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Review on AutoSeed: Smart Seeding Tray Robot with IoT Integration

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ABSTRACT
The rapid advancement of technology presents both opportunities and challenges for contemporary agriculture, necessitating innovative solutions to address labor shortages and inefficiencies. This report delineates the design, development, and application of Autoseed: Smart Seeding Tray Robot with IOT Integration aimed at revolutionizing traditional seeding practices through the integration of robotics and renewable energy technologies. The primary objective is to develop a low-cost, solar-powered agricultural robot equipped with sensors, transceivers, and computational devices to perform tasks such as planting seeds, watering, and monitoring soil moisture and pH levels. The project employs a sophisticated Cartesian arm system for precise seed planting within seeding trays, significantly improving efficiency and accuracy over manual methods. State-of-the-art moisture and pH sensors are incorporated to enable real-time monitoring of soil health parameters. The robot's functionality is enhanced by sun tracking technology, which optimizes solar panel efficiency and ensures continuous operation even in off-grid settings. Users can access comprehensive soil condition data via a seamlessly integrated mobile application, facilitating informed decision-making and tailored adjustments to optimize seed growth environments. Key findings demonstrate Autoseed's potential to alleviate labor scarcity and reduce human error while promoting sustainable agricultural practices. By harnessing solar power and incorporating a rechargeable battery system, Autoseed minimizes its environmental footprint, aligning with ecological consciousness. The system's performance was tested and validated in various agricultural tasks, showcasing its capability to enhance farming efficiency and sustainability. Autoseed represents a significant shift towards automated, sustainable farming, promising increased efficiency and food security while mitigating ecological impact.

1.0 Introduction

In the intricate tapestry of Malaysia's economic landscape, the agricultural sector stands as a cornerstone, supplying vital sustenance and raw materials while serving as a linchpin for rural livelihoods. Despite its pivotal role, the sector grapples with multifaceted challenges threatening its sustainability and growth trajectory. These challenges include a dearth of manpower and a paucity of innovation, necessitating strategic intervention and innovative solutions to ensure resilience and prosperity in the face of evolving global dynamics (Suffian & Suffian, 2021, World Bank, 2019).

The agricultural sector in Malaysia faces a profound scarcity of manpower, exacerbated by demographic shifts and changing societal aspirations (Concepts Groups, 2021). The traditional agrarian lifestyle is increasingly overshadowed by alternative livelihood opportunities, contributing to a diminishing labor force. Consequently, labor shortages across various facets of production, from cultivation to harvest, pose formidable impediments to the sector's efficiency and competitiveness on the global stage (TraceX, 2023). Moreover, a pervasive lack of innovation and technological adoption characterizes Malaysia's agricultural landscape. For example, an innovation like fruit setting position by Nik Yusoff, Ontok & Hasmidah, 2024 still considered new and not yet widely accepted. Despite strides in agricultural research and development, a palpable gap exists between scientific advancements and on-the-ground implementation, hindering the sector's capacity to leverage cutting-edge technologies for enhanced productivity and sustainability (Suffian and Suffian, 2021, World Bank, 2019).

Amid these challenges, seedlings emerge as a linchpin in the agricultural ecosystem, profoundly influencing crop productivity, resource utilization, and food security. Seeding occupies a pivotal position in modern agriculture, serving as the foundational step in the agricultural cycle. Through precise seeding techniques, farmers can orchestrate optimal plant density, spacing, and uniformity, priming conditions for robust crop establishment, growth, and yield (Mississippi State University, 2018). Advanced technologies and methodologies enable farmers to transcend traditional paradigms of seeding, unlocking new frontiers of productivity, efficiency, and sustainability. Precision seeding techniques, informed by real-time data and cutting-edge innovations, optimize resource allocation, minimize input wastage, and maximize output, bolstering agricultural resilience and viability (Mississippi State University, 2018).

In light of these challenges, the AutoSeed project proposes the development of a Solar-Powered Smart Seeding Robot for Sustainable agriculture, representing a pioneering solution designed to address the shortcomings of traditional seeding methods. Leveraging a sophisticated Cartesian arm system, AutoSeed promises unparalleled precision in seed placement, ensuring optimal plant density and uniformity across seeding trays. By harnessing advanced sensing technologies such as moisture and pH sensors, AutoSeed offers real-time monitoring of soil health, empowering farmers with critical insights to optimize seed growth conditions and maximize crop yields. Autonomous operation and customizable features underscore AutoSeed's versatility and adaptability to diverse agricultural settings and cropping systems. Integration of solar power and rechargeable battery technology ensures uninterrupted operation, reducing reliance on fossil fuels and mitigating carbon emissions (Concepts Groups, 2021).

AutoSeed holds immense potential to mitigate the impacts of environmental variability and enhance agricultural resilience in Malaysia, characterized by seasonal monsoons and recurring flooding events. By offering a reliable and efficient seeding solution, AutoSeed empowers farmers to overcome challenges posed by labor shortages and erratic weather patterns, ensuring consistent and sustainable crop production year-round (Concepts Groups, 2021; Bogue, 2024). The development and deployment of AutoSeed represents a significant leap forward in the quest for sustainable and resilient agriculture. By harnessing robotics, sensing technologies, and renewable energy, AutoSeed offers a glimpse into the future of precision agriculture, where innovation and sustainability converge to address the pressing challenges of food security and environmental stewardship.

2.0 Literature review

Seeds are fundamental units of plant reproduction, containing the embryonic plant and nutrients for early growth (Bewley & Black, 1994). They play a critical role in plant life cycles by enabling dispersal, adaptation, and survival across diverse environments. Protected by a hard outer coating, seeds have specialized adaptations for spreading through wind, water, and animal interactions (Kew Royal Botanic Gardens, n.d.). In agriculture, seeds are essential for crop production, with high-yielding, disease-resistant varieties being crucial for food security.

2.1 Stages of Seed

Seed germination begins with imbibition, where the seed absorbs water, activating enzymes that initiate metabolism (Taiz & Zeiger, 2010). The radicle then emerges, forming the primary root, followed by the shoot carrying the first leaves. The seedling relies on stored nutrients until it can photosynthesize, eventually maturing into a full-grown plant capable of producing flowers and seeds (Hartmann, Kester, Davies, & Geneve, 2011). This process varies by plant species and environmental conditions but generally follows these key stages.

The stages of seed growing include sprouting, seedling, vegetative, budding, and flowering phases. Sprouts are the young shoots that emerge from germinating seeds, characterized by tender stems and underdeveloped leaves. Seedlings follow, representing young plants with primary roots and shoots. During the vegetative stage, plants focus on developing leaves, stems, and roots to support future growth. The budding stage involves asexual reproduction, where new plants form from outgrowths of the parent plant. Finally, the flowering stage marks the transition to reproductive growth, where environmental cues trigger the development of flowers (Taiz & Zeiger, 2010).

2.2 Type of Seeds

Dicotyledonous seeds, or dicot seeds, are characterized by having two cotyledons, making them larger and more complex than monocotyledonous seeds (Simpson, 2010). Examples include beans, peas, and sunflower seeds, which are valued for their nutritional content and widespread use in cooking and agriculture. In contrast, monocotyledonous seeds, or monocot seeds, have a single cotyledon and are typically smaller and less complex. Examples such as corn, rice, and wheat are crucial food sources for humans and animals and are staples in many cultures worldwide (Stern & Hodge, 2003).

2.3 Evolution of seeding technology

There are seven common seeding systems implemented: Manual Broadcasting, Hand-Held Seed Drill, Animal-Drawn Seed Drill, Gasoline-Powered Seeder, Battery-Powered Seeder, Solar-Powered Seeder, and Mechanised Robot Seeder. The evolution of seeding technology has significantly improved agricultural efficiency and precision. Manual broadcasting, a traditional method involving hand-spreading seeds, offers direct control but is labor-intensive and less efficient for larger areas. Hand-held seed drills enhance precision by planting seeds at consistent depths and intervals, making them more efficient than manual broadcasting for small to medium-sized plots. Animal-drawn seed drills use animals to pull a wheeled frame, providing controlled seed placement and reducing physical strain on farmers. Modern advancements include gasoline-powered seeders, which offer fast and precise planting for large fields, and battery-powered seeders, which are quieter and environmentally friendly. Solar-powered seeders utilize solar energy for a sustainable and cost-effective planting solution, though they may face limitations in low-sun areas. The most advanced technology, mechanized robot seeders, employs sensors and GPS for automated, highly precise planting, significantly reducing labor and increasing efficiency, despite their high cost and need for specialized maintenance. Table 1.1 shows the observation of the seed planting technologies that exist, and it used.

Table 1.1: The observation of the seed planting technology

Seed Plating Technology	Compare	Contrast	Criticize	Synthesis	Summarize
Manual broadcasting	Manual broadcasting is the simplest method, relying only on human labor and minimal investment, making it ideal for small-scale farming.	Manual broadcasting is less efficient, less precise, and more labor-intensive, and can lead to uneven seed distribution compared to mechanized methods.	Manual broadcasting is accessible and low-cost but impractical for large-scale agriculture due to inefficiency, inconsistency, and higher seed wastage.	Manual broadcasting is relevant for small-scale or subsistence farming where labor is available and precision isn't critical, but it's unsuitable for modern commercial agriculture due to its limitations.	Manual broadcasting is a traditional, labor-intensive seed-sowing method, but its inefficiency and lack of precision limit its use in modern agriculture.
Hand-held seed drill	Hand-held seed drills improve manual broadcasting by providing controlled seed placement, increasing efficiency, and ensuring more uniform distribution.	Unlike manual broadcasting, hand-held seed drills require specialized tools and human labor. They offer better precision but may not suit large-scale farming.	While hand-held seed drills improve seed placement, they require considerable physical effort and may not be practical for extensive farming.	Hand-held seed drills improve efficiency and accuracy over manual broadcasting but are limited by scale and labor requirements.	Hand-held seed drills offer more controlled seed sowing than manual broadcasting but are limited in scalability and labor efficiency.
Animal-drawn seed drill	Animal-drawn seed drills mechanize seed sowing using animal power, boosting efficiency and easing the physical strain on farmers.	Unlike hand-held seed drills, animal-drawn seed drills can cover larger areas more efficiently. They require animal power but offer greater precision and uniformity in seed placement.	Animal-drawn seed drills represent a significant advancement in agricultural technology, but they still rely on animal labor and may be limited by terrain and field size.	Animal-drawn seed drills combine mechanization with animal power, offering improved efficiency and precision in seed sowing. However, they may not be suitable for all agricultural landscapes or scales of operation.	Animal-drawn seed drills improve efficiency and precision in seed sowing by utilizing animal power, but they are still limited by factors such as terrain and field size.
Gasoline-powered seeder:	Gasoline-powered seeders emit pollutants, have higher operating costs than electric alternatives, and can disrupt wildlife with noisy engines in rural areas, contributing to air pollution, climate change, and ecological disturbance.	Gasoline-powered seeders emit pollutants, contributing to air pollution and climate change. They have higher operating costs compared to electric alternatives and can disrupt wildlife with their noisy engines in rural areas.	The environmental impact of gasoline-powered seeders includes emissions, high operating costs, and noise pollution, posing challenges for sustainable agriculture and local communities.	Emissions from gasoline-powered seeders raise environmental concerns, while their fuel costs and noise pollution pose challenges for budget-conscious farmers and local communities alike.	A gasoline seeder, powered by a gasoline engine, efficiently distributes seeds across large agricultural fields due to its mobility and effective seeding mechanism.
Battery-powered seeder:	Battery-powered seeders offer eco-friendly operation with zero emissions, lower costs, and quieter performance, reducing noise pollution.	Battery-powered seeders are eco-friendly and cost-effective, operating quietly compared to gasoline-powered models, yet they are constrained by battery capacity, affecting their range and endurance.	Battery-powered seeders are constrained by battery capacity, impacting operational flexibility with longer charging times and high initial costs posing challenges for farmers.	Despite environmental benefits and lower operational costs compared to gasoline-powered alternatives, battery-powered seeders have limitations in range, endurance, and initial costs.	A battery seeder operates on rechargeable batteries, offering operation and suitability for smaller-scale farming and gardening due to its mobility and ease of use compared to gasoline speeders.

Seed Plating Technology	Compare	Contrast	Criticize	Synthesis	Summarize
Solar-powered seeder:	Solar-powered seeders utilize renewable energy, producing zero emissions and minimizing operational costs through free solar energy.	Solar-powered seeders rely solely on renewable energy, minimizing environmental impact, and operational costs, but their effectiveness depends on sunlight availability.	Despite being environmentally friendly, solar-powered seeders are limited in low-light conditions or nighttime, with high initial costs and variable efficiency depending on the weather.	Solar-powered seeders provide a sustainable, emission-free option with reduced operational costs post-installation, yet they are constrained by sunlight availability and initial investment expenses.	A solar seeder uses sunlight to plant seeds, making it environmentally friendly and ideal for areas without access to traditional power sources.
Mechanized robot seeder:	Mechanized seeders provide high efficiency and versatility for large-scale farming, handling diverse seeds and soil conditions with automation.	However, high initial costs, reliance on fossil fuels or electricity, and the need for skilled operators and maintenance pose challenges for mechanized seeders.	Mechanized seeders excel in efficiency, productivity, and versatility for farming tasks but rely on fossil fuels or electricity for power.	Despite their efficiency and productivity, mechanized seeders entail substantial initial costs and environmental considerations.	Mechanised seed drills automate seed sowing with engine power, enhancing agricultural efficiency and scalability, despite environmental trade-offs.

3.0 Methodology

The methodology covers project design, including prototype development, drawings, and flow charts to illustrate project functionality and methods. It also details the size, materials, concept, and costs, along with data analysis methods used for the project.

3.1 Project design

Figure 1.1 depicts a prototype, a preliminary experimental model used to test and validate ideas, facilitating quick and cost-effective improvements and adjustments in design. Figure 1.2 showcases freehand sketching, a universal language among designers, enabling the visualisation of ideas and aiding in problem-solving and communication within project teams.

Figure 1.1: Prototype

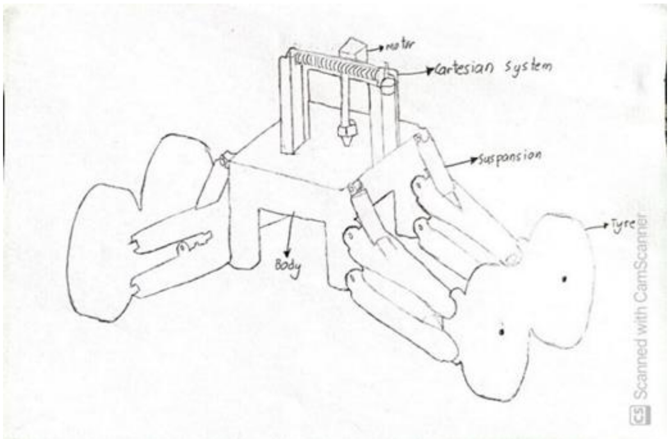

Figure 1.2: Freehand sketching

Figure 1.3 depicts the AutoSeed AutoCAD design comprised of a solar-powered smart seeding robot for sustainable agriculture, monitoring soil health, moisture, and water with the ESP32 microcontroller, soil sensors, watering system, and steel-reinforced base platform, and aluminum cover.

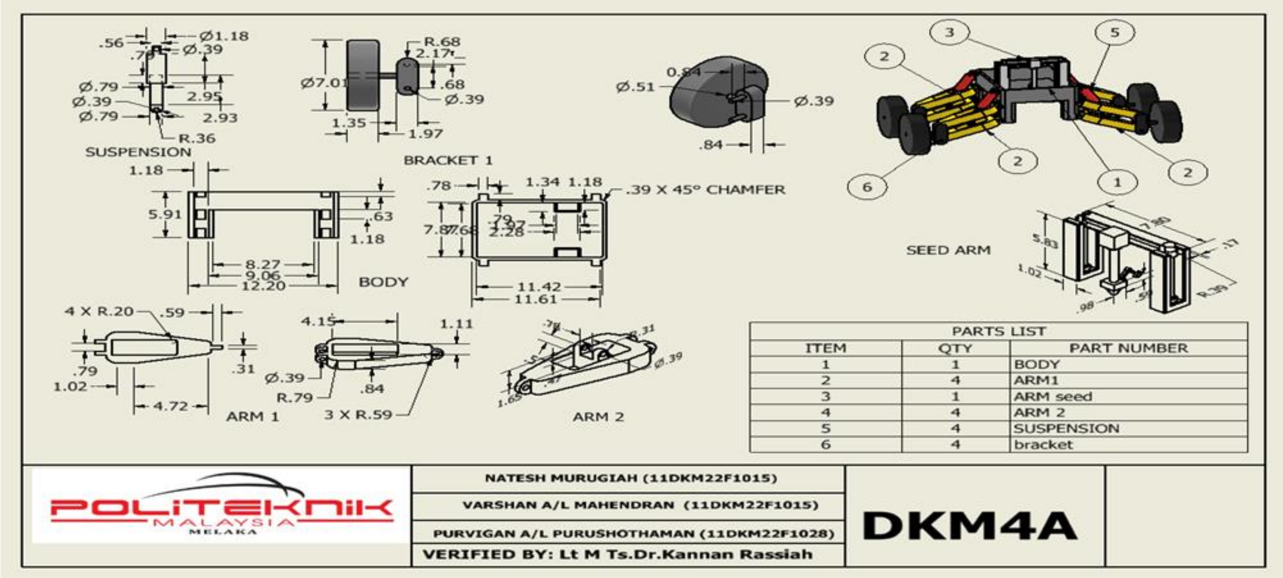

Figure 1.3: Autoseed: Smart Seeding Tray Robot with IOT Integration

3.2 Material and Equipment

Materials used in this project are ESP32, linear motor, moisture sensor, power window motor, pH sensor, 20W solar panel, e-bike shock absorber, RC crawler tires, 12V battery, and a 12 MP camera.

4.0 Discussion of analysis and findings

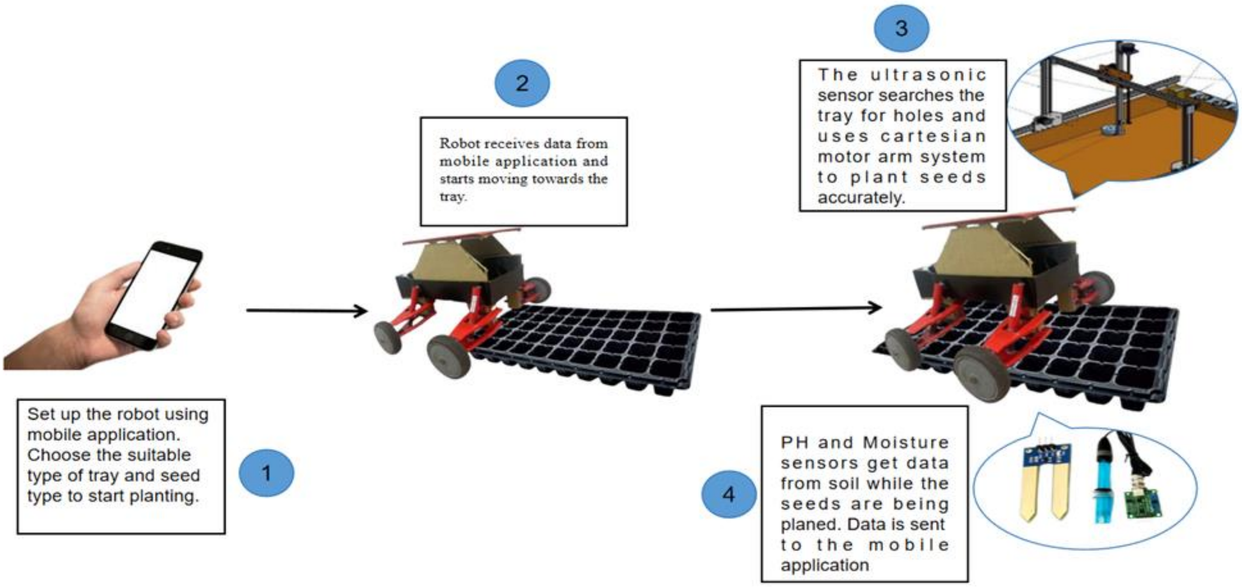

Figure 1.4 shows how the project will function.

Figure 1.4 shows how the project will function. It starts with a mobile application to set up the robot, and the robot receives orders from the mobile application. This will make the robot start moving and planting seeds on the tray. The robot will also collect data from soil using its sensors. The novelty of our project is the robot’s ability to plant seeds in a seeding tray. Which is a very cost and time-effective method. Furthermore, this mechanism is much more accurate and better to monitor the seedlings’ yield. This mechanism is also a very big step of innovation in the Malaysian agriculture sector's seeding industry. The second novelty of our project is that the seeds that are planted will use a camera with an AI-based detection system to detect the holes in a tray to plant accurately and time efficiently.

5.0 Conclusion and Future Research

This work proposes developing agricultural technology in Malaysia to combat declining soil quality, climate change, energy shortages, and labor issues. It aims to assist farmers by automating tasks and assessing soil health using a novel method of seed planting in trays for efficiency and accuracy in seedling yield monitoring. This innovation represents a significant advancement in Malaysia's seeding industry. It incorporates an ESP32 microcontroller, moisture and pH sensors, a Cartesian robot arm, high-torque motors, a solar panel, and a 12V battery, with a durable aluminum and composite construction, lug tires, suspension, and Wi-Fi/Bluetooth connectivity for operation over large seeding trays.

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Author Contributions

Natesh M.: Conceptualization, Methodology, Software, Writing- Original Draft Preparation, Writing – Review & Editing; **Varshan M.**: Methodology, Investigation; **Purvigan P.**: Methodology, Investigation; **Kannan R.**: Supervision, Validation, Resources, Project Administration, and **Arwizet K.**: Resources.

Conflicts of Interest

The manuscript has not been published elsewhere and is not being considered by other journals. All authors have approved the review, agree with its Submission, and declare no conflict of interest in the manuscript.

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