 2016) developed an innovative digital pedagogy for teaching mathematical -based courses especially in engineering and science (**Omijeh &** Ehikhamenle , 2015):. This model has become very useful in this 4IR era. See Fig

BOURDIGITAL MODEL (VIDIC Algorithm)

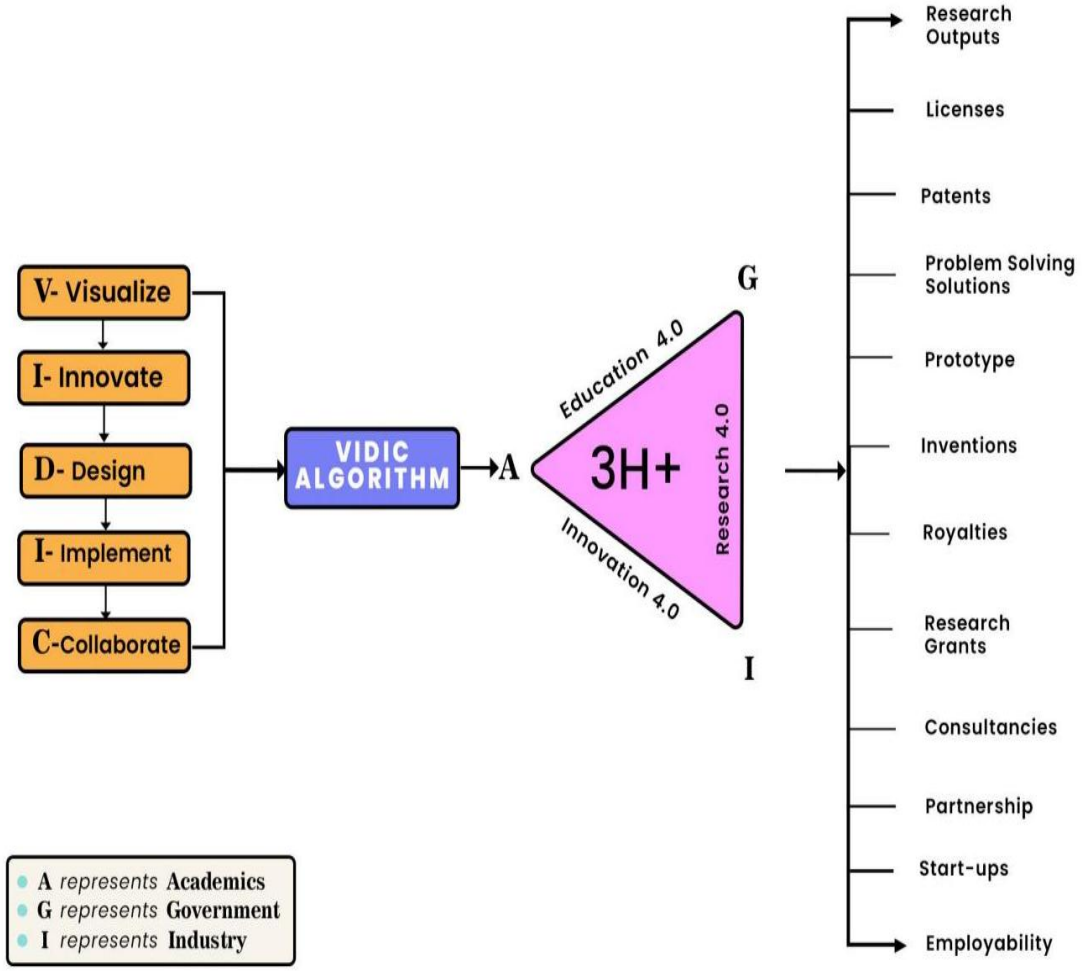

Fig .12: Bourdigital Model

Significance of the Bourdigital Model-

I. To help students to demystify the complexity of engineering, physical sciences, math-based and other related courses.
II. To create More visual, friendly and interactive leaning environment
III. To create more innovative models with the ultimate goal of invention and production.
IV. To help bring industrial realities into class room experience
V. To help our students improve in their quality of research with patentable results

This model was presented at KTH-Sweden during an International Workshop on Capacity Building for Higher Education, 2023. Please see plates 11-13.

n

Plate 11: Higher Education Workshop at KTH-Sweden, 2023

Plate 12: Prof. Omijeh presenting his innovative pedagogical Model at KTH-Sweden

Plate 13: Certificate Award at KTH-Sweden, 2023

5.5 Institutional Impacts of Research Outputs and Industry-Collaboration

a. Collaboration with Yokogawa (Japanese) Company

These early research breakthroughs with a the clear vision of an entrepreneurial university, inspired our esteemed **7th Vice Chancellor, Professor Joseph Ajienka** inline with the request from the Faculty of Engineering (then a college) to demerge the Department of Electrical /Electronic Engineering into two, namely: Department of Electrical Engineering (EE); and Department of Electronic and Computer Engineering (ECE) respectively in 2013 after senate approval . The Department of Mechatronic Engineering was also created inline with NUC guidelines. The department of Electronic and Computer Engineering was to house Communication Engineering, Computer Engineering, Embedded Systems, Automation, Robotics and emerging digital technologies. This new department of ECE gave UNIPORT an automatic global visibility and advantage in the field of Control, instrumentation and automation . This new development made the department of EEE to attract her first ever International Collaboration with Yokogawa Instrumentation and Automation Company, a global Japanese leading company in automation, Control and Instrumentation.

The impact of this collaboration is unquantifiable till today. Through this partnership today, the Department has received some digital equipment in control and automation; some of the students have gotten Six(months) Internship placements with both industrial experience and good monthly allowances to complement; and also, some of the exceptional students were given NYSC placements and gainful employment thereafter. This new Department (ECE) also led to the birth of the Centre for Information and Telecommunication Engineering (CITE). Plates 14-15.

The creation of the Department of Electronic and Computer Engineering by Prof. J. Ajienka , the 7th Vice Chancellor was an excellent idea in the right direction! A good product is not difficult to market. University of Port Harcourt became a pacesetter and reference point in this direction until it was merged again and we returned to status quo quo in 2018. **Quite unfortunate indeed!**

Plate 14: First UPH- EEE Graduate employed at Yokogawa through Partnership

Plate 15: First UPH (EEE) Interns at Yokogawa

b. Collaboration with Nigerian Army Heritage and Future Centre (NAHFC)

The Nigerian Army through her center, **Nigerian Army Heritage and Future Centre (**NAHFC) visited University of Port Harcourt to solicit for possible collaboration on the development of embedded systems/Artificial Intelligence-based solutions to enhance the performance of our security Agencies in tackling insurgency and other security treats in the country. According to the team lead, he said, "we have been following the technological research breakthroughs in CITE under your leadership for a long time ; and we are convinced, that our proposed collaboration with the university through CITE will be fruitful" . Plate 16.

c. Collaboration with National Information Technology Development Agency

In 2019, it was easier for me to facilitate the partnership between UPH (CITE)and NITDA because of my research break throughs in embedded systems and robotics technologies which I showcased to them. Today, this partnership has produced the following laudable results:

i. MSc Scholarship scheme (2019-2021) for CITE Students
ii. **A fully furnished one-storey building with equipment** donated to UPH by NITDA (Current Worth: Approx. 1.5 Billion Naira) which was commissioned by the former honorable minister of Communication and digital economy, Prof. Isa Pantami. on the 17th December, 2019 . Please see Plates 17 & 18).
iii. In 2022, donated an AI & Robotics Lab (current worth: approx.. 120 M) to UPH through its subsidiary National Centre for Artificial Intelligence and Robotics . Please see plate 12.

Plate 16: NAHFC Team visits VC-UPH on AI Partnership through CITE

Plate 17: CITE-UPH Building donated by NITDA

Plate 18: Commissioning of the donated building Prof. Isa Pantami, Fmr. Minister of Communications & DE

d. Collaboration with National Centre of Artificial Intelligence and Robotics

In 2023, **National Centre for Artificial Intelligence and Robotics (NCAIR).** partnered with CITE-UPH Catch Them Young (CTY) holiday bootcamp on capacity building digital initiatives on Ai and Robotic technologies. The participants were trained and the robotic devices developed were exhibited to the great delight of guests present. NCAIR gave awards of brand-new laptops and training kits to winners in the various categories while others got other gift items. Plates 19 & 20

Plate 19 : 2023 Catch them young winners and Awards

Plate 20: Collaboration with NCAIR

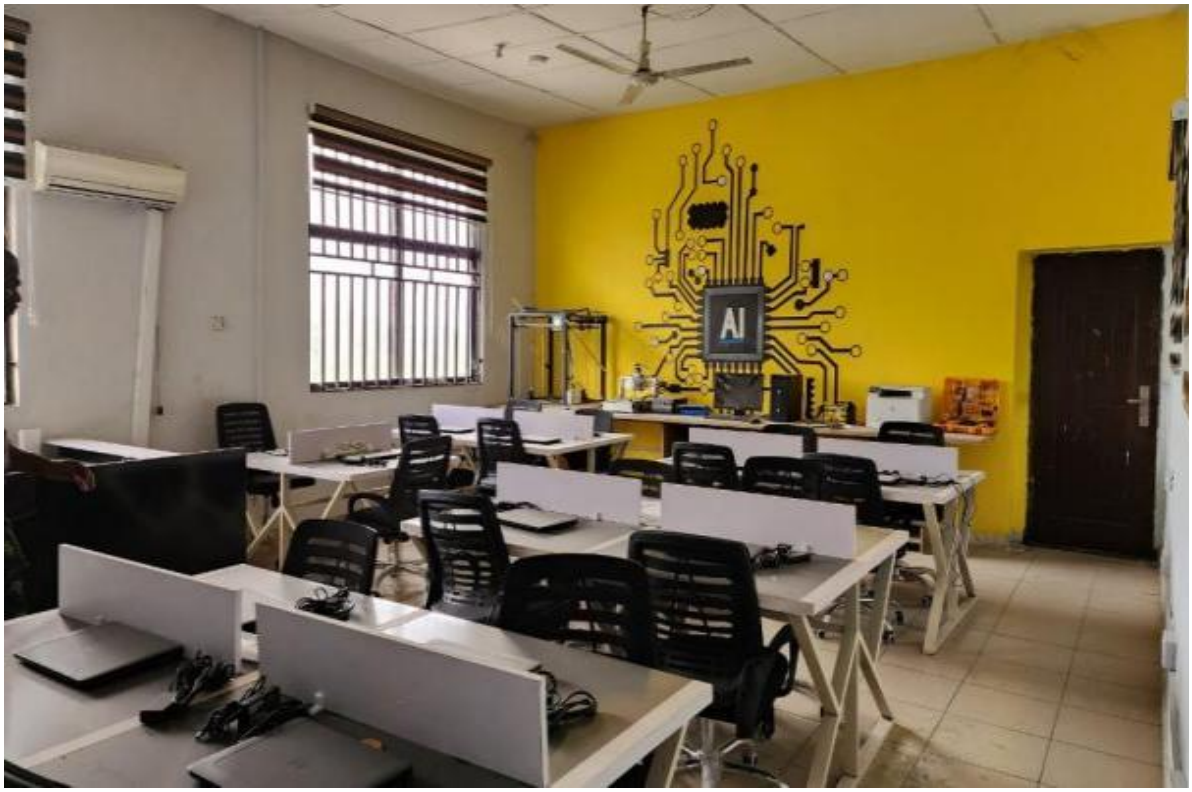

Plate 21: AI- LAB Donated by NITDA (NCAIR) , 2022

e. **Collaborations with Huawei (Chinese) Communication Company**

These research break throughs and model developed for teaching telecommunications gave UNIPORT the advantage to be the only Institution in Nigeria with two Huawei Academies . Today, the impact and benefits of this partnership are uncountable:

-Over 1500 students have been trained and graduated with Huawei international certifications for free at CITE under my leadership.

- Six months SIWES and NYSC internship placements for our students

-International "on the Job training" for some outstanding students

- Overall best global award for our team in Huawei global ICT Competition. Plate 22-25.

Plate 22 : 2019 GRADUANDS WITH HUAWEI PROFESSIONAL CERT.

Plate 23: CITE-UPH in China on 5G-Training, 2021

Plate 24 : CITE (UPH) Students win 2019/2020 Huawei global ICT Competition

Plate 25: Director CITE gets the global Award on behalf of CITE, for being the most cooperative academy

5.6 Embedded Artificial Intelligence

The relationship between Embedded Artificial Intelligence (AI), the Triple Helix Model, modern industrialization, and collaboration lies in their collective impact on technological advancement, economic growth, and innovation. Each concept plays a critical role in shaping smart industries and fostering cross-sector cooperation.

Embedded AI refers to AI systems integrated into hardware devices to enable real-time processing, automation, and intelligence at the edge (Sze et al., 2017). In modern industrialization, it enhances efficiency through predictive maintenance, robotics, and autonomous decision-making, reducing reliance on cloud computing and enabling smart factories, smart cities, and Industry 4.0 (Lee et al., 2018).

The **Triple Helix Model** (Etzkowitz & Leydesdorff, 2000) describes the interaction between universities, industries, and governments in fostering innovation. This model is essential for AI development and adoption:

-Universities contribute research, knowledge, and talent for AI model development.
-Industries apply AI in production, automation, and efficiency improvements.
-Governments create policies, regulations, and funding mechanisms for AI-driven industrialization.

This collaboration is evident in AI hubs, research labs, and national AI strategies that promote embedded AI innovation in industrial processes (Wagner et al., 2021).

Modern Industrialization and AI-Driven Economies

Modern industrialization integrates AI, the Internet of Things (IoT), robotics, and automation to create intelligent production systems (Kusiak, 2019). Embedded AI plays a key role in:

-Smart Manufacturing: AI-powered process optimization and defect detection;
-Supply Chain Management: Real-time tracking, demand forecasting, and automation and Sustainability: AI-driven resource efficiency and waste reduction.

This shift aligns with the Fourth Industrial Revolution, where AI and automation redefine industrial capabilities (Schwab, 2017).

Collaboration as a Key Enabler

Collaboration between academia, industry, and government fosters the growth of AI-powered industrialization by:

-Funding & Policy Support: Governments create AI-friendly policies and invest in AI research (Brynjolfsson & McAfee, 2017). -
R&D Partnerships: Universities and industries co-develop AI solutions (Bresnahan & Trajtenberg, 1995). -
Cross-Sector Applications: AI is deployed across healthcare, automotive, agriculture, and cybersecurity.

Global AI initiatives, such as public-private partnerships and AI regulatory frameworks, showcase the need for collaboration in AI-driven industrialization (Makridakis, 2017).

5.6.1 EU-Erasmus Embedded AI Award

In 2022, I facilitated and won the European Union -Erasmus Grant Award (Worth : 115,000 Euros) for Uniport. The consortium consist of eight (8) tertiary institutions which includes three (3) foreign Universities: University of Siegen (USI)-Germany, Kungliga Tekniska Högskolan (KTH)-Sweden, Alpen-Adria-Universität Klagenfurt (AAU)-Austra; and Five Nigerian Universities: University of Port Harcourt (UPH) , Abubakar Tafawa Balewa University (ATB, Obafemi Awolowo University (OAU), Michael Okpara University (MoU), Umudike and University of Abuja (UoA)with UPH ,the coordinating Institution; and Prof. B. O. Omijeh as the National Coordinator of the Project in Nigeria.

The overall objective of the EmbeddedAI grant is to establish an international M.Sc program in the field of embedded Artificial Intelligence with a key specialization in embedded systems and a strong emphasis on industrial involvement, which includes application domains for agriculture, healthcare, telecommunication, energy and manufacturing. EmbeddedAI will help Nigerian Higher Education Institutions (HEIs) engage with various EU HEIs and cultural backgrounds to promote globalization and technological growth based on their preferences and expectations. Plates 26-28.

Plate 26: Nigerian EU- EAI Consortium Team visit to USI-Germany 2024

Plate 27.: EU -Equipment (worth over 197,000 Euros) received by the VC-UPH on Jan 7, 2025 and was distributed to the other consortium members in Nigeria accordingly

Plate 28: EU-EAI Leadership at USI, Germany

Prof. Dr. Roman Obermaisser
Chair of Embedded Systems, University of Siegen, Germany/ Project Director, EU -Erasmus EAI.

Dr, Daniel Onwuchekwa (Alumnus of UPH)
Project Manager, EU-Erasmus EAI, Univ. of Siegen, Germany

Engr. Prof. Bourdillon O. Omijeh
National Coordinator, EU-Erasmus EAI , Nigeria/ Director, CITE-UPH

5.6.2 Google-TensorFlow Award

Google TensorFlow is a leading open-source machine learning (ML) framework that plays a crucial role in Embedded AI research, enabling AI models to run on resource-constrained devices, edge systems, and IoT applications. Through TensorFlow Lite (TFLite) and TensorFlow for Microcontrollers (TFLM), the framework allows AI models to operate efficiently in real-time, low-power, and embedded environments (Abadi et al., 2016). The framework also facilitates privacy-preserving AI through Federated Learning, making it a critical component of next-generation AI research and development.

Based on my research and academic activities on AI, machine learning , Robotics and data analysitic Google Tensorflow gave me an grant award 2021 to develop and train youths on machine learning and Ai. This same award , I have won back to back, in 2022, 2023 and 2024. This grant has enabled me trained several students on AI, Machine Learning , Data Analytics & Matlab with access to professional Certifications.

6.0: CONCLUSION

In this inaugural lecture today, **Embedded Systems have been successfully presented as a game -changer in modern industrialization**, driving advancements in automation, real-time processing, and smart technology integration. These specialized computing systems, designed to perform dedicated functions within larger mechanical or electrical systems, have transformed industries such as manufacturing, healthcare, automotive, and telecommunications.

The integration of Artificial Intelligence (AI), the Internet of Things (IoT), and 5G connectivity has further enhanced the capabilities of embedded systems, enabling autonomous decision-making, predictive maintenance, and real-time analytics. In Industry 4.0, embedded AI-driven automation is optimizing supply chains, smart factories, and energy-efficient industrial operations, reducing downtime and increasing productivity.

Additionally, frameworks such as Google TensorFlow Lite and TensorFlow for Microcontrollers have facilitated AI deployment on low-power embedded devices, expanding applications in edge computing, robotics, and intelligent monitoring systems. These innovations, combined with 5G-enabled ultra-low latency and high-speed data transfer, ensure seamless communication between embedded devices, making modern industries more efficient, adaptive, and data-driven.

As industrialization continues to evolve, embedded systems will remain at the forefront, powering next-generation smart automation, AI-driven decision-making, and cyber-physical systems as an undisputable **game-changer.**

7.0: RECOMMENDATIONS

7.1 Recommendations for Higher Education Institutions

Higher Education Institutions must integrate practical skill development with academic learning to enhance employability, align with the Sustainable Development Goals (SDGs), and foster startups in embedded systems devices,.

Below are key recommendations:

a. **Curriculum Enhancement for Embedded Systems & Emerging Technologies**

Practical-Oriented Learning: Incorporate hands-on projects, prototyping, and simulations in courses on microcontrollers, IoT, FPGA, and AI-driven embedded systems. Use problem-based learning (PBL) to solve real-world challenges in healthcare, agriculture, and smart cities (aligning with SDGs). Interdisciplinary Approach: Blend embedded systems with AI, robotics, cybersecurity, and sustainability principles to create future-proof solutions. Industry Certifications: Offer professional certifications in Arduino, Raspberry Pi, Embedded Linux, RTOS, IoT security, and cloud-based IoT systems.

b. Skills Acquisition and Capacity Building in Embedded Systems

Hardware and Software Development Skills: teach PCB design, firmware development, real-time systems programming (C, Python, Rust), and embedded AI. **Testing and**

Debugging Skills: train students in debugging techniques, power optimization, and hardware-software integration. Open-Source Platforms: Encourage the use of open-source tools like KiCad, Free RTOS, Zephyr OS, and Edge Impulse for affordable prototyping.

d. Entrepreneurial Skills & Startup Ecosystem Development

Startup Incubators & Innovation Labs: Establish university-backed incubators for embedded hardware startups with funding, mentorship, and prototyping facilities. Funding and Grants: Provide access to funding sources like government grants, venture capital, and hackathon competitions to support prototype-to-product transitions. Tech-Business Integration: Teach students business models, intellectual property (IP) protection, patent filing, and venture building for embedded system innovations. Collaboration with Industry and Research Institutions: partner with chip manufacturers (e.g., NVIDIA, Texas Instruments, STMicroelectronics), IoT firms, and automation companies to facilitate knowledge transfer and internships.

e. Emerging Digital Skills for Embedded Systems Startups

IoT & Edge Computing: Develop expertise in cloud-edge hybrid models AI & Machine Learning in Embedded Systems: Train students in TinyML, TensorFlow Lite, and edge AI applications for low-power devices. Cybersecurity & Secure Embedded Systems: Teach secure coding, encryption techniques, and penetration testing for IoT and embedded devices.

e. Alignment with SDGs for Sustainable Innovation

Smart Agriculture and Climate Solutions (SDG 2, 13): Develop embedded solutions for precision farming, automated irrigation, and environmental monitoring. Healthcare & Wearable Technologies (SDG 3): Encourage innovations in portable medical devices, biosensors, and assistive tech for disabled individuals. Energy Efficiency and Smart Cities (SDG 7, 11): Promote the development of embedded smart grids, energy monitoring systems, and intelligent transport solutions.

f. Life long Learning and Industry-Academia Synergy

Continuous Learning Platforms: offer MOOCs, boot camps, and university-led short courses on cutting-edge embedded systems topics. Internships and Apprenticeships: Embed mandatory industry exposure through internships with leading hardware and IoT firms. Hackathons & Competitions: organize hardware hackathons, IoT challenges, and AI-embedded competitions to promote innovation.

7.2 Recommendations for the Industries .

Industries can enhance productivity, profitability, and technological advancement by actively collaborating with academia through research, capacity building, and student skill development. Establishing joint research centers and industry-sponsored labs within universities can drive innovation while funding problem-driven research projects ensures that academic work aligns with real-world industrial needs. Industries should offer structured internships, apprenticeships, and mentorship programs, allowing students to gain hands-on experience and develop industry-relevant skills. Engaging professionals as guest lecturers and curriculum advisors can bridge the skill gap and prepare students for emerging job markets. Investing in infrastructure,

scholarships, and hackathons fosters talent development and encourages students to explore entrepreneurial ventures. Collaborative startup incubators and corporate venture capital initiatives can support university-led innovations, transforming them into viable businesses. Industries should also co-develop patents with universities, ensuring mutual benefits from intellectual property commercialization. Establishing public-private partnerships, university-industry advisory boards, and long-term funding strategies can create a sustainable model for continuous collaboration. Recognizing and incentivizing companies that actively engage in academic partnerships will further strengthen the connection between research institutions and industries, ultimately driving economic growth and innovation.

7.3: Recommendation For University of Port Harcourt

Make University of Port Harcourt can become the "Silicon Valley" Institution of Africa like Stanford University in California, United State.

Future Academic and Professional Activities

I. Commencement of Masters Programme on Embedded AI in CITE
II. Unveiling of the "International Journal on Embedded AI, Telecommunication and Digital Innovations", first of its kind.
III. Hosting of International Conference on Embedded AI, Telecommunications and Digital Innovations
IV. Creation of Start-ups and innovations hubs Embedded Systems Innovations
V. **Launching of Bourdillon Omijeh Foundation (BOF):** For capacity building and skills acquisitions especially for youths and the less privilege . Also, to solicit for funds and support for the Catch Them Young legacy Digital Initiatives and start-ups entrepreneurial teams.

Final Word:

Embedded systems are at the heart of **Silicon Valley's technological evolution**, driving AI, autonomous tech, IoT, and semiconductor innovation. As the demand for smarter, faster, and more efficient computing grows, embedded systems will continue to shape the future of Silicon Valley and global technology landscapes as the "**GAME-CHANGER".**

University of Port Harcourt can become the "Silicon Valley" Institution of Africa like Stanford University in California, United State. YES, WE CAN!

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CITATION OF PROF. BOURDILLON O. OMIJEH

PROF. BOURDILLON ODIANONSEN OMIJEH

B. Eng(AAU), M.Eng(UPH) & PhD(AAU)

FNIEEE, FAAN, FIPMLD, FNIIA, FOSHA, MIEEE, MNSE, MCSEAN, MSSPI, MCPM, COREN

Professor Bourdillon Odianonsen OMIJEH was born on the 12th day of August 1972 into the family of Mr Augustine Omijeh and the late Mrs Veronica Omijeh as the first child. He hails from Ebhoyi in Uromi Town, Esan Northeast Local Government Area, Edo State. He is proudly, a Nigerian.

Educational Qualifications

He attended Igun Primary School, Benin City, Edo State, from 1978-1983; Baptist High School, Benin City, 1983-1988; Ambrose Alli University (formerly known as Edo State University), Ekpoma,1990-1997; University of Port Harcourt, 2003-2005; and Ambrose Alli University again, 2009-2014 for his PhD Programme.

Membership of Fellowships

He is a registered Engineer with membership in several professional bodies and associations, namely: **Fellow**, Nigerian Institute of Electrical & Electronic Engineers (FNIEEE); **Fellow**, African Academic Network (FAAN)**; Fellow,** Occupational Safety and Health Association (FOSHA) U.K; **Fellow,** Institute of Industrial Administration of Nigeria (FNIIA) **Fellow,** Institute of Policy Management and Leadership Development; **Membe**r, Computer Professionals of Nigeria (CPN)**; Member**, Cyber Security Expert Association of Nigeria; **Member**, Society of Satellite Professionals International (SSPI)**; Membe**r, Institute of Electrical and Electronic Engineering (IEEE); **Member**, Council for the Regulation of Engineering in Nigeria; **Membe**r, Nigerian Society of Engineer (NSE),

Administrative Experience

Professor Omijeh is the current director of the Centre for Information and Telecommunication Engineering (CITE); pioneer Head, Department of Electronic and Computer Engineering, NCC- Chair Occupant on ICT and Telecommunications in Uniport; Vice President (Research) Triple Helix Association ,Nigeria; Editor and

Reviewer to reputable Journals, external Assessor and Examiner to many Institutions both in Nigeria and in Europe.

Collaborations attracted to the University of Port Harcourt and Nigeria.

2014: **H**e attracted the collaboration between University of Port Harcourt and Yokogawa Nigeria Ltd, a leading Japanese company in Instrumentation and Automation. As a result, UniPort- Students in relevant disciplines today, now have the opportunity to do six (6) months Industrial Training with the company; and exceptional students are giving employment opportunities.

2018: **H**e attracted the partnership between UniPort (CITE) and Huawei Technologies (a Chinese Company) which led to the establishment of the CITE- Huawei ICT Academy in May, 2019. Today, CITE-Huawei ICT Academy has graduated over 1000 students with relevant professional certifications in Networking and Telecommunications within a very short time.

2019: **H**e initiated and attracted, the University partnership with National Information Technology Development Agency (NITDA) with the MoU signed on April 16, 2019; and this led to the donation of a well-furnished one- storey building (over 750M) to University of Port Harcourt which now houses the Centre for Information and Telecommunication Engineering (CITE).

2019: Facilitated the collaboration between the Federal Ministry of Communication and Digital Economy that inspired the immediate past Professor Pantami to visit Uniport for the first time to commission the CITE-Building Project.

2020: In 2020, He produced three of students who won the first prize award in the Huawei global - ICT Competition beating the rest of the world.

2022: **H**e facilitated the donation of an Artificial Intelligence (AI)-LAB (over 90M) from NITDA, first of its kind in this region.

2022: He facilitated the Nigerian Communication Commission (NCC) professorial endowment in the University of Port Harcourt. First of its kind in this region.

2022: **H**e facilitated and won the European Union -Erasmus EmbeddeAI Grant Award (over 200M) for Uniport.

2023: **H**e initiated the donation of a multi-million naira ICT-Research facility to Uniport from the Universal Service Provision Fund(USPF)-*yet to be delivered*

2024: **H**e facilitated the collaboration between the University of Port Harcourt and the International Innovation Institute of Beihang University , Beihang University, Hangzhou, China on exchange students linkage and intellectual property transfer.

2024: He won the TensorFlow Google Award for AI and machine learning Initiative from a U.S.A- based International Organization . The same award he has won in four record breaking- consecutive times (back-to-back) in 2021, 2022, 2023 and 2024.

2025: **H**e attracted an EU- Erasmus Equipment (Worth: over 62 M Naira) for Embedded Artificial Intelligence Research in UPH

Awards and Recognition

Prof. Omijeh as an innovative and result-oriented digital Professor has won several outstanding awards both in the local, national and international spheres. Just to mention a few: In 1988**, Professor Omijeh** was awarded as the Best Graduating Student in Mathematics, and Additional Mathematics from Baptist High School, Benin City, Edo State, Nigeria. In 2019, He received an award of excellence from Huawei Technologies for being an outstanding industry-academia facilitator and mentor. In 2020, he received the “Staff of the Month” (February and March) prestigious Award from the University of Port Harcourt for his numerous achievements and collaborations attracted to the

University. In 2021, he won the TensorFlow Google Award for AI and machine learning Initiative from a U.S.A-based International Organization. The same award he has won in four record-breaking-consecutive times (back-to-back) in 2021, 2022, 2023 and 2024.

Christian and **Family Life**

Finally, Professor Omijeh is a man of one wife. He is **blissfully** married to **Bliss Chiwendu Omijeh** whom he met in DLBC. In fact, **he was her choirmaster**. The union is blessed with five children; two boys and three girls, namely: **David, Delight, Divine, Destiny and Dominion**. Prof. Omijeh is a lover of GOD and a pastor in Redemption Ministries Worldwide.