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Applications of Mechatronics and Autonomous Systems in Smart Agriculture: Potentials and Challenges for Nigeria

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Abstract

Food remains one of the most important primary human needs in all ages, and agriculture remains the primary, if not the sole source of real food. However, with ever increasing global population, advancements in knowledge, changes in taste, diet, food pattern and preferences; the demand for food has expanded from just having enough quantity of food, to having it in different desired qualities and forms and ensuring safety and health of the consumers. So the agricultural industry is increasingly becoming complex and highly tasking compared to traditional practice. Advancements in science and technology have brought a lot of useful innovation into agriculture, and this has resulted in what is now being referred to as smart agriculture or precision agriculture which simply implies the application of mechatronics, automation and artificial intelligence into agriculture. This includes countless areas of application involving both plant and animal farming, from production and all through the stages until final consumer either as food on the table or as industrial raw material for other products. As a way of illustrating in specific cases, some of the applications of mechatronics and autonomous systems in agriculture; this paper specifically discusses machine vision system for weed density estimation in cassava fields, machine vision system for sorting and grading of tomato fruits, wheeled mobile robot for site specific crop field management, smart weather stations for environment and crop field variables measurement, monitoring, prediction and control and solar recharged multipurpose electric tractor for smart farming. The paper concludes by discussing some of the potentials and challenges of Mechatronics and smart agriculture in present Nigerian context.

Keywords: *Mechatronics, Autonomous Systems, Smart Agriculture, Precision Agriculture, Machine Vision.*

1. Introduction

Today, products and processes are a lot different from what they were a few decades ago, and this has cut across all spheres of work and life; domestic, industry, agriculture, military, mining, search and rescue, health, security and socials, environment, education, construction, planetary exploration, transport, communication, to mention but a few. Modern products and processes are now being designed and developed with a multidisciplinary mind set to include more and more integration, sophistication, robustness, intelligence, feedback and control. Mechatronics, coined out from mechanisms and electronics is the mindset or philosophy in design where computer, control, electronics and mechanical elements and systems are all integrated to develop whole products or processes to function better than similar ones developed independently without integration and

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synergy. In such products and processes, many mechanical functions are replaced with electronic ones; and this results in more flexibility, easy redesign and reprogramming, and the ability to carry out automated data collection and reporting.

Mechanization in agriculture has been applied to reduce human drudgery involved in farm work, do more work in less time, improve efficiency and timeliness of field and post harvest operations, and expand the scope of production from subsistent to commercial production, processing, packaging, storage and delivery. This has progressed from hand tools technology (HTT), to draft animal technology (DAT), engine or mechanical power technology (EPT). Presently, mechanization in agriculture has moved on, now involving ICT in agriculture, electronics, automation, artificial intelligence and mechatronics, otherwise known as smart agriculture (SA) or precision agriculture (PA).

In this paper the following aspects of smart agriculture is presented: machine vision system for weed density estimation in cassava fields, machine vision system for sorting and grading of tomato fruits, wheeled mobile robot for site specific crop field management and smart weather stations for environment and crop field variables measurement, monitoring, prediction and control, and solar recharged multipurpose electric tractor for smart farming.

2. **Smart Agriculture (SA) and Site Specific Cropfield Management (SSCM)**

The primary aim of smart agriculture (SA) or precision agriculture (PA) is to solve the problem of uniform application of farm input on variable field conditions. SA/PA was defined as the use of different kinds of information and communication technologies such as satellite, GPS, GIS, sensors, electronic systems, computer, camera, in observing, measuring and analysing variations within agricultural fields or animals; and using the information obtained in decision making through control of soil, water, farm inputs, micro-climate, environment, machines and machine-related parameters for optimum and sustainable production of crop and animal [1]. Precision Agriculture basically involves observing, measuring and responding to intra and inter variability in the farm field [2]. It has to do with managing the field despite the presence of unfavourable conditions with the goal of increasing production, profit in crop farming or animal farm without any indication of soil degradation. The goal of PA is not to obtain the same output everywhere but rather to direct the exact amount of input required in a site specific crop to increase long term output at that site with minimum input [3]. Precision agriculture has also been defined as observation, impact appraisal and timely strategic reaction to fine-scale variation in causative components of an agricultural production process, and in this way may cover a scope of agricultural ventures, and can be applied to pre- and post-production aspects of agricultural enterprise(Drysdale & Metternicht 2003)[4].

Precision Agriculture is commonly applied to the following areas: i) Guidance systems**:** This allows exact directing inside the field, and helps avoid covering application zones [5], ii), Precise Sowing**:** With precise sowing, a consistent number of seeds sown, accurate alignment of seeds (with the same spacing) and the variation of sowing density can be accomplished, iii) Fertilizer application: The volume of fertilizer to be applied is adjusted to the real nutritional status inside the field [6], iv) Plant protection: Variation of pesticides (herbicide, fungicide and insecticide) within a field [7], v) Soil management: Tillage (e.g. ploughing intensity/depth) according to the soil properties [8], vi) Irrigation: Precise irrigation according to the soil water status [9], vii) Yield mapping**:** For quality control of the management decisions and yield [10], viii) Documentation: All taken actions can be documented precisely for each management zone, including the information about the total amount of material and working hours.

According to Arshad, Site Specific Crop Management (SSCM) or Site Specific Agriculture or Precision Agriculture is a farm management concept which is mainly based on observing, measuring and responding to inter or intra-field variabilities in the field; its practice involves the division of the field into spatial small patches so that there will be no room for misapplication of farm inputs [11]. In observing, measuring and responding to inter or intra-field variabilities in crops the following are considered: yield monitoring and mapping, soil resource variability, managing variability, engineering technology, profitability, environment, and technology transfer [12and Robert]. Skotnikov and Robert also refer SSCM as rapid development of agricultural system that promotes variable agricultural management practices within a field according to site conditions.

3. Components of a Machine Vision System

The major components of a machine vision system include the lighting, lens, image sensor, vision processing, and communication. Lighting illuminates the part to be inspected allowing its features to stand out so they can be clearly seen by the mounted camera[13].Machine vision systems create images by analysing the reflected light from an object, not by analysing the object itself. A lighting procedure involves a light source and its arrangement with respect to the path and the camera.

A particular lighting procedure can better the image being captured such that it negates some features and enhances others [13-15]. The lens takes the image captured and presents it to the sensor in the form of light. The lenses for capturing do vary in optical quality and price, the lens used is a very important factor determining the quality and resolution of the image captured. Cameras used in most vision systems offer two main types of lenses: interchangeable lenses and fixed lenses. Interchangeable lenses are basically C-mounts or CS-mounts [13]. The right combination of lens and extension will help give the best possible image. A fixed lens as part of a standalone vision system typically uses autofocus that could either be a mechanically adjusted lens or a liquid lens that can focus automatically on the part to be captured. Autofocus lenses most at times have a fixed field of view at a particular distance. The sensor in a machine vision camera does the work of converting this light from the lens into a digital image which is then sent to the processor for further analysis. The ability of the camera to acquire a correctly-illuminated image of the object of interest doesn't just depend on the lens, but also on the image sensor within the camera. Image sensors typically use a charge coupled device (CCD) or complementary metal oxide semiconductor (CMOS) technology in the conversion of light (photons) to electrical signals (electrons)[13, 16]. Essentially the work of the image sensor is to capture light and convert it to a digital image balancing noise, sensitivity and dynamic range.

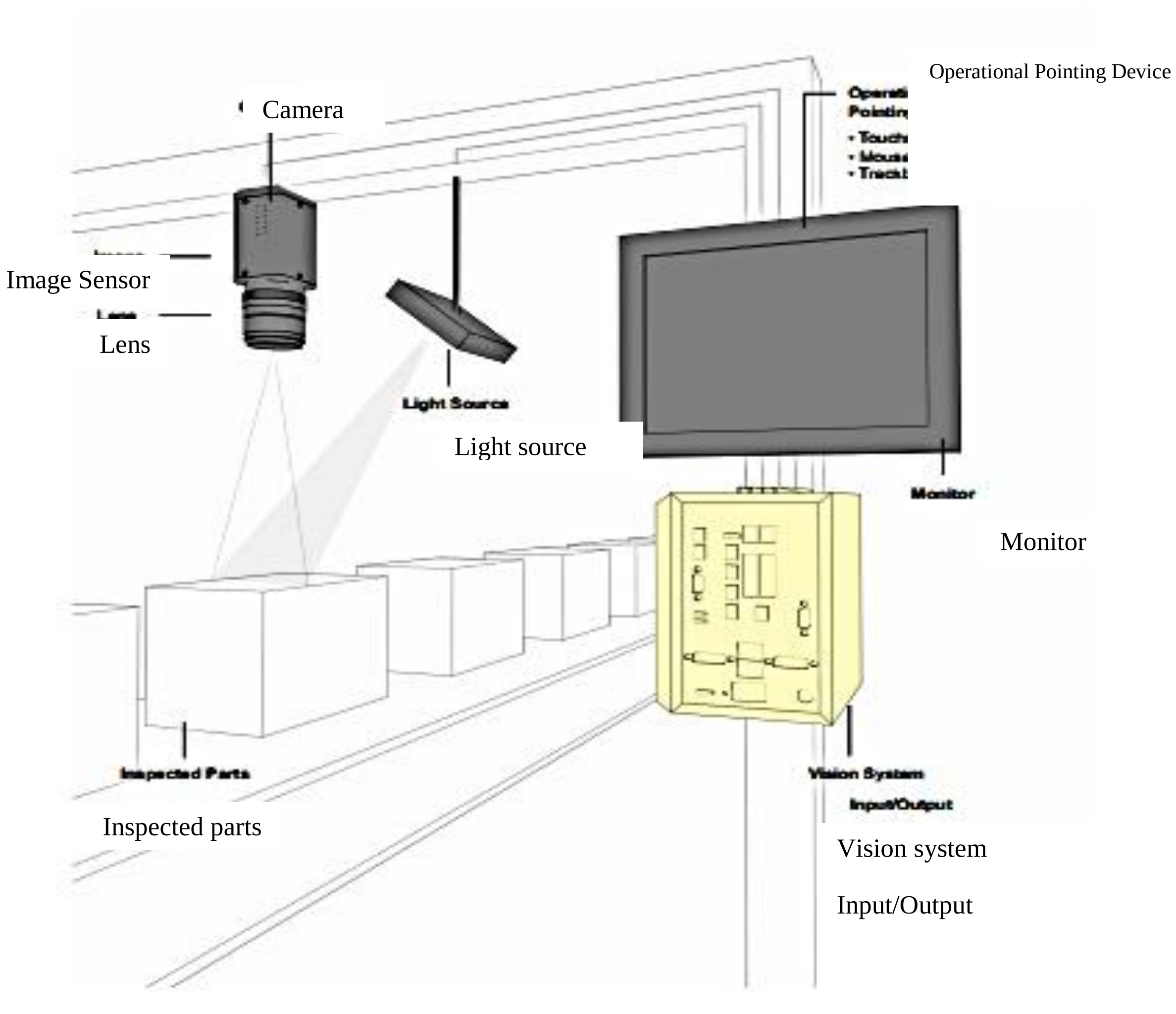

Figure 1: Main components of a machine vision system (Source: COGNEX 2014).

The image is made up of a connection of pixels. If the lighting on the object under inspection is poor, dark pixels are produced, while bright light gives rise to brighter pixels. It's very essential to ensure the camera has the right sensor resolution for the application. The higher the resolution, the more detailed an image will appear, and the more accurate the measurements will become. Part size, inspection tolerances, and other parameters will dictate the required resolution. Vision processing is made up of some algorithms that help in reviewing the image and bring out the required information, carry out the necessary inspection, and take a decision. Processing is the mechanism used for extracting information from digital images. It may take place externally in a PC-based system, or internally in a standalone vision system. Processing is done by some software and takes several steps[13]. The first step is image acquisition from the sensor. Sometimes, pre-processing may be needed to optimize the image and make sure all the important features stand out. Next, the software points the specific features, runs measurements, and compares these to the specification[17, 18]. A decision is then made and the results are communicated. Finally, communication is typically accomplished by either discrete Input/Output signal or data sent over a serial connection to a device that is either logging information or using it real-time[13]. Most machine vision hardware components, such as lighting modules, sensors, and processors are available commercial off-the-shelf (COTS). Machine vision systems can be assembled from commercial off the shelf, or procured as an integrated system having all components in a single device[13].

4. Machine Vision System for Weed Density Estimation in Cassava Fields

Weeds compete with plants for light, water, space and soil nutrients. Autonomous robotic weed detection and control system (machine vision based approach), holds promise towards the automation of hand weed control, with weed control being one of the few remaining drudging tasks to be mechanized in agriculture[14, 19]. Autonomous robotic weed control minimizes the rate of dependency of agriculture on herbicides, thereby increasing its sustainability and having the impact on the environment drastically reduced. Most autonomous robotic weed control systems make use of machine vision approach[20]. The machine vision based approach makes use of shape, texture, colour and location based features either individually or jointly to differentiate between weed and crop [16]. The design of vision systems for the measurement of plant features are affected by many things like the scale of plant measurement (leaf or canopy level), and the measurement environment (Laboratory or in the field).

A large number of machine vision systems dependent on different image processing techniques have been invented for different operations in agriculture. For weed detection, a success was recorded in making use of colour indices for the identification of weed under various soils, residue and lighting conditions [21]. Some other people made use of colour and shape analysis techniques for differentiating between crops, weeds and soil [22]. An invention of an image processing component for detecting and for mapping system based on the intensity of green colour [15]. Hemming and Rath in 2001 was successful in the classification of plants and weeds using colour indices [15, 23]. Meyer et al., verified the colour vegetation indices for automatic threshold using plant-soil-residue images and Burgos-Artizzu et al discriminated between weeds, crops and soil in real-time by machine vision. However, application on cassava crop particularly in the quantification of the extent of weed infection has been rarely found. The only work done on application of machine vision in cassava crop was Aduwo et al., (2010) who developed a vision system for diagnosing cassava mosaic disease, and the identification of brown leaf spot in cassava [23].

In crop pests and disease diagnosis, machine vision has been widely applied in the identification of diseases in the farm. Carmago and Smith developed an algorithm for determining the threshold for disease detection in the farm [24, 25]. Carmago and Smith again used the machine vision system to identify diseases on cotton. Cui et al made use of image processing based on multi-spectral image quantitatively detect rust in soybean [26]**.** Weizheng et al proposed an image processing method for grading plant diseases. Before an image is processed, it goes through several steps. Some of the steps taken in processing an image are as shown in the Figure 2.

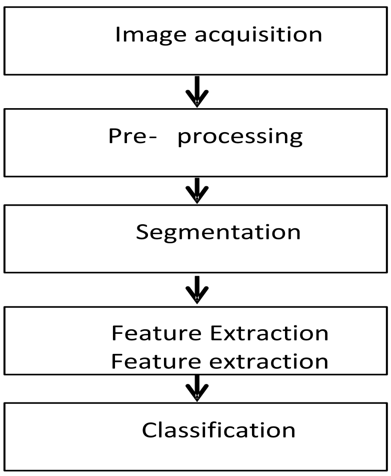

Figure 2: General image processing flow chart

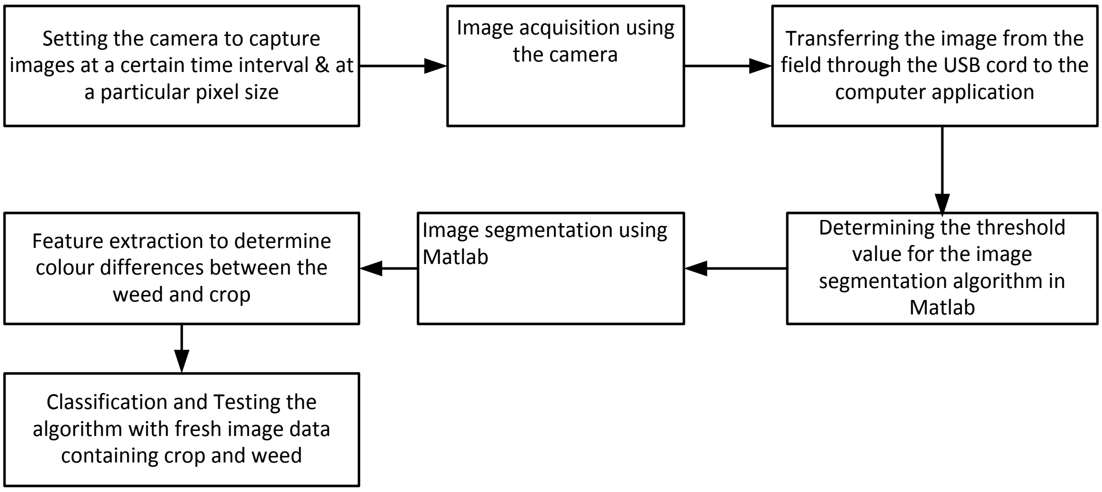

Figure 3: Implementation procedure for this work

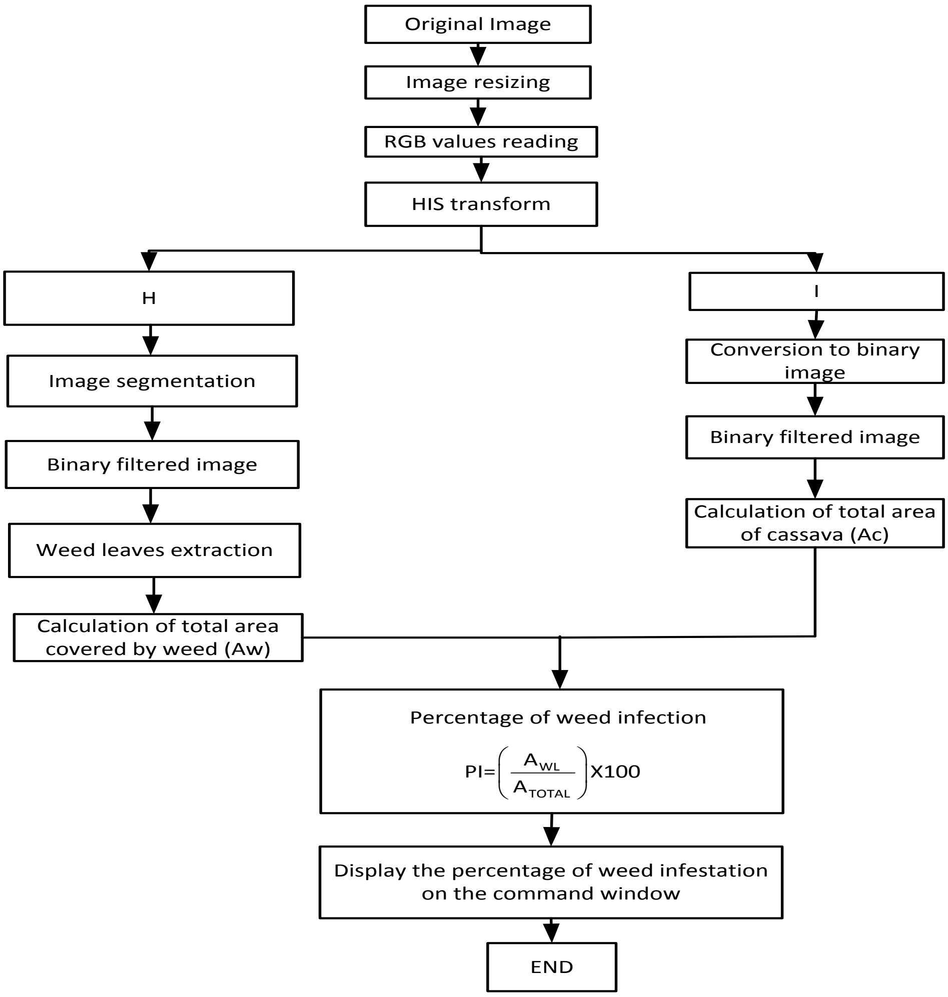

Figure 4: Flow chart of image processing algorithm for evaluating the density of weeds in the farm

The authors carried out a research work that involved detection and estimation of weed density following the procedure shown in Figures 3 and 4. The work developed a kNN embedded colour-based machine vision system for weed detection and density estimation in a cassava farm for site-specific application of herbicides or other weed control measures. The farm was divided into three sections and images of the three sections were captured. The captured images of the sections of the sample farm were enhanced or pre-processed using MATLAB software to reduce the effects of varying lighting conditions, the RGB (Red, Green, and Blue) values of the pixels of the images were determined and the images were converted to L*a*b colour space to bring out the slightest distinguishing features in the colours of the images. With this, the colour features of the pixels of the images captured were noted and the Euclidean distance metric of this colour features of the pixels of the image was determined. By k-means clustering, the objects in the image having similar colour features were segmented and put in one cluster, where k is an integer determining the number of clusters to be created. Three image clusters containing the background (soil), the cassava leaves and the weed (spear grass) were created respectively. Results showed that, the system recorded 0%, 0%, and 8% percentage weed infestation for the three different sections of the farm immediately after the sprouting of the cassava, and then 11.74%, 8.02% and 12.01% for the sections three weeks after sprouting. Quadrat method of vegetation sampling was used to validate the results obtained from the machine vision system. Results obtained showed that percentage weed infestation of the three sections of the field immediately after sprouting were 0%, 0%, and 12%, then 11.5%, 8.0% and 14.4% for the sections three weeks after sprouting. The system recorded an average accuracy of 91.3%. This work is a phase in a bigger research project to develop an intelligent and automatic weed sprayer that will operate based on real-time information on the density and spatial variability of weeds (spear grass) in a cassava farm.

5. Machine Vision System for Sorting and Grading of Tomato Fruits

Postharvest process include cooling, cleaning, sorting, grading and packaging and the efficiency of each of these affects the quality of fruits [27]. Sorting is usually accomplished based on texture, appearance, maturity level, size and shape [28-31]. Manual sorting by human operators in which the operators individually check the fruit quality by means of visual inspection is tedious, time consuming and may be affected by individual human factors and experience. These disadvantages of manual sorting can be overcome by machine vision assisted sorting techniques which are more accurate, cost effective and faster [32-34]. Steps usually undertaken in machine vision include capturing the images, analyzing and processing of images. This technique makes it easy to achieve sorting and nondestructive assessment to determine visual quality characteristics in food products [35, 36]. Nigeria is a major producer of tomato in Africa, and the product is made available to end users mostly as fresh fruits in local markets and some are utilized as raw material by food processing and packaging industries. Majority of the production and post-harvest processes are still done manually. This work aimed to develop an image processing algorithm in MATLAB that can detect and classify fresh tomato fruits based on size, and to test the performance of the algorithm using fresh tomato fruits that were obtained from the open market in Nsukka, Enugu State Nigeria.

work proposed an automatic tomato sorting algorithm using image processing technique in MATLAB. Images of the tomatoes were acquired using a digital camera in a controlled environment. The system made use of histogram equalization, median filter, edge detection, RGB colour and the Grayscale image to acquire the physical parameters of the processed tomato image such as major axis length, centroid and the diameter used for sorting the tomatoes into small, medium and large sizes. Ninety-six images of the tomatoes were used to train the algorithm and subsequently thirty different sizes of tomatoes were captured and processed to evaluate the performance of the algorithm, and the result was validated using similar metrics gotten from physical measurements using a Vernier Caliper. The algorithm classified small, medium and large size tomatoes as 10, 9 and 11 numbers respectively; while visual classification based on physical measurements classified small, medium and large size tomatoes as 10, 10 and 10 numbers respectively. This result showed that the system could successfully extract the physical parameters from the images of the tomatoes which were used in sorting them. The process time for each image was 20 seconds. The flow chart of the algorithm is shown in Figure 5.

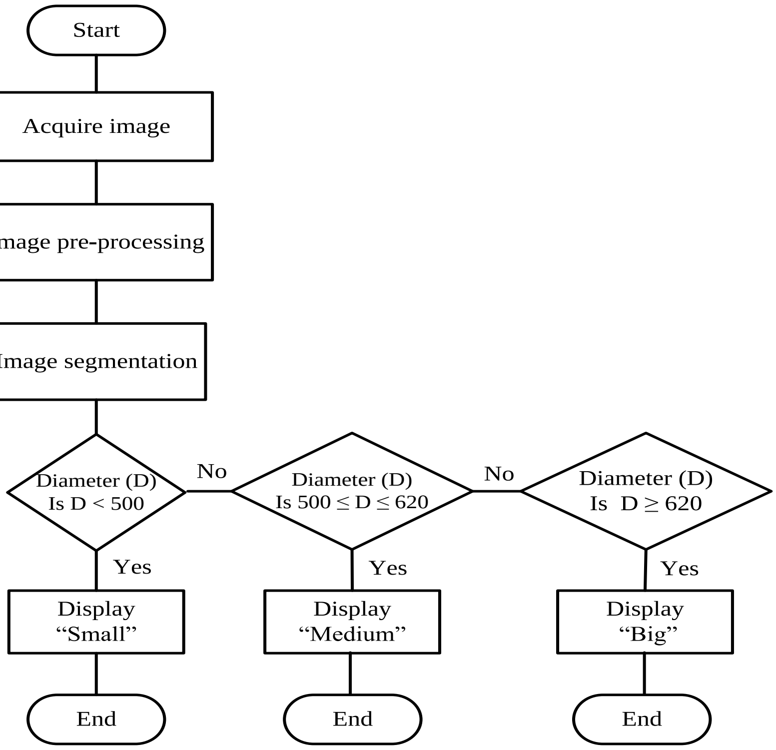

Figure 5: Image processing algorithm flow chart

6. Wheeled Mobile Robot for Site Specific Crop Field Management

Figure 6 is a typical agricultural wheeled mobile robot showing some important functional parts. In traditional crop production practice, after planting, one of the operations usually carried out next is regular field scouting and monitoring of crop development in the field with the aim of determining and controlling the presence and density/level of weeds, pests, diseases and some other unwanted factors; this is known as site specific crop field management in precision agriculture.

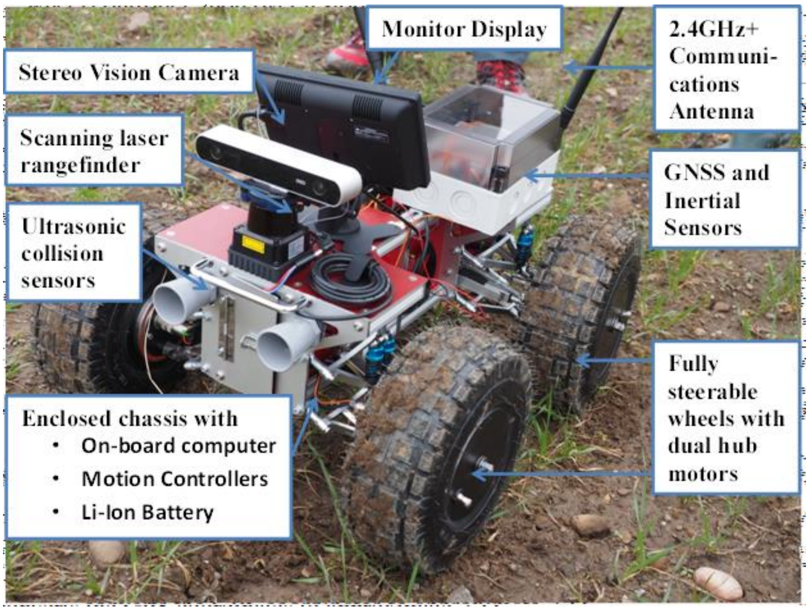

Figure 6: An Agricultural WMR with labelled parts [37]

This work aimed at developing an intelligent wheeled mobile platform which will be able to move autonomously within a crop field carrying a vision system and be able to detect and quantify weed density. This paper presents the first stage of the research project. In this work, a wheeled mobile robot which will serve as a platform for scouting and carrying any intelligent tool for crop protection has been developed (Figure 7). The mechanical design was done using Autodesk fusion 360 CAD software. The major component parts of the mechanical structure include the chassis made of 1 inch by 1-inch aluminium square pipe joined together to form the chassis by bolts and nuts; the floor of the chassis made of 3mm thick Perspex sheet which forms the base carrying the electronic control box and the batteries powering the independent wheels attached to four separate servo motors. The control system consists of electrical control unit and the control program. The control unit include the servo DC motor, the RF module, the microcontrollers and sockets; Atmega328p, the DC stand down and stand up modules, the ultrasonic sensors, the 6 volts 5 amperes battery for powering the control system, the headers, regulators and others. The control program was developed using Arduino IDE; four sets of programs were developed for the different microcontrollers. Two sets of the programs were used to give command to the WMR and the other two for commanding the remote controller. The control of the WMR motion was achieved independently in two ways which are autonomous control and remote control; the remote control was achieved wirelessly using a transceiver. During the use of the RF transceiver, it was observed that multiplex communication is faster with the use of capacitors. The system was constructed and tested, and it was observed that the integrated WMR system could move autonomously along a straight path and also is able to detect and avoid any obstacle along its path as required for the mobile platform.

Figure 7: Developed wheeled mobile robot for site specific crop field management

7. Smart Weather Stations for Environment and Crop Field Variables Measurement, Monitoring, Prediction and Control

In order to foster and harness vast opportunities and potentials possible through academia-industry partnership, for many years now, the Mechatronics Research Group UNN has been partnering and collaborating with the Artificial Intelligence and Instrumentation Research Group based at the National Center for Basic Space Research, situated at Nsukka for research, industrial training and workshops on Mechatronics and Artificial Intelligence. Figure 8 is an advanced automated weather and environment monitoring station. The solar powered EPSm station is a one–stop device for wide scope of environmental characterization. It is an environmental monitor that is highly integrated and boasts of about thirteen (13) real time variables covering weather, environment, climate, atmospheric, soil, gas pollution, GPS, Aerosol etc all in one compact outdoor unit. Variables being measured by the EPSm station include: ambient temperature, relative humidity, solar radiation, atmospheric pressure, soil temperature, soil humidity, soil PH, precipitation, aerosol, UV radiation, gas (CO, CO_2, NO, NO_2, LPG) pollution and GPS position information. The system comprises of the main solar powered outdoor unit and the wireless indoor console. Operational information and measured parameters are transmitted wirelessly to the indoor console for monitoring and preliminary assessment. Data is stored in CSV format on the main unit.

Figure 8: Environmental pollution and soil monitoring station EPSm VER. 2 (Source: Instrumentation Division NASRDA-CBSS, NSUKKA).

In 2018, the lead author visited many commercial and research farms in the United States of America, and there observed the weather stations presented in Figure 9.

Figure 9: Weather stations observed at some commercial and research farms in USA

8. Smart Farming with Solar Electric Multipurpose Tractor

Recently, the lead author is partnering with a research team from Michigan State University, USA to redesign and adapt a solar recharged single axle electric multipurpose tractor for smart farming in Nigeria. The uniqueness of this system is that apart from being environmentally friendly, not emitting any greenhouse gas to the environment or causing pollution of any sort, the multipurpose electric tractor is easy to operate, more affordable to an average Nigerian farmer, can power both field and stationary post-harvest operations, can power irrigation for a small farm and at the same time can be a source of electricity to light and power one household after the day's work.

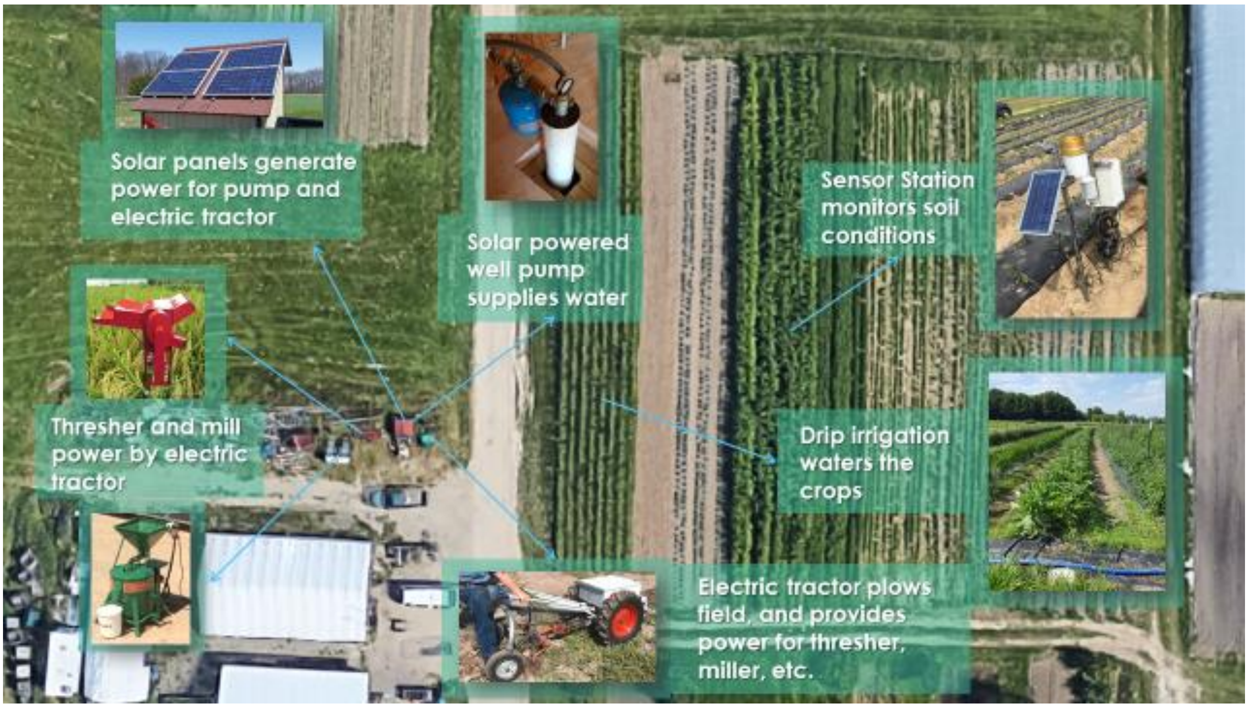

Figure 10: Smart farming using solar electric multipurpose tractor (Source: BAE, MSU)

9. Potentials and Challenges of Mechatronics and Smart Agriculture in Present Nigerian Context

In November 10-15, 2014, the lead author in collaboration with the National Center for Equipment Maintenance, UNN convened a training workshop on Mechatronics Engineering and LabVIEW Software at the University of Nigeria, Nsukka and 37 participants, including Engineers, Technologists, PG students and lecturers, covering the major geo-political zones of the country were in attendance. During the workshop a Group Dynamics was organized, and participants were shared into three groups of about ten each. They were asked to deliberate on the following issues and come up with their recommendations on the way forward. The areas of discussion included the following: (1). Is Mechatronics needed in Nigeria (2). Problem/need based mechatronics curriculum development (3). How do we tackle the problems of equipment and human resources necessary for mechatronics engineering program in Nigeria. Each group had a very fruitful deliberation and at the end, one person selected made a presentation of the summary of their group highlighting the key points and their suggestions on the way forward. Below are the summaries from each group which can largely be related to the context of applying mechatronics for smart agriculture in Nigeria, since the situations and challenges are similar. Also this is like a result of actual survey carried out on the issue, presented as follows:

Is Mechatronics Needed in Nigeria

Mechatronics is needed in Nigeria considering the following:

i. Large population of Nigeria which is about 160 million people (in 2014) is an advantage as a large market where products from various parts of the world are being imported. Most of these products are highly mechatronic in nature, therefore Nigerians need to be trained to be able to grow from being only a consumer to a producer of mechatronic products as well as acquire the capacity to design, develop and maintain the use of such products. It is no longer a gain say that most products and processes commonly used in Nigeria and elsewhere are increasingly becoming mechatronic in nature.

ii. The application of Mechatronics which are very relevant to Nigerian economy should cover the following areas: Agriculture, Manufacturing, Automobile, Household appliances, Hospitals, Education, Security etc.
iii. Considering vision 202020, the industrialization plan of Nigeria, there is need for Nigeria to embrace mechatronics since industrialization in the 21st century cannot be achieved without advanced manufacturing technologies and systems which are highly mechatronic in nature.
iv. A school of thought may think that mechatronics may not be needed in Nigeria because it may lead to unemployment in Nigeria owing to the fact that these mechatronic systems can bring about retrenchment at work places or industries; however human resources displaced from one field could be retained in new and emerging fields of endeavour to acquire skills relevant for the present industrialization and advancement process.
v. Mechatronics is needed in Nigeria especially in hazardous applications such as deep sea operations in oil companies since the economy of Nigeria depends largely on the oil sector.
vi. The transformation agenda of the present government of Nigeria is all about developing Nigeria into a developed nation, mechatronics is a technology that is sin qua non to such a vision.

Problem-Based Curriculum Development

Where do you think we should focus the curriculum for institution that are planning to establish Mechatronics as a department? Mechatronics finds application in the following areas by providing efficient and reliable systems for the production of consumer goods and services. We propose the following as the areas where the Nigerian curriculum on mechatronics should be centered on:

i. Medical science: Artificial limbs for amputees, mass production of drugs
ii. Agriculture/ food production: Mechatronics makes it possible to have intelligent systems that aid agricultural mechanization for sustainable food production. This will help to avoid food importation and thus save foreign exchange.
iii. Mining: Cases of casualties resulting from trapped underground miners in some foreign countries can be prevented by developing smart robots to handle such mining operations.
iv. Automobile: CAD/CAM/CNC gives impetus to the mass production of automobiles. Intelligent robots will help Nigeria realize her dream of manufacturing cars locally. This will in no small way provide employment as well as help revive the economy.
v. Oil and gas industry: Intelligent robots can help to prevent and handle the cleaning of oil spillage that can pose a threat to aquatic as well as human life.
vi. Security: Computer-monitored security systems such as CCTV cameras make it possible to keep close watch on a neighbourhood and the activities of people against theft and other crimes. This helps to forestall ugly situations.
vii. Manufacturing (consumer goods): Mechatronics makes it possible to develop software for the mass production of goods. Manufacturing process from production to packaging can be handled more efficiently by mechatronics.
viii. Military/Defence: Most surveillance equipment for monitoring our borders, seas and air and addressing insurgencies are products of mechatronics.
ix. Food Processing and packaging: canning and bottling can be handled by mechatronics. Drying and storage of agricultural produce can also be monitored by mechatronics for sustainability.
x. Education: Indigenous technology can be developed and sustained through the knowledge of mechatronics. Knowledge acquired from such approach can be used to address existing and emerging challenges in the society.
xi. ICT: Mechatronics systems have reduced the world to a global village. Smart phones, telecommunication gadgets and other communication outfits like road traffic control rely on mechatronics.

xii. Environment and Sanitation: Cleaning of gutters, cutting of weeds, refuse disposal, waste to wealth (even hazardous areas), are activities that a robot can do much more efficiently (almost effortlessly as compared to human effort). This will save cost and time.

Conclusively, graduates of mechatronics engineering will be able to design, operate, maintain and repair mechatronic systems employed in the aforementioned fields. This will make them to be relevant to the country and the world in general.

How do We Tackle the Problems of Human Resources and Equipment for Mechatronics

The problems of human resources and equipment for Mechatronics in Nigeria can be successfully tackled through the following steps:

i. Nigeria should send young engineering graduates and prospective young engineers with evidence of passion and necessary knowledge and intelligence to countries where they can receive necessary training and exposure to train others and to build a strong manpower for industry and research institutions.
ii. Focus should be on producing local equipment and products rather than importing them using available local resources (Equipment development).
iii. To acquire requisite human resources, attention should not be on academic attainments alone, rather it should be with a good blend to functional skills and capability relevant to practical needs problems in the country.
iv. There should be a concerted effort by the government in funding Mechatronics in Nigeria through training and equipping of all institutions offering Mechatronics.
v. Institutions should be mandated to train their manpower in countries with required expertise.
vi. The industries should be maintained as a corporate social responsibility partner with institutions towards Mechatronics development in Nigeria.
vii. Effort should be made to reduce corruption both in government and in our institutions.
viii. More Engineers should go into politics to make changes in government policies that will positively affect engineering development in Nigeria.
ix. Mechatronics based research should focus on solving particular problems in the local environment.
x. There should be emphasis on product development, especially the production of test kits locally.
xi. A very large percentage of educational fund eg TETFUND, PTDF, etc should be channelled towards mechatronics development in Nigeria since Mechatronics can make Nigeria an industrial hub of Africa.

In summary, there are great potentials in exploring the applications of Mechatronics and autonomous systems for realizing smart agriculture in Nigeria; the need or potentials do not only exist for agriculture but also for many other sectors of the economy as aforementioned. This is especially so in agriculture, given the ever increasing global population, increasing pressure on land and water, limited energy resources, climate change, advancements in knowledge, changes in taste, diet, food pattern and preferences; the need to have food not only in the right quantity, but having it in different desired qualities and forms and ensuring safety and health of the consumers. Mechatronics brings the kind of advanced Engineering, technology and innovation that can match the level of sophistication and complexity that the agricultural industry tends to pose with time through the employment of automation, artificial intelligence and robotics for smart farming. Smart farming will no doubt draw the interest and participation of more and more young University graduates to agriculture and farming business. However, among others, some challenges that seem to be outstanding at present is the lack of requisite trained and skilled manpower and basic equipment infrastructure as well as a dare need to customize the mechatronics curriculum to train the kind of human capacity required for Nigeria.

Conclusion

It is therefore concluded that Nigeria should advocate for smart farming and precision agriculture based on the following reasons: some aspects of precision farming can be applied successfully as at present e.g. sensors and measurement systems for land, water, fishery, climate, environment, etc. monitoring and control. GPS and GIS are presently being widely used in Nigeria for positioning and mapping for both natural and unnatural resource management and control. There are many mechatronics and artificial intelligence service providing and small manufacturing SMEs increasingly springing up in Nigeria by very smart young and passionate Nigerian graduates trained in Nigeria, and this brings a lot of hope for future Nigeria, especially for smart agriculture, if well incubated and harnessed. Nigeria is rapidly-gradually developing, quest for advanced technology and applications is increasing for individuals, institutions, government, industry, business sector, etc; and many things not possible or suitable today will be in the near future. Nigeria is part of global technological development and should not be left behind; although Nigeria need not necessarily move at tandem with the developed world.

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