DESIGN OPTIMIZATION AND NAVIGATION FOR AUTONOMOUS GUIDED VEHICLE (AGV) IN AGRICULTURE PLANTATION

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ABSTRACT

The Industrial Revolution (IR) 4.0 is altering the way we communicate, work, and live. However, automation and artificial intelligence (AI) have increasingly the potential to be applied in agricultural plantations. Nowadays, most plantations need humans to collect soil data and require high labor and time consumption. To solve this problem, designing and implementing an automated guided vehicle (AGV) system in the agriculture plantation has high *potential. The AGV is based on plantation monitoring, and sending the data readings to the cloud server without humans is desired. In this project, the LIDAR is used as the main sensor for navigational purposes for travel around the experimental area. For obstacle avoidance, the same LIDAR is applied with the obstacle detection algorithm to detect the human or object around the AGV to prevent any collision. The multi-sensing system, such as the rotary encoder, is the supported sensor to accurately measure the wheel rotation and position. All signal data from the sensor fusion will be processed by the Robot Operating System (ROS) to optimize robot navigation, such as robot movement and data analysis for obstacle avoidance. Some simulations and experiments have been successfully performed in a computer-based simulation and farm.*

Keywords: Autonomous guided vehicle, LIDAR, Sensor fusion, Robot operating system.

INTRODUCTION

Autonomous robotics in agriculture can offer several benefits for farmers, consumers, and society at large. Autonomous robots can reduce the dependence on human labor, which is often scarce, expensive, or unsafe in agricultural settings. Autonomous robots can also work around the clock, in harsh weather conditions, and in remote locations (Aras, M.S.M., et. al 2013). Productivity improvement: Autonomous robots can increase the yield and quality of crops by performing tasks more accurately, consistently, and efficiently than humans. Autonomous robots can also collect and analyze data from sensors to optimize crop management and decision-making (C. Zhang and N. Noguchi, 2017). Autonomous robots can reduce the environmental impact of agriculture by minimizing the use of inputs such as water, fertilizer, pesticides, and fuel (Kassim, A.M., Termezai, et. al 2020). Autonomous robots can also monitor and detect environmental conditions such as soil moisture, temperature, humidity, and pests. Autonomous robots can enhance the social welfare of farmers by improving their income, health, safety, and well-being. Autonomous robots can also contribute to food security by increasing the availability and affordability of food (Lowenberg-DeBoer J., et. al 2020).

However, autonomous robotics in agriculture also faces several challenges that need to be addressed before widespread adoption. Autonomous robots require sophisticated hardware and software components that are often costly, difficult to maintain, or prone to failure. Autonomous robots also need to cope with the variability and uncertainty of agricultural environments, such as terrain features, crop characteristics, weather conditions, and human interference (Gaus H., et. al 2017). Autonomous robots raise ethical questions about the impact of automation on human dignity, employment, responsibility, trust, and privacy. Autonomous robots also pose ethical dilemmas about the moral status of animals, plants, and ecosystems that are affected by their actions (Rose D.C., et. al 2018). Autonomous robots create legal issues about the ownership, liability, and regulation of robotic systems and their outputs. Autonomous robots also challenge existing legal frameworks that are based on human agency, intent, and control (Rose D.C., et. al 2021). Autonomous robots influence social issues such as public perception, acceptance, and adoption of robotic technologies and their implications for rural communities, culture, and identity. Autonomous robots also affect social issues such as power relations, equity, and justice among different stakeholders involved in agricultural production and consumption (Kassim, A.M., Said, et. al 2022).

Autonomous robots in agriculture can be classified into different types based on their mobility, functionality, or morphology. Unmanned aerial vehicles (UAVs): UAVs are flying robots that can carry cameras, sensors, or payloads to perform tasks such as aerial imaging, crop scouting, precision spraying, or pollination (Hunt E.R.Jr., et. al 2019). Unmanned ground vehicles (UGVs): UGVs are wheeled or tracked robots that can move on land to perform tasks such as soil sampling, weed control, harvesting, or transportation. Unmanned surface vehicles (USVs): USVs are floating or submerged robots that can operate on water to perform tasks such as water quality monitoring, fish farming, or irrigation management. Unmanned underwater vehicles (UUVs): UUVs are diving or swimming robots that can explore underwater environments to perform tasks such as aquatic weed removal, sediment analysis, or aquaculture inspection (Xu Z., et. al 2018)]. Stationary robots are fixed or modular robots that can perform tasks such as milking, packing, or sorting in indoor or outdoor settings (Bogue R. et. al 2018).

Autonomous robots in agriculture can be applied to various crops and livestock, such as cereals, fruits, vegetables, flowers, dairy, poultry, or fish. Crop monitoring involves collecting and analyzing data from sensors or images to assess crops' health, growth, and quality. Autonomous robots can perform crop monitoring by using techniques such as remote sensing, machine vision, or machine learning (Kise M., et. al 2019). Crop management involves applying inputs such as water, fertilizer, pesticide, or seeds to optimize the yield and quality of crops. Autonomous robots can perform crop management by using techniques such as precision agriculture, variable rate application, or site-specific management (Zhang C., et. Al 2020). Crop harvesting involves picking or cutting crops from the field or greenhouse. Autonomous robots can perform crop harvesting by using techniques such as mechanical manipulation, optical recognition, or force feedback. Livestock monitoring involves collecting and analyzing data from sensors or tags to assess the health, behavior, and productivity of animals. Autonomous robots can perform livestock monitoring by using techniques such as radio frequency identification (RFID), global positioning systems (GPS), or wireless sensor networks (WSNs) (Halachmi I., et. al 2019). Livestock management involves applying inputs such as feed, water, medicine, or hormones to optimize the welfare and performance of animals. Autonomous robots can perform livestock management by using techniques such as automatic feeding systems (AFS), automatic milking systems (AMS), or automatic weighing systems (AWS) (Bechar A., Vigneault C. et. al 2016).

The design and development of autonomous robots in agriculture involves several steps: problem definition, conceptual design, detailed design, prototyping, testing, and evaluation. The design and development process can be guided by various principles, such as user-centered design, participatory design, or responsible innovation (Mohamed Kassim, A., et. al 2016). Problem definition involves identifying and analyzing the needs, requirements, and constraints of the intended application's users, stakeholders, and context. Problem definition can be done using interviews, surveys, observations, or focus groups (Kassim, A.M., Jamri, et. al 2012). Conceptual design involves generating and selecting ideas for the robot's structure, function, and behavior. Conceptual design can be done by using methods such as brainstorming, sketching, modeling, or simulation. Detailed design involves specifying and refining the robot's components, parameters, and algorithms (Bin Mohamed Kassim, A., et. al 2021). Detailed design can be done by using methods such as CAD, MATLAB, ROS, or Python (Kassim, A.B.M., Yasuno, et. al 2010). Prototyping involves building and testing physical or virtual models of the robot. Prototyping can be done by using methods such as 3D printing, Arduino, Raspberry Pi, or Gazebo (Ribeiro A.F., et. al 2018). Testing involves evaluating the robot's performance, reliability, and usability under different conditions and scenarios. Testing can be done by using methods such as experiments, trials, or benchmarks (Stahl B.C., et. al 2016). Evaluation involves assessing the robot's impact, value, and satisfaction for the users, stakeholders, and society. Evaluation can be done by using methods such as feedback, analysis, or indicators (Kassim, A.M., Jamri, et. al 2012).

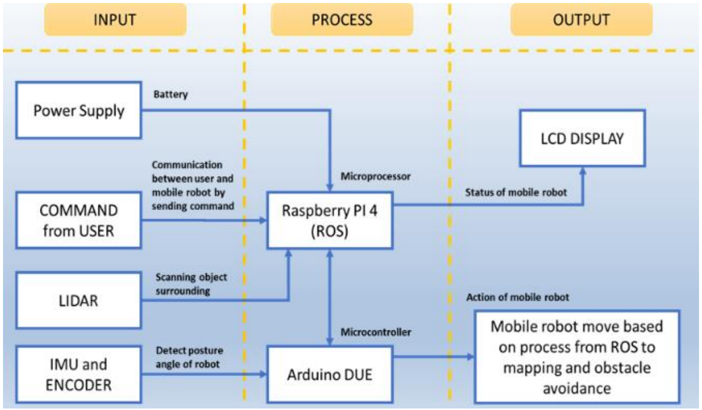
This project explains the design and development of a multi-sensing system by ROS of autonomous guided vehicles (AGV) implemented using an Agriculture Mobile Robot. The multi-sensing system includes LIDAR scanning to avoid obstacles and detect the location, of other support sensors such as a motor encoder to most accurately know the turning of the Agriculture Mobile Robot wheel and position, this all-data signal of the sensor will be processed by Robot Operating System (ROS) and for the next action, like the movement of robot and data analysis on obstacles avoidance. The aim of this study is to implement a variable mission from user-given and varying terrain by the system the Agriculture Mobile Robot will base on missing given to execute it.

MATERIALS AND METHODS

System Configuration

The system configuration of the agricultural machine is the core of the system's framework, as it must command and join countless components shown in Figure 1. The link between electronic sensors, connectors like LIDAR, encoder activators sensing the items, and extra detectors like wheel control units including the microcontroller (Kassim, A.M., Jaafar, et. al 2013). The concurrent connection of these detectors in the AGV is a tremendous stride towards building the machine's aptitude to journey across the region of agricultural areas, which led the agricultural robot to become more powerful and adaptive (Bogue R. et. al 2018). The appendage or chapter of inset in the chip and a regulator for data processing and machine learning operates the ROS panorama with the control AGV of expansion of the entire hurdle of the agricultural scene work (Kassim, A.M., et. al. 2011).

Figure 1. System configuration



LIDAR Sensors for Agriculture Mobile Robot

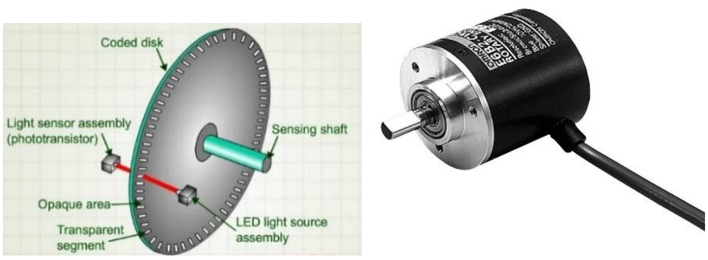
A LIDAR sensor is selected to be built into the AGV as a sensing device for scanning any object surrounding that will be suitable for field use. LIDAR sensors are often used for AGV applications such as detection, mapping, localization, navigation, and position tracking (Kassim, A.B.M., Yasuno, *et. al* 2010). The function of LIDAR sensors are conversion devices that transform microwave echo signals into electrical signals. They use wireless sensing technology to detect motion by figuring out the object's position, shape, motion characteristics, and motion trajectory (Kassim, A.M., *et. al.* 2011). AGV uses the stage of the actions, the real-time facts of motion use the laser mechanism, and then the collected data of the surroundings of the AGV is used to make the latter able to roam in a variety of land patterns, and there is no collision of relay hurdles (Hasim, N., *et. al* 2012).

Figure 2. System configuration

Encoder Actuator: Transforming Motion into Signals

The other sensor used is the encoder actuator, which converts a shaft or axle's angular position or motion to an analog or digital signal shown in Figure 3. The function of it is to convert the angular position of a shaft to an electrical signal that can be read by a controller. The controller can use this signal to determine the shaft's speed, direction, or position (E. Yurtsever, *et. al.* 2020). Encoders are useful for providing feedback and control in many applications. The shaft-things are switching the shaft area in electrical signals that the controller can grasp and act on by controlling the device. For any part of the device, this gives real-time data about the area and direction of the device giving the order on the motion of the device (Kassim, A.M., *et. al* 2012). This is the way; the motion is given to take the form of the people. Or the device should be used for the varied tasks in farming. The place data from the shaft-things is used to follow the path of the farmer in the field. By putting sensors such as shaft-things in the devices, it is possible to be used to back the performance of such a control algorithm. This is the reason the reference path forms the manual control is matched with the present path of the device, and thus, command action is produced (Kassim, A.M., *et. al* 2021). It means that the enrichment is assured in the device that would follow the same path as of the people.

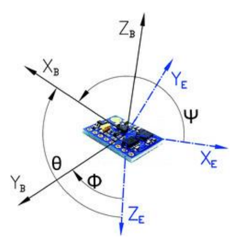
Figure 3. Encoder working principle and encoder example



Inertial Measurement Unit (IMU) Sensor

IMU sensor is the sensor across the majority of gadgets and is intended to give data on motion and orientation of technical gizmos, accelerometers, and gyros are the stuff to implement a device to fix the speed and acceleration across any number of axes shown in Figure 4. Therefore, while also knowing where the device goes and what happens to it, it works on the motion in space (Kassim, A.M., Yasuno, *et. al* 2015). The significance of the sensors in many gadgets is tremendous so motion tracking is one of the major and significant things. Apparently, operating airplanes, drones, agricultural robots, and phones need the thingy indeed, moreover, all the technical gizmos need motion tracking parts to pass the control and operation. Followed by the possibility of mounting multiple sensors, Pecka and Osadčuks implemented the module of robots in agriculture, providing control at a time. It would be impossible to go on with their activity without a module providing real-time data on motion and speed.

Figure 4. IMU sensor and orientation



Robot construction

The robot's base structure is made of aluminium profiles, and it looks sleek and sturdy. It has four wheels that glide smoothly on the ground. The AGV is powered by a DC motor on the rear wheels, which gives it speed and agility while the front wheels are controlled for the turning mechanism Azam, M.A., *et. al* (2021). The robot’s size is optimal for moving between the rows of the fertigation farm without harming the crops.

Figure 5. Mechanical structure 2D drawing using AUTOCAD

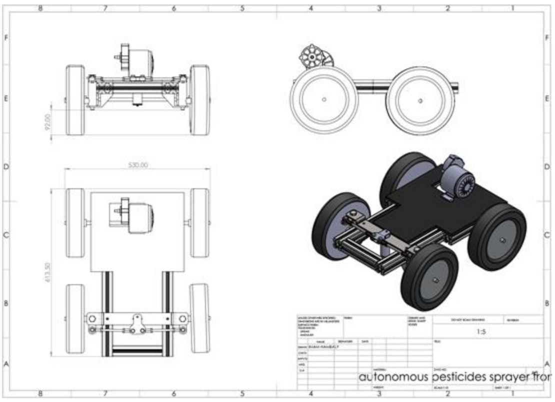


Figure 6. Mechanical structure 3D drawing

Mechanical structure 3D drawing

Fabrication of agriculture robot

RESULT AND DISCUSSION

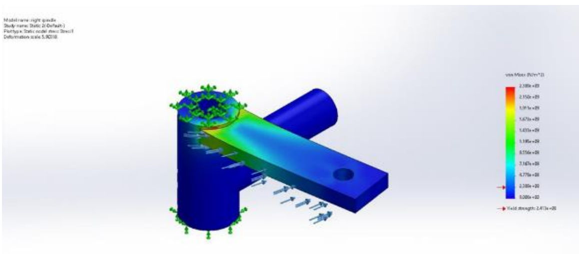
A. Analysis of steering mechanism component by using Solidworks

We performed a static force analysis on the robot’s chassis and steering mechanism using Solidworks software. The simulation results reveal the following insights.

i) Material properties including force on the steering spindle

The arrow in the simulation Figure 7 is the force push angle; when the part receives a large force from the bending force, the simulation diagram will show the strength force from blue to red; if the part is presented as red, it means that the part receives the most strength compared with the other side of the object.

Figure 7. Spindle static stress test



ii) Simulation of steering wheel angle and curvature radius

After designing and simulating part of the agriculture mobile robot with the software Solidworks, run the simulation of the steering wheel angle and curvature radius and see the output of the design in the Figure 8, if it can turn preferred, if not change the parameters of the design.

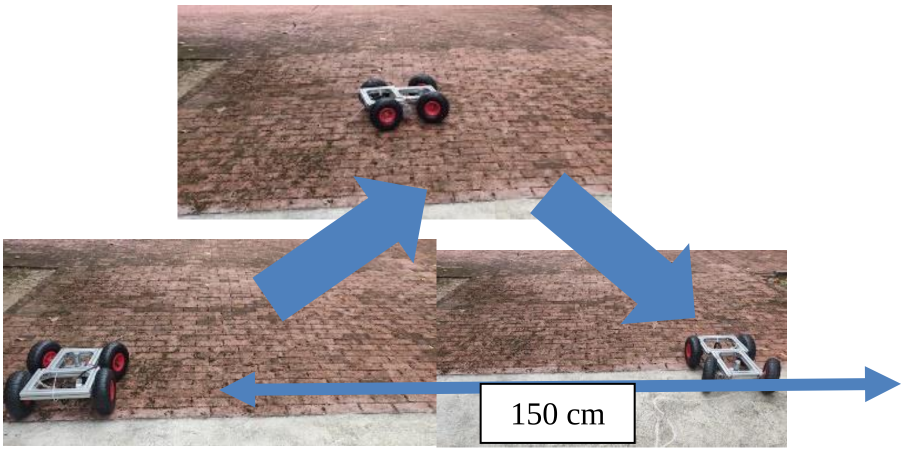
Figure 8. Simulation of steering wheel angle and curvature radius

B. Determining the turning radius of the AGV

To ascertain the turning radius of the multipurpose agriculture robot, a systematic experiment was conducted on a flat surface shown in Figure 9. This experiment aimed to determine the robot's turning capabilities, providing valuable insights for its navigation and operational efficiency in agricultural contexts. The robot, equipped with a wheel-base of 420mm, underwent the following steps:

i. Placement: The robot was positioned on the field, ensuring a stable starting point.
ii. Steering angle setting: Manually, the steering angle was adjusted to +12 degrees and securely locked in place.
iii. U-Turn motion: With gentle force, the robot was pushed forward, executing a U-turn.
iv. Distance measurement: The distance covered from the initial position to the last point of the U-turn was meticulously measured.
v. Data recording: The obtained data was recorded in a tabular format.
vi. Iterative process: Steps 2 to 5 were repeated for steering angles of +16, +20, and +24 degrees.

Figure 9. Real-field measurement of steering wheel angle and curvature radius



C. Experimental results of steering wheel angle & radius of curvature

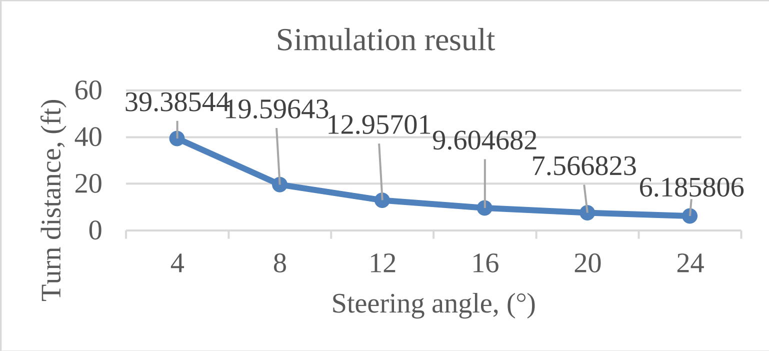
i) Simulation steering wheel angle & radius of curvature in Solidworks

The experimental results from the simulation and real field test can be compared, and the closeness of their output results can be seen. The output data analysis from the Simulation is shown in Table 1. The collected data are turn angle (°), wheelbase (mm), turn radius (mm), and turn distance (ft). The data analysis results are shown in the graph shown in Figure 10.

Table 1. Data analysis for simulation of steering wheel angle & radius of curvature

Turn angle (°)	Wheelbase, (mm)	Turn radius, (mm)	Turn distance, (ft)
4	420	6006.28	39.38544
8	420	2988.455	19.59643
12	420	1975.945	12.95701
16	420	1464.714	9.604682
20	420	1153.941	7.566823
24	420	943.3354	6.185806

Figure 10. Data analysis for simulation of steering wheel angle & radius of curvature



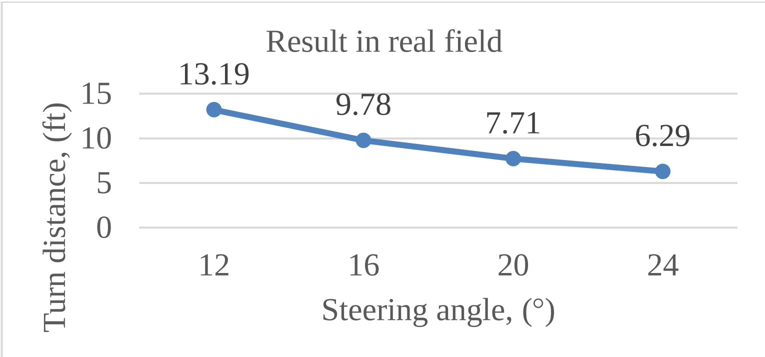
ii) Data collection steering wheel angle & radius of curvature in real fields

The output data testing and collection from the real field test are shown in Table 2. The data include turn angle (°), wheelbase (mm), turn radius (mm), and turn distance (ft). The data analysis results in the graph shown in Figure 11.

Table 2. Data collection steering wheel angle & radius of curvature in real fields

Turn angle (°)	Wheelbase, (mm)	Turn radius, (mm)	Turn distance, (ft)
12	420	2012	13.19
16	420	1492	9.78
20	420	1175	7.71
24	420	961	6.29

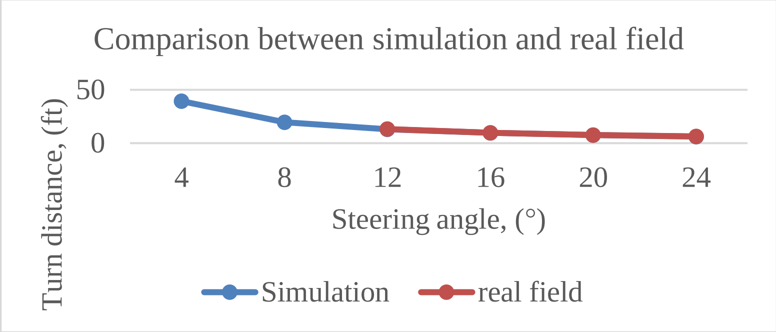
Figure 11. Data collection steering wheel angle & radius of curvature in real fields



iii) Comparison between simulation and real field test result

Figure 12 compares simulation and real field test results for steering angle versus turn distance. The blue line is data from the simulation, and for red line presents a real field test,

Figure 12: Comparison between simulation and real field test result

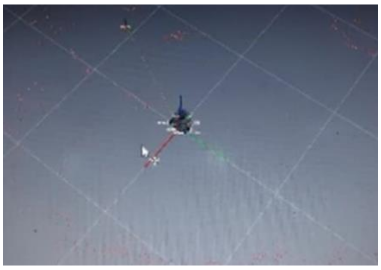


iv) LIDAR sensor outdoor field mapping by ROS

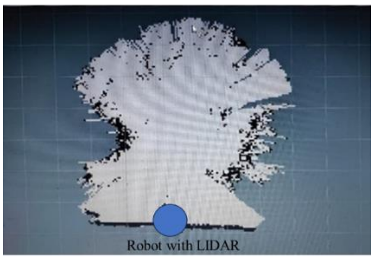
The robot's LIDAR sensor was used for the initial LIDAR sensor test. When the LIDAR was on, the robot connected to the system through ROS and showed the detection value at Windows RVIZ. Figure 13 shows the software's detection output (red-colored dot). The robot was used for outdoor mapping, and the scanning mapping was plotted at windows, as shown in Figure 14.

Figure 13. LIDAR sensor outdoor mapping

Figure 14. Output mapping from LIDAR sensor



LIDAR sensor field detection using ROS



LIDAR sensor output mapping

CONCLUSION AND FUTURE WORKS

The design and development of an autonomous guided vehicle (AGV) system in an agricultural plantation is the subject of this article. The primary sensor for navigation while traveling within the experimental region was the LIDAR sensor. In order to avoid collisions, the AGV uses the same LIDAR in conjunction with an obstacle identification algorithm to identify any objects or people in the vicinity of the AGV. Besides, the rotary encoder is a multi-sensing device that may be used to precisely measure the location and rotation of the wheel. The Robot Operating System (ROS) processed all of the signal data from the sensor fusion to optimize robot navigation, including robot movement and data analysis for obstacle avoidance. Some experiments and simulations have been successfully conducted.

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REFERENCES

Aras, M.S.M., *et. al* (2013), 'Tuning process of single input fuzzy logic controller based on linear control surface approximation method for depth control of underwater remotely operated vehicle', *Journal of Engineering and Applied Sciences*, 8(6), pp. 208–214

Azam, M.A., *et. al* (2021), 'Structural characterization and electrochemical performance of nitrogen doped graphene supercapacitor electrode fabricated by hydrothermal method', *International Journal of Nanoelectronics and Materials*, 14(2), pp. 127–136

Bechar A., Vigneault C. *et. al* (2016), 'Agricultural robots for field operations: Concepts and components. *Biosystems Engineering*. 149:94–111

Bin Mohamed Kassim, A., *et. al* (2021), 'Performance analysis of wireless warning device for upper body level of deaf-blind person', *2015 54th Annual Conference of the Society of Instrument and Control Engineers of Japan, SICE 2015*, pp. 252–257

Bogue R. *et. al* (2018), 'Robots for the dairy farm. Industrial Robot: *An International Journal*, 5(1):12–17.

C. Zhang and N. Noguchi (2017), 'Development of a multi-robot tractor system for agriculture field work," Comput. Electron. Agric., vol. 142, pp. 79–90

E. Yurtsever, *et. al.* (2020), 'A Survey of Autonomous Driving: Common Practices and Emerging Technologies', *IEEE Access*, vol. 8, pp. 58443–58469

Gaus H., *et. al* (2017), 'BoniRob – an autonomous field robot platform for individual plant phenotyping. *Precision Agriculture*. 2017;18(4):589–615.

Halachmi I., *et. al* (2019), 'Precision livestock farming: Tools and concepts. *Biosystems Engineering*. 184:38–50.

Hasim, N., *et. al* (2012), 'Development of fuzzy logic water bath temperature controller using MATLAB', *Proceedings - 2012 IEEE International Conference on Control System, Computing and Engineering, ICCSCE 2012*, pp. 11–16

Hunt E.R.Jr., *et. al* (2019), 'Applications of unmanned aerial vehicles for high spatial resolution remote sensing for agriculture and natural resource management. *Journal of Unmanned Vehicle Systems*. (1):39–69.

Kassim, A.M., *et. al.* (2011), 'Design and development of MY 2nd EYE for a visually impaired person', *2011 IEEE Symposium on Industrial Electronics and Applications, ISIEA 2011*, pp. 700–703

Kassim, A.M., Termezai, *et. al* (2020), 'Design and development of an autonomous pesticide sprayer robot for fertigation farm', *International Journal of Advanced Computer Science and Applications*, (2), pp. 545–551

Kassim, A.M., *et. al* (2021), 'Potential of on-the-go gamma-ray spectrometry for estimation and management of soil potassium site specifically', *Sustainability*, 13(2), pp. 1–17, 661

Kassim, A.B.M., Yasuno, *et. al* (2010), 'Moving control of quadruped hopping robot using adaptive CPG networks', *2010 IEEE Conference on Robotics, Automation and Mechatronics, RAM 2010*, pp. 581–588

Kassim, A.M., Jaafar, *et. al* (2013), 'Performances study of distance measurement sensor with different object materials and properties', *Proceedings - 2013 IEEE 3rd International Conference on System Engineering and Technology, ICSET 2013*, pp. 281–284

Kassim, A.M., Jamri, *et. al* (2012), 'Design and development of obstacle detection and warning device for above abdomen level, *2012 International Conference on Control, Automation and Systems*, pp. 410–413

Kise M., *et. al* (2019), 'Crop-weed classification using a convolutional neural network with data augmentation. *Biosystems Engineering*. 2019;184:188–196.

Kassim, A.M., *et. al* (2012), 'Design and development of vibration method for Vehicle Reverse System (VRS)', *Procedia Engineering*, 41, pp. 1114–1120

Kassim, A.M., Yasuno, *et. al* (2015), 'Vision based of tactile paving detection method in navigation system for blind person', *Jurnal Teknologi*, vol. 77, no. 20, pp. 25-32, 2015

Kassim, A.M., Said, *et. al* (2022), 'Performance Analysis of Spraying Coverage Rate by Using Mobile Robot for Pesticide Spraying Application on Chili Fertigation Farm, *Lecture Notes in Electrical Engineering*, vol 842, pp. 639-650

Lowenberg-DeBoer J., *et. al* (2020), 'The Economics of Agricultural Robotics: Setting Research Priorities. *Journal of Field Robotics*. 37(5):891–909.

Mohamed Kassim, A., *et. al* (2016), 'Conceptual design and implementation of electronic spectacle based obstacle detection for visually impaired persons', *Journal of Advanced Mechanical Design, Systems and Manufacturing*, 10(7)

Ribeiro A.F., *et. al* (2018), 'Prototyping and testing of a new light autonomous robot for weed control. *Biosystems Engineering*. 173:50–60.

Rose D.C., *et. al* (2018), 'Involving farmers in decision making about farm animal welfare: A review of potential methods to achieve this goal. *Animal Welfare*. 27(2):111–124.

Rose D.C., *et. al* (2021), 'Responsible development of autonomous robotics in agriculture. *Nature Food*. 2021;2(6):306–309.

Stahl B.C., *et. al* (2016), 'Ethics of healthcare robotics: Towards responsible research and innovation. *Robotics and Autonomous Systems*. 86:152–161.

Xu Z., *et. al* (2018), 'A survey of sensing and communication systems for underwater robot operation. *Sensors*. 18(10):3329.

Zhang C., *et. Al* (2020), 'A review of current status and challenges for UAV-based crop management and crop condition monitoring in precision agriculture. *Remote Sensing Applications: Society and Environment.* 19:100354.