Review Article

AUTOMATION IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING

ABSTRACT

During the industrial revolution, agriculture saw a tremendous improvement in the way it was done. For the first time in the history of agriculture, steam and internal combustion engines were used to carry out laborious on-site farm activities, the first milling machines were built, and several other hitherto manually-operated tiresome operations were mechanized. Since then, however, just like in other fields, the industrial revolution has served as a turning point in the way things are done. Continuous research was carried out in a quest for more improvements and developments.

Agricultural machinery has never seen as much improvement as it has in the technological age, which started around the mid-twentieth century. Transformations occurred in the way agricultural machines are being built and one of the most significant transformations is the automation incorporated into machines. Machines were known to make work easier, faster, and more efficient, but not without the full supervision of man. Automation, however, ensures that work is carried out more efficiently by making machines work on their own accord, precisely and accurately, with very little or no human supervision. This research is carried out to show how agricultural machines have been automated in developed countries and to suggest how they can be emulated by a developing country like Nigeria. Nigeria, as a developing country blessed with resources, can rise and become the next great nation by fully harnessing the power of automation in agriculture.

KEYWORDS: Automation, Engines, Machinery, Agriculture, Technology

INTRODUCTION

1.1 BACKGROUND OF STUDY

Agricultural machinery, like any other machinery used in other fields, has gone through a series of developmental stages over the years. Since the inception of time, man has always fought for survival and depended solely on his surroundings, mostly plants and animals. He used everything he could to feed himself. Man, also cultivated plants and raised animals to sustain himself, as his only source of energy was his own.

However, Shearer et al. (2010) reported that man first discovered how to use animal power around 200 years ago, beginning with the growth of US agriculture. In conclusion also added, Manpower, however, is not sufficient for Agricultural Activities. The result was that, on average, man produces about 0.1 HP (0.075 KW), which justifies the introduction of animal power, which is many orders of magnitude greater than that of man. Man harnessed the animal's power, combined with the development of a heat engine ten times more powerful than manpower. Man, now has control over more than 600 horsepower (450KW) of modern tractor power.

Farming and agriculture are critical in our day-to-day activities. The significance is as old as time itself. There are a lot of new techniques and technologies in place to improve the quantity and quality of farm produce. The use of transformative technologies like automation in Agricultural Machineries can make farming and agriculture become much more efficient and highly productive. Automation is the issuing of orders that involves setting tasks for the system, adjusting positioning factors, controlling energy input and output then comparing and analysing the information generated in the system to send out different signals and warnings. Automation of Agricultural machinery helps to save production time, increase the quantity of farm produce, increase economic benefits, improve preservation methods, and improves the quality of agricultural products. Some of the aspects into which automation has found its way include, not limited to weeding and planting which uses robots to effectively carry out the pre-planting and planting operations, harvesting which makes use of sensors-inbuilt robots to visualize and harvest only the right crops, consequently increasing the field yield, capacity and field efficiency, irrigation and remote supervision and control which makes use of drone technology in the aerial survey and supervision.

1.2 PROBLEM STATEMENT

The demand for food and bioenergy is increasing, and with the world population expected to exceed 9 billion by 2050, agricultural production would need to double. To achieve this goal by reducing the enormous pressure agriculture places on the environment, agricultural production efficiency is expected to increase by 25%, taking into account the limited resources of land, water, and manpower. As a result, it is critical that the agricultural industry moves at a rapid pace to ensure that supply meets demand (Jakasania & Yadav, 2017). This will entail more intelligent machines performing agricultural tasks rather than mechanical machines that cannot function without full human supervision. To achieve this goal, technology such as automation, which consists of developing and deploying technologies to perform tasks with minimal human intervention, is required.

1.3 AIMS AND OBJECTIVES

The goal of this research is to improve existing knowledge and broaden horizons regarding agricultural machinery automation and the prospects for such automation.

The objectives of the project are;

1. to show areas where agricultural machinery can be automated to enhance productivity

2. to see the importance and benefits of automating agricultural machinery

3. to understand how automating agricultural machinery works

1.4 OVERVIEW OF AUTOMATION IN AGRICULTURE

Automation in agriculture contributes to many industrial advancements and helps farmers save time and money, and calls for high investment in this area of technology. As submitted by (Walker et al., 2016), investment in advanced agricultural technologies has increased by 80% annually since 2012, a great portion of which is majorly focused on Automation with a great interest existing in the new robotic technologies according to Tillett (2003) and Oberti et. al (2016). Numerous elements of agriculture are already being silently transformed by robots and drones. Ranging from mobile robots used in fields and farms for harvesting to the ones used in the processing sections, agricultural activities are getting more efficient. According to (Jakasania & Yadav, 2017), the installation of thousands of robotic milking parlours has already generated a $1.9 billion industry that is expected to grow to $8 billion by 2023. In dairy farms, mobile robots are even more common, automating activities like pushing and cleaning waste. Self-driving tractors with high incorporation of GPS technologies are also being manufactured. In actuality, over 300,000 tractors with automated transmissions were sold in 2016, with over 66,000 units sold annually by 2027 (Jakasania & Yadav, 2017). Interestingly, the use of robots is not limited to the already-developed countries; rather, farmers in developing countries show interest in using robots in their fields for taking care of simple but repetitive tasks such as plucking and picking fruits and maintaining the animals. (Jakasania & Yadav, 2017).

1.5 LIMITATIONS OF AGRICULTURAL MACHINERY WITHOUT AUTOMATION

There are a number of limitations associated with agricultural machinery without automation, which include increased quandaries, power dilemma, obsolescence of machines. Many agricultural producers use large machinery to reduce labour costs and improve operational timeliness. Pesticide application errors associated with larger equipment result in overapplication, reduced yield due to crop injury, and poor pest control. According to a recent study, manually operating a 24.8 m boom (5 control sections) resulted in an average over-application of 12.4% across a wide range of field shapes and sizes (Luck et al., 2010). Over-application increases with boom section width as operators try to control boom sections manually.

Problems associated with off-rate application errors are also results of the use of larger equipment, as increased boom widths result in greater velocity, pressure, and height variations across the spray boom. Previous research has indicated that off-rate errors resulting from turning movements on a sprayer with a 24.8 m boom could affect between 3% and 23% of fields (of a variety of shapes and sizes) receiving an application rate beyond ±10% of the target rate (Luck et al., 2010).

Speaking of power dilemma, the trend has always been higher machinery when using equipment in the production of grain crops. To effectively utilise the power produced by the engine, the tractor must be adequately ballasted. To achieve the best possible performance and fuel efficiency, tyre inflation pressures are reduced to the bare minimum because of the soil-tyre interface. As stated by Scott et.al, The dilemma in Europe is that tractor manufacturers must work within the 3.0 and 3.5 m transport widths, thereby limiting tyre spacing and/or section widths.

More importantly, machine life and obsolescence pose a great limitation to non-automated agricultural machinery. obsolescence is when the service of an object is no longer wanted even though it may still be in good working order. In short form, obsolescence occurs when newer technologies emerge, and then older technologies cease to be used. ASABE (2009) lists the anticipated life of agricultural tractors at 10,000 h. However, some diesel engine manufacturers boast of the development of million-mile engines. We can never fully utilise the capacity of machines produced by manufacturers because with the rate at which new technologies are developed, older technologies become obsolete prior to the end of their physical life.

1.6 AREA OF APPLICATION OF AUTOMATION IN AGRICULTURAL MACHINERY

Research has proven that a number of agricultural machines and equipment have already experienced a substantial amount of automation and are moving from the usual automatic guidance of today to the fully autonomous field robots of tomorrow. Some of the areas of advancement include but are not limited to automatic vehicle guidance and steering system, automated harvesting, machinery coordination, machinery communication and data structures, and automated turn management (Shearer, et.al 2010)

Another area advancing swiftly is agricultural robotics with vision ability. In organic farming, for example, robotics tools with vision capabilities have been used successfully for a while. These tools aid in mechanical hoeing, follow crop rows and detect weeds. These cutting-edge robotic tools' subsequent generation is currently beginning to be used commercially. (Jakasania & Yadav, 2017). An example of this is the orchard intelligent weeder automation program design (Xiong et al., 2018).

The domain of guidance and steering control has received appreciable improvement with the introduction of automation technologies into them. These systems use GPS-based navigation or technologies that position the vehicle in relation to the crop to precisely guide vehicles while requiring little driver input.(Lipinski et al., 2016; Thanpattranon et al., 2016). One of the main objectives of automatic guidance is the elimination of overlap during planting, spraying,fertilising and harvesting, which consequently reduces input cost and improves machine efficiency (Hameed et al., 2016; Antille et al., 2018b). And according to ('Autonomous Technologies in Agricultural Equipment, 2019," these systems have been available for about 20 years, although depending on the positioning technology being employed, varying degrees of positional precision have been recorded. Additionally, they vary in the degree of control, which can be anything from steering-wheel attachments for automatic control to fully integrated automatic control, as well as light-bar guidance for operator control.(Han et al., 2004; Taylor et al., 2004).

One leading company in the manufacture of machines with these systems is John Deere. With its AutoTrac product, which makes use of NavCom's StarFire GNSS (Global Navigation Satellite System) navigation system, John Deere provides guidance and steering control. The StarFire system provides a variety of positioning accuracies that can be chosen dependent on the application and is compatible with local RTK (real-time kinematic), which permits 2.5-cm positioning precision, or satellite-broadcast correction information. (Han et al., 2004; Taylor et al., 2004).

It should however be noted that these machines still require some amounts of human interactions, although very minimal, and hence more efficient compared to the traditional machinery that require full interaction and total supervision. Different navigation issues must be considered in light of the likelihood that numerous completely autonomous vehicles may operate in a single agricultural field in the future. (Blackmore et al., 2009)

Another aspect of agriculture that has experienced the touch of automation is harvesting. This particular activity done in the traditional way is prone to low efficiency, however, the introduction of automated harvesting is one turning point in the way it's done. The harvesting operation is gradually transitioning from the traditional ways of harvesting using crude equipment or agricultural implements where enormous losses are recorded to the automated harvesting systems, with higher precision and hence efficiency. One of the most important advancements in harvesting technology over the past 20 years has been the use of yield monitors (Shearer, et.al 2010). These technologies are continually improved to give information about moisture content and yield of crops during harvest operation and to accurately provide information to pre-processing units.

These systems have incorporated vision-enabled facilities to detect the quality and ripeness of crops and to separate diseased crops from healthy ones. One way overall harvest efficiency can be improved is by increasing the quantity of healthy and quality grains harvested while reducing grain loss (Shearer et al., 2010). With these automated harvesters, harvesting operations increase in efficiency. Some manufacturers also incorporated automated guidance systems and steering systems into their machines to enable them to move through stalks. John Deere and New Holland are two of the leading producers of automated harvesters (Shearer, et.al 2010).

Precision Agriculture-Based technology is another important area where agriculture has been greatly improved. The precision agriculture technology system has been refined using information technology to support crop science, agronomy, soil science, plant protection, resource and environmental science, intelligent equipment and automatic monitoring, decision support, etc. The system creates a crop yield distribution map, a crop management database and growth and development simulation model, a crop management assistant decision system, and a crop management prescription map using agricultural machinery intelligent equipment technology. (Xiong et al., 2018)**.**

1.7 SOME EVOLVING AUTOMATION TECHNOLOGIES

In order to fully achieve automated agricultural machinery, new technologies are essentially needed to be put in place. Some of these new technologies include but are not limited to wireless communications, positioning systems, ground knowledge of data structures and algorithms, with their applications, and automated guidance.

Wireless communications stand at the heart of modern automation systems, in contrast the wired which require both high cost of resources and their maintenance. The capability to transfer data wirelessly can help monitor the working statuses of agricultural machineries and allow the reallocation of tasks dynamically in the event of malfunctions. As stated by (Scott et.al) For large-scale high-tech agricultural operations, establishing vehicle-to-vehicle and vehicle-to-office communication is becoming imperative to manage the logistics of the tasks and to ensure the safety of the machines working in the field. Cell GSM, Wi-Fi, WLAN and Wireless stand-alone modems are typically used for vehicle-to-vehicle and vehicle-to-office communications.

An essential aspect of automation is sensing. Sensing technology is achieved with sensors. It entails accurately and promptly discovering signals. The use of space-based positioning systems is an effective sensing technology that is used in the machine automation field. As stated by Scott et.al Advancements in sensing, communication and control technologies coupled with Global Navigation Satellite Systems (GNSS) and Geographical Information Systems (GIS) are aiding the progression of agricultural machines from the simple, mechanical machines of yesterday to the intelligent, autonomous vehicles of the future. The benefits of GPS, specifically in the agricultural industry, have been well documented as they have progressed from point location mapping (soil sampling or yield monitoring) to real-time equipment control (auto-steer or map-based automatic section control) (USCGNC, 2010)

Data structures are also an important technology needed to be put in place in order to achieve automation in agricultural machinery. It involves the transfer from the farm office to Agricultural machinery on the field and back to the farm office. The need to reconcile data is driven by map-based applications. Farm managers have data transfer needs that range from moving prescription maps from the farm office to agricultural machinery and then returning field operations verification files along with sensor data for summarizing crop health and performance to the farm office. Prescription maps direct where and how the inputs will be applied to crop production systems.

An attempt to coordinate data transfer has been proposed and adopted by Macy (2003) and is termed the Field Operations Data Model (FODM). FODM is based on three components: a description of field operation, a framework, and a general machine model. Field operations are described using one of four models: whole-field, product-centric, operations-centric, or precision agriculture. The FODM framework is object-based, which includes resources (people, machines, products, and domains) and operation regions (space and time). Data logged to summarize field operations can either be infrequently changing data (ICD) or frequently changing data (FCD).

To autom**a**te agricultural machines like tractors and other mobile engines, automated guidance must be incorporated. As stated by Scott et al. Two basic types of automated guidance systems are typically used today by producers. The first system consists of a steering actuator that is mounted to the tractor's steering wheel. The second system is integrated into the tractor's steering system and utilizes a control valve to actuate the hydraulic steering cylinder directly. The overall accuracy of these systems relies heavily on the type of GPS technology used (RTK GPS provides the highest accuracy) as well as proper installation and setup.

1.8 CONCLUSION

Agriculture automation is a growing field. To support the farming system based on small intelligent machines, a whole new mechanization system may be created using the research technologies currently available. Several technologies have been developed and are used as building blocks for fully automated crop-row guidance. Fibre-optic gyro sensors, GNSS, and accelerometers are examples of devices that have been used to determine position and orientation. Rotary encoders were used to measure the steering angle, and proximity sensors were used to observe the clutch and brake positions. Geometrical data structures were used to compute an origin-to-destination path. (Almeida Bessa et al., 2015; Bechar and Vigneault, 2017).

However, in a developing country like Nigeria, little progress has been made toward the automation of agricultural activities.

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