FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

SPIRITUAL INTELLIGENCE:
BEYOND MECHATRONICS ENGINEERING AND ARTIFICIAL INTELLIGENCE

By

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Professor of Mechatronics Engineering

INAUGURAL LECTURE SERIES 60

30TH NOVEMBER, 2017

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University Seminar and Colloquium Committee

This 60th Inaugural Lecture was delivered
under the Chairmanship of

Professor M. A. Akanji, FNSMBM, FAS
Vice-Chancellor
Federal University of Technology, Minna
Nigeria.

ISSN 2550 - 7087

Published by:
University Seminar and Colloquium Committee
Federal University of Technology, Minna

30th November, 2017

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Signature Date

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Protocol

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Eminent Invited Guests,

Fellow Researchers,

Students,

Gentlemen of the Press,

Friends and Family Members,

Ladies and Gentlemen.

1.0 Preamble

It is with absolute humility and joy that I stand before you all today to deliver this inaugural lecture, titled "***Spiritual Intelligence: Beyond Mechatronics Engineering and Artificial Intelligence***".

Sir, before proceeding, let me share with us the different perspectives of what an "inaugural lecture" is all about. I believe this would help us to understand why we are here today. Or should I just continue with the lecture? Sir, I can ***Mechatronically*** predict what your answer would be.

So, it will be interesting to quickly appreciate some of the reasons why people have spared man-hours, have traveled from far and near, why some are watching the live broadcast of this lecture online, and why many have converged inside this hall today to listen to this lecture. This will facilitate our being on the same frequency. Thus, the question then is: What is an Inaugural Lecture meant to achieve? Or put differently, "Why the need for a Professorial Inaugural Lecture?"

The answer is quite simple, and is highlighted in the following views:

1. An inaugural lecture affords a professor to speak *ex cathedra*. We should not forget that *ex cathedra* is a Latin phrase which simply means "*from the chair*". Thus, in this case, an inaugural lecture affords someone occupying a professorial chair to speak with complete authority on anything he or she feels like without being questioned or challenged [1].
2. It is an opportunity for a newly-promoted or appointed Professor to inform the public and colleagues in the university community about his/her research career and efforts made so far. This is expected among other things to

help update colleagues and the public on current and future research directions of the lecturer [2].

3. It is a special occasion in which a newly appointed Professor is introduced not to a new job, but to a new rank - his/her professorial chair [3].
4. It is meant to concentrate on the development of the department, if the lecturer is also the occupant of the chair to which the leadership is attached [4].
5. It is an avenue for a Professor to speak on any general topic where the professor considers that he/she has something fresh and stimulating to tell the academic community and general audience [4,5].
6. An inaugural lecture is expected to bring "town and gown" together in what can be referred to as a celebration of academic excellence [6].

Hence, being a newly appointed Professor, occupying a professorial chair, saddled with the responsibility of developing the Mechatronics Engineering Programme in this great citadel of learning and loaded with new ideas and innovations to tell the academic and general community, the *onus* thus lies on me to stand before this gathering today to deliver this professorial inaugural lecture. Therefore, in this lecture, I will try as much as possible to cover if not all, then at least some, of the reasons previously enumerated on what an inaugural lecture is meant to achieve.

It is important to observe that this lecture is conversational in tone. Since, we are bringing *town and gown* together here today; this lecture will be delivered in an easily understandable language, using simple terminologies, approaches and methodologies [6].

The conversational tone approach adopted for this lecture would benefit us in many ways. First, it will enable me to

achieve one of the basic reasons why we are here today, which is the meeting of "*town and gown*"[6]. Second, the tone will enable you to connect with me and the lecture. Third, I want you to have that personal connection with our efforts, with my team and with those that have contributed to the success we are celebrating today. Lastly, the conversational approach will help you – my audience to get more involved with our approaches and contributions especially in solving societal problems. Thus, this lecture will be presented using simple language and concepts that will be understood by everyone here today and generations yet unborn.

It is important to note that, whenever and wherever I use "ours" or "we" in this lecture, ***Mechatronically***, I simply mean myself and other team members that have contributed to that work. These include but are not limited to: my teachers, my lecturers, my mentors, my students, my colleagues, and co-researchers. This is simply because Mechatronics is about team work.

So, welcome on board as we begin the lecture.

2.0 Introduction

As a teacher, lecturer and an advocate of Outcome Based Education (OBE), the onus is on me to state some of the expected outcomes of this lecture. This will also be in tandem with the approach adopted in [7].

Today's lecture has been divided into four main climes. These are: conceptual clarification, Chronicle of some of my contributions, Beyond now, and Recommendations. I will like to lay more emphasis on Section 4 of this work as it contains my contributions to knowledge in relation to Mechatronics Engineering and Artificial intelligence. There, the focus will be on my professional endeavors which include: (i) Teaching (ii) Research, Innovation and Development (iii) Community Social Responsibilities (iv) Training, Mentoring and Collaborations.

Aside my contributions in teaching, mentoring and community services, other contributions of mine in research, innovation and development that will be presented will include:

1. Development of a novel technique for detecting vascular intersection in retinal fundus images [8-10].
2. Development of new approaches for estimating autoregressive and autoregressive moving average model parameters using artificial intelligence techniques [11].
3. New data classification procedures based on artificial intelligence techniques applicable to different types of signals and images [12].
4. Development of Cognitive phone based on the principle of Multiple Operators enabled SIM cards (MOES) and intelligent network handover scheme [13].
5. Introduction of new hybrid optimization approach that involves the use of Genetic Algorithm and K-Means clustering technique [14].

6. Development of several Mechatronics systems, repair and maintenance of equipment for public and specialized usage [15-16].

These various contributions of ours have been applied in solving various societal problems in the following areas: Diabetes modeling, detection and prediction; Fruit identification and grading, Handover decision in Mobile communication, Colpitts Oscillator Design, Spectrum sensing in Cognitive Radio, Earthquake prediction, Gold and Silver Price prediction, Route Optimisation, Biometric System, Scorpion vibration detection and many others. Furthermore, some of these discoveries are being scaled up to commercial ventures with about three patents now at the filing stage. I have also enjoyed coverage from print and online news media based on my little contributions. Some of my research findings and contributions have been exhibited at various events, won several awards and have been published in different high impact journals, and in the proceedings of various international conferences.

Ladies and gentlemen, we are now about finishing the introductory part of this lecture, with four more sections to go. Now, kindly adjust your seat, optimise the settings of your mobile device for online audience, and let us move on to the next section. Are we ready?

3.0 Conceptual Clarification

This section presents clarification of two major keywords in the title, namely: Mechatronics Engineering and Artificial Intelligence.

3.1 Mecha... What? Mechatronics Engineering

In this sub-section, my aim is to introduce the concept of Mechatronics Engineering. In line with that, we shall focus on the history of technology and engineering in the first part. This will involve us looking at various technological revolutions. Immediately after that, we shall examine the origin of Mechatronics Engineering. In the second part, we shall review some of the existing definitions of Mechatronics Engineering. So let's start by taking it one step at a time, *poco a poco, little by little, one step at a time*.

3.1.1 From Simple to Intelligent Systems: Technological Revolutions to Date

Within the last three centuries, we have witnessed nothing less than four technological revolutions. These are; the Industrial Revolution, the Semiconductor Revolution, the Information Revolution and we are now experiencing the Mechatronics Revolution. Figure 1 presents these four technological revolutions. Kindly note that different technological evolutions have occurred within each revolution.

Figure 1: Technological Revolutions to date

3.1.1.1 Industrial Revolution

As many of us are aware, the Industrial revolution witnessed the design of products and processes that allowed the conversion and transmission of energy from one form to another. In this era, most of the known inventions and contributions were mechanical in nature. These systems made use of mechanical energy to do meaningful work. Perhaps this may be the reason why we were all taught in our respective physics classes that energy is the ability to do work. Thus, during this era a lot of computations, transmissions, and other activities were purely done using mechanical systems such as: gears, levers, cams, etc. These systems as we were made to know, suffered from energy losses because of: friction, tolerance, inertia, coupling, and inability to perform power amplification. It is worthy to

mention that this period lasted for over a century before it gave way to the semiconductor revolution.

3.1.1.2 Semiconductor Revolution

The Semiconductor revolution was birthed to solve some of the problems encountered during the Industrial revolution. This revolution witnessed the invention of integrated circuitries (ICs) that were able to amplify and transfer the needed amount of energy and power to actuators and other devices. In addition, the ICs provided the basic computational and decision-making circuitries and energy storage capabilities needed for the control of mechanical devices which were not totally possible in the mechanical systems of the industrial revolution era. The Semiconductor age also witnessed the miniaturization of some of the bulky systems used during the Industrial age and with corresponding increase in the efficiency of the existing mechanical systems. Permit me to say that this is the first period where electronics were used to augment and improve the efficiency of mechanical systems and this marked the beginning of what we sometimes refer to as ***electromechanical systems***.

3.1.1.3 Information Revolution

The development of the Very Large Scale Integrated (VLSI) circuit technology heralded the information age. This age was characterized by the introduction of microprocessors, microcontrollers, and the microcomputers. This made computing hardware to become cheap, common, and smaller in nature than what was witnessed under the semiconductor age. Thousands of semiconductors were usually housed in a single VLSI circuit with a corresponding increase in the system's performance and efficiency. These smaller VLSI circuits were also able to perform lots of decision making activities. The era also witnessed the interfacing of hardware systems with the

already existing electromechanical systems of that time leading to what we now call the Human Machine Interface (HMI).

3.1.1.4 Mechatronics Revolution

It is often said that "*nothing lasts forever*" and so the information age eventually paved way for the coming of the ongoing revolution, termed the Mechatronics Revolution. This revolution has transformed the old saying of "*Jack of all trades, master of none*" to "***Jack of all Trades, Master of ALL***".

The Mechatronics revolution witnessed the introduction of a unifying interdisciplinary, intelligent and team-based engineering paradigm, where machines are made to be intelligent and to perform lots of independent decision-making tasks. The revolution has given birth to a multitude of innovations and proliferation of machines that are smarter and smaller in size than what we used to have during the previous revolutions. Consequently, this revolution has empowered the design, development, and support of novel concepts for the realization of intelligent human-oriented machines that coordinate and cooperate intelligently with their human users. Aside from the intelligent machines produced in this age, the revolution also necessitated the introduction of the mechatronics engineering discipline.

3.1.2 Origin of the Word, "Mechatronics"

It should interest us to know that the coinage of the word, "Mechatronics" has been consistently attributed by various authors, researchers and writers to Yaskawa Electric Co., Tokyo; when it was used by the company in 1969 to describe the combination of two different words, namely mechanism and electronics [17, 18].

Mechatronics: **Mecha**nism + Elec**tronics**

In the usage, Mechanism refers to machines that '*move*'. This contradicts what easily comes to mind when we meet the word "Mechatronics" for the first time. It is usually assumed, and sometimes erroneously concluded, that the "**Mecha**" in **Mecha**tronics stands for Mechanical, while the "**tronics**" stands for Electronics, thereby limiting Mechatronics to just the fusion of Mechanical and Electronics Engineering. This notion is inaccurate, and it is not in consonance with the idea behind the coinage of Mechatronics in 1969 [17, 18].

3.1.3 What is Mechatronics and What is Not Mechatronics?

After we have understood the origin of Mechatronics and what each component in the name stands for, we can now have a look at some definitions and descriptions of what Mechatronics Engineering is all about. Permit me to use this medium to remind us that [20] has succinctly defined what Engineering is. So, here we shall only be concerned with defining and describing Mechatronics. Hence, whenever I say Mechatronics in this lecture, what should come to our mind is Mechatronics Engineering. We may now begin, not in any particular order, with the question, **"What is Mechatronics?"**

1. "Mechatronics is the synergistic combination of precision mechanical engineering, electronic control and systems thinking in the design of products and manufacturing processes" [21].
2. "The union between Electrical Engineering, Mechanical Engineering, Computer Engineering and Applied Control Engineering" [23].
3. "Mechatronics represents a unifying interdisciplinary and intelligent engineering science paradigm that fuses, permeates, and comprehends modern engineering science and technologies" [26].

4. "Mechatronics is regarded as a philosophy that supports new ways of thinking, innovations, design methodologies (synthesis and analysis), and practices in the design of new intelligent products and engineering systems" [26].
5. Mechatronics can be regarded as a "holistic, concurrent and interdisciplinary engineering science discipline that concentrates on achieving optimum functional synergy from the earliest conceptual stages of the design process" [26].
6. "Mechatronics enables the creation, design, and support of new concepts for realising intelligent human-oriented machines that coordinate and cooperate intelligently with their human users" [26].
7. "Mechatronics system is nothing but synergistic combination of computer, mechanical, electronics and electrical engineering" [29].
8. "Mechatronics is a natural stage in the evolutionary process of modern engineering design" [36].
9. "A mechatronics system is not just a marriage of electrical and mechanical systems and is more than just a control system; it is a complete integration of all of them" [19].
10. "The addition of intelligence to a mechanical design or the replacement of mechanical designs with an intelligent electronic solution" [23].
11. "The integration of mechanical engineering with electronics and intelligent computer control" [21].
12. "The use of a synergistic integration of mechanics, electronics, and computer technology to produce enhanced products or systems" [22]

You will all agree with me that despite the numerous definitions that exist for Mechatronics, most of these definitions or descriptions agree on these three keywords:

i. Synergistic
ii. Intelligent
iii. and new product or process.

When we say synergistic integration, we simply mean the integration of two or more technologies or concepts acting together to create an effect greater than that produced by only one of the separate effects of the individual technologies; not only creating a greater effect but creating intelligent effects that reduce the level of human involvement in the development of new products or systems. This explanation encompasses the focus of Mechatronics Engineering. This simply shows that Mechatronics is concerned with the synergistic integration of different technologies in generating new and novel products and systems with functionality integrated across those core technologies [24–35]. Thus, anything that is neither in consonance with any of the aforementioned definitions nor in conformity with the previously presented philosophies and is lacking the three keywords cannot be regarded as Mechatronics.

3.1.4 Everything is Mechatronics

In our world today, is there anything that is not mechatronics in nature? Let us start from the simplest example that may be with you, which is your mobile phone. Is your mobile phone not a mechatronics device? What are the basic components in today's mobile phones? You have the usual communication system; the sensors and data acquisition sensors; the graphical user interface; the artificial intelligence system; the mobile applications; and the biometric system, all working synergistically to provide a better device. Will you not agree

with me that we have moved from the initial debut of wired telephone systems for receiving and making phone calls to an era where our mobile phones are almost everything? Of course, you will. Our mobile phones are wireless with the capability for data communication, security, speech processing, health monitoring, etc.

Another classical example we can think of is the automobile system. Until the 1960s, the radio was the only significant electronics in any automobile system with other functions being entirely mechanical or electrical. Thus, all the engine systems were controlled by the driver and/or other mechanical control systems. It suffices to say that no form of intelligence was introduced into the earlier automobile systems. The introduction of electronic ignition system in 1970s heralded the deployment of the first mechatronics systems in the automobile industry [36]. This typical electronic ignition system consists of a crankshaft position sensor, camshaft position sensor, airflow rate, throttle position, rate of throttle position change sensors, and a dedicated microcontroller used in determining the timing of the spark plug firings. In the 1970s, the introduction of Antilock Brake System (ABS) was implemented. The ABS works by sensing a lockup of any of the wheels and then modulating the hydraulic pressure as needed to minimize or eliminate sliding. Another example is the Traction Control System (TCS), which was introduced in automobiles in the mid-1990s. Also, the Vehicle Dynamics Control (VDC) system was introduced in automobiles in the late 1990s. Now, almost all the systems today in our automobile systems are mechatronics systems. And you will agree with me that the debut of autonomous vehicles in recent times with the capability for collision avoidance, vehicle to vehicle communication, and vehicle to infrastructure communication, has totally changed the traditional automobile system into a total mechatronics system.

Other examples of Mechatronics systems in our environment include the Automated Teller Machine (ATM), Cloth Washing Machine, Airplane, Vacuum Cleaners, Air-conditioning System, Public Address System, Digital Thermostats, Robots, and Bioloids, just to mention a few [24-36].

3.1.5 Mechatronics and its Variants

In Nigeria, Africa and Europe, the most popular name is Mechatronics Engineering though some institutions prefer to use System Engineering or Robotics Engineering. It is a known fact that Robotics is a subset of Mechatronics since almost all robots are mechatronic, however, not all mechatronic systems are robots. Furthermore, Mechatronics Engineering curricula at the university level includes the design and construction of robots or robotic elements as an option for specialisation.

Are you aware that in most Chinese speaking regions, Mechanical and Automation Engineering are more popular than elsewhere? This is a known fact. While in the Eastern bloc, the preferred name is Electro-Mechanical. What is quite noticeable in most of these variants is the subtle difference in areas of focus and areas of applications. Also, little emphasis is placed on the issue of synergistic integration via artificial intelligence in some of these other options.

3.2 Brief Introduction to Artificial Intelligence

Why are you behaving like a machine? Can't you think? Can't you use your brain? Can't you comprehend what I have been telling you? These and many more are some of the common rhetorical questions or comments we must have read about or heard. You will observe that most of these questions have either direct or indirect correlation with intelligence, thus, showing the extent we value intelligence. The question then is "Why do we often question our intelligence, especially when the person

being questioned is performing below expectation?" In this section, we shall try to explain why those statements have continuously been used to question peoples' intelligence.

Ladies and gentlemen, this sub-section on Artificial Intelligence (AI) is divided into two parts. In the first part, we shall be looking at motivation for AI with emphasis on some basic definitions. In the second part, we shall look at selected AI techniques with emphasis on those that you shall come across in the later part of this lecture. Let me conclude this introduction to AI section by stating that the aim of this section is to lay the foundation upon which later parts of this lecture will be built since most of my contributions involve the use of Artificial Intelligence in the transformation of manual systems to intelligent systems.

3.2.1 Artificial Intelligence: The Mitochondria of Mechatronics Engineering

Let us be reminded that in the first unit of this same section we looked at various definitions of Mechatronics Engineering and we established the basic components of Mechatronics Engineering. Can we still recollect? Let's quickly review this, so that we can appreciate why we need to apply the same concept to AI. Let me ask, what are the three keywords in the description of Mechatronics Engineering mentioned in the previous section? Anybody there to give it a try? Ok!

Yes, Synergistic, intelligent, and product or process development. However, let us zoom down on one of the keywords with little modification by calling it Artificial Intelligence (AI).

One of the previous descriptions of Mechatronics Engineering, especially the description that explains the distinguishing factor between a mechanical system and a Mechatronics system in sub-section 3.1.3, states that:

Mechatronics Engineering *"is the addition of intelligence to a mechanical design or replacing mechanical designs with an intelligent electronic solution" [39].*

So, it is obvious from this little description that AI is very important and we can say it is the Mitochondria of Mechatronics Engineering. It would therefore not be out of place if we tried to understand what AI is all about. Ahead of that, we must not forget that justice cannot be done to AI in this single lecture; however, we can stimulate our interest and inquisitiveness in the area.

3.2.1.1 Artificial Intelligence: Motivation

As human beings, we are continuously surrounded by different tastes, smells, aroma, feelings, sounds and colors which we observe, perceive, conjure, learn and internalise through our different senses. From these, we perform our intuitiveness, deductiveness, convergences, divergences and interpretation of thought, leading to interpretation of the world possible in a holistic, panoramic, parallel, flexible and contextual way. The aforementioned are products of our imagination, creativity and spontaneity, giving us the ability to give different meanings to the happenings around us [37]. Our ability as homo sapiens to give different meanings, solve-problems, and learn from life has been described as Intelligence [38, 42].

Thus, despite knowing fully well that as human beings, our lives are determined and influenced by various dimensions: (1) a biological inheritance from parents and ancestors (2) physical appearance which helps in distinguishing us from other living beings (3) a psychological make-up that governs our mental, emotional, linguistic, behavioural, and moral aspects (4) social need which affects all aspects of our existence and lifestyle (5) spiritual dimension which helps us to distinguish right from wrong as dictated by man's religious and belief system. It is still expected that man should be able to perform his duty and task

intelligently. Thus the inability to give different meanings, solve-problems and learn from life's daily experiences, do attract the question: ***Why are you behaving like a Machine? Stop acting like a robot and use your brain?***

Man from time immemorial has always endeavoured to master his life and influence his physical environment through discoveries and innovation using his intelligence. He has relentlessly strived to achieve this until he became a slave to his own discoveries and inventions, all in his bid to make life easier for himself. This has led him to exploit the power of the computer system with the intention of creating similar intelligence in machines that we find and regard high in humans. In an attempt to answer the question, "Can a machine think and behave like humans do?" man came up with the concept of Artificial Intelligence.

3.2.1.2 Artificial Intelligence: Definitions and Engineering Goal

What is Artificial Intelligence?

Just as we made efforts at providing different descriptions of Mechatronics Engineering in the first part of this lecture, let us also try to do same for AI in this sub section. Let us just use some easy but simplified descriptions, although we can consult other texts for more rigorous descriptions and definitions. So, again, *what is Artificial Intelligence?*

Artificial intelligence (AI) has been described as:

1. "The science of creating machines capable of performing activities that requires intelligence when they are done by people" [38, 43].
2. "Systems which attempt to mimic the way humans think" [38, 44].

3. "The science and engineering of making intelligent machines, especially intelligent computer programmes" [39].
4. "A way of making a computer, a computer-controlled robot, or a software think intelligently, in the similar manner the intelligent humans think" [39].
5. "The study of the computations that make it possible to perceive, reason and act" [40].
6. "The art of creating machines that perform functions that require intelligence when performed by people." [41, 45].
7. "The study of how to make computers do things which, at the moment, people are better at." [41].

Looking at the descriptions and definitions, we can easily conclude that AI is simply meant to make the existing machines intelligent by transferring intelligence in man to machine.

We must also not forget that the engineering goal of AI is to solve real societal-problems. This can only be achieved by using AI as an armamentarium of ideas about representing knowledge, using knowledge and assembling systems [41]. In addition, the engineering goal of AI includes the development of intelligent systems which evolved from the technological evolution of the last three centuries. Thus, the Mechanical System that was introduced during the Industrial Revolution was to take away the use of energy to do work from man; while the Electromechanical System that came out from Semi-Conductor Revolution was to allow electronics to take the control of machine away from man, Automated system from Information Revolution reduces the distance between man and man and man and machine and now intelligent system coming out from Mechatronics revolution is to free man from thinking, thereby transferring the continuous thinking ability of man to machine.

3.2.2 Artificial Intelligence: Some of the Known Techniques

Some AI techniques that have found usage in various engineering projects include: Artificial Neural Network, Genetic Algorithm, Fuzzy Logic, Particle Swamp Optimisation, Ant Colony, Bee Colony, and Hill Climbing, to mention a few. We should know that no matter how long this list looks like, it can never be exhaustive as more and more AI techniques are being introduced almost on regular basis. Only two that I have been using in the last few years will be discussed in this section.

3.2.2.1 Introduction to Artificial Neural Network (ANN)

Artificial Neural Network (ANN) is one of the popularly known AI techniques. It emulates the biological neurons of the human body [46]. We all know that brain power in man has always been giving high regards and the ability to use it constructively has been the distinguishing factor between man and other lower animals. Thus, ANN has been developed to emulate the structure, processing methods and the learning ability of the physical biological neurons of the human brain. ANN has proven to be flexible and with capability to learn the underlying relationships between the inputs and outputs of a process, without needing the explicit knowledge of how these variables are related. ANN can learn, adapt, predict and classify just like man and in some cases, we can say far better than man. We should note that the fundamental principle of ANN is based on finding relationship between the inputs and outputs of a problem, thus making connections between input and output layers and performing operations on a learning system [11-13].

Ladies and Gentlemen, let's go a step further by understanding this ANN better and learn some technical terms associated with it. ANN can be regarded as an information processing system constituted by an assembly of many simple processing elements

that are interconnected to perform a parallel distributed processing required for solving problems, such as; pattern classification, function approximation, clustering (or categorisation), prediction (forecasting or estimation), optimization, and control.

A typical ANN consists of interconnection of simple processing elements called nodes. These nodes are arranged in layers and are joined together by interconnection of synaptic weights to form structures; the most popular method of arrangement is called feedforward neural network [11-13]. A typical ANN structure shown in Figure 2 consists of two types of layers namely, the hidden layer and the output layer. The first interface, though passive in nature, is where data are fed to the network, this is called the input nodes. Another interface, where processed data are released out of the network, is the output layer and sandwhiched between these two layers are the hidden layers. Let me also state that each layer except the input nodes consists of one or more processing units. A processing unit is made up of an adder and an activation function. The adder sums the weighted input values and computes the input to the activation function. An activation function maps the input to a new output range, examples of which include sigmoid, tanh, linear, cubic, and radial. There are weights on each side of the processing unit in the hidden layer (left and right hand side) of the input layer and one side (left hand side) of the output layer. These weights are altered during the training process to ensure that the inputs produce an output that is close to the desired value [12]. There is interconnection of weights between nodes in the two consecutive layers but there exist no connections between nodes in the same layer.

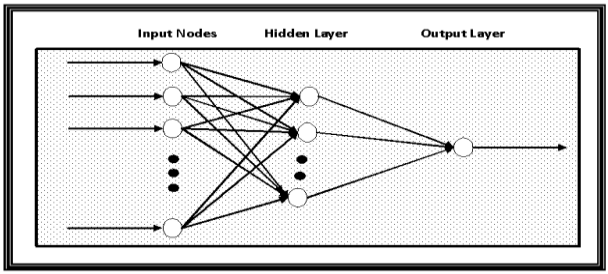


Figure 2: Artificial neural network structure

Generally, the ANN system can be divided into two main parts, namely the ANN structures and ANN training algorithm. The two parts cannot function independently, but can be combined with other AI techniques [12]. ANN structures can be sub divided into categories, among which are single-layer feedforward networks, multilayer feedforward networks and recurrent networks. A single layer structure consists of only the input nodes and the output layer while the multilayer feedforward network consists of the input node, the hidden layer(s) and the output layer. The presence of the hidden layer makes it possible for the network to extract higher-order statistics [46]. A recurrent neural networks differs from the two aforementioned networks by having at least a feedback loop from the output to the input layer. A simple multilayer feedforward structures is as shown in Figure 2. ANN structures can also be classified as: statics in which the number of parameters in the structures remains constant from the beginning of the training to the end or dynamic. But in a dynamic structure, the number of the parameters (weight, activation function, nodes) is optimised during training. The basic elements in any ANN are: the connecting weights, the summer, and the activation function in the nodes.

There are various algorithms for training ANN, the most popular one is the Back propagation algorithm (BP). Back propagation is a supervised learning algorithm used in training

a multilayer perceptron or feedforward neural network in a sequential or batch mode [47]. It is a versatile training tool for neural network structures where the backward propagation of an error signal through the network is achieved in a multilayer structure. The back propagation of errors through the network makes it possible to change the synaptic weights connected to the neurons in the hidden and output layer(s). BP can be divided into three main steps, namely the forward pass, the backward pass and the weight update.

3.2.2.2 Introduction to Genetic Algorithm (GA)

Genetic Algorithm (GA) is a type of evolutionary algorithms (EA) that is based on the principles of biological evolution process. Just like ANN that emulates the biological neuron system, GA also emulates nature in the search for the optimal solution of a given problem by using the biological natural evolution process [14]. By considering many points in the search space simultaneously, GA reduces the risk of convergence to local minima and it uses probabilistic rules to guide its search; by favoring the mating of the fitter individuals, the most promising areas in search space are explored.

GA is an effective and robust search algorithm that allows the quick location of high quality solution areas in a large and complex search space It distinguishes itself from other search algorithms by working on a population of individuals each representing a possible solution to the problem [14]. The basic principle of GA include population solution encoding and decoding, fitness function evaluation, selection, reproduction and convergence, just in line with Darwin's evolution process. Shown in Figure 3 is GA process and you will observe that it operates on the principle of survival of the fittest in a population of possible solutions to generate an approximate better solution. Another thing to observe is that at each generation, a new set of approximations is generated by the method of

selecting likely solutions (individuals) with respect to its fitness value within the problem area. This is achieved by the application of operators borrowed from natural genetics. The result of this process is the evolution of populations of offspring that are more adapted to their environment than their parents.

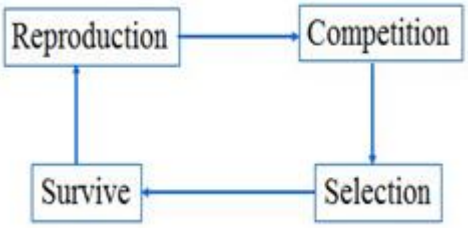


Figure 3: Darwin's Evolution principle

Other numerous advantages of GA over other traditional optimisation techniques include the ease of understanding of concepts; robustness for usage in noisy environments; ease of running in parallel; capability of altering or changing the fitness function from iteration to iteration hence facilitating the incorporation of new data if available in the model; and ability to support multi-objective optimisation. In addition, GA has been shown in various works to always lead to optimal and global solutions [14, 48, 59].

GA has been widely applied in various areas of human endeavour among which include Surveillance, Digital Image processing, Digital Signal processing, Finance, Prediction, Unmanned area vehicle (UAV), Optimisation, Automatic Programming, Machine and robot learning, Economic models, Immune system models, Ecological models, Population genetics models and models of social systems [14, 48].

4.0 What I have been doing

In this section, my professional contributions as well as my contributions to the society at large will be presented. Thus, in Section 4.1, my contributions in setting up Mechatronics Engineering Program at Federal University of Technology, Minna, Nigeria will be succinctly presented. I will also mention my efforts in teaching Mechatronics related courses both at Undergraduate and Postgraduate levels.

In Section 4.2, my contributions to research, innovation and development will be chronicled. We shall go through the evolution process of some of our research efforts where I hope you will laugh a bit at our stupidity and the adopted approaches in solving some selected societal problems. Nevertheless, I believe that at the end, you will see and appreciate the results of our sleepless nights in various laboratories, offices and workshops in Africa, Europe and Asia. I believe that you will have so much fun in that section and it will be interesting as you will also realise that most often, the journey of ten to twenty years would have been summarised in less than ten to twenty minutes only if we knew what we were doing.

In Section 4.3, various efforts in making the world a better place to live in will be presented. These will include x-raying my involvement with the society and the Military establishment especially the Nigerian Air Force and the Nigerian Army. Aside our involvement with the military, I will also share our efforts in organising mentoring activities within our small circle of influence. So let's begin by taking it one step at a time, *poco a poco, little by little, one step at a time.*

4.1 Mechatronics Engineering at Federal University of Technology, Minna

Let me tell you that the idea behind the establishment of the Department of Mechatronics Engineering (DOME) in Federal University of Technology (FUT), Minna, was first conceived in 2010. It was harangued that the department in not too long a time would be able to produce world-class graduates with a high academic standard coupled with adequate practical exposure in industries that will enable them to fit into either the academic or industrial set-up. The bar was raised a bit high again when we in the department agreed that we shall make "the department one of the leading departments in both teaching and research in Mechatronics Engineering in Nigeria".

The Department officially took off during the 2014/2015 FUT Minna academic session after passing through series of accreditation and approval processes by the National Universities Commission (NUC) and the Council for the Regulation of Engineering in Nigeria (COREN). This was why admission of the first set of students to the department occurred during the 2015/2016 academic session. Currently, the department has almost reached 300 Level with over a hundred students in the department and we should be graduating our first set of students in the year 2020. The first Head of Department who is also my mentor and doctoral research supervisor was Prof. Momoh Jimoh Eyiomika Salami while I happen to be the present and second Head of Department, DOME.

The department has been structured to become the leading academic hub of excellence in Mechatronics Engineering within the next few years. Hence, we are focussed on nurturing the upcoming generation of Mechatronics Engineers. We hope to achieve this by providing necessary support and skills for achieving breakthroughs in the technological sector. We are

highly resolute in building and developing human capacity to a high level through pragmatic and dynamic training, research and developmental services of high standards in the field of Mechatronics Engineering. As a result, our courses have been carefully selected and structured to enable our students to have seamless transition from easy to hard concepts during their course of study.

Presently, the objectives of our Bachelor degree programme in Mechatronics Engineering include: producing graduates with competencies in engineering design and analysis, providing research opportunities in Mechatronics Engineering or related disciplines, and providing required advanced professional knowledge in the industrial set-up.

Our Mechatronics Engineering programme at DOME, FUT Minna focusses on the following key elements namely: Artificial Intelligence, Signals and Systems, Digital Signal and Image Processing, Sensors and Actuators, Physical System Modeling, Software and Data acquisition and Human Machine Interface.

4.1.1 Competencies of our Graduates

The continuous and rapid changes in the computing field have made us to formulate and design our curriculum to be in line with current trends. Hence, we feel that Mechatronics engineers ***must be life-long learners.*** This will assist them in improving their knowledge and skills within their chosen discipline. Our graduates from DOME, FUT Minna should:

a) Possess the ability to design complex systems that include both hardware and software required in solving engineering problems subject to trade-offs involving a set of competing goals and constraints. In this context, “design” refers to a level of ability beyond “assembling” or “configuring” systems.

b) Have a breadth of knowledge in mathematics and engineering sciences, associated with the broader scope of engineering and beyond that narrowly required for the field.
c) Have the ability to work with other team members.
d) Possess entrepreneurship skills that commensurate with those that can float a start-up, or manage a large organisation.
e) Acquire and maintain a preparation for professional practice in engineering.

Students graduating from DOME FUT Minna shall be strongly equipped to seek careers in: Robotics and Manufacturing companies, Military and Defense organisations, Automobile and Autotronics industries, Computer Manufacturing companies, Telecommunications companies, Oil and Gas companies; Research Institutes and other schools and colleges as researchers and lecturers, and any 21st Century ICT driven company. More importantly, they shall be equipped with skills to start their own companies. Presently, we engage and include our students in running some start-ups in and around Minna, Nigeria.

4.1.2 Mechatronics in Nigeria

Aside DOME FUT Minna, I have participated in setting up and nurturing of various Mechatronics Engineering programmes in Nigeria. I have served and I am still serving in various capacities in higher institutions of learning in Nigeria as: external assessor, external examiner, programme coordinator, programme consultant, member of accreditation teams, visiting Professor, etc. I have presented numerous talks and conducted several training sessions on Mechatronics Systems to a broad spectrum of learners. Worthy of mention is the idea of setting up the Nigerian Robotics Championship (NIROC) in 2013 and the ROBOTIS Kidslab programme in 2012 for students between the ages of 6 and 13. I am sure that some of my students are here

today, while a broader spectrum of them are watching this presentation via different online real-time systems.

4.1.3 Teaching Mechatronics Related Courses.

Within the last 10 years, I have been involved in teaching Mechatronics Engineering-related courses such as: Digital Signal Processing, Digital Image Processing, Machine Vision, Artificial Intelligence, Multimedia Communication and Data Representation, Intelligent Systems and Applications, Advanced Computer Communication Networks, Engineering System Reliability, Applications of Computer to Project Management, Mechatronics Laboratory, Complex Analysis and Partial Differential Equations, Robotics, Introduction to Mechatronics, etc. both at the undergraduate and postgraduate levels.

4.2 My Humble Contributions in Research, Innovation and Development

Mr. Chairman, Ladies and gentlemen, as previously mentioned, my research interest covers four major areas, namely: Digital Image Processing, Digital Signal Processing, Artificial Intelligence, and Mechatronics System Development. Figure 4 shows the taxonomy of my interest in Research, innovation and development while Figure 5 zoomed-in on my interest and focus on AI. I have also included in the chart different areas of application I have dipped my hands in over the last few years. Detailed discussions regarding the what, how, why and when of my humble contributions in the four mentioned areas are presented from Section 4.2.1 to Section 4.2.4. You will see the connection with what I have presented under the conceptual clarification section with some of the discussions in this section.

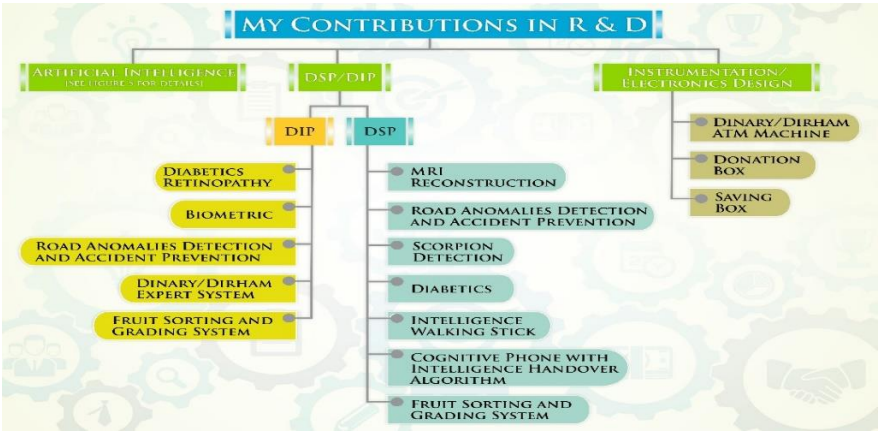


Figure 4: My Contributions in Research, Innovation and Development

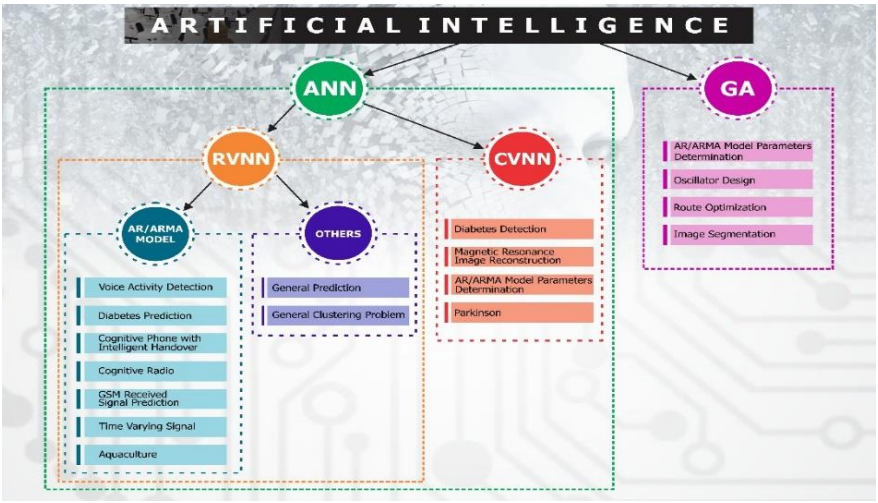


Figure 5: My Contributions in Artificial Intelligence

4.2.1: Intelligent System for early Detection, Diagnosis and Monitoring of Diabetes

Do you know that advancements in Digital photography, Digital Image Processing (DIP) and Digital Signal Processing (DSP) have opened new dimensions to medical diagnosis? Some of us

might be unaware of this but medical diagnosis is becoming easier, faster and more intelligent than we can imagine, and this is because of the application of techniques in DIP, DSP and AI. A typical example we can consider is the diagnosis of diabetes from acquired digital retina fundus image. Currently, acquiring retina images involves using specialised cameras, if need be, one may need to enhance the acquired images; and then an ophthalmologist or a trained screener will check the images for related artefacts or signs.

We must not forget that Diabetes is a metabolism disorder in the body [8-10]. It occurs frequently among a known age-group and it is one of the different societal diseases recently known to be on the increase. As we know, the energy required by our bodies is obtained from glucose which is produced during food digestion. This digested food enters our blood streams, reaches our body cells with the aid of a hormone called insulin. Insulin allows and controls the glucose absorption from the blood into the cells, while the pancreas in our bodies takes care of producing the correct amount of insulin. In individuals with diabetes, the pancreas either produces too little or no insulin or the cells do not react properly to the insulin that is produced. This in turn increases glucose in the blood, which overflows into the urine that is passed out of the body. Uncontrolled diabetes can be extremely dangerous. It can harm the eyes by damaging the blood vessels of the retina, which in turn can cause loss of vision. When the retina is affected because of diabetes, the resulting effect is a disease that is referred to as Diabetic Retinopathy (DR) [9-10].

DR occurrence has been generally categorized into three main phases and these are:

1) *Background Diabetic Retinopathy (BDR):* In this phase, the arteries in the retina become weak and start to leak, forming small, dot-like bodies called Hemorrhages. These leaking

vessels often lead to swelling or edema in the retina and decreased vision [9].

2) *Proliferate Diabetic Retinopathy (PDR):* In this phase, circulation problems cause areas of the retina to become oxygen-deprived or ischemic. New fragile vessels develop as the circulatory system attempts to maintain adequate oxygen levels within the retina. This phenomenon is called Neovascularisation. Consequently, blood may leak into the retina and the vitreous causing spots or floaters, along with decreased vision.

3) *Severe Diabetic Retinopathy (SDR):* This is the last phase, where there is continued abnormal vessel growth and scar tissue, which may cause serious problems such as othereisis detachment and glaucoma and gradual loss of vision.

It is important for us to note that the aforementioned three phases usually occur with any of the following artefacts: Microaneurysms, Haemorrhages, Hard Exudates, Soft Exudates, Neovascularization, Abnormal Vein-Artery Crossover, etc. [8-9].

4.2.1.1 The Problems to be solved

Let us put the problems we addressed in cogent forms. Three major challenges that were seen at the beginning of the work were: Uneven illumination, Neovascularisation and Intelligent system development. I will point out briefly, what these problems simply mean to appreciate the work that has kept us in the laboratories, offices and workshops over the years.

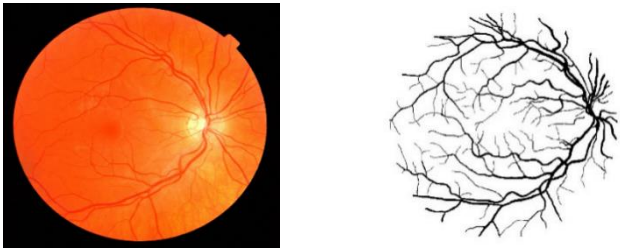
a. *Uneven illumination in acquired Retina Fundus Images (RFI):* Some acquired Retina Fundus Images (RFI) usually have severe quality problem. In ensuring that screeners have good view of the whole retina, more than the needed number of images is sometimes taken. If there exists an image processing algorithm, that can improve and consistently

guarantee good image quality, especially in dark areas of the image and if such an algorithm could retrieve all the corrupted details in an image, there will be a drastic reduction in the image storage space requirement. Why? The reason is simply because only the sufficient number of images will be saved. In addition, the intelligent diagnostic system will also depend on the quality of the acquired RFI [10]. This problem can be surmised as developing an algorithm to solve the problem of uneven illumination in captured RFIs. Figure 6a shows a sample of RFI with uneven illumination problem.

b. *Neovascularisation:* We often describe Neovascularisation as the abnormal growth of blood vessels in some areas of the eye including the retina. This occurs in response to Ischemia, or diminished blood flow to ocular tissues. These new blood vessels have weaker walls and can rupture, subsequently leading to bleeding or scarred tissue growth. An increase in the number of such veins can lead to lifting the retina away from the back of the eye. When the retina is lifted away, this is called retinal detachment, and if left untreated, this can cause severe vision loss, including blindness [8,10]. Neovascularisation and bleeding in RFIs are associated with Bifurcation Point (BP) and Crossover Point (CP) changes. In summary, this problem involves the development of an intelligent approach for detection, localisation, monitoring and counting of Vascular Point (VP) in form of BP and CP in RFIs. Figure 6b shows vasculature in a typical RFI [10].

c. *Intelligent System Development:* It is opined that the development of intelligent diagnosis of DR will be of immense value in our various societies. This will involve the development of algorithms that can augment the manual screening process for the detection and diagnosis of DR and also be autonomous. The algorithms are also expected to

determine the presence or otherwise of DR artifacts. Succinctly put, the problem involves the determination of an appropriate framework, artefacts and AI techniques to be used for intelligent DR diagnostic systems with high True Positive Rate (TPR), low False Positive Rate (FPR) and high sensitivity [9].



(a) **(b)**

Figure 6: Retinal Fundus Images: (a) Uneven Illumination in RFI (b) Vascular RFI

4.2.1.2 What we Intend to Achieve

It is very true that early detection and diagnosis have been identified as one of the ways we can achieve reduction in the percentage of visual impairment caused by DR. We were made to realize that this involves greater emphasis on routine medical check-up for monitoring DR. Our aim over the years has been to apply DSP, DIP and AI techniques to reduce the time and stress undergone by the ophthalmologists and other members of the DR screening, diagnosis, treatment and monitoring team. We also opined that over time we shall be able to infuse enough intelligence into the developed system and accurately diagnose, monitor and treat DR with little or no human intervention. Thus in our own world, we dreamt of developing an intelligent handheld device that should be able to assist patients in this regard. The journey from 2006 to date is presented as a two-stage approach herewith, though the development of the

handheld device is on-going and we are very close to the end of the project.

4.2.1.3 Our Approach and how Far we have Gone

This work was initiated in 2006 at Blekinge Tekniska Hogskola i.e. Blekinge Institute of Technology (BTH) Sweden under the leadership of Mikael Nilsson then of BTH (now of Lunds University, Sweden). Our aim was to develop an automated system. In the team, aside myself and M. Nilsson were: Victor Adolfsson of Optimum Biometric Labs acting as liason officer between the technical team and Dr. Jack Bergen, an Ophthalmologist; Iqbal, M.I; Gubbal, N.S; and Khan, A. [49]

Stage 1: 2006 - 2010 Development of Automatic DR Diagnosis System

In 2006, we applied various techniques from DSP and DIP to solve the problems. A three-stage process for detecting DR that involved pre-processing, segmentation and detection, and classifier stage was propounded [49]. The results obtained shows that application of DSP and DIP can solve the problems.

From 2007 to 2010, efforts were concentrated on improving the results obtained from the proposed three-stage technique reported in 2006 by focusing on improving each stage of the work. I will briefly explain how we went about solving the identified problems.

Solution to Problem 1 - Uneven Illumination Problem

In our proposed three-stage technique, the problem of uneven illumination was solved in the pre-processing stage. We proposed the use of a point transformation within a local fairly large window with the assumption that the intensity value within is a statistical representation of the local distribution of the intensity value of the entire image [8-10,49]. This local

small window is assumed to be unaffected by the gradual variation of intensity between the image centers and edges. The point transformation distribution is localised around the mean intensity of the window and it covers the entire intensity range of the image. This approach of ours was termed Global-Local Adaptive Histogram Equalization using Partially-Overlapped Windows (GLAPOW) and results obtained have been published in [10].

Solution to Problem 2 - Neovascularisation

In solving the problem of vascular intersection detection in RFI, we proposed and developed a new hybrid approach called the Combined Cross-point Number (CCN) method which makes use of two vascular intersection detection techniques, namely the Modified Cross-point Number (MCN) method and the Simple Cross-point Number (SCN) method [8,49-51]. The CCN method combines the advantages of both the MCN and the SCN methods while eliminating their disadvantages.

The segmented vein RFI is first thinned to produce an image in which each blood vessel is one pixel thick. The CCN technique is then applied to detect likely bifurcation and vascular intersection points.

The CCN method also uses a 5x5 window for BP and CP detection but with a slight modification to its configuration unlike what we proposed in the MCN technique. The new 5x5 window contains a central pixel surrounded by 8 pixels in the internal layer and another 16 pixels in the external layer as shown in Figure 7.

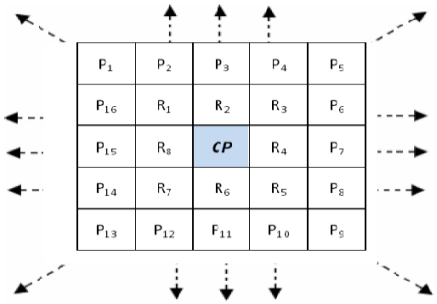


Figure 7: A new CCN Method

A new set of criteria combining SCN and MCN was then proposed. We must not forget that SCN is given as

$$cpn_{SCN} = \frac{1}{2}\sum_{n=1}^{8}\left|R_n - R_{n+1}\right| \quad (1)$$

And MCN equation is also given as

$$cpn_{MCN} = \frac{1}{2}\sum_{n=1}^{15}\left|P_n - P_{n+1}\right| \quad (2)$$

From here, a point is regarded as CP if and only if

$$cpn_{MCN} \geq 4 \quad and \quad cpn_{SCN} \geq 4 \quad (3)$$

Else the detected point is BP if it simultaneously satisfies

$$2 < cpn_{MCN} < 4 \quad and \quad 2 < cpn_{SCN} < 4 \quad (4)$$

This is one of our major contributions to knowledge and the academic world in general. The work and approach has been cited by various researchers, and has been applied to other related problems. Our proposed approach was tested on images obtained from two different publicly available fundus image databases. The results show a very high precision, accuracy, sensitivity and low false rate in detecting both bifurcation and crossover points compared with both the MCN and the SCN

methods. In 2010, we compared our proposed technique for detecting vascular intersections in RFI with some of the existing techniques using public dataset [8]. Our proposed CCN technique performed favorably better than some of the existing techniques. In our post 2010 activities, efforts are ongoing to improve the method, though some researchers have been using it to benchmark their own approaches and to improve their works. We are presently applying AI techniques to improve on the solution to the problem and this will be mentioned shortly [50-51].

Solution to Problem 3 - Disease Identification and Classification

The disease classifier stage was used to distinguish between victim's lesions and other information. A method for the diagnosis of red spots, bleeding and detection of vein-artery crossover points was also developed in this work. The method used the color information, shape, size, object length to breadth ratio, as contained in the digital fundus image to detect the disease. The proposed algorithm was tested with a separate set of 25 fundus images. From this, the Receiver Operating Characteristics (ROC) was determined for red spot disease and bleeding, while cross over points were only detected leaving further classification as part of future work needed to complete this global project. Sensitivity (classify abnormal fundus images as abnormal) and specificity (classify normal fundus image as normal) were calculated for the algorithm and a percentage result of 98% and 61% respectively were obtained [9]

Solution to Problem 4 - Other related problems and contributions

Aside from all the contributions previously mentioned, we also developed two Graphical User Interfaces (GUI's) for the collection of lesion data information. One of which was used by

the ophthalmologist in marking RFI for the database, while the second GUI was used for automatic diagnosing and for displaying the diagnosis results in a friendlier manner for users. We also used K-Means algorithm for image segmentation stage in some of our works and this has motivated other researchers in this area [8,49].

Mr. Chairman, it will interest you to know that these little efforts have continuously been cited by other researchers in this field over the years and have inspired more contributions from other researchers. Mr. Chairman, sir, I ask you, what is more inspiring and rewarding than one's works and contributions to his/her own field being referenced by other international scholars and researchers? I will therefore end this sub-unit by quoting from [52], where he wrote:

"Here, we inspired from [15] and the steps involved in the K-means algorithm are as follows…" It is good to note that the reference being mentioned is one of our notable contributions.

Stage 2: 2010 to Date- Development of Intelligent DR Diagnosis System

In 2010, we changed focus and started working on the application of Artificial Intelligence techniques to address some of the earlier mentioned problems and other related problems. I will address this by enumerating and discussing some of our published works.

1. In 2008 [50], we reported the use of ANN and Fuzzy Logic (FL) techniques developed in the form of MCN approach in solving this problem. Results obtained were promising and we compared the results obtained to that of the MCN technique. Some improvement in detection of vascularisation point was recorded.
2. In improving the results obtained from the use of ANN and FL reported in 2008, we experimented with the method of

vascular point detection using only artificial neural network. This involves the use of only a 5x5 window in detecting the combination of bifurcation and crossover points in a RFIs. Simulated images were used to train the ANN and upon convergence the trained network was used to test some selected real RFIs obtained from DRIVE datasets. Performance analysis of the system showed that ANN based techniques achieve 100% accuracy on simulated images and minimum of 92% accuracy on RFIs obtained from DRIVE database. Although performance doesn't really show better improvement as compared to the use of CCN, at least a viable alternative has been tested. Furthermore, the use of ANN shows cases of undetected VP and this was further analyzed as it was observed that the pattern for that point was not in the training database images. Hence, inclusion of necessary and likely VP pattern is required while training ANN systems [51].

3. As part of post 2010 activities in this area, we have applied various modeling techniques to VP detection in RFI. This will be presented under the section for AR, ARMA modeling techniques as it also constitutes significant contributions [12].
4. Other attempts of ours include [53], where we applied AI approach in Diabetes classification, [54] where we used modeling technique to generate RFI mask, [55] where we used statistical moment and principal components analysis on RFI.
5. Presently, we are working on a handheld device, though this is still at the stage of infancy. However, we hope that with the proliferation and miniaturisation of embedded device, we should be able to achieve this in not too long a future.

4.2.1.4 Research Funding, Supervision and Awards

Mr. Chairman, invited guests, ladies and gentlemen, before moving to the next contribution, let me mention that we would not have gone this far without financial funding from various quarters. Hence, it will also be appropriate for me to acknowledge some of the funding agencies that have sponsored this work to date in chronological order. At the onset of the work, sponsorship was done by BTH, Sweden; an enabling environment and laboratories facilities were made available to us. Our industrial liason officer Victor Adolfsson of Optimum Biometric Labs also contributed in no small measure in ensuring the successful take off the project. Also worthy of mention were the efforts of the consultant ophthalmologist.

The fortunes of the work took a positive turn in 2012 when we received funding from the Malaysian Government under Fundamental Research Grant Scheme (FRGS) through International Islamic University Malaysia (IIUM), with research grant number FRGS12-080-0229.

In 2014, we also received funding from the Nigerian Government via TETFUND under the Institutional Research Grant Scheme from the Federal University of Technology, Minna, Nigeria.

I am pleased to inform us that to date, the work has been used to train over 14 students in Sweden, Malaysia and Nigeria at both undergraduate and post graduate levels.

In addition, we have exhibited the work at various fora and have won several awards. We can find the list of awards won so far at [68].

Mr. Chairman, in this sub-unit, the development of a novel technique for detecting vascular intersection in Retinal Fundus Images has been succinctly presented. And this marks the end of the story of my first contribution to knowledge.

4.2.2 Development of AI based Autoregressive and Autoregressive Moving Average Parameters Estimation

In our world presently, parametric modeling techniques have been applied to quite a lot of fields of endeavour.These include, but are not limited to the field of: biomedical signal processing, digital image processing, building and built environment industry, nuclear plant and communication. In some of these aforementioned fields, parametric modeling has been applied in many cases. Some of these are used: to determine an unknown system by the knowledge of the input and output data (system modeling and identification), to predict the future values based on past output values (linear prediction), for filtering purposes (signal filtering), and to find the frequency content or response of a system (spectral estimation), etc. Let me also say that among the widely used parametric models are: Autoregressive (AR), Moving Average (MA), and Autoregressive Moving Average (ARMA).

We have come to understand mathematically that an ARMA model involves representing the input-output data of a system by a difference equation of the form:

$$y(n) = -\sum_{k=1}^{p} a_k\, y(n-k) + \sum_{k=0}^{q} b_k\, x(n-k) \qquad (5)$$

where a_k and b_k are the model coefficients, p and q are real-valued model order for the AR and MA parts respectively. If the coefficients in (5), are complex numbers and either $y(n)$ or $x(n)$ are complex valued data, then we can conclude that the ARMA model is a complex - valued autoregressive moving average (CARMA) model [11-12, 56-57].

In recent times, the introduction of Complex-Valued Neural Networks (CVNN) has widened the scope and applications of

ANN. The inevitability of dealing with Complex-Valued Data (CVD) has shown that this emerging mathematical paradigm has become very necessary and needful, especially in the field of: digital signal processing, digital image processing, Magnetic Resonance Imaging (MRI) reconstruction, digital communications systems, quantum neural devices and systems, spatiotemporal analysis of physiological neural systems and not forgetting biomedical signal processing as well, just to mention a few [56-58].

This evolving paradigm has gained much attention not only because there are situations where CVNN are inevitably required or greatly effective than their counterpart, the Real-Valued Neural Network (RVNN), but because of their usefulness which is enshrined in the fundamental theorem of Algebra: Every polynomial of degree n with complex coefficients has n roots in the complex plane. These roots are either real or complex-number, thus emphasizing the importance of complex numbers in mathematics and engineering fields [57].

4.2.2.1 The Problems to be Solved

Despite the success of parametric models especially AR and ARMA models in various areas of applications, there are two main drawbacks with these models. These are:

a. Complexity, associated with the determination of model coefficients.

b. Difficulty in estimating the model order.

Consequently, these problems have limited extent of the application of both AR and ARMA modeling techniques. Some of these limitations are in MRI reconstruction where the modeling approach is often adopted in order to recover the un-acquired high frequency components [11]; and in shape analysis and prediction, where it is of utmost concern to diagnose and

analyse various shapes of concern either for content retrieval or pathology identification purposes.

4.2.2.2 What we Intend to Achieve

Our aim at the begining of this work was to adopt the use of AI based approach in solving these problems. Some might ask "why the need?" But the reason is quite understandable. It was to be a means for us to cover much broader areas of applications. We know that there is an exisiting linear relationship between AR coefficients and the autocorrelation lag which makes it easier to determine the AR coefficients than the MA coefficients. The relationship between the MA coefficients and the autocorrelation matrix is non linear in nature, hence the determination of ARMA model parameters poses some difficulties. In our findings, we realised that previous researchers had solved this technique's problems using sub-optimal techniques as well as iterative techniques [59]. However, these techniques produce satisfactory results only for some specific applications. It is for this reason that we aimed at using AI approaches to solve these problems and to extend their usage.

4.2.2.3 Our Approach and How far we have gone

In solving these two problems, we set out with the use of ANN and GA. We addressed the two problems using the following approaches:

Solution to Problem - 1: Determination of Model Coefficients

It is conjectured that an ANN-based technique for the determination of the coefficients of both AR and ARMA models would be most appropriate. Why? Because, it is a general non-linear mathematical computing procedure that emulates the operations of biological neural systems in the human body.

More so, ANN has the ability to learn complex mappings and relationships between input and output signals. One challenge is trying to adopt this learning capability in conventional model parameters' estimation methods. Notwithstanding this difficulty, it has been done and it was utilised in the development of RVNN and CVNN based models which are applicable to RVD and CVD respectively. In both cases, the determination of model coefficients was carried out by a process of learning from input and output data presented to the neural network. During this learning phase, known input and output signal pairs were applied to the network and the network learnt by adjusting the synaptic weights between layers based on the error signals. Upon satisfactory learning, the weights and coefficients of the activation functions were then used to estimate the model coefficients [56].

For the benefit of this lecture, kindly allow me to share that of the RVNN-AR model, which involves four stages namely data acquisition; data formatting; model training; and parameter estimation for the determination of AR model coefficients from the synaptic weights and activation function coefficients of an RVNN. This model is shown in Figure 8 and detailed discussion regarding data simulation or acquisition and data formatting and all intermediate steps can be found in [56-59]

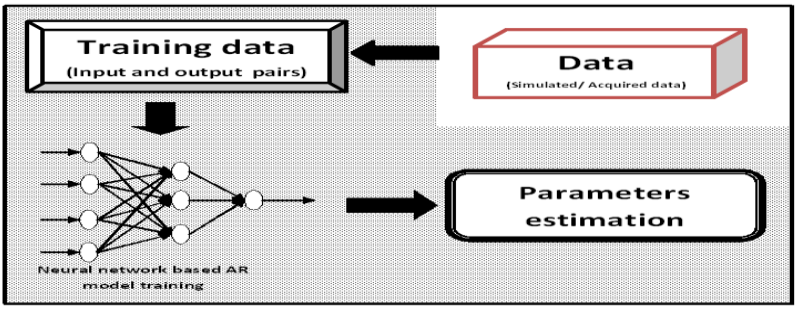


Figure 8: RVNN-based AR model network diagram

The AR coefficients are given as

$$a_k = \alpha \sum_{l=1}^{M} w_{l1} v_{kl} \beta_l \qquad (6)$$

Thus, we can say that AR model coefficients a_k are estimated from the synaptic weights (w_{l1} & v_{kl}) and adaptive activation function (α & β_l)coefficients of a properly trained two-layer RVNN [56].

Solution to Problem 2 - Model Order Determination

In using AI to solve this problem, we adopted the use of GA. Also, potential model order solution is represented as a set of parameters called genes. And these genes are joined together to form a string of values called chromosomes [56,59]. Chromosome representation in this work is an array of bits called binary, thus each chromosome consists of a binary representation of the model order solution.

From the available population space of likely optimal model order solutions, individuals are selected for recombination and reproduction for the next generation population space. Parents are selected randomly from the population using roulette wheel selection scheme. The selected chromosomes are then recombined using the mechanisms of single point crossover technique. Single point mutation is applied to each individual child to change its gene. This alters each gene with a small probability. The population evolves over successive generations so that the fitness of the best and of average individuals in each generation increase towards the optimum model order. Thus, convergence is the progression towards increasing uniformity of the solution space [48].

In our determination of an appropriate model order, we proposed a new fitness function that takes into account both the test and training data error with the number of network variables.Thus, we applied GA and ANN in solving model order determination [59].

Our Solution to Problem 3 - Other Related Works

In the course of our ANN-based parametric model training, the traditional back-propagation algorithm was replaced by GA. And we discovered that this approach overcame some of the inherent limitations of the former technique; reason being that the proposed technique adopts an intelligent searching procedure thatuses parameter coding to determine the optimal coefficients from a population of likely solutions. Of course, one would expect that new problems will come into existence and so they did. Thus, we had to develop a new method of parametric structure optimisation for a system with known model order using GA with a constraint. Futhermore, the proposed method uses the prior data length information in formulating the necessary constraints by finding the solution or solutions to a set of linear equations that give the best performance over unseen data. The block diagram for the proposed system is as shown in Figure 9[56].

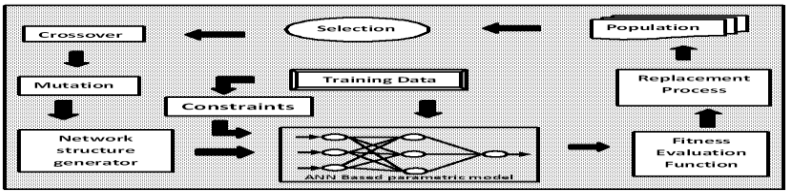


Figure 9: ANN-based model structure optimization using GA

Let's now consider a parametric model with model order p, l pairs of input and output data, M nodes in the hidden layer with just one output node. So that the total number of training

equations N_{eq}, that can be formulated from the network is a function of the l and the model order p.

We can now go ahead and express the parametric model as;

$$N_{eq} = p*l \qquad (7)$$

but if the system is configured with M nodes in the hidden layer, the number of the unknowns N_{un} from such a network is given as

$$N_{un} = (p+1)*M + (M+1) \qquad (8)$$

- **Case 1:** Our objective here is to ensure that the number of equations is minimum and equals the number of unknowns in the resulting equation, that is ;

$$N_{eq} = N_{un} \qquad (9)$$

In this case, memorisation sometimes occurs and sometimes gives poor performance for unseen data and may not even be able to learn the input and output mapping in the data.

- **Case 2: Under-determined model**

When we have fewer equations than unknowns, then there are many solutions that satisfy the equations and because of this, the solution is said to be under-determined or incompletely specified. The solution to such a model is to increase the available number of data or reduce the number of neurons in the hidden layer, that is;

$$N_{eq} << N_{un} \qquad (10)$$

- **Case 3: Over-determined model**

The over-determined system of equations is given as

$$N_{eq} >> N_{un} \quad (11)$$

Results obtained from some of our previous works show that over-determined system gives good performance over unseen data. Thus, the number of neurons in the hidden layer can be formulated as a minimisation function given by;

$$Minimize : \hat{0}(M) \quad (12)$$

Subject to:

$$N_{eq} >> N_{un} \quad (13)$$

and

$$1 \leq M \leq N_{eq} \quad (14)$$

where $\hat{0}(M)$ is the objective function of the network and M is the number of neurons in the hidden layer.

Mr. Chairman, the above discussions have focused on how we have developed new approaches for estimating the autoregressive and autoregressive moving average model parameters using artificial intelligence techniques as I had mentioned in the introductory section of this lecture. We should also note that developing equations or models is not the main crux of the matter, but rather how these equations were applied and the problems they have been used to solve. I will now enumerate some of what we have done with the developed equations within the last eight years.

4.2.2.4 What we have Done with the Developed Approaches

a. In 2010, we applied the proposed approach to MRI reconstruction problem using Transient Error Reconstruction Algorithm. Upon successful application,

images with improved resolution and less artefacts were obtained from the work [57-58]

b. In 2011, we applied the approach to biomedical signal classification using the complex-valued pseudo autoregressive (CAR) modeling approach. This involved simply computing the CAR coefficients from the synaptic weights and coefficients of a split weight and activation function of a feedforward multilayer CVNN. The approach was tested using PIMA Indian diabetes. Results obtained from this work compared favorably with some of the reported results by other researchers. Thus, in this work, we were able to propose a new classification technique [12].

c. In 2012, we examined the performance of the system on sinusoidal data and recorded speech to examine the spectral resolution, line splitting and its ability to detect voiced and unvoiced data section from a recorded speech. Results obtained shows that the method could accurately resolve closely related frequencies without experiencing spectral line splitting. It was also able to distinguish between voiced and unvoiced segments in a recorded speech [56,60].

d. Between 2014 and 2017, we applied the developed approach to the design of an Energy Detector (ED) for use in Cognitive Radio (CR) related applications. The Power Spectral Density (PSD) of the AR system transfer function was estimated using our approach and subsequent Receiver Operating Characteristic (ROC) curves of the detector were generated and analysed. High detection performances with low false alarm rates were observed under various conditions. This signifies the viability of the proposed technique for ED in CR application [61-62]. We further evaluated how occupancy variation affects the performance of the system under various conditions. We observed that the RVNN based ED would provide better precision performance characteristics

over the Periodogram, Welch and Multitaper based ED schemes [63].

e. In 2016, the approach was applied to GSM pathloss model prediction via a three-stage approach using some selected and easily measurable atmospheric parameters such as atmospheric temperature, relative humidity and dew point. Comparisons of the results obtained from this work show that the developed model can efficiently determine the GSM Rxlevel using atmospheric temperature, relative humidity and dew point as input parameters [64].

   Further analysis of this approach was reported in 2017 where the developed pathloss model showed better performance in predicting the received signal strength at a given distance from the transmitter. The developed approach also showed better performance as compared to the basic empirical pathloss models such as Hata, Egli, COST-231, Ericsson models and modified pathloss approach [65].

f. We have applied this approach to solve problems in areas such as: Parkinson classification, time varying signals, Skin detection problem, Aquaculture, Dinar price prediction, etc.

4.2.2.5 Research Funding, Supervision and Awards

Our research efforts have continuously received funding from various organisations. In 2008, the Malaysian Government under E-Science Research Grant Scheme (E-Science), through International Islamic University Malaysia (IIUM), with research grant number 01-01-08-SF0083 provided the first major funding for the work. This is apart from the institutional grants provided by IIUM via grant number EDW B0701-07. Fund was also received from the Ministry of Higher Education, Malaysia with grant number FRGS12-065-0214.

I am pleased to inform us that to date, the work has been used to train over 10 students in Malaysia and Nigeria at both undergraduate and post graduate levels and we have exhibited the work at various fora and have won several awards.

Mr. Chairman, Ladies and gentlemen, the foregoing chronicled the development of new AI based approaches for estimating autoregressive and autoregressive moving average model parameters and data classification procedures based on AI techniques applicable to different types of signals and images. This marks the end of my second and third contributions to knowledge.

4.2.3 Cognitive Phone and Multiple Operators Enabled SIM Cards

Mr. Chairman, I am pleased to share with us another contribution to the field of mobile wireless communication systems. This contribution of ours had been succinctly captured at the beginning where I mentioned that, I have contributed to the Development of Cognitive phone based on the principle of Multiple Operators Enabled SIM (MOES) card and intelligent network handover scheme [13]. This work of ours is presently in the filing processing stage and we hope to complete the patent filing stage soon so as to produce a market-ready cognitive phone. This phone will have AI incorporated for taking necessary decisions especially as it concerns switching Quality of Service (QoS) from one Mobile Network Operator (MNO) to another.

We all agree that the advent of the Global System for Mobile communications (GSM) in Nigeria has revolutionised the country's mobile communication sector. Consequently, the GSM telecommunication industry has recorded tremendous growth since its debut in Nigeria. We are aware that a transparent auction for four GSM licenses was conducted by Nigerian Communications Commission (NCC) in 2001, from

which four companies, MTN, ECONET, NITEL and CIL emerged as winners [66]. However, CIL, a Nigerian-based company's license was withdrawn due to its inability to meet the funds deposition deadline. As at September 2017, Nigeria had over 230 million active mobile phone subscribers according to the information released by NCC [66,67].

Consequently, you will agree that mobile communication has become a powerful tool for liberating Nigerians from the shackles of the once powerful, but now extinct, national telecoms monopoly, popularly known as the Nigerian Telecommunications Limited (NITEL). It has significantly contributed positively in boosting economic activities in all sectors in Nigeria. The technology provided by the currently existing GSM service providers in Nigeria ranges from the progress in the network, from 2G to 3G and to 3.5G today. In addition, because mobile communication has become essential for easing communication, our country has over the years, been flooded with different grades of mobile phones from different manufacturers.

At this juncture, let me quickly point out that the definitions of "smart" in relation to software and hardware are a bit different. Smart or intelligent software, which in this case means AI has the capacity to improve its performance on a given task with increase in experience. But, smart hardware should be regarded as the one that has the capacity to run smart software. However, smart phones have continuously been used in literature and in the community to describe phones with enhanced capability, instead of phones that are both smart in hardware and software [68]. In our own case, we are looking at designing a phone that will be smart both in software and hardware, hence the origin of what we call Cognitive Phone (CP). The proposed smart hardware will mean having an operating system with the relevant sensors and actuators. Smart software will simply be regarded as having the ability to intelligently take handover

decisions across various MNOs and other existing technologies. Readers can check a small notebook we wrote on Handover for more information on the expected handover types and detailed information on Handover in Mobile Communication Systems [69].

4.2.3.1 The Problems to be Solved

Not quite long ago, we came to the knowledge during our research that, despite the obvious benefits of mobile cellular communication, the increasing poor QoS experienced by subscribers do manifest itself in the forms of call failure, call drops, and low received signal strength. These problems have continuously been raising a great deal of worries and uncertainty among the populace and the network providers. In making efforts to solve the problem of poor QoS coupled with the high demand for quality and efficient on-the-go communication capabilities, MNOs have resulted to the deployment of mobile cellular network stations in the form of Base Transceiver Station (BTS).

But the increase in the number of BTS has not resolved the problem. On the other hand, as subscribers, we have resulted to the use of mobile phones with multiple SIM slots in providing temporary solution to these non-abating problems. Some of us even have more than one mobile phone with the hope of enjoying good QoS using the appropriate SIM or phone where necessary. In some instances, “porting” of mobile numbers is suggested. “Porting” as used in the community simply means retaining the mobile identity number but changing the network or service provider.

In summary, the problem can simply be solved by asking “how can a subscriber enjoy better mobile communication QoS through seamless transfer of service from one MNO provider to another with little or no disruption to an active communication service?”

4.2.3.1 What we Intend to Achieve

The development of artificial intelligence based portable device, in form of mobile phone, capable of providing seamless data and voice connections over the existing MNOs, is envisioned as the solution to the QoS-induced problems experienced by mobile communication subscribers in Nigeria [13]. The proposed device is expected to provide subscribers with the privilege of enjoying good services from available operators without the added expenses of having more than one phone or phone with multiple SIM slots. Furthermore, the proposed cognitive phone is expected to guarantee all time access to networks with the best available signal strength and QoS, even while on transit on Nigerian highways and roads.

4.2.3.3 Our Approach and how Far we have Gone

The seamless data and voice connection involves the development and fabrication of a miniaturised embedded system integrating the existing mobile communication SIM card information and mobile communication hardware with artificial intelligence based MNOs handover software applications. I am pleased to inform us that our work has evolved over the last five years and herewith I present the evolution to date.

Stage 1: 2013 - 2014: Development of SIM Card Information Extraction Software and Switching Interface System

The work started from ground zero in 2013 with a team of about twelve researchers comprising eight research fellows and 4 students. Our objectives were: finding a method of extracting appropriate information from SIM card, determining method of categorising SIM card parameters, and determining relevant pin configuration for SIM Card switching. Let me remind us that SIM is an acronym for Subscriber Identity Module. And

SIM is a logical module that runs on an Integrated Circuit Card (ICC) type of smart card called Universal Integrated Circuit Card (UICC) [70]. The UICC and the logical application/module running it are commonly referred to as a SIM card. The main purpose of the SIM card is to provide a compact and secure storage of the components required for the GSM/UMTS authentication scheme. This is usually achieved by the authentication and key generation algorithms which make use of the International Mobile Subscriber Identity (IMSI) and the Subscriber Authentication key (Ki). Figure 10 shows a typical SIM card interface.

Figure 10: A typical SIM Card [70].

We constructed testbeds and SIM cards with programmable Micro-controller having various Graphical User Interfaces [70]. We also conducted tests over several months. In our tests, we observed that information contained in a typical SIM card can be categorized into two broad categories namely MNO dependent and MNO independent parameters. Only few of these parameters in the MNO independent cluster are appropriate for MOES work. We also observed that irrespective of the SIM card type and size, the pins' configuration in a SIM always remains the same, however, their functions may differ. From testbed experiments conducted, it was identified that switching from one SIM card to another can be best achieved by switching the clock pin of the SIM card. This produces better results than the use of Vcc pin (C1) and the Input/Output pin (C7). In addition to received signal strength, Channel

availability and GPS coordinate can be used for handover criteria in the proposed cognitive phone. This forms the basis of our subsequent research and endeavour in this field [70,71].

Stage 2: 2014- 2017: Development of Hybrid AI System for Handover in MOES System and Cognitive Phone

Handover (also known as Handoff) refers to the process of transferring the point of attachment of mobile phone to the network, from a BTS to another BTS. This occurs as the mobile station moves from the region of coverage of the initial BTS to the coverage region of the target BTS. The process is expected to be seamless, thus ensuring that any ongoing mobile activity is not dropped, and we the users do not experience poor QoS [69].

In developing this algorithm, we made use of our knowledge of parametric signal modeling that was introduced in Subsection 4.2.2. We adopted the use of a two-stage approach with the first stage involving the development of mathematical steps, which in turn involved the k_step ahead ANN based prediction algorithm. The second stage involved the development of Fuzzy logic based Handover decision making algorithm. The block diagram is as shown in Figure 11.

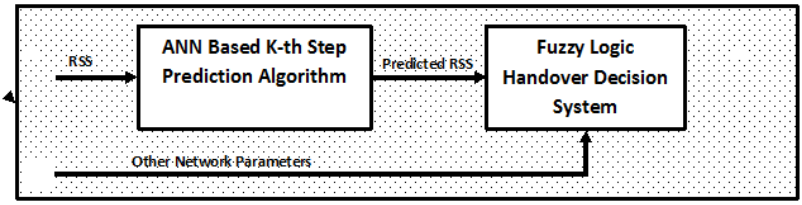


Figure 11: The block diagram of the proposed Hybrid AI based Handover Decision Algorithm

The k_step ahead ANN based RSS prediction model coefficients are estimated from the synaptic weights and the coefficients of the adaptive activation function of a properly trained two-layer ANN. The extracted coefficients were used to form a matrix from which appropriate prediction levels can be easily obtained via simple matrix multiplication.

Similarly, for the second stage, the developed Fuzzy logic based handover decision algorithm consists of three different stages, namely: Fuzzification stage, Fuzzy inference stage and Defuzzification stage. It is from here that the handover decisions are taken. Details from this work have been published and are freely available online [13].

Stage 3: 2015 to Date: Fabrication of Cognitive Mobile Phone and Evaluation of its Performance

Since 2015, we have been working tirelessly to fabricate laboratory scale model of this work. We produced our first MOES card in 2015 and evolving over time, we are presently in version 4 of the work. Table 1 shows the evolution and capabilities of each model over the other while Figure 12a shows the MOES card system.

Figure 12a: MOES Card System

No	Characteristics	MOES PCB VERSION 1	MOES PCB VERSION 2	MOES PCB VERSION 3	MOES PCB VERSION 4
1	No of SIM	4	4	4	4
2	SIM Type	Macro	Macro	Macro	Mini
3	Board Size	91.44mm x 49.2mm	114.3mm x 49.2mm	110mm x 49.2mm	47mm x 31mm
4	No of Layers	Single Layer	Double	Double	Double
5	On board Microcontroller	No	Yes	Yes	Yes
6	On board Driver circuit type	No	IC 4066	TS3A1459A	TS3A1459A
7	Interface type	Wired	Wired	Wired	Wireless (Bluetooth)
8	DIO Capability	No	No	Yes	Yes
9	AIO Capability	No	No	No	Yes
10	Programming Capability	No	No	No	Yes

In addition, we have applied the concepts from this work successfully to the design and development of an Emergency Phone booth system and Tracking system. I am happy to inform us all that the laboratory models of these two designs have been produced and are presently being optimised for production of market ready prototype [71].

4.2.3.4 Research Funding, Supervision and Awards

Mr. Chairman, invited ladies and gentlemen, just as I mentioned during the presentation of the previous research work, let me mention that we could not have gone this far without financial funding from the Nigerian Communications Commission (NCC), under research funding NCC/CS/007/15/C/040 of 2014. Similarly, in 2017, we exhibited this research work at the Federal University of Technology, Minna 26th Convocation Research and Development (R&D) Exhibition and we were given the best research award. I am also pleased to inform us that to date, the work has been used to train over 16 students in Nigeria at both undergraduate and post graduate levels. With some of the findings, we shall soon be completing the patent filing of this work.

In this sub-unit, the development of Cognitive phone, based on the principle of Multiple Operators Enabled SIM cards (MOES) and intelligent network handover scheme has been laconically presented. And this marks the end of the story of my fourth contribution to knowledge.

4.2.4 My Contributions to Mechatronics System Development

I would have loved to continue on the same pedestal that I have used in establishing my first three contributions in research, innovation and development, however, taking a clue from page 13 of the Chairman's inaugural lecture presented at the University of Ilorin in 2002, where he postulated that it is practically impossible to extensively discuss the matter before an inaugural speaker based on the duration and nature of this type of lecture [72], I would rather not continue. Mr. Chairman, ladies and gentlemen, kindly permit me to present other contributions of mine especially in Mechatronics System Development in a summarised version. I will present one of our

ongoing works in infographic form while the second aspect will focus on some of my notable works in the cause of the establishment of Dinar (Gold) and Dirham (Silver) coins in Malaysia. I will present these contributions from users' perspectives rather than presenting it from the technical complexity.

a. Development of Intelligent Walking Stick

Fig. 12b. Intelligent Walking Stick

b. **Dirham Coin Box:** In 2009, in collaboration with other "Dinarist" activists and researchers in Malaysia, we developed the first Dinar (Gold) and Dirham (Silver) saving box shown in Figure 13. The developed box has mechanism for detecting and rejecting other coins except dinar and dirham coins using the principle of electromagnetism. The box has been exhibited and has won various awards around the world [73]. In 2010, it was used during the official launch of Dinar and Dirham coins in Kelantan Malaysia and has been widely reported in various news media such as Harian Newspaper Article of August 26th 2010. The work has also received funding from IIUM Malaysia via endowment fund research grant [73-75].

Figure 13: Dinar and Dirham Box

c. **Dinar and Dirham ATM Machine:** In 2011, we developed the first dinar (gold) and dirham (Silver) dispensing ATM Machine. The machine was infused with contactless Biometric AI based algorithms for recognition and authentication purposes. The work won the Gold medal award at IIUM exhibition in 2011 and funding opportunity came in 2011 with research grant number EDW A11-100-0891

d. **Robotic Donation Box:** An Intelligent Robotic Donation Box (IRDB) for specialised gatherings was developed in 2011 [16]. The developed IRDB system has capability to collect donation from people in an organized assembly or gathering. Also incorporated into this system is the ability to attract attention of people by making audible sound, gesture recognition as well as avoiding any obstacles in its path. New skin detection algorithm was also developed using ANN and pseudo-modeling technique from YCbCr color spaces. The developed IRDB can conveniently replace the existing manual boxes used in some organised gatherings around the world and yet it is at a reasonable cost as compared to the existing donation boxes [76].

Mr. Chairman, ladies and gentlemen, I will pause a bit on my contributions to research, innovation and development and focus on my other contributions especially in mentoring and community social responsibilities.

4.3 My Other Contributions: Mentoring and Community Social Responsibility

Apart from my contributions in Research, Innovation and Development, Mechatronics Education and teaching of mechatronics related courses, two areas I will like to quickly mention are the areas of mentoring and community social responsibilities.

4.3.1 Why Mentoring?

Let us start with mentoring. Mentoring can be described as one of the most effective tools in people development and I have been exposed to it over the years. I have also learnt from great mentors. I can confidently tell you that having people around you with more experiences than you in teaching, coaching, counseling and rendering encouragement, has never failed to produce the desired results.

Over the years, I have observed the lack of mentoring related activities in the academia and in the society at large. As a way of giving back to the society, having been mentored over time, and in conjunction with other colleagues and mentors, we have introduced series of mentoring related activities over time. Some were successful while some are still at the first stage of introduction. Let me share one approach that has sufficiently worked and produced satisfactory results over five years and the other approach that is still at the infancy stage but which has been applied in the academia.

4.3.1.1 Technical Mentoring

There is no doubt that acquisition of relevant technical skills has continued to be a thing of concern to all in Nigeria. Efforts have been made by government and relevant agencies in introducing technical skill acquisition. However, results from such efforts, so far, have not been encouraging. Therefore, we need to solve this problem using a pragmatic approach.

I set up mechanisms for training students (mentees) on relevant technical aspects of Mechatronics Engineering some years ago. The programme involves introducing ways of enhancing the personal development of the mentees with a view to improving their technical and general performances over time. During the programme, we ensured increase in mentees' personal effectiveness and encourage them to think about career

planning/mapping for the future and at the same time, to solve societal problems. Mostly, mentees come in on a six-month or a three-month internship programme and are allocated different tasks and projects under my watchful eyes. Three layers of mentoring are available in the programme and most undergraduate students enter from the lowest level, which is the basic mentee level. During the training period, we exposed the mentees or interns to various aspects of design, development and repair of various engineering projects. With this kind of exposure, they were expected to solve societal problems and proffer practicable and implementable solutions. They were also trained in public speaking, presentation, and administration skills, etc. Mentees were also exposed to people of "timber and caliber" in the society. Within the last five years, we have successfully trained over fifty mentees and I am proud of what they can do. Feedbacks from parents and employers have been so much encouraging and we can say that they are doing very well across various fields, in and outside Nigeria. In a recent experience, we came across some mentees that were able to move up the ladder, and reach the second level of hierarchy in our organisation within a period of six months. Also, some of the mentees have remained with us to date and have now reached the highest level in the organisation. Let me say that this technical mentoring scheme has worked, and I will surely recommend it to others.

4.3.1.2 Academic Mentoring

At the infancy stage is the "Ph.D. Clinic". The clinic is aimed at providing support mechanism to Ph.D. candidates, during their period of study at FUT Minna. We started the idea after noticing problems faced by Ph.D. candidates. We also operate hierarchical mentoring and supervisory model in the Clinic and we do invite consultants (senior academics) to diagnose and

proffer solutions to problems being faced by the patients (Mentees, i.e. Ph.D. candidates).

Mr. Chairman, invited guests, let me state that within the last three years that we commenced this "clinic", we have been able to successfully administer some necessary doses of academic excellence on five students who have completed their doctoral studies. Within the last three years, consultants and patients in the clinic have been able to publish over 7 ISI journal papers and over 12 conference papers. Once we fine tune some noticeable challenges in the present arrangement, we hope to expand the operational mechanism of the clinic. This will allow us to learn from our errors and improve on the system. We shall also use the opportunity to admit more mentees and consultants to the group.

Furthermore, at the Department of Mechatronics Engineering, we have setup a mentors and mentees programme for our students and members of staff. We have an online system for monitoring mentors and mentees activities and at the same time we have organised mentors-mentees days. We are presently test-running the system and it is our aim that such a platform will assist the young and teeming "Mechatronists"

4.3.2 Giving Back to the Society: My Involvement and Community Social Responsibility

One other area that I will like to share my contributions is in the area of community social responsibility. I will try as much as possible to itemize my various contributions in this area.

4.3.2.1 Military Establishments

On several occasions, I have contributed my knowledge and efforts in the development of Research and Innovation in military establishments. I have also participated in the repair and development of military hardware and software.

Other times, I have been invited as a speaker to their events and to other related issues. For over five years, I have been part of the team working towards the actualisation of the memorandum of understanding between FUT Minna on one hand, and the Nigerian Air Force and the Nigerian Army on the other. I have worked on numerous projects within this short period of stay at FUT Minna. Figure 14 shows a picture taken during one of my engagements with senior officers from Nigerian Air Force.

Figure 14: Engagement with the NAF

4.3.2.2 The Nigerian Robotics Championship (NIROC)

In 2013, as part of our efforts towards introducing robotics and mechatronics education in Nigeria, we organised robotics training across the nation. One of such efforts organised in Minna was the Nigerian Robotics Championship (NIROC) in 2013. Over 500 students from various secondary and primary schools in Niger state participated in the event. We have also organised school visit programmes as a form of follow up. This, we hope, will produce new generations of inventors and mechatronics enthusiasts in Nigeria.

Mr. Chairman, I am proud to say that some of these students of mine have started representing Nigeria in Robotics competitions outside the country. Some that are now in

secondary schools are looking forward to come and join us here at DOME, FUT Minna.

4.3.2.3 Public Speaking

Mr. Chairman, within the last few years, I have featured and have been invited as Keynote speaker, Guest Speaker, Speaker, Panelist, Moderator, Reviewer, etc. to various events. These have given me opportunity to share my views and knowledge with those within and outside the four walls of the University. I have used such opportunities to proffer solutions to community problems and further enlightened the audience on relevant areas as expected at such occasions.

5.0 Beyond Now

Ladies and Gentlemen present here today, I have divided this Section 5 into two different subsections. In Subsection 5.1, I will explain my dream about Mechatronics Engineering education at FUT Minna and in Nigeria. Also, I will state my future research direction, while in Subsection 5.2, I will talk about Spiritual Intelligence and how we can apply it to solve our problems here in Nigeria. So let us start.

5.1 My Major Focus on Mechatronics Engineering

Two major short term goals will be of my utmost priority regarding Mechatronics Engineering education in Nigeria for the next 5 years. These are: the development of Mechatronics Engineering Innovation Centre, and the development of Mechatronics Engineering instructional materials. Details are as provided herewith.

5.1.1 Our Dream: Mechatronics Engineering Innovation Centre

My plan for the next five years (short term goal) will involve working with other researchers in Advanced Engineering Innovation Research Group (AEIRG) and other research groups in realising a functional and dynamic Centre of Excellence in Mechatronics Engineering, to be called Mechatronics Engineering Innovation Centre (MEIC). My long term goal in this regard will be presented under the recommendation section. The Centre among other things is expected to house our research group. The proposed design of MEIC to be located at FUT Minna is as shown in Figure 15.

Let me indulge you a bit about our research group, AEIRG. The Advanced Engineering Innovation Research Group (AEIRG) is an industry-oriented, multi-disciplinary research group that

specialises in the design, development and production of Intelligent Mechatronics Systems. The research group's activities range from basic and applied research to commercialisation through partnership with industries, other educational institutions and the Defence industry. The research group also provides training and consultancy services to all sectors and strata of the society.

Our core competencies are in the areas of: Communication, Wireless Personal Area Network, Intelligent System Design, Control, Nanotechnology, Mechatronics, Artificial Intelligence, Physics-Based Vision, Biomedical Image and Signal Analysis, Embedded System Development, Precision Engineering, Digital Signal Processing, Digital Image Processing, Unmanned Aerial Vehicles, Autonomous Vehicles and Spectrum Sensing. The group has well equipped laboratories with state-of-the-art test and measurement equipment as well as first-class computational facilities.

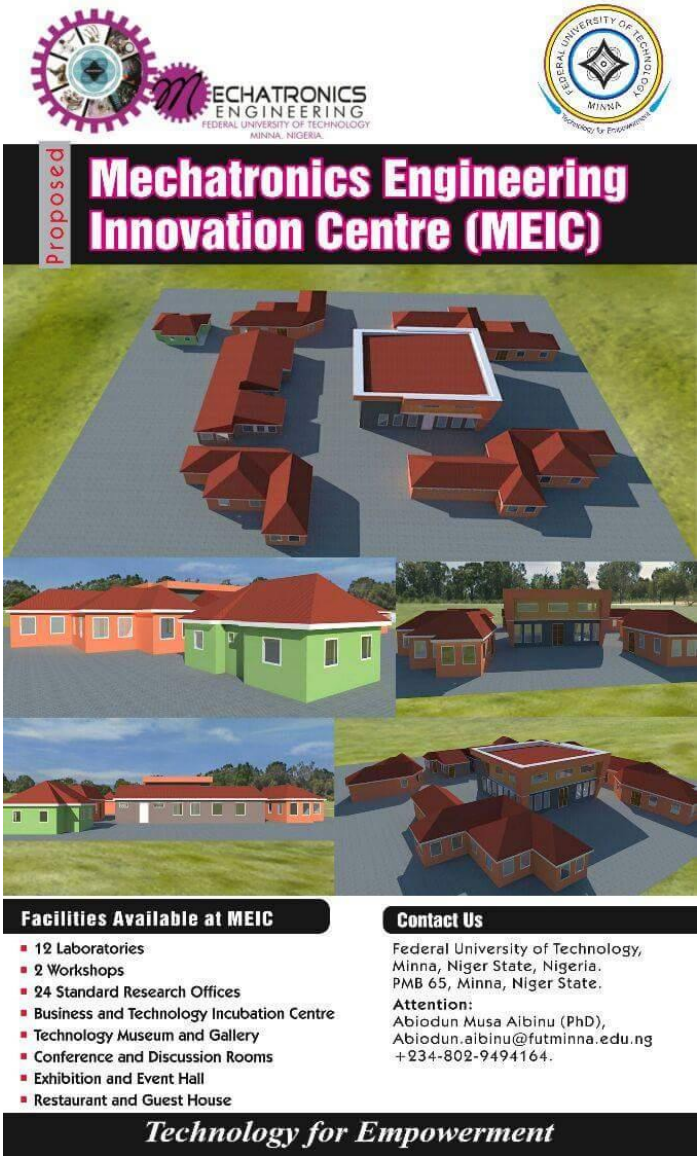


Figure 17: Proposed Mechatronics Engineering Innovation Centre

5.1.2 Mechatronics Engineering Curriculum, Textbooks and Equipment

There is no doubt that Mechatronics Engineering is still at the infancy stage in Nigeria. A mechanism needs to be put in place for a review of the present curriculum as well as the standardization of textbooks and laboratory equipment for the programme. My efforts for the next few years will include finding mechanisms to address some of the anomalies observed in the present curriculum. In conjunction with other colleagues, we shall work assiduously to produce textbooks to use for Mechatronics education at all strata of our educational system in Nigeria. We shall also be looking at developing laboratory equipment that will be in tandem with the developed curriculum and our national technological agenda.

5.1.3 Manpower Development in Mechatronics Engineering

In sustaining and increasing awareness about Mechatronics Engineering, efforts will be geared towards manpower development in Mechatronics Engineering. Young, able and willing academia will be trained along our major areas of expertise. This will assist in developing adequate manpower for the field. Collaborations will be established with partners across the globe with the view of cross pollinating ideas between colleagues.

5.1.4 My Future Research Direction

My research taxonomy has already been presented in Subsection 4.2. There, I mentioned my areas of specialization and later zoomed in on some of the projects that we have implemented. In the short term, my research efforts will be geared towards developing market ready prototypes for all the completed research works. For the on-going projects, efforts will be made to complete them.

A new area of research that will attempt to unify both the physical and metaphysical worlds will be established. This area of research will go beyond Mechatronics Engineering and Artificial Intelligence, but more importantly, it will be capable of solving our problems in Nigeria. This field is nothing but what we call, Spiritual Intelligence.

5.2 Spiritual Intelligence

Mr. Chairman, invited guests, ladies and gentlemen, solving our societal problems, elevating innovation and creativity to new levels via deductions from spiritual texts, and giving insight into what will be my focus after this sojourn in Mechatronics Engineering and Artificial Intelligence, brought about this title, ***Spiritual Intelligence: Beyond Mechatronics Engineering and Artificial Intelligence***. However, since I signified intention to talk on this topic and coined out the title, I have continuously been bombarded with questions regarding the need to clarify and explain the title and topic beyond this lecture. Even though the title has been laconically formulated, the topic has generated ripples, more than what I envisaged at the beginning.

Thus, it has reinforced my conviction that, we put on scientific lenses in our official and professional dealings, while in the actual sense, we view nature and daily activities through our religious eyes [42], hence anything religious attracts our interests and comments.

There is no iota of doubt in saying, that even scientists and researchers in the field of Artificial Intelligence are becoming interested in the untapped potential of the mind, consciousness and spirituality [42]. They are now even talking of creating artificial intelligence “god” for robots and man to worship. This is a total departure from what we used to know some years ago especially in science and engineering worlds. The reason is

because, then, we hardly heard discussions or talks about: God, inner voices, outer signs, or a guiding presence. But now, the trend is gradually changing as materialism and individualism, the twin evils of Western culture have created empty spaces in our lives. In our country, Nigeria and around the world, there has been an increase in the search for spirituality, community, and identity among the populace in recent times. Perhaps the inability of modern-day theories and theorists, to proffer solutions to the ongoing economic and security crisis around the globe, may not be unrelated to the increasing march by the populace to trust their own inner authority in seeking a purposeful path, and creating their own vision, and in the realization of a purposeful sense of empowerment [42].

Once again, I choose to hide behind what the Chairman posited in 2002, that limitation in time and space will not allow for adequate discussion on a topic of this nature [72]. However, I will try to cover the needful herewith.

5.2.1 Evolution of Intelligence in Man

As human beings, we do pass through four stages of intelligence. If you didn't pass through some of these stages, it therefore means that***... I reserve my comments***. The first stage which is the stage of physical intelligence occurred when we were all young (i.e. infancy stage) trying to control our bodies. The next stage involves the development of our linguistic and cognitive abilities (i.e. basically, when we learnt how to read and write), and this we refer to as the Intelligence Quotients, that is where Mechatronics and Artificial intelligence greatly resides. Lastly, we developed Emotional Intelligence in the third stage before moving to Spiritual Intelligence which is the highest level of human intelligence [77].

In a related article, spiritual intelligence was regarded as the epic and the tenth intelligence in man that integrates other existing intelligence [42]. Other existing intelligence include:

linguistic, logical, mathematical, musical, spatial, bodily-kinesthetic, intrapersonal, interpersonal and later added naturalist and emotional intelligence [42]. Hence, this shows the importance of Spiritual Intelligence.

5.2.2 What is Spiritual Intelligence?

Different definitions and descriptions have been put forward on what we should describe or regard as Spiritual Intelligence. However, for the sake of this lecture, we shall adopt the following descriptions:

1. “Spiritual Intelligence can be described as "the adaptive use of spiritual information to facilitate everyday problem solving and goal attainment” [78-79].
2. “Spiritual Intelligence is the set of abilities that individuals apply, manifest and embody as spiritual resources, values and qualities in ways that enhance their daily functioning and well-being” [77].
3. “Spiritual Intelligence can be described as “the ability of individuals to behave with wisdom and compassion, while maintaining inner and outer peace, regardless of the situation” [82].
4. “Spiritual intelligence is an individual’s ability to utilize spiritual talents to know more; searching for meaning and analyzing existential, spiritual and practical issues” [83].
5. “Spiritual Intelligence is “being concerned with the inner life of mind and spirit and its relationship to being in the world”. Thus, creating a capacity for a deep understanding of existential questions and insight into multiple levels of consciousness” [84].
6. “Spiritual intelligence can be described as a deep self-awareness in which one becomes more and more aware of the dimensions of self, not simply as a body, but as a mind, body and spirit” [42]

5.2.2.1 Are you Spiritually Intelligent?

Spiritually intelligent individuals are characterized by the following:

i. Capacity to transcend the physical and material;
ii. Ability to enter into heightened spiritual states of consciousness;
iii. Ability to invest everyday activities, vents, and relationships with a sense of the sacred;
iv. Ability to utilize spiritual resources to solve problems; and
v. Capacity to engage in virtuous behavior or to be virtuous (to show forgiveness, to express gratitude, to be humble, to display compassion).

These five core components represent individual differences in spiritual personality characteristics [78]. Individuals with higher spiritual intelligence have shown a holistic approach in life, an increase in flexibility, further self-awareness, and additional insight into issues and views [80-81].

Spiritual Intelligence involves: Inner knowing, Deep intuition, oneness with nature cum universe, and problem solving. Mostly, in this write up, I will focus on the use of spiritual intelligence to solve problem and increase innovation.

5.2.3 Benefits of Spiritual Intelligence

In [84], Entrepreneurship was succinctly referred to as the spiritual intelligence in business form. Various researchers have shown how spiritual intelligence has been used in solving various problems, while some have shown the benefits associated with spiritual intelligence. In [84], the investigation conducted showed that spiritual intelligence influences up to 99.8% of the innovations of engineering entrepreneurs in the sampled space. In [83], it was reported that spiritual intelligence training was able to decrease psychological

disorder and increase the expected levels of mental health among high school students. Aside innovation and problem solving other benefits of spiritual intelligence reported in literature include: increase in marital satisfaction, increase in ability to tolerate others despite differences in beliefs and consciousness, increase in entrepreneurial success, allowing for individual motivation, intrinsically instead of extrinsically, just to mention but a few.

5.2.4 Differences Between Spirituality, Religiosity and Spiritual Intelligence

Before going deeper, let me state that we should not confuse spirituality with Spiritual Intelligence, neither should we muddle it up with religiosity. While we know that spirituality is quite a broader and much more encompassing construct, we can say that spirituality is like searching for something sacred. We can also say that it is a search for an experience that is meaningful within itself. On the other hand, Intelligence, as we all know, is when we use a set of tools to arrive at a more productive, effective, happier, and ultimately more meaningful life. If we then combine both terms, we can then define Spiritual Intelligence as a mechanism by which we can improve our overall quality of life. So, it is the application of the religious domain of knowledge to our day-to-day problems solving and well-being. Because Spiritual Intelligence promotes our well-being, it is largely a positive and adaptive construct, whereas spirituality may be positive or negative, depending on how it is expressed in particular contexts [77-78]

A Religious person is by all means different from a spiritual person. We define a religious person as an individual who believe in God or gods to be worshipped, usually expressed in conduct and ritual.

In other words, such individual believes in many specific system of belief, worship, etc., often involving a code of ethics. In short,

a religious person is an individual who believe in a set of beliefs and rituals that claim to get a person in a right relationship with God. A spiritual person can be described as a person who believe in the equality or fact of being spiritual, nonphysical or predominantly spiritual character as shown in thought, life, etc.; spiritual tendency or tone.

In a nutshell, a spiritual person is an individual who focus on spiritual things and the spiritual world instead of physical/earthly things.

5.2.5 Developing Spiritual Intelligence

A number of ways have been advocated in literature through which spiritual intelligence of an individual could be raised. Some of the methods that could be employed include: emphasis on community's core values, connectedness and oneness of all, compassion, a sense of balance, responsibility and service. One of the most important steps in developing spiritual intelligence is the ability to find a sense of purpose and creating a vision. In this case, immediately after setting the goal, there must be total commitment to it, followed by the intention or will to carry through the identified goal, desire or want. Sensing the connectedness of everything to everything, and shifting one's focus of authority and perception in life from external to internal will assist in developing spiritual intelligence. At this last stage, let me quote suggested steps for developing spiritual intelligence from [42] verbatim:

1. "Think about your goals, desires and wants to bring your life into perspective and balance, and identify your values.
2. Access your inner processes and use visualization to see your goals, desires and wants fulfilled; and experience the emotion connected with this fulfillment.

3. Integrate your personal and universal vision and recognize your connectedness to others, to nature, to the world and to the universe.
4. Take responsibility for your goals, desires and wants.
5. Develop a sense of community by letting more people into your life.
6. Focus on love and compassion.
7. When chance knocks at your door, let it in and take advantage of coincidences".

5.2.6 Spiritual Intelligence: Beyond Mechatronics Engineering and Artificial Intelligence

With respect to AI, it is not untrue that the two concepts are concerned with intelligence. Spiritual Intelligence is based on the human emotion and conscious mental state. AI on the other hand, has to do with the ability to give human intelligence to machine. Thus, while Spiritual Intelligence may be limited to individuals like us, the AI will mostly be concerned with machines and robots. Interestingly, these two concepts are related simply because we will not be able to achieve AI if we are not in a good state of mind.

My research interest on spiritual intelligence will focus on its adaptation to advancing learning, innovation, problems solving and development of self-consciousness. Thus, I will focus on the cognitive and logical points of view, where interest will be in the ability to utilize spiritual resources to solve problems in our daily life, just in tandem with the spirit of innovation and problem solving in Mechatronics and Artificial Intelligence. Despite the attributed success and expected contribution of SI to human development, there is still no expert system to automatically measure SI level the same way we can measure intelligent quotient in man. Hence, my research focus will try as

much as possible to solve this problem. Other areas that I will be looking at will include but would not be limited to solving the following challenges:

1. **Innovation, Creativity and Life Long Learning:** One of the major benefits of SI to us include: its ability to present skills of problem solving that we can use to achieve scientific purposes so as to attain positive results and national development via innovation, creativity and life-long learning. The existing Science Technology Engineering and Mathematics (STEM) has not produced the much-needed innovation and creativity that is capable of transforming Nigeria, to occupy a seat among the developed nations. Hence, the need to apply SI for an increase in innovation and creativity and at the same time, produce graduates that are conscious of their environment and committed to life-long learning.
2. **National Integration:** Another benefit of SI is the ability to develop a deep sense of community, despite differences in beliefs and in levels of consciousness. SI has been shown to have the capacity of development of a clear and stable sense of identity among individuals especially in the context of national integration. This is arrived at by finding the deepest and innermost resource from an individual from which the capacity to care, the power to tolerate and adapt is obtained. This is what is needed for our national integration.
3. **National Resource Control:** The problem of national integration and resource control that has continued to plague our country can be addressed through proper use of SI. We have no doubt that SI will increase the individual's capacity to understand others at higher levels. It will assist in the creation of the ability to discern both the "true cause" of behavior, without judgement and serve the "true needs" of others (the areas without natural resources) until they themselves learn to meet their own needs from available

resources in their localities. Thus, with much concentration on SI, the present agitation for resource control would be amicably resolved.

6.0 Conclusion and Recommendations

Mr. Chairman, sir, Ladies and Gentlemen, at the beginning of this lecture, we set out to achieve some set objectives. These were: conceptual clarifications, examination of my professional contributions in Teaching, Research, Innovation and Development, Community Social Responsibility, and Mentoring. We also set out to know the various things I would be engaging in outside my present endeavor and that led us to the field of Spiritual Intelligence. In there, we jointly examined the concepts of spiritual intelligence and what its benefits and importance are to us in Nigeria.

As a concluding remark, I want to say that everybody has a role to play in making this society a better place to live, technologically and spiritually. Hence, the need to be mechatronically focused on what we bring to our society the much-desired development.

My recommendations are to the following:

1. **Parents, You and Me**: We can take advantage of children's love to play by buying educational toys that can contribute to the spirit of invention and creativity in them. However, let me put a caveat on the above statement. We should note that there are numerous ways of sparking creativity in our children, asides purchase of toys. For this reason, I will like to advocate the use of specialized toys or mechatronics devices in our various homes. In other words, we should not throw away those old or damaged appliances in our houses. Instead, let us use them to enhance the creativity and ingenuity in our children.
2. **Management Team and members of staff of FUT Minna**: We, at DOME FUT Minna, have taken the first step towards the development of Mechatronics Engineering as a discipline and as a way of life in the University. Now, time

has come for us to support the realisation of Mechatronics Engineering Innovation Centre (MEIC). The realisation of which will assist, within a period of five years, in transforming the proposed Mechatronics Engineering Innovation Centre to School of Mechatronics Engineering and Technology (SMET), with the following departments:

i. Department of Autotronics Engineering
ii. Department of Robotics Engineering
iii. Department of Signal Processing and Engineering
iv. Department of Artificial Intelligence and Engineering.

This recommendation is in tandem with our University's vision. In addition, this will strengthen the technological development of the nation. Let me at this time state that there is an abundance of availability of staff and facilities for the take-off of SMET and I am assuring you that students are available for admission into those departments. Therefore, it will be a thing of joy if FUT Minna to take the lead in this field.

3. **Private Sector**: Private sector can take the lead in the field of Spiritual and Artificial Intelligence. Sponsoring of research activities in these areas should be likened to oil-exploration. However, unlike oil exploration where there is no certainty of success, in these two areas, success is staring at you in the face. You just need to take the first step and you are there.

4. **Government**: There is an urgent need for us to tame the duo of religious intolerance and technology decadence in this country. And there is no better way of doing this than the inclusion of Artificial Intelligence (AI) and Spiritual Intelligence (SI) in our educational agenda. This is only achievable when Government stops focusing on Science Technology Engineering and Mathematics (STEM). Rather

we should start advocating for Spiritual Intelligence Technology Engineering Artificial Intelligence Mathematics and Science (STEAMS). With this, the problems of religious intolerance and technology decadence would be put to a final stop once and for all, and the much-desired technological advancement would then begin.

Mr. Chairman, invited guests, ladies and gentlemen, I hereby attenuate this lecture at this point.

7.0 Acknowledgements

First and foremost, all praises and adorations belong to Almighty Allah (SWT), the Creator of Heavens and the Earths, the King of the day of judgement. To HIM only, I humbly submit.

Having benefitted from numerous: people, communities, families, socio-religious groups, associations, mentors, counselors, administrators, students, teachers, lecturers, etc. that I must acknowledged. I am afraid I may unintentionally miss out some names and due to space cum time constraints, I will also not be able to list all concerned entities. Hence, I have decided to use this approach to capture all concerned entities.

My appreciation therefore goes to the following: entities, friends, colleagues, groups and associations whom I am so much indebted to and I will continue to. These include:

1. **My Father:** Pa Iyiola B. Aibinu for teaching and guiding me to Allah, sharing stories, experiences and continuous prayers. Baba mi Akanmu, Odi mode Iresa…
2. **My Mother**: Raliat Apeke Aibinu of blessed memory: Though you had no Western education but you struggled to see me through what you missed in life. Always motivating me through the whole journey till your departure some months ago. Truly, "iya meta ki nje obe, ti ko ba lepo, a ni iyo tabi ko ni ata". I love you and will continue to miss you. May Allah overlook all your short comings and admit you to paradise. Apeke, Iyeru Okin Omo olofa mojo, omo abisu joko…
3. **My Foster Father:** Pa Isaac Adejare Atanda Edu Odeniyi of blessed memory, for providing the needed counselling periods, guidance and support till your exit. Atanda Edu, Omo Elepe ni Iseke, ….

4. **My Online/ Distance Mentor**: Muhammad Ali, The Greatest Boxer of All Time (GOAT); for being an inspiration to all, master of strategy, an audacious mentor.
5. **My Siblings**: Always supporting and encouraging my decisions.
6. **My Maternal Family members**: For believing in my dream and supporting it financially, morally and spiritually, providing shelter and support during my days at The Polytechnic, Ibadan and Great-Ife.
7. **My Paternal Family members**: Your cordial relationships is well appreciated.
8. **My Great In-Laws**: For giving me your daughter to marry and for the continuous support to date.
9. **My Professional Mentors**: for always guiding and encouraging me to succeed, and for your ability to look at me in the face and ask me to drop some ideas and approaches.
10. **My Spiritual Mentors**: For teaching and leading me to God and inculcating in me the need for success and spirituality.
11. **My Daddies and Mummies**: I love you all, you are all appreciated. Truly, Igba oju ni nwo omo, sugbon oju merin ni nbi.
12. **Bright Future Club Members**: For always being there even during the tough periods in my life. You supported the dream financially when it was about to be aborted due to lack of funds.
13. **Omowunmi Togetherness**: For building Abiodun Musa Aibinu; your support and rancor-free childhood is parallel to none. I love you all.

14. **My Teachers**: For your continuous contribution to the growth of my career and knowledge.
15. **My Supervisors**: for deepening my interest and expanding my horizon in Mechatronics, AI, DSP, DIP and for giving me a career and life path to follow.
16. **My Students**: For your wonderful contributions both in and outside the classroom, getting the work done and supporting all the initiatives.
17. **My PAs**: For always assisting and keeping tabs on our commitments.
18. **2-ICs**: For always getting the job done and looking after all our "issues".
19. **SEET Members**: For your love and care.
20. **MCE Family**: For making the department another home for me.
21. **Spiritual Organisations**: MSSN, UNIFEMGA, NASFAT, TMC, Companion, Islamic Redeemers NSCIA, etc. - for spiritual and religious upliftment. Without time spent with you, I might not have been able to trace my way back to Spirituality and God.
22. **CODEL family**: For the cordial working relationship since I joined CODEL family.
23. **My School/ Class Mates**: From LGPS, EBSS, OAU, BTH and IIUM for that enabling environment.
24. **My Professional Colleagues/ Organizations**: For supporting and overlooking my inadequacies.
25. **My Neighbors**: Nothing is as good as a good neighborhood. Thanks for the peace and love.

26. **Ph.D. Clinic members**: For supporting the idea of continuous improvement and togetherness policy.
27. **IIUM Families**: For supporting and giving me that enabling environment to work while in Malaysia.
28. **Malaysia Families**: For accepting me as part of your family despite the obvious differences in culture.
29. **Dinarists**: For true sense of Islamic brotherhood.
30. **FUT Minna Families**: For your love, care and providing enabling environment.
31. **My Esteemed Clients**: For believing in us and allowing us "to do the work".
32. **Research Groups**: For providing the enabling environment to conduct research and share ideas.
33. **NAF/NA/ONSA**: For the trust imposed in us regarding your R & D drive.
34. **Tech Cabal**: For allowing me to always ask, "where is my work" and our numerous arguments.
35. **Elders at FUT Minna**: For mentoring and accepting me as your little son that must be nurtured to greatness.
36. **Immediate Past FUT Minna Management**: For giving me that opportunity to visit FUT Minna in 2011 and giving me the opportunity to join FUT Minna in 2012.
37. **Present FUT Management**: For your continuous confidence in our abilities to get the work done and supporting all our initiatives. Without you, I will not be standing here today.
38. **My Daughters**: Abolanle Maryam Aibinu and Abolade Mardiyah Aibinu - for your love and attention.

39. **My Wife**: Raimat Adenike Aibinu - for showing me love and taking care of me, M and little M (The 3M).
40. **Opposition/Naysayer**: For always pushing us to success. Your doubts and comments are well appreciated.

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Brief Profile of the Inaugural Lecturer

Abiodun Musa AIBINU (Ph.D.), is a highly-motivated career driven achiever with over Eighteen (18) years working experience in the fields of: Mechatronics Engineering, Telecommunication Engineering, Spectrum Management, Industrial Automation, Teaching, Research and Project Management.

Born on the 9th of January 1973, Engr. Prof. Aibinu received his: First School Leaving Certificate from Local Government Primary School, Mushin Lagos, Nigeria; Secondary School Leaving Certificate from Euba Boys' Secondary School, Mushin, Lagos, Nigeria; National Diploma award from The Polytechnic, Ibadan, Nigeria; B.Sc. degree from Obafemi Awolowo University (OAU), Ile-Ife, Nigeria; M.Sc. degree from Blekinge Institute of Technology (BTH), Sweden and Doctoral degree from International Islamic University Malaysia, (IIUM), Malaysia.

He has been actively involved in teaching, supervision, mentoring and research activities at various universities in Nigeria and Malaysia. He joined the services of Federal University of Technology (FUT), Minna in 2012 and is presently a Professor of Mechatronics Engineering at the Department of Mechatronics Engineering, FUT, Minna, Nigeria.

However, prior to joining FUT Minna Nigeria, he has worked at: IIUM Malaysia; MTN Communication (Nigeria) Limited; GS Telecom (Nigeria) Limited; DCC Satellite and Networks Limited; Oganla Consulting and Investment (OCI) Limited; Communications Associates (COMSAC) (Nigeria) Limited just to mention but a few.

Professor Aibinu has participated and won several academics and research awards at various international and national exhibitions. He was among the recipients of the following

awards: Deans Honors Award, Faculty of Technology, Obafemi Awolowo University Ile-Ife, Osun State, Nigeria in 1997; Lagos State Honors Award for deserving National Youth Service Corps (NYSC) in 2003; Best Graduating PhD Student (Engineering) Award, 26th Convocation, International Islamic University Malaysia in 2010; 53rd Anniversary, Nigerian Air Force Research and Development Award in 2017. He was also nominated for 2012 promising researcher award and best teacher award at IIUM, Malaysia.

He has also won several research grant awards in and outside Nigeria and has authored and co-authored several publications in both local and international journals and conferences. He has discharged numerous public service assignments at various levels aside supervision and mentoring both at Undergraduate and postgraduate levels in Nigeria and Malaysia.

He is presently, the Head of Department, Mechatronics Engineering Department, FUT Minna, Nigeria; Director, Center for Open Distance and e-Learning (CODeL), FUT Minna, Nigeria. He is also the pioneer and coordinator of Advanced Engineering Innovation Research Group, FUT Minna, Nigeria; He is a senior consultant at Ph.D. Clinic, FUT Minna, Nigeria.

Professor Aibinu is married with children and is a registered Engineer with COREN and NSE. His research interests include: Digital Signal and Image Processing; Instrumentation and Measurement; Intelligent System Design and Artificial Intelligence with emphasis on Artificial Neural Networks and Genetic Algorithm.

His hobbies include: Reading, Learning, Public Speaking, Coaching, Mentoring and Traveling.

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