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Monitoring and Control Systems in Agricultural Machineries and Equipment with a Low-Power Smart Antenna System

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ABSTRACT

The agricultural industry today has been highly dependent on modern technologies such as automated agricultural machinery and equipment which are replacing the tedious tasks done by humans. The advancements in agriculture have been made successful through the continuous development of new systems and technologies and it has become an essential component for these technologies to be part of the next generation of animal and plant factories. In the future, the world is expected to have more people and more demand and consumption of the earth’s natural resources and materials. The challenge here is to reanalyze how agriculturally based systems can help meet the needs of the society. Also, as it moves away from the sophisticated manual process of doing farm work like planting, harvesting, fertilizing, etc. we move towards the automation of agricultural vehicles to help the farmers work efficiently and systematically.

Key words: Modern Technologies, Agricultural Machineries, Control Systems.

1. INTRODUCTION

In recent times, technologies in agriculture have been emerging specifically intelligent sensor techniques, and have gained popularity [1]. The advancements in agriculture have been made successful through the continuous development of new systems and technologies. According to Sigrimis, et. al., (2001) the agricultural industry must be dependent on advance control systems and computer integrated management to be more efficient [2]. It has become an essential component for these technologies to be part of the next generation of animal and plant factories.

Today’s agribusiness industry has been highly dependent on modern technologies such as robotics, automation, and computer-based systems that are replacing the complicated tasks done by humans, with better performance in most cases. Sophisticated methodologies are needed to aid with the increasing complexity of agricultural systems. Li, Zhang, et al., (2019) states that it is necessary to update the technology to achieve sustained agricultural growth [3]. Improving the efficiency and effectiveness of the operations of the agricultural enterprises followed by the consistency and quality of the products is one goal that should be achieved by agricultural companies.

There have been numerous problems in agricultural engineering that involves drainage and irrigation systems, crop scheduling, and the optimization of different types of biosystems. Most likely, these problems occur due to the lack of agricultural technologies that help monitor and control these systems or types of machinery. The article also stated that control systems were used to optimize the growth of their crops during the seedling stage. Furthermore, robotic advancements and machine vision were hailed as promising technologies for the future of the agricultural industry [4,5].

As time moves on, the world is expected to have more people and more demand and consumption of the earth’s resources and materials. Because of this, the concept of “sustainability” is being integrated into social, economic, and technological issues to address the protection of the environment and the development of the economy. The challenge here is to reanalyze how agriculturally based systems can help meet the material needs of society. Besides, control management systems and information systems will play an important role in ensuring their efficient execution.

2. BACKGROUND OF THE STUDY

The first people in history evolved, from hunting and gathering to farming. During those early years of development, the people mostly relied on their bare hands, and sometimes aided by sticks and stones. Tools evolved as man evolved, from knives to scythes to plows and even their way of taking care of crops. These dominated the agricultural world for thousands of years. During those times, these early people worked in agriculture because each family could barely raise enough food for themselves with the limited technology given at that time. With the revolution of technology, the world population also grew, demanding more food, faster production, and better quality.

With that said, machines were made to get the job done as quickly as possible. In the modern world, being fast would not suffice. The products now need to improve frequently at the same time provide the best quality. With the application of modern monitoring systems and control systems, being quick and having a high quality can be attained at the same time. Having said the technology will monitor defects and other things that would require professional modifications and control systems will make the job easier, more efficient, and as fast as possible. Ensuring the best quality of products and food will help other businesses grow due to the absence of sickness and other health issues about food consumption.

Businesses and other sciences need to grow to help and continue the technological revolution not only in the agricultural world but also in technology in general. From the application of different pesticides and its needed timing to the health of different crops, these are all needed to be monitored to ensure the best quality before reaching the market. These are all possible with the continued study of the agricultural engineers. These people specialize in processes, power systems, and machine design to help the production system as efficient as possible keeping the quality at its best.

3. STATEMENT OF THE PROBLEM

The world's population continues to increase and the demand for sustainable products goes up with it. Ideally, the advancements in production and its technology will be at par with the speed of the increase in population but with the lack of efficient monitoring and control systems, productivity will not be able to progress at the same rate as population. Also, as the technology of farming and everything related to it evolves, it is ideal to be able to improve the farmers or operators to work as if not, more efficient and sustainable process.

In today's market, there are news articles and evidence that the production sometimes suffers, and farmers are forced to provide products with poor quality. According to an article in 2015 by inquirer.net in the Philippines, there have been cases of rice being fake and health experts have warned that consuming such products can be lethal and if not, can damage the digestive system. Once technology advances in the agricultural world, farmers will not be forced to do such things and will provide farmers a secure source of income.

4. SIGNIFICANCE OF THE STUDY

The advancement of agriculture technology will help improve the farming system and at the same time will minimize the hazards in the agricultural world. Having an efficient system that will be able to provide farmers security in production and monitoring sensors that will help minimize the hazards in their working environment will help production become sustainable and keep up with the population demands. According to an article by Farm Management, agriculture, having a great impact on the livelihood of people and farmers and feeding people all over the world, it is a need to improve its system's efficiency and productivity to ensure that consumers will be healthy and other business prosper due to the absence of sickness and other food-related problems.

Improving the production process does not focus solely on being able to provide for the generations then and generations to come. According to Farm Management, implementing technology to agriculture means ensuring that the products are to be in good quality by the proper application of herbicide, pesticide, fertilizer, and seed improvement.

5. DESCRIPTION OF THE SYSTEM

A feedback crop simulation system is advantageous for crop production forecast and for investigating their growth. The monitoring feature of this system improves its ability to collect data and provides the ability to accurately display the crop's growth stage because of the real-time monitoring feature. The model is continuously corrected during the whole lifecycle of the crops until the simulated data matches closely with the real data. In addition. This information shall be used as the simulation's input [6].

The system uses two methods for yield prediction, the first is based on the growth model while the second is based on crop monitoring through the technology of image processing. The figure below shows the simulation of the system. The block diagram of the simulation of the system is shown in Figure 1.

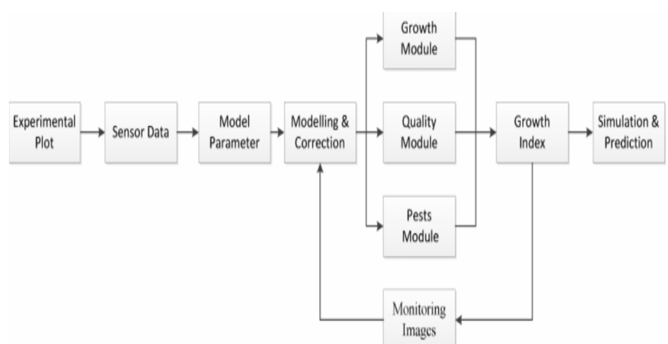

Figure 1: Simulation of the system

6. METHODOLOGY

Alter the design trends of the vehicles to prevent soil compaction and its effects. The process flow chart of the system is shown in Figure 2.

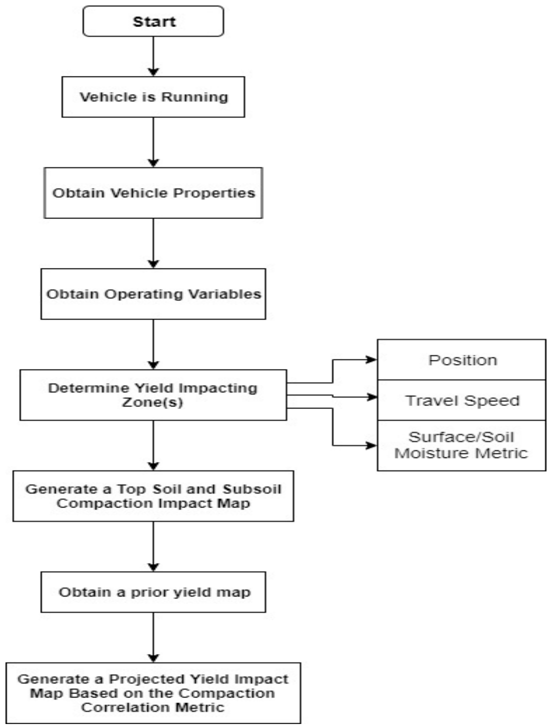

Figure 2: Process Flowchart of the System

To develop an agricultural monitory and control system in types of machinery, the hazards and consequences must also be considered. From the studies mentioned in the design considerations, vehicle characteristics and habits are identified, and in future projects, they must be eradicated. According to Kou & Wu (2018), modeling agricultural machinery must consider the following:

1) *Acceleration.* The study implies that sudden accelerations harm the engine of the machinery. It is implied that taking off like a shot would not just use a significant amount of gasoline (conventional vehicles) but would also be hard on its engine.
2) *Operation*.
3) *Braking.* According to the study, sudden breaks do a lot of damages to the machinery. This is due to the rate of change of acceleration during the deceleration process.
4) *Idling.* When the vehicle is in idle mode, the engine is still working, and the sound of the engine is much louder than a stalling state and less than the working state. With this, the vibration also concentrated on the soil that the vehicle is at.
5) *Booming Throttle.* This practice is a bad habit only when parking, according to the study. It is where the sudden change of engine sound intensity and vibration happens as well.

Emerge with ICT (Internet Communication Technologies) and/or IOT (Internet of Things)

According to a study by Bochtis et al. (2018), automation and communication technologies like geographic information systems, wireless networks, GPS, etc. have brought noticeable improvements in the system's productiveness, which offers the advantages through applications such as sensing, data mining, and analytics [7]. Autonomous machines and other robotic technologies can be the next step towards advancement in agricultural systems' productivity. Although technological advancements are for the betterment of the community, there are still socioeconomic factors that need considerations. These are factors that influence the farmers' ability to purchase or maintain such systems[8]**.** Wireless sensor networks in greenhouses can be a great help to monitor the temperature, humidity, and light. A study by Rodrigues et al. (2017), has designed and implemented an agricultural environment data monitoring system that could transmit the gathered information to the cloud [9]**.** The researchers have also developed a predictive feature to analyze the data being recorded and use the information for future analysis and other maintenance purposes.

7. REVIEW OF RELATED LITERATURE

The intelligent control system of agricultural machinery engine is a paper by Xin, Kaikang, et. al. (2019) [10]. They talked about how the vibration of agricultural machinery damages the machine. This vibration is caused by high frequency and high amplitude oscillation that occurs continuously lowers the life span of the machine. The researchers realized that to optimize mechanical products to have a better design and structure, these vibration levels must be reduced. As the technology of agricultural equipment develops, farmers are demanding to have quality agricultural machines that are comfortable to use at the same time. Thus, it is necessary to control the vibration caused by these machines. Through research and experiments, they were able to conclude that the vibration strength of agricultural equipment can be improved using a double-layer vibration isolation system in a high-frequency range.

A study by Li, Xu, et al. (2019) talks about the Development of agricultural machinery with an automatic navigation system [11]. They developed agricultural machinery that has a built-in automatic navigation system to have a large-scale automated agricultural operation. The navigation system has a wireless communication unit, steering control device, terminal device, and a steering wheel control as a method for positioning. To generate the instructions, the equipment makes use of a computer to help make the decisions in navigation. After performing a series of system tests and analyses, the vehicle terminal software that they have developed was able to have real-time communication, store, and process data, and was able to display the outputs through an interface.

The Autonomous robotic weed control system is a journal article written by Slaughter, Giles, and Downey (2008) [12]. They mentioned the need for automating one of the few tedious and unmechanized tasks in agriculture, which was weed control. They mentioned that this machine will help remove farmer's dependency on chemicals like herbicides. As a result, sustainability is enforced and the harmful effects to the environment are reduced. While the use of herbicides to control weeds was found to be effective economically, it is not so friendly and beneficial to the environment. After conducting a considerable amount of testing and research, the researchers were able to demonstrate the robotic weed control and it turned out that the proposed machine was able to precisely position itself to target weeds. Consequently, they were able to help reduce hand labor by farmers and the use of harmful chemicals like pesticides.

Another application of control systems in the field of agriculture is a low cost temperature control system for greenhouses. The paper, which was written by Li, Luo, et, al. (2009) [13] talks about a programmable integrated circuit that is capable of temperature control. The IC sets only one control point for the temperature and tries to maintain a constant temperature. While there were already existing automatic agriculture systems at that time, those were not suitable in their place in Hubei, China. The researchers also mentioned that the use of highly automated temperature control systems are only suitable for large scale farms and would cost a lot. With the 16-pin integrated circuit that they developed, temperature detection and switching control could be possibly done at a low cost and by a simple circuit connection. After a series of research and testing, their proposed system for a greenhouse design has proven to be low cost, accurate in controlling the temperature, convenient, simple, and can easily be positioned anywhere in the greenhouse, They also mentioned that their system can also be used in different aspects that needed temperature control other than for agriculture.

A study conducted by Kadage and Gawade (2009) [14] entitled “Wireless Control Systems for Agricultural Motors” highlights the reliability of automated systems that have control systems. The paper states that the high accuracy and reliability are easily achieved by automated systems since they have little to no manual operations. The food shortages in India has motivated farmers to explore and find better methods of irrigating and cropping the fields. While only being limited to electric pumps during that time, there were no systems with wireless control making it difficult for farmers to save water and electricity. Because of this problem, the researchers developed a system that controls induction motors using the SMS technology of mobile phones. This helps track and detect water levels, overload, and temperature. By using this method to control motor operations, the system came out to be safe, cost-effective, and helps reduce manual working time through the remote mobile monitoring process using cell phones.

The Design and Performance of a steering control systems used in agricultural tractors is a paper made by A.P. Julian [15]. The author talks about the analysis and evaluation of a guidance system for an automatic tractor. The process involved having to rapidly scan the outputs from an ultrasonic pulse-echo transducer to locate the change of height. Furthermore, the stability of the system required to mathematically analyze and justify the control systems. Through the experiments, the non-linear simulation of the system was able to provide an accurate image of how the low-speed vehicle control systems performed. Overall, the vehicle was able to respond in the agricultural environment similar to those that were obtained from the test track and can be useful for steering control and ANN [16].

Another study regarding the development of agricultural automation was prepared by Tian, Wang, et al. (2019). The review states the agricultural automation systems will be improved through computer vision technology [17]**.** This technology will be providing insights and suggestions as guidance to the farmers. The system includes image processing as the “eyes” of the system. The paper focused on six areas based on the study over the past three years: (1) crop growth monitoring, (2) disease control, (3) automatic harvesting, (4) quality testing, (5) automated management of modern farms, and (6) monitoring of the land information utilizing UAV. Through the analysis and conclusion of the study, this prototype soon of the agricultural technology since its versatility feature can be applied to every aspect of the sector’s productivity. The automation and intelligent systems used in this study have the potential to solve some current agricultural problems while contributing to the betterment of the economic development of the agricultural sector of a country.

As the advancement of technology provides for the farmers, operators, and other users, guidance programs and training must also be done to make sure that the technology developed is suited to the community or site it will be used in. Some studies focused on the social effects of these emerging technologies to the agricultural communities in different places. In a study prepared by Zhang, et al. (2017), a rescue system was developed to monitor the machinery operators using machine vision. It is an automatic rescue system that would recognize the inattention of the tractor’s driver, such as distraction or fatigue. The researchers used a Kinect sensor to collect the image sequences and the system will rely on the sequence of actions gathered by the sensor [18]**.** The method used to monitor and recognize the driver’s behaviors was a Hankel-based Kernel Mutual Subspace Method (KMSM). The researchers also experimented offline, where it achieved recognition rates of 91.19% when using similar objects and 96.18% when using different objects. While the online experiment obtained an 87.02% using similar objects and 79.97% using different subjects. With these numbers, the method used for the system satisfied both accuracy and the real-time data monitoring of the operator’s behaviors.

A real-time control system was developed by Wang, Ma, et al (2012) to sense a human motion for agricultural machinery training. The researchers devised a 3D virtual human motion control system utilizing a depth-sensing camera for real-time tracking. The project’s objective is to create a system where farmers and other users can become a virtual human (VH) in artificial machinery driving to get familiar with the basic operations of the tractors and other operations in agricultural machinery[19]**.**

8. THEORETICAL CONSIDERATION

Most agricultural machinery and equipment nowadays are automated and "smart." These characteristics make it possible for the machines to respond and behave according to an input parameter sensed by their sensors. Control systems give these machines a higher level of automation which reduces human intervention.

For an agricultural machine to be automated, it must have a control system that helps control a lot of parameters. But for this paper, we will be focusing on the vibration/noise, temperature, steering, and overall safety control.

The vibration/noise control system helps reduce the vibration and noise that are generated by the vehicle. These unwanted characteristics are detected by an error sensor and are canceled through an adaptive filter [20]. The Control System of Vehicle Speed Suspension is shown in Figure 3.

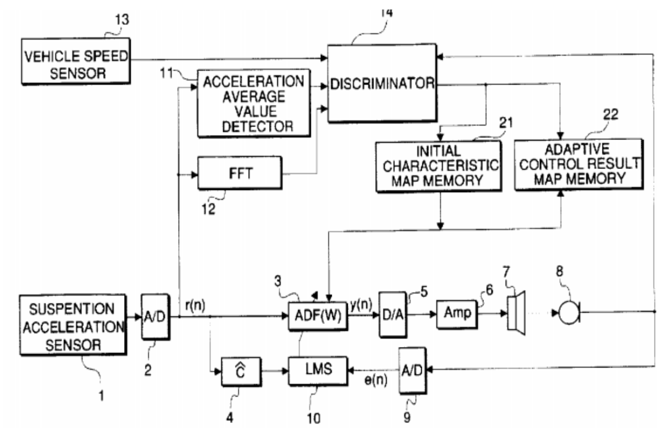

Figure 3: Control System of the Vehicle speed and Suspension Acceleration Sensor

AA temperature cooling control system used in agricultural vehicles is practically important because farmers normally work under the scorching heat of the sun. The figure below shows the air temperature control system used in vehicles. based on the transmission control path from the SAS to the microphone. The canceling sound that was produced from the speaker will interfere with the unwanted road noise and thus reduced. A temperature cooling control system used in agricultural vehicles is practically important because farmers normally work under the scorching heat of the sun. Figure 4 shows the air temperature control system used in vehicles.

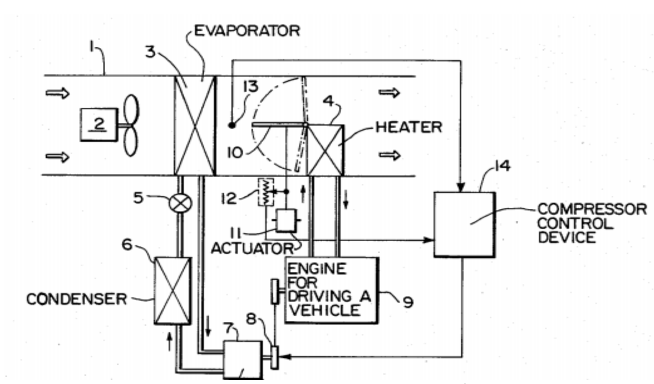

Figure 4: Air Temperature control system design for vehicles

For a vehicle to achieve at least the 1st level of vehicle automation, there must be at least one parameter to be controlled. When using agricultural vehicles to harvest or fertilize crops, it normally moves on a straight line. For the sake of safety, it is best to have a system that controls the steering of a vehicle to help and assist it to stay on the lane. By helping the vehicle stay on the lane and provide steering assistance, the burden on the driver is reduced especially during long drives, through the control device. As a result, the air temperature of the room is being controlled by the system to become equal to the temperature that was set by the user or driver [21].

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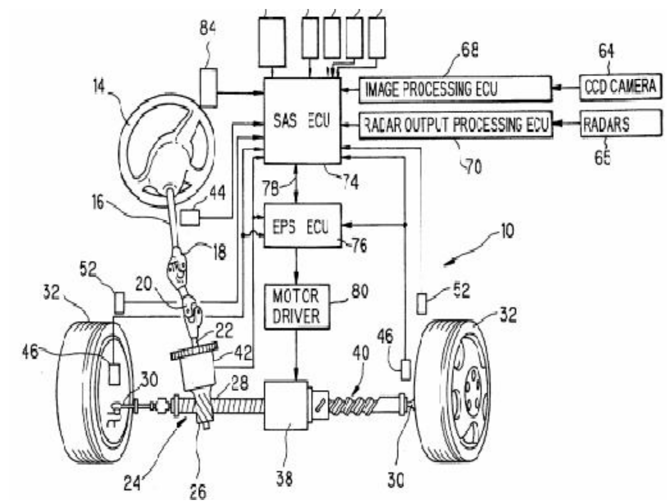

Figure 5: Vehicle Steering Control System

The figure above shows the steering mechanism of a vehicle. It has a CCD camera used to sense the road ahead of the vehicle where its readings are fed to the image processing unit or ECU that analyzes and tries to make sense of the road. The outputs of the radar are also fed through an ECU to determine if an obstruction lies ahead of the vehicle. Finally, the current that is fed through the motor in terms of PWM is determined by another processing unit where its output is fed to a switching device to help regulate the current through the electric motor that produces the torque [22].

According to an article by Naboulsi (2004) [23], a safety control system for agricultural vehicles should have a communication device, at least one sensor capable of reading at least one condition that is related to the operation of the vehicle, and a controller that communicates with the sensor. When these requirements are met, the vehicle can be considered “safe,” at the very least.

9. DESIGN CONSIDERATION

With the rise of autonomous vehicles for monitoring systems, designing and modeling of such machinery should be well-thought-out by considering the needs and factors that might affect the health of the agricultural products or the soil where these are planted. According to the study of Keller, Sandin, et al. (2019), there is a significant increase in soil compaction level, and it is directly proportional to the stagnating crops from the data they have on the historical development of agro-mechanical practices [24]**.** The researchers were able to simulate the data regarding the impacts of the agricultural vehicles on the soil. During the last six decades, the weight of agricultural vehicles has increased, and this had greatly contributed to the soil stress and soil bulk density throughout the years.

Apart from considering the health status of the soil where the crops and other agricultural products are placed and taken care of, the environment has also been a focus with regards to the development of the proper vehicles for monitoring and control systems in agricultural machinery. With this, it is also encouraged by some researchers to emerge with the rising renewable energy technologies present today. A study of Ghoubadpour, Boulon, et al. (2019) [25]states that engaging the agricultural vehicles would not only increase the utilization of electric vehicles but also decrease the amount of greenhouse gas emissions. Going towards the electrification and automation of the present agricultural vehicles provides flexibility in control which results to its full automation capability. The study also indicated that the electrification of the types of machinery and tractors plays an essential role to increase the efficiency and energy independence that would further reduce the costs.

A study performed by Kou & Wu (2018) shows the bad operating habits of a vehicle, such as sudden acceleration, non-uniform operations, sudden braking, excessive idling, and throttle booming. To detect and monitor the mentioned parameters, a smartphone was used, and an Android application was developed to collect the information gathered. The researchers have deducted that in a field, the agricultural machinery works in four stages of operations: accelerating, operating, braking, and making U-turns [26]**.**

10. RESULTS AND ANALYSIS

Through design and theoretical considerations, further research and development regarding the innovation of the monitoring systems and control systems are still needed. According to Antle, Basso, et al. (2017), the next-generation models of agricultural types of machinery could accelerate innovation and achieve sustainable systems [27]. With this, the researchers have designed strategies and models that could meet the needs of a growing community by utilizing a set of Use Cases. The researchers have proposed an implementation that would help improve the existing models and gain more knowledge regarding the machinery and other tools to be used. A demand-driven, forward-looking approach is the principle this study aims to achieve, and the researchers believe that with this, the innovation of the agricultural types of machinery will be for the betterment of the community [28]. Figure 6 shows the comparison of acceleration suring the accelerating stage.

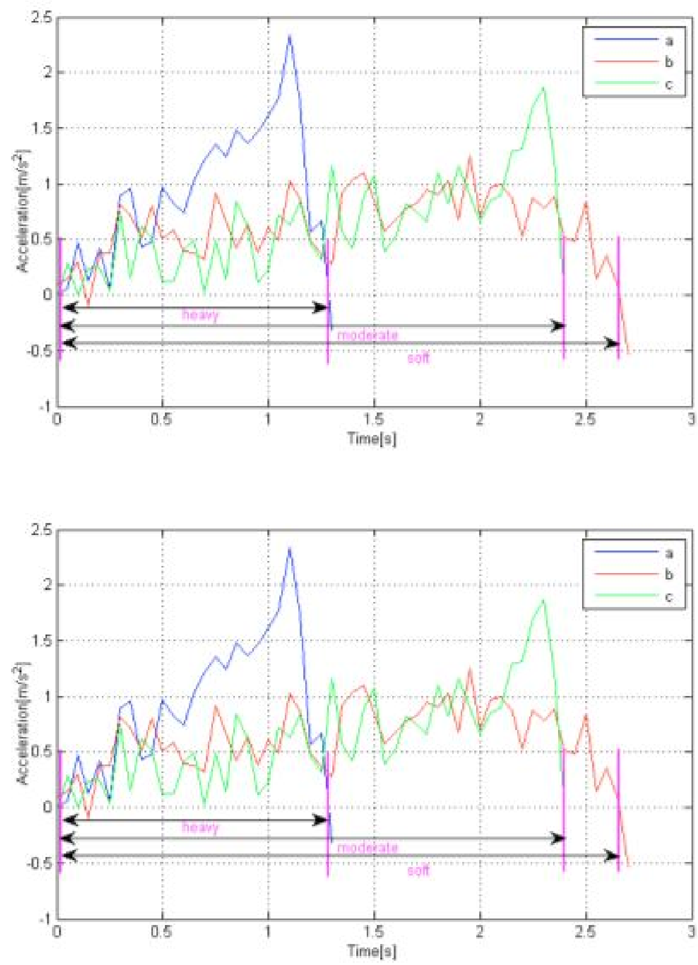

Figure 6: Comparisons of acceleration in accelerating stage

There are also results where technology advancement has historically damaged soil through six decdes. Referring to Fig. 4(a), (b), and (c) show the heavy, soft and moderate acceleration from the same speed at the stage of accelerating, and their jerk are 1.80 m/s^3, 0.49 m/s^3, and 0.78 m/s^3 respectively. The researchers found that the acceleration curve reflects the strengths of the throttle, and so does the acceleration jerk [29]. The output graph shows that further tolerance of bad operating habits would produce more costs.

The costs of soil compaction are significant, especially that it can potentially escalate with climate change every continent is experiencing today. This concludes that there is a need for better knowledge regarding the possible, multiple outcomes once automation takes over a certain agricultural task. With having the proper knowledge regarding the modeling of machinery, the health of the soil can be improved as soon as the awareness of soil compaction is raised among the policymakers. Recovery and mitigation methods can be further implied throughout the development of the agro-mechanical practices.

While there are socioeconomic factors that are needed to consider, according to Mottaleb et al. (2016), there should be a separate, small-scale agricultural machinery to the farmers in Asia [30]. This is because most agricultural countries in Asia are still developing countries, and cost-cutting the said machinery would help the laborers and at the same time increase the returns to land and labor of the farmers. The researchers have emphasized that studying the small-scale agricultural types of machinery would have more impact since most of the agricultural countries are in Asia.

In another study, it is clearly stated that the technology should be compatible with the local environment and must be easily adaptable. According to Mottaleb (2018), although the technology adoption is a key to agricultural development, despite its benefits, a lot of technologies are still unfamiliar to the farmers and locals. With this, researchers around the world must first carefully study the environment and the locals' day-to-day basis before the installation and application of any technology in the area [31,32,33]. To further improve the performance Computer Vision can be used [34,35,36,37].

11. LOW-POWER SMART ANTENNA SYSTEM

The data generated needs to be transmitted. For it to be done a low power smart antenna system was used. The low power antenna has a RF Sniffer. It is a gadget that is utilized to recognize the ideal sign contingent upon the setup and what signs are required. The Antenna framework that will be created in this research will make the RF Sniffer effective by causing it to expend just less force.

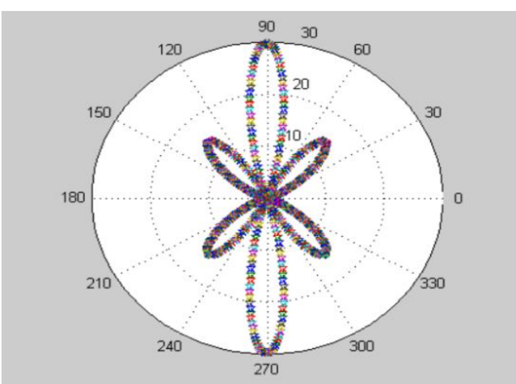

Figure 7: Smart Antenna Radiation Pattern Test A

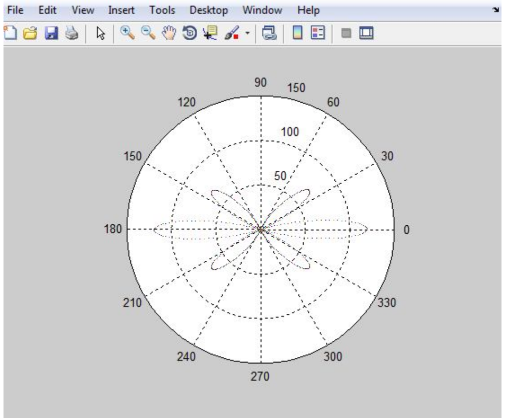

Figure 8: Smart Antenna Radiation Pattern Test B

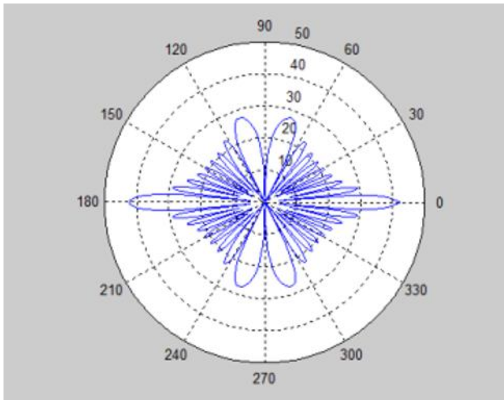

Figure 9: Smart Antenna Radiation Pattern Test C

The framework will be power effective on the grounds that the Antenna that will be planned is rotatable. Which means it can get better addition without any problem. A use of the proposed framework is to expand the effectiveness as far as increase and intensity of RF Sniffers in identifying signals.

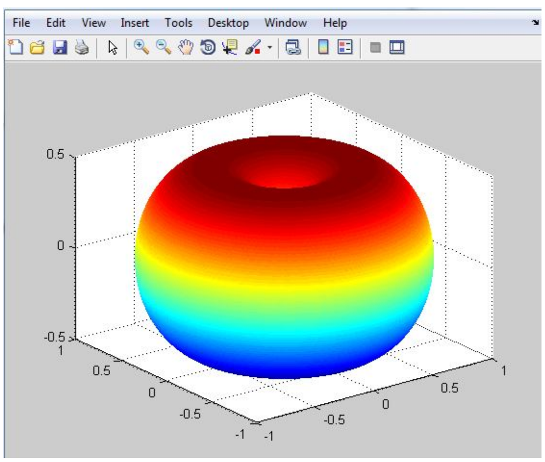

Figure 10: 3D Model of the Smart Antenna

12. CONCLUSION

The development of agricultural technology has brought advanced agricultural types of machinery and equipment in our world. As we move away from the tedious manual process of planting, harvesting, fertilizing, etc, we go towards the automation of agricultural vehicles to help the farmers work efficiently and systematically. The automation and electrification of agricultural machinery and equipment such as harvesting vehicles, tractors, soil cultivators, and other devices that were mentioned on the literature reviews have proven to be more efficient and effective than the traditional agricultural machinery because of their superior data processing methods and other advanced technologies that they implement in their systems.

The application of control systems in the field of agricultural technology has made it possible for their systems to have features such as automatic control, cruise control on vehicles, machine vision systems for crop prediction, IoT connectivity, and many more. In a nutshell, control systems made these agricultural types of machinery and equipment smarter and perform better overall. The technological advancements in this area have significantly reduced the need for manual tasks that farmers perform. Instead, they can operate on these vehicles and types of equipment to do the farming tasks for them automatically.

Going towards the electrification and automation of the present agricultural vehicles provides flexibility in control which results in its full automation capability. Many problems in the field of agriculture have been resolved because of this. The fast-paced technological advancements will likely further improve these systems in the near future to give the farmers a better yield and a better experience in their job. To make communication of data easier, a smart antenna was used as a communication device.

13. RECOMMENDATIONS

The proposed system can still be further improved by adding more features and improving its methodology to make it more effective and efficient when doing agricultural processes. Agricultural vehicles can be improved by making it more environmentally friendly by consuming less gas. Electric equipment and machinery are also highly recommended over the use of gasoline as a source to power these devices. However, that area of technology has a lot of room for improvement to make these electric devices be more superior overall than gas-powered devices. Most importantly, the system will be more sustainable and friendly to the environment. This can be done through further research and study on similar inventions.

REFERENCES

[1] I. Jianmin, T. Syed, F. Chandio, N. Buttar and W. A. Qureshi, “Monitoring and Control Systems in Agriculture Using Intelligent Sensor Techniques: A Review of the Aeroponic System,” J. Sens. Vol. 1, p. 18, 2018.

[2] Y. Hashimoto, H. Murase, T. Morimoto, and T. Torii, “Intelligent systems for agriculture in Japan,” IEEE Control Syst. Mag. Vol. 21, No. 5, pp. 71–85, 2001. https://doi.org/10.1109/37.954520

[3] Y. Hu, B. Li, Z. Zhang, and J. Wang, “Farm size and agricultural technology progress: Evidence from China,” J. Rural Stud. 2019. https://doi.org/10.1016/j.jrurstud.2019.01.009

[4] A. Africa, P. Arevalo, A. Publico, M. Tan, “A comprehensive study of the functions and operations of control systems.” International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 3, pp. 922-926, 2019. https://doi.org/10.30534/ijatcse/2019/89832019

[5] A. Africa, P. Arevalo, A. Publico, M. Tan, “Linear system interconnections, steady-state analysis and stability theory.” International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 4, pp 1395-1398, 2019. https://doi.org/10.30534/ijatcse/2019/56842019

[6] Z. Jiayu, X. Shiwei, L. Zhemin, C. Wei, and W. Dongjie, “Application of intelligence information fusion technology in agriculture monitoring and early-warning research,” in 2015 International Conference on Control, Automation and Robotics. Pp. 114–117, 2015. https://doi.org/10.1109/ICCAR.2015.7166013

[7] D. Bochtis, C. A. G. Sørensen, and D. Kateris, “9 - Advances and Future Trends in Agricultural Machinery and Management,” in Operations Management in Agriculture, D. Bochtis, C. A. G. Sørensen, and D. Kateris, Eds. Academic Press. Pp. 197–208, 2019.

[8] C. Uy, A. Africa, “Development of a cost-efficient waste bin management system with mobile monitoring and tracking.” International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 2, pp 319-327, 2019. https://doi.org/10.30534/ijatcse/2019/35822019

[9] S. Rodríguez, T. Gualotuña, and C. Grilo, “A System for the Monitoring and Predicting of Data in Precision Agriculture in a Rose Greenhouse Based on Wireless Sensor Networks,” Procedia Comput. Sci. Vol. 121, pp. 306–313, 2017.

[10] J. Xin, C. Kaikang, J. Jiangtao, Z. Kaixuan, D. Xinwu, and M. Hao, “Intelligent Vibration Detection and Control System of Agricultural Machinery Engine,” Measurement. 2019.

[11] S. Li, H. Xu, Y. Ji, R. Cao, M. Zhang, and H. Li, “Development of a following agricultural machinery automatic navigation system,” Comput. Electron. Agric. Vol. 158, pp. 335–344, 2019. https://doi.org/10.1016/j.compag.2019.02.019

[12] D. Slaughter, D. K. Giles, and D. Downey, “Autonomous robotic weed control systems: A review,” Comput. Electron. Agric. Vol. 61, no. 1, pp. 63–78, 2008.

[13] W. Li, Q. Luo, Z. Li, and Y. Li, “The design and implementation of a low cost temperature control system for agriculture greenhouses,” in 2009 International Conference on Energy and Environment Technology. Vol. 1, pp. 399–401, 2009. https://doi.org/10.1109/ICEET.2009.103

[14] A. Kadage and J. Gawade, “Wireless control system for agricultural motor,” in 2009 Second International Conference on Emerging Trends in Engineering & Technology. Pp. 722–725, 2009.

[15] A. Julian, “Design and performance of a steering control system for agricultural tractors,” J. Agric. Eng. Res. Vol. 16, no. 3, pp. 324–336, 1971. https://doi.org/10.1016/S0021-8634(71)80024-0

[16] L. Torrizo, A. Africa. “Next-hour electrical load forecasting using an artificial neural network: Applicability in the Philippines.” International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 3, pp. 831-835, 2019. https://doi.org/10.30534/ijatcse/2019/77832019

[17] H. Tian, T. Wang, Y. Liu, X. Qiao, and Y. Li, “Computer vision technology in agricultural automation —A review,” Inf. Process. Agric. 2019.

[18] Y. Zhang, P. Gao, and T. Ahamed, “Development of a rescue system for agricultural machinery operators using machine vision,” Biosyst. Eng. Vol. 169, pp. 149–164, 2018.

[19] C. Wang, Q. Ma, D. Zhu, H. Chen, and Z. Yang, “Real-time control of 3D virtual human motion using a depth-sensing camera for agricultural machinery training,” Math. Comput. Model. Vol. 58, No. 3, pp. 782–789, 2013. https://doi.org/10.1016/j.mcm.2012.12.026

[20] A. Africa, G. Ching, K. Go, R. Evidente, J. Uy. “A comprehensive study on application development software systems.” International Journal of Emerging Trends in Engineering Research. Vol. 7, No. 8, pp 99-103, 2019. https://doi.org/10.30534/ijeter/2019/03782019

[21] R. Fukumoto, S. Oyagi, Y. Yoshida, and R. Akimoto, Air temperature control system for vehicles. Google Patents. 1985.

[22] H. Kawagoe and S. Ishida, Vehicle steering control system. Google Patents. 2001.

[23] M. A. Naboulsi, Safety control system for vehicles. Google Patents. 2012.

[24] T. Keller, M. Sandin, T. Colombi, R. Horn, and D. Or, “Historical increase in agricultural machinery weights enhanced soil stress levels and adversely affected soil functioning,” Soil Tillage Res. Vol. 194, p. 104293, 2019. https://doi.org/10.1016/j.still.2019.104293

[25] J. M. Antle et al., “Towards a new generation of agricultural system data, models and knowledge products: Design and improvement,” Agric. Syst. Vol. 155, pp. 255–268, 2017.

[26] Z. Kou and C. Wu, “Smartphone based operating behaviour modelling of agricultural machinery,” IFAC-Pap. Vol. 51, no. 17, pp. 521–525, 2018. https://doi.org/10.1016/j.ifacol.2018.08.156

[27] A. Ghobadpour, L. Boulon, H. Mousazadeh, A. S. Malvajerdi, and S. Rafiee, “State of the art of autonomous agricultural off-road vehicles driven by renewable energy systems,” Energy Procedia. Vol. 162, pp. 4–13, 2019.

[28] M. Cooper and T. Perez, “Dual-particle-filtering for Recursive Estimation of Agricultural-machinery Dynamics,” IFAC-Pap. Vol. 51, no. 15, pp. 658–663, 2018.

[29] P. O. Skobelev, E. V. Simonova, S. V. Smirnov, D. S. Budaev, G. Y. Voshchuk, and A. L. Morokov, “Development of a Knowledge Base in the ‘Smart Farming’ System for Agricultural Enterprise Management,” Procedia Comput. Sci. Vol. 150, pp. 154–161, 2019. https://doi.org/10.1016/j.procs.2019.02.029

[30] A. Eitzinger et al., “GeoFarmer: A monitoring and feedback system for agricultural development projects,” Comput. Electron. Agric. Vol. 158, pp. 109–121, 2019.

[31] K. A. Mottaleb, “Perception and adoption of a new agricultural technology: Evidence from a developing country,” Technol. Soc. Vol. 55, pp. 126–135, 2018. https://doi.org/10.1016/j.techsoc.2018.07.007

[32] A. Africa, F. Espiritu, C. Lontoc, R. Mendez. “The integration of computer systems into the expansive field of video games.” International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 4, pp 1139-1145, 2019. https://doi.org/10.30534/ijatcse/2019/22842019

[33] A. Africa, “A rough set-based data model for heart disease diagnostics,” ARPN Journal of Engineering and Applied Sciences. Vol. 11, No. 15, pp 9350-9357, 2016.

[34] P. Loresco, I. Valenzuela, and E. Dadios, “Color Space Analysis Using KNN for Lettuce Crop Stages Identification in Smart Farm Setup.” TENCON 2018 - 2018 IEEE Region 10, 2018. https://doi.org/10.1109/TENCON.2018.8650209

[35] P. Loresco, A. Namdala, A. Culaba, and E. Dadios. “Computer vision performance metrics evaluation of object detection based on Haar-like, HOG and LBP features for scale-invariant lettuce leaf area calculation.” International Journal of Engineering and Technology. Vol. 7, No. 4, pp. 4866-4872, 2018.

[36] P. Morales, M. Abugan, J. Olisea, A. Aralar and P. Loresco. “Intelligent Traffic Light System Using Computer Vision with Android Monitoring and Control.” TENCON 2018 - 2018 IEEE Region 10, 2018.

[37] A. Africa, T. Dolores, M. Lim, L. Miguel, and V. Sayoc. “Understanding logical reasoning through computer systems.” International Journal of Emerging Trends in Engineering Research. Vol. 8, No. 4, pp 1187-1191, 2020.