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Design And Development Of An Autonomous Agricultural Rover For Planting And Irrigation Systems Using TRIZ Design Principles

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***Abstract*— This research article describes the design and development of an autonomous agricultural rover for planting and irrigation systems using TRIZ (Theory of Inventive Problem Solving) concepts. This project intends to propose novel answers to present agricultural difficulties such as labor shortages, water conservation, and rising food production demand. A primary focus is on using TRIZ concepts to improve seed-spreading mechanisms and agricultural irrigation systems. The study carefully identifies existing challenges and suggests novel solutions with the goal of revolutionizing planting and irrigation processes for more efficiency, sustainability, and resource conservation.**

***Keywords*— Agriculture Farming, Irrigation Systems, Rover, autonomous rover.**

I. Introduction

The goal of this study is to develop an autonomous agricultural rover designed for planting and irrigation systems using the inventive design concepts of TRIZ (Theory of Inventive Problem Solving). This decision is motivated by the urgent need to handle contemporary agricultural difficulties such as labor shortages, water conservation, and rising food production demand. We hope to use TRIZ to develop ground-breaking solutions to improve the efficiency and sustainability of agricultural practices. This research has enormous societal and industrial implications. It has the potential to reduce agricultural labor shortages, particularly during peak seasons, while also assisting in water conservation through precision irrigation techniques. Furthermore, it has the potential to greatly contribute to increasing food production and more sustainable farming practices, reducing resource waste and the environmental effect of agriculture.

The key goals of our research are the design and construction of an autonomous agricultural rover capable of sowing seeds and irrigating crops using TRIZ concepts. Furthermore, we intend to develop enhanced sensing and control technologies to aid in precise soil analysis, irrigation, and planting. Field testing will be critical in analyzing the rover's performance in real-world agricultural situations, allowing for empirically-based optimization of its design and functionality.

The innate urge to address and resolve the significant difficulties confronting modern agriculture is the driving force behind this research. Agriculture, as the foundation of human subsistence, must adapt to meet the needs of a growing global population while also reducing its environmental impact. The attractiveness of applying TRIZ concepts, a tried-and-tested technique in numerous engineering fields, to agricultural difficulties is a driving force behind this endeavor.

The combination of TRIZ design ideas with agricultural technology distinguishes this study. The application of TRIZ to uncover and resolve inherent conflicts within agricultural systems leads to unique design solutions in this novel methodology. It also entails the creation of a multifunctional autonomous rover capable of not only planting but also precision irrigation, hence optimizing resource utilization. The use of modern sensing and control systems ensures adaptation to a wide range of soil and weather conditions. Real-world field tests are used to assess the effectiveness of the TRIZ-inspired design in realistic agricultural contexts. Our research strives to provide cutting-edge solutions that have the potential to revolutionize farming practices, boost food security, and advance the cause of sustainable agriculture, eventually benefiting everyone.

II. LITERATURE REVIEW

The study conducted by Azmi et. al[1] describes the creation of a low-cost agricultural robot for crop seeding, solving the issues associated with hand seeding and waste in tractor-based approaches. The system consists of a four-wheel mobile base and a seed injection mechanism based on a crank-slider design. Crop seeding studies show that the robot is 35% more efficient than human workers, spreading 138 seedlings in 5 minutes with 92% accuracy. Its 4-hour battery life and 1.5-hour charging time ensure no downtime. Future innovations, including self-driving vehicles, have the potential to dramatically reduce labor costs and improve seeding efficiency. The research proposes a novel mobile agricultural robot with a dual Prismatic-Revolute (PR) arm design, with an emphasis on affordability and usefulness for both farmers and home horticulturists. The four major subsystems of the proposed robot prototype are a digging module, seed module, moisture sensor-based watering module, and inline motion module. Pramod et al. [2] present this unique robotic technology as a cost-effective and practical answer to the agricultural problems of farmers, as well as its possible applications in residential agriculture. The study includes detailed evaluations of the kinematics, statics, and dynamics of the robot system, as well as time-history plots of the two-arm mechanism and displays of static and dynamic analysis results. Practical field trials of the prototype provide critical information, demonstrating its potential as a cost-effective and practical answer to farmers' agricultural issues, as well as its application in households.

The Indian Academy's focus on agriculture is reflected in its recognition of India's rapid agricultural expansion. Although considerable agricultural technology and robots have been developed to increase production, the concept of a universal agricultural robot is relatively new in this context. Weeding, seed distribution, and pesticide spraying still take time, and traditional animal methods are not sufficient to meet the energy needs of Indian agriculture. Anjikar et al. [3] see the potential of an intelligent and affordable system ideal for small-scale agriculture. Their concept is a multipurpose agricultural machine capable of sowing, applying insecticides and fungicides, fertilizing, and mowing. This alleviates labor shortages and meets the needs of a country where agriculture employs 70 percent of the population.

Min Hyuc et. al[4] investigate the increasing use of technology-driven solutions in agriculture to combat labor shortages and rising costs. They suggest a system-of-systems method for constructing a mobile robotic platform for agricultural operations, specifically pesticide spraying. Integrating mechanical, sensor, actuator, navigation, control, electronic, and software components is required. The study describes a three-stage approach to obtaining self-driving navigation: learning, implementation (training), and testing. Path patterns and real-world vehicle behavior are defined during the learning step. The training step is concerned with advanced steering algorithms and error reduction, whilst the testing stage effectively exhibits autonomous navigation on random courses. The potential commercialization of this medium-sized mobile robot for greenhouse cultivation shows its promise to meet the changing needs of the agricultural industry. The agricultural sector needs rapidly accessible and usable technology that saves manpower, time, and money in implementation. Jayakrishna et al. [5] created a four-wheel drive robot capable of autonomously spreading seeds in plowed fields, eliminating the need for manual labor. This unique robot uses field parameters such as length and width, as well as user-defined seeds, to follow a path and distribute seeds evenly. The presentation will introduce the design process of the robot, the components used in its construction, and the challenges encountered in the different stages of the project. It also includes step-by-step instructions for making a wheeled robot, highlighting important variables to consider before building a prototype. This research has the potential to transform agriculture by increasing its efficiency and cost-effectiveness.

In response to the need for more efficient and cost-effective seeding in agriculture, Kumar et al. [6] present a study focusing on the design and manufacturing of an intelligent seed-sowing robot. This unique robot has a robotic arm controlled by a smartphone app that enables precise placement of seeds. Once the important locations are identified, the robot plants the seeds autonomously. The smartphone application also controls the wheel of the robot and fully automates the seeding process. This strategy not only reduces manual labor but also reduces seed costs, representing a major advance in agricultural technology. Nithin et al. [7] developed a versatile agricultural robot that can run on both battery and solar power. As agriculture employs a significant portion of the world's population, interest in autonomous agricultural technologies is growing. This robot has easy communication via voice input thanks to friendly controls like relay switches and IR sensors. It's hands-free operation and fast data methods are quite useful. The importance of the success is underlined by the possibility that several small self-driving devices will surpass traditional tractors and human labor. Plowing, seeding, leveling mud, and spraying water are robotic capabilities that will ultimately increase the production and sustainability of the agricultural industry.

In response to the growing demand for user-friendly and cost-effective agricultural technology, Naik et al. [8] present a project focusing on the design and construction of an autonomous agricultural robot. This robot can perform several agricultural tasks such as pesticide spraying, inspection, weeding, and material handling. The robot is powered by a solar panel rechargeable battery and has four self-propelled wheels driven by adapted DC motors. Raspberry Pi acts as its main controller, responding to inputs from cameras and ultrasonic sensors, and is controlled by a mobile app. This breakthrough represents a big step towards the automation of field monitoring, employing GPS technology to follow established route plans, and has the potential to tremendously help the agricultural business.

Sowjanya et al.'s[9] suggested solution that addresses the crucial need for multipurpose autonomous agricultural robots that may be controlled by Bluetooth to perform tasks such as plowing, sowing, and irrigation. This concept is especially significant in areas where agricultural activity poses a risk to employees' safety and health. These robots contribute to a reduction in human intervention while also ensuring appropriate irrigation and resource utilization. Automatic weed control, precise fertilizer application based on soil conditions, and the installation of soil sensors for efficient drip irrigation in rain-fed locations are some of their applications.

Kumar et. al[10] investigate a skid-steering mobile platform with four wheels and a Cartesian serial manipulator, with the goal of improving agricultural processes. This revolutionary design enables the platform to execute a variety of agricultural jobs, including heavy material handling. Notably, parallel manipulator-based end-effectors were used in experimental robotic harvesting scenarios, demonstrating their ability to handle large fruits such as watermelons and muskmelons. The study goes through conceptual and component design in detail, as well as simulation on undulating terrains and control mechanisms such as proportional derivative control. Structural analysis ensures safety and low deformation, while calibration tests reduce linear motion rail variation. The successful field testing demonstrates the mobile manipulator's use and efficiency in agricultural settings.

The advancement of agricultural automation technology has prepared the way for the birth of sustainable agricultural robotics, necessitating the development of unique multi-purpose robotic platforms built for field application. Werner et. al[11] respond to this demand by creating Flex-Ro, a versatile robotic platform with variable height adjustment to support different crop growth stages. An electronic control unit (ECU) for engine management, a hydrostatic gearbox system, and a vertically adjustable frame for crop entrance are all part of the entire design. Although significant standard variation was discovered, particularly at higher operational speeds, control mechanisms utilizing unique CAN messages ensure precise functioning. The continued development of subassemblies for completely autonomous navigation and field operations bodes well for the advancement of agricultural robotics. Sidapara et. al[12] research provide a new automated sprayer attachment that tackles the constraints of existing agricultural sprayers. This attachment, which uses a microcontroller and a flow sensor, enables for exact formulation of solutions in ratios defined by farmers, removing the need for manual intervention. Furthermore, it has customizable characteristics such as spray height, span, nozzle periodicity, and spray rate, making it adaptive to different crops and growth phases. The attachment considerably improves the efficiency and precision of spraying operations with features such as an in-built stirrer and effective coverage.

Jagtap et. al[13] research provide a new automated sprayer attachment that tackles the constraints of existing agricultural sprayers. This attachment, which uses a microcontroller and a flow sensor, enables for exact formulation of solutions in ratios defined by farmers, removing the need for manual intervention. Furthermore, it has customizable characteristics such as spray height, span, nozzle periodicity, and spray rate, making it adaptive to different crops and growth phases. The attachment considerably improves the efficiency and precision of spraying operations with features such as an in-built stirrer and effective coverage.

Over the last two decades, as a result of the severe issues encountered by farmers in rural India, the development of automated robots to aid in agricultural chores has gained speed globally. In this context, Ramesh et. al[14] describe a trailblazing effort to create a prototype of an indigenous, cost-effective, semi-automatic agricultural robot. This robot performs critical activities such as seed spacing and depth control, as well as plant hydration regulation. This innovation's applications range from improving commercial farming efficiency to aiding research and backyard gardening. The successful testing of the robot in a confined space indicates its functionality and performance, particularly in automating seed sowing and accurate watering based on soil moisture readings. The goal of eco-friendly design is becoming increasingly important in the field of mobile robotics. Majdoubi et. al[15] make a considerable investment in the development of an ecological mobile agricultural robot designed for accurate strawberry cultivation within greenhouses. This inventive robot combines a four-wheeled mobile platform with stereo camera vision for plant detection and localization, manipulator arms with nozzles for focused maintenance, and an environmental mapping laser telemeter. The energy autonomy of this robot is achieved using an inbuilt rechargeable battery system linked to a photovoltaic charging station.

III. METHODOLOGY

Figure 1 shows the Design of an autonomous agricultural rover. Selecting necessary components such as DC motors, an L298N stepper motor controller, an Arduino Uno, a water pump, and a tank is part of the hardware and software setup. The rover is built with sensors for navigation and obstacle detection. The water pump is linked to guarantee that irrigation is controlled and efficient. Based on sensor inputs, Arduino programming is required to control the rover's movement, seed-distributing mechanism, and watering procedure.

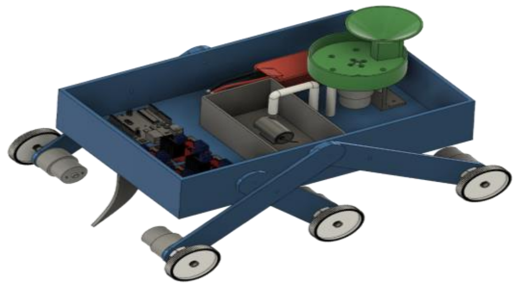

Figure:1 Design of Autonums agricultural rover

To assure the rover's operation and sensor accuracy, rigorous testing and calibration are carried out. Autonomous operation logic is used to allow the rover to navigate and operate without the need for human involvement. During rover operation, data is collected to evaluate rover performance in terms of seed distribution precision and watering efficiency.

The application of TRIZ (Theory of Inventive Problem Solving) methodology to the seed-spreading mechanism in an autonomous agricultural rover involves a methodical approach to increasing its efficiency and precision. The current mechanism consists of a plastic hopper connected to a rotating disc powered by a motor. When a hole in the disc coincides with a pipe intake, seeds from the hopper are transferred to the rotating disc, and seeds are ejected onto the ground. To employ TRIZ concepts effectively, we must first identify the current difficulties, such as potential inefficiencies and inaccurate seed placement. The desired output is then established, with the purpose of developing a system that is as precise and efficient as possible. Then, using TRIZ principles like segmentation and universality, we look for new solutions. For instance, we may break down the seeding process into smaller, more manageable parts, potentially improving precision. Adding feedback systems and sensors may also increase seed release control and accuracy. By ideating, creating, testing, and iteratively applying these solutions, we can design an optimized seed-spreading system that meets the stated objectives while adhering to the principles of TRIZ for innovative problem-solving in agricultural technology.

When it comes to agricultural irrigation systems, there is usually a well-established structure that includes water supply, distribution pipes and canals, and various methods of providing water to crops, such as sprinklers and drip irrigation. We first used the Inventive Problem Solving Theory (TRIZ) to improve the efficiency, accuracy, and sustainability of this irrigation system by solving problems such as water wastage, uneven distribution, and energy consumption. Identify challenges and shortcomings of the current system, including:)methodology. The best result is an irrigation system that conserves water, maximizes coverage, and minimizes power usage. And solve these problems using TRIZ ideas. Segmentation allows us to divide our irrigation area into smaller, controllable zones for more precise management and water savings. The term “versatile” refers to building systems that can handle many types of crops and soil conditions, increasing adaptability and efficiency. “Another dimension” refers to the integration of advanced sensing and automation technologies to monitor soil moisture levels, weather conditions, and plant growth, providing real-time feedback for precise water delivery. The “feedback” principle can be used by integrating sensors and intelligent controls that adjust water flow and distribution patterns based on the data received. Then, generate new ideas based on these TRIZ ideas. Some concepts include automated soil moisture systems, variable rate irrigation, and the use of drones for aerial monitoring and targeted water distribution. After the most promising ideas are selected, prototypes are built and thoroughly tested in different environments, including different plant species and temperatures.

IV. RESULT AND DISCUSSION

This research study provides a detailed methodology for the design and development of autonomous agricultural rovers for planting and irrigation systems using TRIZ (Theory of Inventive Problem Solving) concepts. This study describes the rover's hardware and software setup, focusing on the selection of key components such as the DC motor, L298N stepper motor controller, Arduino Uno, water pump, and tank. The rover is equipped with sensors for navigation and obstacle detection, as well as water pumps for effective irrigation control. Arduino programming controls the rover's movement, seed dispersal mechanism, and watering routine. Extensive testing and calibration methods ensure the rover's accuracy and sensor accuracy are maintained. The key innovation is the use of TRIZ principles to improve the efficiency and accuracy of the seed distribution mechanism, converting the plastic hopper and rotating disc system into a more accurate and efficient seed distribution system.

The methodical application of TRIZ principles to the seed distribution process is the study's distinguishing feature. Existing seed-planting technology, which consists of plastic funnels and revolving discs, has been criticized as possibly inefficient and incorrect. To produce unique solutions, TRIZ principles such as subdivision and universality are applied. The seeding procedure should be split down into smaller, more manageable processes to improve accuracy. It is also advised to incorporate feedback systems and sensors to increase seed release control and accuracy. Using TRIZ concepts in this way provides a logical method to solve specific agricultural difficulties.

This study uses TRIZ approaches in the context of agricultural irrigation systems to uncover present system flaws such as water waste, uneven distribution, and energy consumption. The goal is to design irrigation systems that use as little electricity as feasible while conserving water. Subdivision, universality, additional dimensions, and feedback are TRIZ concepts that are used to produce new ideas. Water management and conservation are improved by dividing the irrigated area into smaller manageable zones. Creating systems that adapt to varied crops and soil conditions improves efficiency. The concept of "another dimension" refers to the utilization of modern sensors and automation technology to provide real-time feedback for proper water supply. Sensors and intelligent controls should be utilized in accordance with the feedback principle to change water flow based on data and ensure effective distribution. The following precision irrigation alternatives are proposed in this study: B. Soil moisture-based automation and the use of drones for targeted water distribution.

V. CONCLUSION

The complete process of designing and building an autonomous agricultural rover for planting and irrigation systems is described in this article, with an emphasis on creative problem-solving utilizing TRIZ concepts. A systematic approach to tackling agricultural problems is shown by the systematic application of TRIZ concepts to increase the efficiency and accuracy of seed distribution. Furthermore, the application of TRIZ in agricultural irrigation systems shows novel methods for water conservation and coverage optimization.

Finally, this research establishes a foundation for the development of new agricultural technology with the potential to greatly improve planting and irrigation practices. This research proposes a road to more efficient, precise, and sustainable agricultural practices, ultimately leading to food production in the agricultural sector, by incorporating TRIZ principles into the design and employing a unique problem-solving approach. Contributes to increased water and resource conservation.

The thought of robot swarms is intriguing. The study of how swarms of autonomous agricultural rovers communicate and coordinate their activity has the potential to revolutionize agricultural practices. Seeding, harvesting, and weed control are all joint activities that can improve efficiency and coverage on big fields.

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