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# Application of Mechatronics in Agriculture: A review

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## Abstract-

Mechatronics has found quite a number of useful applications in agriculture. Agriculture as one of the oldest industries, dating as far back as the nomadic age originally depended solely on human effort, then apprehended animal labour, and then came mechanical advances such as diesel/steam-engine tractors and mechanical tools with hydrostatic power which needed control. The answer to unresolved problems relies on more advances that necessitate the replacement of human intellect to meet the requirements for superior autonomy in more indefinite and unstructured environments. Promising disciplines in this framework include Mechatronics, Large-scale optimization and Complex system automation, and our focus is on the advancement of irrigation system. Some of the applications of mechatronics in agriculture and their processes are discussed to gain insight on the state of the art, advantages and weaknesses of several methods employed.

**Keywords:** Agriculture, Application, Automation, Irrigation, Mechatronics

## 1. Introduction

Mechatronic systems are used in different sectors/fields of application, such as agriculture, automotive, health, lifestyle and consumer products, etc. Current and future mechatronics are developed based on the technological trends required to better and make easier human living and sustain the environment. Mechatronic systems help provide a competitive advantage in a harsh industrial environment [1]. As a result, mechatronics has found quite a number of useful applications in agriculture. Agriculture is one of the oldest industries, dating as far back as the nomadic age. It originally depended solely on human effort, then apprehended animal labour, and then came mechanical advances such as diesel/steam-engine tractors and mechanical tools with hydrostatic power which needed control. The answer to unresolved problems relies on more advances that necessitate the replacement of human intellect to meet the requirements for superior autonomy in more indefinite and unstructured environments. Promising disciplines in this framework include Mechatronics, Large-scale optimization and Complex system automation. Necessity is driving the implementation of information technologies into agricultural technologies, it could be in the guise of a process controller, a machine, or a management and planning system [2].

Technology today plays the role of a feeding hand to agriculture[3],[4]. Elements of Mechatronics, such as actuators and sensors, play vital roles in our farms of seeding, cropping, cleaning, fertilizing and monitoring our vegetation. Sensors are applied in detecting colour, ambient light levels, alcohol levels for ripeness, moisture levels and dangerous levels of



chemicals including insecticides and pesticides. Different mechanisms have also been designed and constructed to aid agricultural processes, for example, robot arms that nurture the roots of plants and revolving machines to seed, collect, and clean produce, and to regenerate the soil [5].

In contemporary, multifaceted agricultural facilities, numerous Mechatronics and embedded systems, such as microcomputers and microcontrollers, are already in application. These autonomous elements are the foundation and building blocks of a modern agricultural complex. The basic of today's modern agriculture is the precision agriculture (PA), where crop production is made more effective using sophisticated control systems. The essence of precision agriculture is essentially the manuring and irrigating by needs and with high precision [6].

Several of the innovations presented to agriculture by the scientific and Industrial revolutions paved the path for a qualitative transformation in the nature of agricultural production. Various helpful effects have been attained by the application and integration of technology in agriculture. It has not just lessened the labour, but it has also decreased the cost of crops by producing massive yield [7]. We discuss several areas where mechatronics systems have been applied to gain insight into the advantages and demerits on the technology for improvement and adventure into new areas.

## **2. Mechatronics in Agriculture: A Review**

### **Precision Agriculture**

In the 1980s, precision agriculture was first applied in industrial manufacturing, it concerns the application of sensors, mechatronics and automation to improve efficiency of monitoring and interference techniques. The dawn of mechatronics and autonomous systems allows us the chance to create a new range of agricultural equipment based on little, smart technologies that reduces waste, environmental impact, progresses economic capability, and increases food sustainability. Also, sensory data obtained by robotic platforms in the plantation provides rich information and insights into yield optimization, improved planning, level of resources needed, and when and where the resources are needed in order to reduce waste and improve yields [8].

### **Animal Production**

In the past decade, animal production has been introduced to a number of innovative technical tools in farms so as to aid decision making, particularly for management, feeding strategies, animal health and fertility. In addition, special electronic systems have been created in order to process the related variables and to provide the farmer with the appropriate tools and alert signals. With the progressions in mechatronics, biosensor technology has great potential for improving animal welfare, health and production efficiency [9].

### **Autonomous Tractors**

Tractors are the toilers of modern mechanized farms. Tractors are used for several agricultural processes. When equipped with the proper riggings, tractors can till, fertilize, plant, spray, weed, mow, haul and harvest. Such flexibility makes tractors an important equipment to be automated. Mechatronics has allowed for the automation of these machines thereby increasing productivity, improving safety, and reducing costs for many agricultural procedures. [10] presented a system for tractor automation in which a task is programmed by driving the relevant routes. The task is then broken down into subtasks and assigned to a convoy of tractors that drive different parts

of the routes. Each tractor is equipped with on-board sensors to detect people, animals, and other large objects in the path of the machine, halting for such obstructions until an instruction is given from a supervisor over a wireless connection.

### **Crop Seeding**

Seeding is one of the major agricultural procedures in a crop cultivation. Appropriate seeds selection, sowing process and acknowledging the agricultural dates has a significant impact on the final yields. Today, with the aid of mechatronics, automated combined tilling-and-sowing machines are available to carry out tedious processes. The machine allows for both ploughing and minimum tillage as well as for concurrent sowing cereals and catch crops. The application of this machine allows for soil preparation and sowing in a single pass. The use of a tilling-and-sowing combined machine will progress the economic and agronomic impacts [11].

### **Crop Monitoring and Analysis**

[12] proposed a using Wireless Sensor Network in order to create a low cost agricultural remote monitoring and controlling system. The sensor network is made up of minute autonomous devices called sensor nodes. The major objective is to monitor and control the environmental requirements of each specific plant. The Wireless Sensor Network is made up of small, low cost wireless sensor nodes. Each node observes, senses and gathers data intermittently and then sends this information to the base station. The system is based on Zigbee which is a low power wireless communication device. A microcontroller serves as the brain of the system which controls all the sensors, activates it and runs them in harmonization.

### **Crop Weeding and Spraying**

[13] presented a robot for agricultural weed control that uses vision systems: a color-based vision system and one gray-level vision system. [14] proposed a multi-functional intelligent machine for automatically removing weeds while also allowing for flexible rate irrigation. This system allows for the weed removal without harming the cultivated crops. Spraying pesticides and weed killers onto fields can be wasteful, and also harmful to the environment. Application of mechatronics provides a smart system which is much more efficient [15].

### **Crop Fertilization**

Soil fertility is very significant factor in determining soil quality, as it shows the degree to which it can sustain crop life. Soil fertility is determined by the amount of macro and micronutrients, water, pH etc., present in the soil. In the case of deficiency, fertilizers are added to the soil in order to maintain high nutrient level. [16] proposed and designed an automated system for the measured addition of fertilizers to soil so as to prevent deficient/excess fertilizers in the soil. The system consists of three main parts: sensors, microcontroller, dispensary system. Currently, there are developments being made in advanced application systems for targeted crop fertilization. Photographs of the plantation are taken via satellite and then decoded to make available data on the state of every part of the plantation. A program for fertilizing the entire plantation will then be created bearing in mind the soil state, type of crop, weather conditions, etc. The program will then be loaded to the control unit of mechatronic dozing device on the tractor. The tractor with the aid of GPS and auto-guidance will then carry out the application of fertilizer [17].

### 3. Related works on Irrigation

Irrigation is the process of artificially supplying water to land or soil. It is used to aid in the growth and development of agricultural crops, revegetation of damaged soils in dry areas, maintenance of landscapes, and during periods of insufficient rainfall [18].

Irrigation is a very indispensable factor in crop farming. Irrigation has always been an ancient practice which has evolved through so many stages over the years, there are various methodologies that have been applied to achieve proper irrigation, the larger the farmland, the greater the need for a better means of irrigation, hence, an automated irrigation system. [19]. An approach to more efficient irrigation and uses of water is the use of soil moisture sensors to control the irrigation process. This maintains a well irrigated field whilst reducing water wastage [20].

An automatic irrigation system is integrated with an Arduino UNO microcontroller that is set and programmed to send a signal to the irrigation system based on the moisture content of the soil. The amount of moisture in the soil is determined with the aid of soil moisture sensor. When there is a change in the moisture level, the sensor sends a signal to the Arduino (microcontroller). With the aid of a water level sensor, the microcontroller confirms that there is sufficient water in the overhead tank and then activates or deactivates the irrigating system accordingly. The designed system helped in improving plant growth, reducing costs, minimizing water wastage and reducing labour [21].

Agriculture requires and uses water in high quantity, this makes water wastage a big problem in agriculture. According to [22] there are a few methods that are used to control excess of water from agriculture such as ditch Irrigation, terraced Irrigation, drip Irrigation, sprinkler System, rotary Systems. The three key approaches of irrigation are surface, sprinkler and drip irrigation. Surface irrigation (flood irrigation) is application of water over the soil surface with the aid of gravity. It is the most common method of irrigation in application. Sprinkler irrigation applies water to soil by spraying water droplets. Drip irrigation (trickle irrigation) applies water to the plants by dripping water slowly into the plants' roots. It is implemented with the use of tubes that deliver water directly to the roots of the plant. This method saves water and prevents the loss of soil nutrients [23], [24].

#### Surface Irrigation

According to [25] surface irrigation is a commonly used method in the irrigation of crops in a field, it involves the introduction and dispersal of water on the soil surface of the field and relies on gravity flow of water through the soil to the roots of the crops. The soil stores water and acts as the medium over which water is conveyed as it spreads and infiltrates. Irrigation water generally penetrates into the root zone during transference and reduction of water at the soil surface. Furthermore, in surface irrigation, water can be applied by a conduit located at an upper elevation of the field. Water may be dispersed to the crops in long parallel strips, in smaller rectangular basins or in small channels between crop rows. Surface irrigation methods can be classified into two - flooding method and furrowing methods. In flooding method, water is made to cover the entirety of the soil but the water used in furrowing method covers just a portion of the soil surface [26]. According to [27], surface irrigation is the cheapest and easiest method, but is usually greatly inefficient as less than 10% of water dispersed is used by the plant. In

addition to the inefficient use of water, surface irrigation can often be labour intensive. Unfortunately, surface irrigation systems are found to be the most commonly used methods of irrigation all over the world [28].

### **Sprinkler Irrigation**

Sprinkler irrigation is an irrigation method which involves the application of water in a way similar to natural rainfall. In this system, water is dispersed by pumping and spraying into the air through sprinkler heads. This allows the water to be broken into small droplets which fall onto the soil like rainfall. The sprinkler heads disperse water uniformly over the surface of the soil, this makes the method efficient for minimal to wide-ranging coverage of land areas [29]. [30] classifies the different sprinkler available into the various types detailed below:

#### **Based on method of water application**

- ❖ Rotating Sprinkler-Impact sprinkler, gear driven, reaction type and fixed head sprinkler, perforated pipe system

#### **Based on portability**

- ❖ Portable system, Semi-portable system, Semi-permanent system, Permanent system

#### **Based on precipitation rates**

- ❖ Low volume sprinkler, Medium volume sprinkler, High volume sprinkler

#### **Based on principle of operation**

- ❖ Whirling sprinkler, Turbo hammer sprinkler, Propeller sprinkler, Mini-sprinkler

#### **Based on movement**

- ❖ Set move irrigation system, Hand move, Tow move, Side roll, Gun type, Solid set system, Continuous move system, Center-pivot, Linear move, Traveler

Sprinkler irrigation method has been adopted in many communities and individuals in small and large scales. This is because this system is readily available, easy to install and provides high water efficiency. Nevertheless, the high investment costs, along with high fuel costs required for running the pressure pumps, constitute a major constraint. This is the common reason why the employment of this system is unsuccessful and discarded [31].

### **Drip Irrigation**

Drip method is a method of irrigation used in conserving water usage in agriculture. In drip irrigation, water is sustained at a constant level as water is delivered to the plant roots, drop by drop. This is essential because it reduces water use and ensures the survival of the crops and avoids damage to crops due to excessive irrigation [32]. This makes drip irrigation the most advanced method of irrigation with the highest application efficiency. This is due to the fact that water is delivered only to the root zone of each crop which is where the water is majorly needed [33]. There are two major ways in which drip irrigation is applied for crop cultivation—surface drip and subsurface drip. With surface drip irrigation, the tubing or pipe is installed on the soil's surface, in a groove, or just beneath the soil surface. However, in subsurface drip irrigation, the tubing or pipes are installed just under the soil. This reduces the sideways movement of the tubing or pipe due to temperature fluxes or wind movement. Subsurface drip irrigation makes use of thick-walled tubing or pipes buried in the soil at a depth below tillage equipment. Subsurface drip system makes the irrigation installations more permanent [34].

As posited by [35] drip irrigation is an effective system of irrigating crop soil directly at the root zone and thus, reduces conventional losses like deep percolation, soil erosion and runoff. In contrast to surface irrigation, drip irrigation is more appropriate and cost-effective if it is applied in dry areas having undulated topography, shallow and sandy soils. As a result the drip irrigation system is today viewed as a solution to many complications in dry land cultivation and for increasing the effectiveness in irrigated cultivation.

The inefficient use and wastage of water that occurs due to the use of surface irrigation has been reduced by the application of drip irrigation method. Furthermore, the environmental problems, such as salinity and waterlogging, encountered during the use of surface irrigation are entirely absent in drip irrigation. Drip irrigation helps in achieving increased efficiency of water-use, increased crop harvests, higher quality products, decreased tillage requirement, and higher fertilizer-use efficiency [36].

#### **4. State of the art on Irrigation Processes**

Soil moisture level can usually be determined via two methods, direct soil sampling method or indirect soil moisture detecting method. The direct method of determining soil water content is not generally applied for irrigation anymore because they require a lot of labour and cannot provide instant feedback. Thanks to technological advancements, soil moisture sensors can be permanently positioned at strategic locations in a crop plantation in order to obtain repeated moisture readings that can be used over time for irrigation management [37].

An automatic decision support system was designed and developed to control irrigation. The major property of the system is its use of constant soil measurement and climatic conditions to accurately determine how much irrigation the crops need. The application of instantaneous data from the soil in a feedback control system makes the decision support system very adaptable. [38].

[39] propose a system to optimize the water use in crop plantation. The system automates the irrigation process by implementing a wireless network of soil-moisture, temperature and humidity sensors. The sensors are placed into the root zone of the plant thereby allowing for the determination of the exact field state allowing for precise regulation and control of water wastage in the field. The monitoring of the system is carried out with the aid of ZigBee and GSM

[40] designed an instantaneous intelligent sensor arrangement for determining soil temperature and moisture content. The arrangement is made up of several sensor nodes positioned all around the farmland and a central receiver connected to a laptop/computer. The sensor nodes are made up of a peculiarly designed circuit board, soil moisture sensors, thermocouples, and a Radio Frequency Identification (RFID) tag that sends information to the central receiver. This is a closed loop irrigation system whereby the intelligent sensor arrangement will resolve the timing and quantities for instantaneous irrigation implementation

[41] developed and constructed a system to automatically obtain and save specific environmental data in crop plantations. These data include air temperature, soil temperature, and soil moisture level. The system makes use of a microcontroller-based circuit in order to

achieve automation. This allows for sensor power, and data storage and retrieval functions. Dependability of data retrieval and storage was found to have an average of 91%, where most lost or bad data occurred during times of severe weather and electrostatic disturbances.

[42] designed a microcontroller based automatic irrigation system to allow for the irrigation of regions of a field where water is needed, while circumventing regions where suitable soil moisture is detected. Each region requiring irrigation had at least one sprinkler head, water dispensing device and a solenoid valve with "on" and "off" state to control the movement of water. The regions had moisture sensors positioned in the soil, which measure and sends the moisture level of the soil to a microcontroller joined in controlling connection to the solenoid valves. The microcontroller, which includes the circuitry and software selectively triggers each solenoid valves on a given irrigation day, starting with the pre-programmed start time and lasting for a pre-programmed time period unless that period is shortened because the moisture sensor for that region indicates that the predetermined adequate moisture level has been obtained.

[43] developed a system to automate water supply for irrigation of home garden and farm fields. It was carried out through the use of moisture and temperature sensors which are installed at root area of the crops. The values detected by the sensors are sent to a base station where real-time data from the field is collated and uploaded to the internet using ESP8266 Wi-Fi module. The station also notifies the user concerning any irregular conditions like low moisture and high temperature. Whenever the detected value is more than the set point the valve of irrigation system is triggered open. Technological advancements as we approach Internet of Things (IOT) makes it possible for the user to continuously monitor the state of the soil.

A SCADA-based system is useful in places where there is adequate sunshine but deficient water to perform the required farming activities. An automated SCADA system that uses a Programmable Logic Controller (PLC) is very significant in agriculture. The system can be energized by a smart solar system with solar panels that target the sun's radiation. The system works using soil moisture and level detection sensors. Soil moisture sensor detects the moisture content, whereas the level detection sensors detects the water level in the water tank. The biggest gain of solar energy is that it is a freely available, unlimited source energy [44].

[45] designed an automatic irrigation system to eliminate the stress of manual irrigation and also conserve water usage. Increased irrigation efficiency greatly reduces the cost of production agricultural products, thereby creating a more competitive and sustainable industry. Furthermore, a microcontroller integrated with sensors should be used to help monitor the soil moisture content and control water usage thereby saving water.

## 5. Conclusion

The agricultural sector is quickly being changed into an industry of key importance that must depend seriously on advanced control systems to manage the growing intricacy of agricultural systems, progressively sophisticated practices are required. The basic of today's modern agriculture is the precision agriculture (PA), where crop production is made more effective using sophisticated control systems. The essence of precision agriculture is essentially the manuring and irrigating by needs and with high precision. Various helpful effects have been attained by the application and integration of technology in agriculture. It has not just lessened



the labour, but it has also decreased the cost of crops by producing massive yield. Some advantages and weaknesses of common irrigation methods were highlighted the insight on the methods can be enhance to develop better processes.

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