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FPGA PROTOTYPING FOR MOBILE-CONTROLLED AGRI BOT WITH TERRAIN ADAPTABILITY

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ABSTRACT
This paper presents the design and implementation of a Mobile-Controlled Agri Bot prototype, a robot created to work in different farmlands, including areas with rough and uneven terrain. The heart of this bot is the DE10 Nano FPGA board, which gives it the power to manage tasks effectively and process information in real time. The communication between the FPGA and the bot is handled through the UART protocol, a system that ensures commands from a mobile device are received quickly and reliably.The main goal of this project is to enhance agricultural productivity by allowing farmers to perform precise and flexible tasks even in challenging landscapes. By controlling the bot through a mobile interface, users can easily navigate and operate it in the fields, making it a valuable tool for modern farming.
Keywords: Agricultural Robotics, FPGA, Mobile- Controlled Systems, Terrain Adaptability, UART Protocol, Precision Agriculture.
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I. Introduction

Agriculture is crucial in ensuring global food security and supporting economic stability. Nevertheless, conventional farming practices often encounter significant obstacles, particularly in challenging environments like hilly or rugged landscapes. In such regions, standard agricultural techniques may prove ineffective, complicating the ability of farmers to cultivate crops and manage their land efficiently. The integration of robotics into agriculture has emerged as a promising solution to address these difficulties.

In recent years, advancements in agricultural robotics have been made to streamline various farming operations. These robots facilitate tasks such as livestock management, seed planting, and crop harvesting, thereby reducing reliance on manual labor and enhancing the accuracy and efficiency of agricultural processes. However, for optimal performance, these robots must navigate diverse and rough terrains. Un- fortunately, many traditional robots struggle in this regard due to their complex software, which often lacks the adaptability required for uneven surfaces.

To tackle this problem, this paper presents the Mobile- Controlled Agri Bot, a robot specifically engineered to excel in demanding agricultural environments. Unlike conventional robots, this Agri Bot is powered by a DE10 Nano FPGA board, enabling rapid information processing and multitask-ing capabilities. This design allows the bot to maneuver smoothly and operate effectively, even in challenging and uneven landscapes. A prominent aspect of the Agri Bot is its communication system, which employs the UART (Universal Asynchronous Receiver/Transmitter) protocol. This system is vital as it guarantees reliable data transmission between the FPGA and the bot, even under low power conditions. Effective communication is critical for the bot to accurately execute commands and perform its tasks efficiently. In the absence of this reliable system, the bot would struggle to respond promptly or operate effectively in real-time scenarios.

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The Agri Bot is operated via a mobile application, providing users with a straightforward means of control. This application features an intuitive interface that enables farmers to track the bot's movements and make real-time adjustments. Regardless of their proximity, farmers can utilize their mobile devices to manage the bot and ensure it is executing the required tasks. This capability offers a level of convenience and adaptability that is particularly beneficial in expansive or challenging environments.

This paper thoroughly examines the design, construction, and testing of the Mobile-Controlled Agri Bot. It empha- sizes how this cutting-edge robot addresses the limitations of conventional farming robots, especially in navigating difficult terrains. By overcoming these obstacles, the Agri Bot enhances the efficiency of agricultural practices and contributes to increased overall productivity.

II. Literature

A. *Role of FPGA in Agricultural Robotics*

Field-programmable gate arrays (FPGAs) are increasingly gaining popularity in the field of modern robotics due to their ability to perform parallel processing and their high level of reconfigurability. These features make FPGAs particularly well-suited for tasks that require quick adaptability and real- time processing, which are crucial in dynamic environments like agriculture. Unlike traditional processors, FPGAs can be programmed to execute multiple operations simultaneously, allowing them to handle complex algorithms and control systems efficiently. This versatility has led to their successful implementation in a variety of robotics projects, ranging from commercial automation systems to autonomous vehicles. In agricultural robotics, FPGAs offer the flexibility needed to manage diverse tasks, such as sensor integration, motor control, and data processing, making them an essential component for developing advanced robotic solutions in farming[1].

B. *Advances in Terrain-Adaptable Robotics*

Advances in terrain-adaptive robotics have led to significant enhancements in the mobility and performance of robots across various surface types. A notable development is the introduction of specialized suspension systems that enable robots to adapt to uneven terrain, thereby improving their stability and effectiveness in challenging environments. Additionally, the emergence of adaptive control algorithms has been pivotal. These algorithms allow robots to automatically modify their movements in response to terrain changes, ensuring seamless operation even under difficult conditions.

Moreover, the incorporation of sophisticated sensors has been instrumental in these advancements. These sensors enable robots to identify obstacles, surface variations, and potential dangers in real-time. With this data, robots can swiftly adjust their actions to maintain balance and navigate more effectively. The synergy of these technologies has greatly enhanced the mobility and dependability of robots, equipping them to tackle a wide range of tasks across diverse terrains, from smooth indoor surfaces to rugged outdoor areas[2].

C. *UART Protocol in Embedded Systems Communication*

The UART (Universal Asynchronous Receiver/Transmitter) protocol serves as a crucial communication method within embedded systems. Its simplicity and reliability make it particularly suitable for real-time applications. In the field of robotics, UART facilitates effective communication between various components of a system. This protocol ensures that data is transmitted accurately, allowing for smooth and efficient interactions. Its widespread adoption can be attributed to its ease of implementation and capability to manage communication tasks effectively. By utilizing UART, robots can function with high precision and respond promptly to commands. Its uncomplicated design contributes to its popularity in numerous embedded systems [3].

III. PROBLEM STATEMENT

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Agricultural robots face considerable obstacles when navigating uneven and steep landscapes. These challenging environments can significantly affect their precision and overall functionality. For larger robotic systems, a key concern is ensuring dependable communication between the control unit and the robot. In agricultural settings with intricate data networks, maintaining consistent and reliable communication is essential for optimal performance.
To tackle these issues, this study introduces an innovative design for a mobile-controlled agricultural robot. This robot is specifically designed to adeptly traverse rough and varied terrain. It features an advanced suspension system that improves its ability to maintain stability and adapt to different ground conditions. This sophisticated suspension mechanism enables the robot to adjust its positioning and balance, ensuring smoother operation even in demanding environments.
The design of the robot integrates FPGA (Field- Programmable Gate Array) technology for real-time power management. The use of FPGA technology allows for high- speed processing, which enhances the efficiency and accuracy of the robot in task execution. This capability is vital for sustaining the robot’s performance and dependability across diverse operational contexts.
Moreover, in addition to the cutting-edge suspension and FPGA processing, the robot employs the UART (Universal Asynchronous Receiver/Transmitter) protocol for communication. UART is a well-established communication standard recognized for its simplicity and reliability. It guarantees effective data transmission between the control unit and the robot, enabling smooth and precise control. This protocol is instrumental in minimizing communication errors and delays, which are critical for the robot’s successful operation.
The proposed agricultural robot seeks to improve its performance and reliability in challenging conditions through the integration of advanced technologies. By utilizing a sturdy suspension system, real-time processing via FPGA, and re- liable communication through UART, the robot is engineered to operate effectively across diverse agricultural settings. This strategy is intended to enhance the efficiency and capability of agricultural robots, even in the face of difficult terrain and intricate operational demands.

IV. PROPOSED SYSTEM DESIGN

A. System Architecture

FPGA DE10 Nano board: It Acts as a central processing unit, executes control algorithms, processes sensor data, and manages communication with the bot.

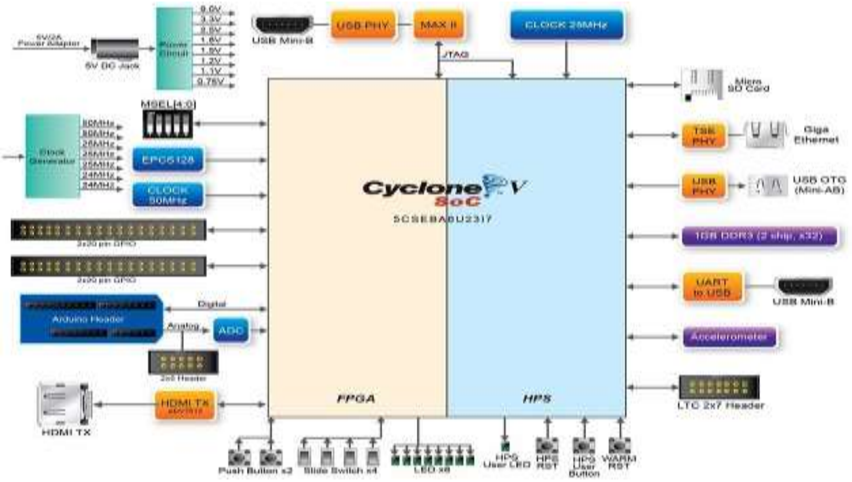

Fig. 1. FPGA DE-10 NANO block diagram.

We present its main features in Figure 1 and Figure 2.

- Intel Cyclone® V SE 5CSEBA6U23I7 device (110K LEs)
- Serial configuration device – EPCS64 (revision B2 or later)
- USB-Blaster II onboard for programming; JTAG Mode

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- HDMI TX, compatible with DVI 1.0 and HDCP v1.4
- 2 push-buttons
- 4 slide switches
- 8 green user LEDs
- Three 50MHz clock sources from the clock generator
- Two 40-pin expansion headers
- One Arduino expansion header (Uno R3 compatibility), can be connected with Arduino shields
- One 10-pin Analog input expansion header (shared with Arduino Analog input)
- A/D converter, 4-pin SPI interface with FPGA

2. Terrain-friendly device: It is equipped with a specially designed chassis and suspension system to handle rough ground conditions. The chassis provides structural strength, ensuring the robot remains stable and durable when navigating uneven surfaces. The suspension system is engineered to absorb shocks and impacts, reducing the strain on the robot and enhancing its ability to move smoothly. This combination allows the robot to maintain traction and stability even on challenging terrain. The design helps the robot adjust to various ground levels, making it more adaptable to different environments. With this setup, the robot can travel across difficult and uneven surfaces with greater ease and efficiency. This advanced design improves the overall performance and reliability of the robot in agricultural settings.

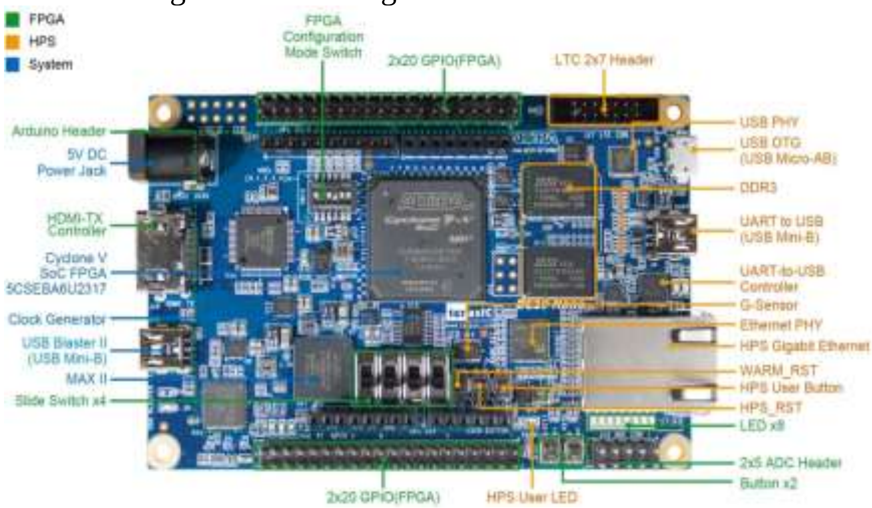

Fig. 2. FPGA DE-10 NANO

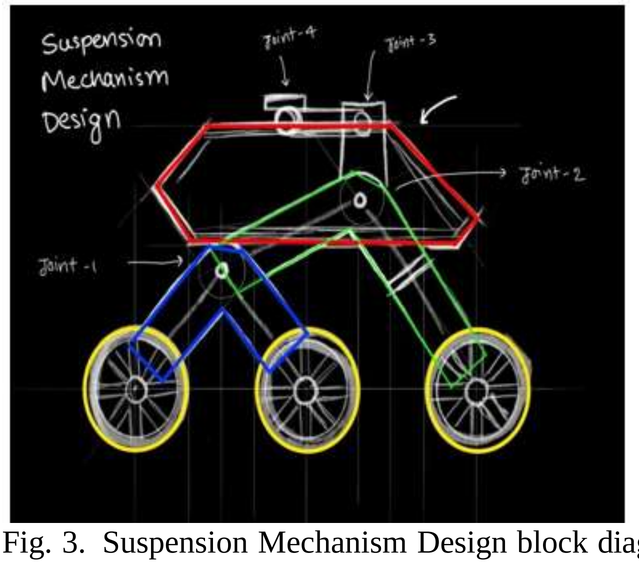

Fig. 3. Suspension Mechanism Design block diagram

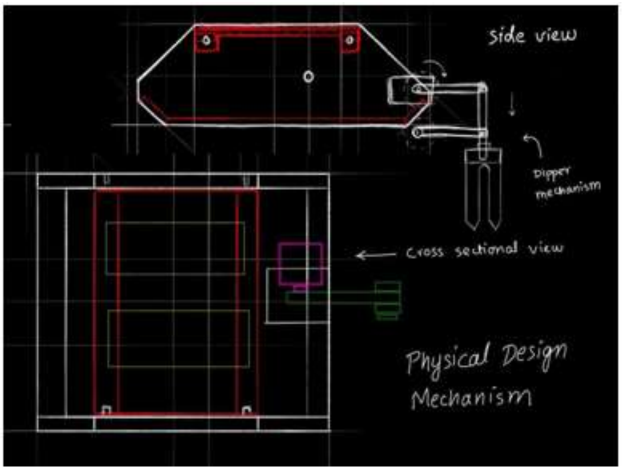

Fig. 4. Side view of Suspension Mechanism Design block diagram.

3. Mobile Interface: The mobile interface is an Android application designed for the real-time management of the bots. It features a user-friendly layout that simplifies the process of overseeing the bot's operations directly from a Smartphone. Users can maneuver the bot, check its status, and modify settings using the app's straightforward controls. The real- time capabilities guarantee immediate execution of commands, facilitating efficient and responsive management. This mobile interface improves convenience by enabling users to engage with the bot from any location, thereby streamlining the oversight and control of its functionalities.

Fig. 5. Android Application.

B. UART Protocol: The UART communication protocol is essential for facilitating effective communication between the FPGA and the bot. It guarantees rapid data transmission with minimal latency, which is crucial for avoiding errors or data loss. Designed for seamless data transfers, UART ensures that messages exchanged between the FPGA and the bot are both accurate and timely.

Through UART, the connection between the FPGA and the bot is dependable, enabling optimal collaboration between the two devices. This reliability enhances the control and management of the bot, as UART maintains a steady and precise data flow, thereby supporting the bot's performance and ensuring its proper operation.

Furthermore, UART fosters effective coordination between the FPGA and the bot, contributing to the smooth functioning of the entire system. By establishing a consistent method for data exchange, UART eliminates delays and communication errors, which are vital for the bot's functionality and overall efficiency.

C. Functional Overview

The mobile-controlled agricultural robot is entirely managed through a mobile application, enabling users to operate it from a distance and modify its actions in real-time. This capability offers

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considerable adaptability, making it suitable for a variety of environments. The robot features a suspension system that

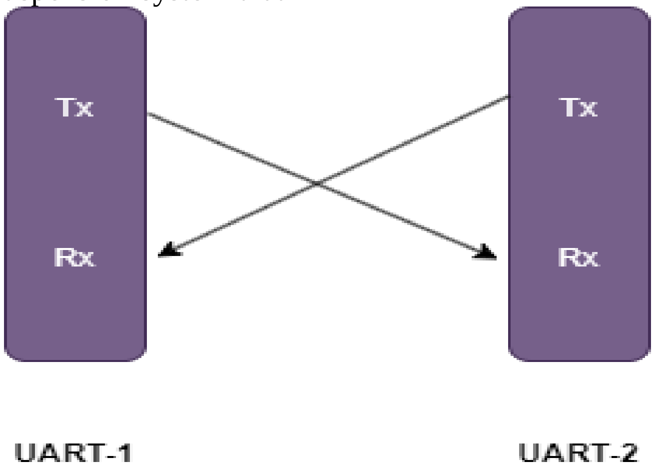

Fig. 6. UART Protocol.

can traverse different types of terrain, allowing for smooth movement even on uneven surfaces. This design ensures that it can function effectively in various fields without the risk of becoming immobilized or losing its balance. Communica- tion between the FPGA and the robot is facilitated by the UART protocol, which is well-regarded for its reliability and efficiency. This protocol guarantees that data is transmitted and received swiftly and accurately, keeping the robot and FPGA aligned. Consequently, the robot responds promptly to commands and carries out its tasks effectively. The stable communication provided by UART is vital for maintaining the robot's overall performance and ensuring its proper operation in all environments.

V. IMPLEMENTATION METHODOLOGY

A. *Hardware Design and Integration*

Developing mobile-controlled agricultural robots requires meticulous hardware design to guarantee swift responsiveness and operational efficiency in farming settings. The design pro- cess must prioritize real-time functionality, enabling the robot to respond immediately to commands and manage the diverse requirements of agricultural activities. This strategy ensures that the robot is both dependable and capable of enhancing productivity across a range of farming environments.

1. FPGA Configuration: The DE10 Nano FPGA board serves as the brain of the agri-bot, handling all the processing tasks needed for the bot to work effectively. It is programmed to manage the control algorithms that allow the bot to op- erate smoothly and efficiently. The FPGA is to be highly responsive to inputs from the mobile app, meaning it can quickly process real-time control commands from the user. This makes it possible to control the bot instantly through the mobile interface, offering a high level of flexibility. The FPGA communicates directly with the sensors and actuators on the bot, ensuring precise control over the bot's movements and actions. For example, when the bot needs to adjust its speed or direction, the FPGA processes the necessary data.

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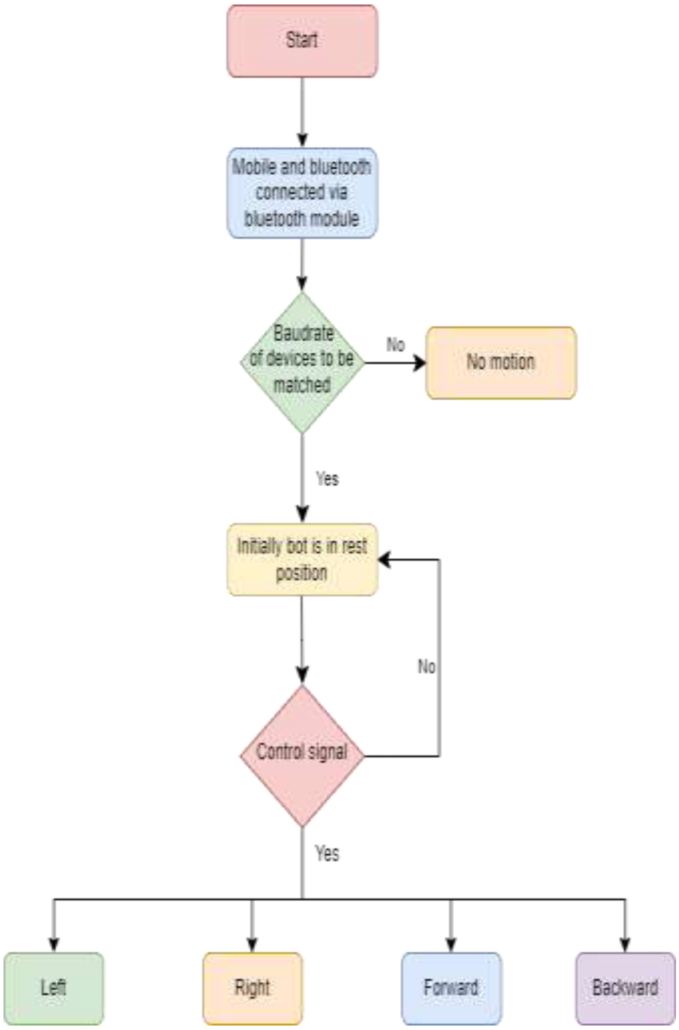

Fig. 7. Project flowchart.

and sends commands to the actuators, making the bot responds accurately. One of the key strengths of the FPGA is its ability to perform parallel processing. This means it can handle multiple tasks at the same time, which is essential for running complex algorithms. This capability allows the bot to adapt to changing environments, such as uneven terrain or obstacles, without losing performance. By using the DE10 Nano FPGA, the bot can maintain high performance even in dynamic and challenging agricultural settings, ensuring it functions reliably and efficiently.

1. Technical design: The technology behind the bot is con- structed around a chassis that incorporates a unique suspension system. This system is pivotal for the bot's ability to glide smoothly over diverse terrains, including those that are uneven or steep.

It is specifically designed to absorb shocks and impacts, which aids in maintaining stability even when traversing rough or bumpy surfaces. By lessening the effects of sudden terrain variations, the suspension system is instrumental in keeping the bot balanced and functional. This capability allows the

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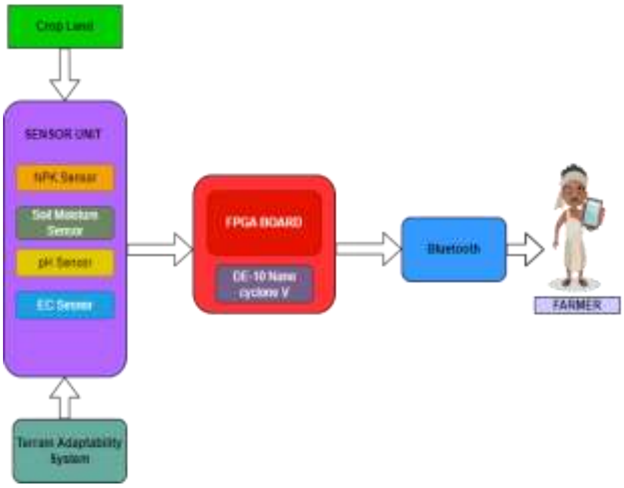

Fig. 8. Block diagram: overview of the developed system.

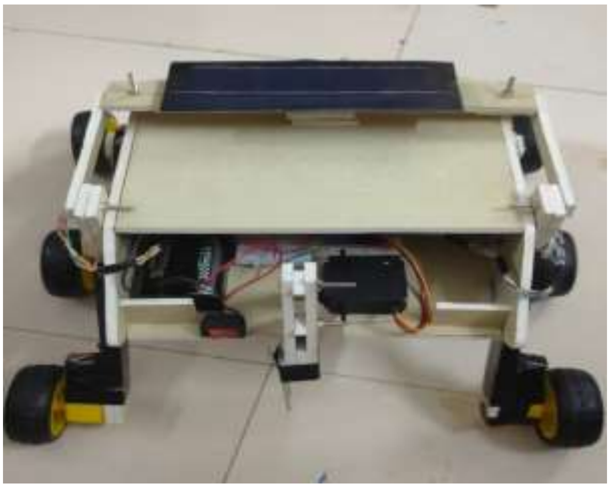
Fig. 9. Front view.

bot to perform effectively in challenging environments without being impeded or damaged by the rugged ground. Moreover, the suspension system serves to prevent mechanical wear and tear by cushioning the bot against harsh jolts or bumps. This is particularly significant in agricultural contexts, where the terrain can be erratic and severe. The advanced design of the suspension system enables the bot to uphold its performance and dependability, even in difficult conditions. It facilitates smooth navigation through fields, hills, and other challeng- ing terrains, ensuring that the bot can carry out its tasks without disruption. The overall configuration of the chassis and suspension system renders the bot exceptionally suitable for agricultural work, where both stability and durability are critical.

2. Communication Strategy: The UART (Universal Asyn- chronous Receiver/Transmitter) protocol plays a crucial role in the control system of the bot, facilitating dependable com- munication among its various components. This protocol is designed for serial communication, ensuring precision in data

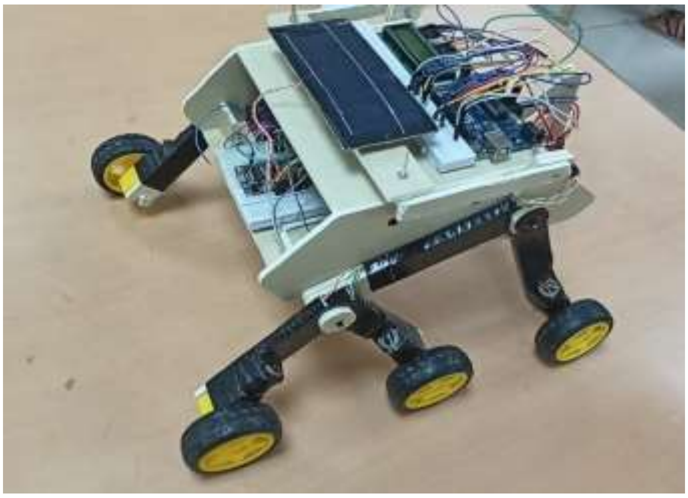

Fig. 10. Top view.

transmission. By utilizing UART, the FPGA can seamlessly interact with the bot's subsystems, guaranteeing that every sensor input and actuator output is handled with accuracy. This connectivity is vital for enabling the bot to respond to real-time commands, particularly when operated remotely via a mobile application.

Fig. 11. Side view.

The UART protocol guarantees that commands issued from the mobile interface are transmitted to the bot swiftly and without errors, even in typical agricultural settings where the bot may not be far away. This reliability prevents data loss, allowing the bot to execute tasks with precision and capability. This configuration is essential for sustaining the bot's performance, as it enables the system to swiftly adapt to environmental changes. Whether navigating new terrains or ex- ecuting commands, the bot depends on the UART protocol to ensure optimal functionality. This dependable communication allows the bot to operate efficiently, regardless of the distance or complexity of the farming environment.

B. *Software Development*

1. Mobile Application: The mobile application serves as the central control interface for Agri Bot, crafted to be straightforward and user-friendly. It allows users to monitor bot operations directly through Bluetooth, providing real-time remote control capabilities. The design prioritizes accessibility, ensuring that even those with limited technical knowledge can effectively utilize the bot. This application establishes a connection to the bot's FPGA through the UART interface, which is crucial for sending commands and receiving status updates. For example, when a user inputs a command, it is transmitted to the FPGA, which then instructs the bot to carry out the requested action. In addition to fundamental control features, the app delivers real-time telemetry, enabling

users to track the bot's sensors as it moves across different terrains. This functionality is essential for evaluating the bot's performance and confirming its operational integrity. The app also includes diagnostic tools for troubleshooting and identifying bots, streamlining the repair process. By leveraging a Bluetooth-based application, users can control the bot wire- lessly, offering adaptability in agricultural environments with varying distances and terrain types. This system ensures that the bot can be operated safely and efficiently, regardless of the location. Thus, the mobile app is integral to the management of the Agri Bot, providing a comprehensive and user-friendly management solution.

2. FPGA Function: The FPGA serves as the core element responsible for managing the bot's communication, processing sensor information, and overseeing all control logic. It is pro- grammed using Verilog HDL, a hardware description language that facilitates precise control over the FPGA's operations. The Verilog code is structured in a modular way, allowing for easy customization and enhancement to incorporate new features or functionalities as required.

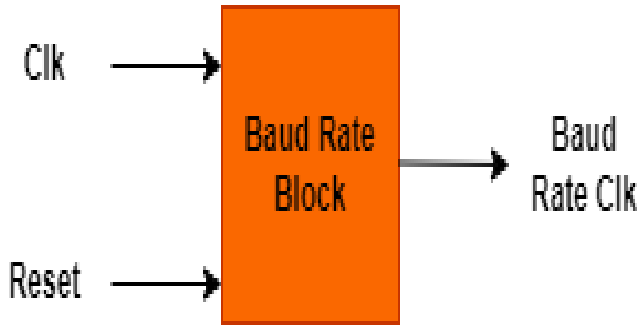

Fig. 12. Baud Rate Module.

The FPGA design leverages its parallel processing capabil- ities, enabling it to execute multiple tasks concurrently, which is essential for the bot's seamless operation. For instance, the FPGA can simultaneously handle motion control, process sensor data, and maintain communication with a mobile appli- cation. This capability ensures that the bot can quickly respond to commands while effectively monitoring its environment.

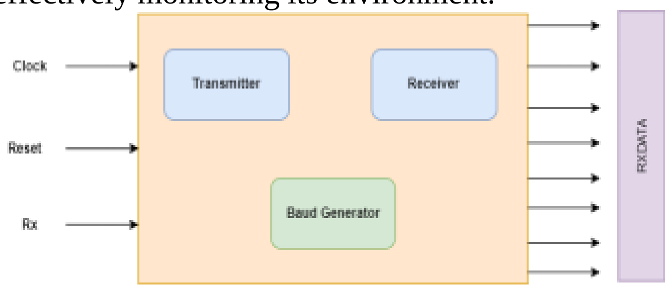

Fig. 13. Decision Unit Process.

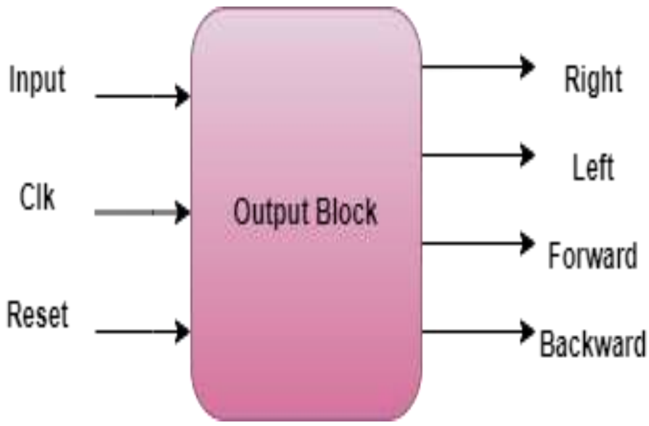

Fig. 14. Output Unit.

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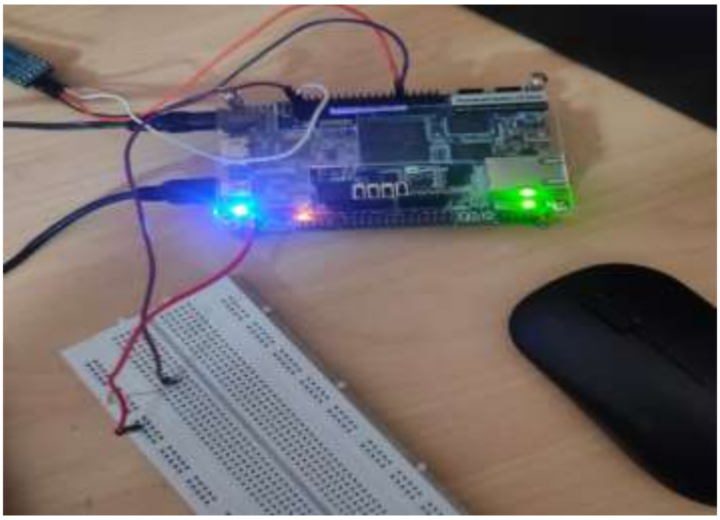

Fig. 15. Fpga Results.

By executing various tasks in parallel, the FPGA contributes to the bot's consistent and efficient performance. Whether it is adjusting based on sensor feedback or carrying out control commands from a mobile app, the FPGA guarantees smooth operation without delays. This reliability and responsiveness are vital for effective functioning in field systems, making parallel processing a crucial aspect for enabling bots to manage complex tasks in real-time. Additionally, the bot's functionality can be modified and expanded, allowing it to adapt to diverse challenges and requirements.

VI. EXPERIMENTAL RESULT

The Agri Bot was tested in various agricultural environ- ments to see how it works:

Ground navigation: The robot adeptly traversed steep and sloped surfaces, showcasing its capability to handle highly challenging environments. The suspension system was pivotal in this achievement, maintaining the robot's stability on uneven ground. This stability is essential for safeguarding the robot's vital components, ensuring it operates smoothly despite the rough terrain. Additionally, the suspension system contributed to the robot's seamless performance, enabling it to perform its tasks without disruption or risk of damage. As a result, the robot proves to be more dependable and efficient in navigating various agricultural landscapes.

Communication Reliability: The UART protocol established a robust and dependable link between the FPGA and the bot. It guarantees uninterrupted data transmission, which is essential for optimal bot performance. This dependable connection facilitated the accurate transmission of commands from the mobile application to the bot, ensuring prompt and precise responses to each command. By employing a consistent set of commands—such as left, right, forward, and backward—the system enabled swift and accurate operations, allowing the bots to function seamlessly and effectively.

Mobile Control Efficiency: A mobile application tailored for Bluetooth control offered a straightforward and user-friendly interface for managing bot movements. The app concentrated on essential commands like left, right, and forward, utiliz- ing background monitoring for enhanced functionality. This streamlined design simplified the user experience, allowing for effortless operation of the bots. The Bluetooth connection en- sured that every command was transmitted reliably and swiftly, enabling real-time responses from the bot. This approach to bot control proved to be both simple and efficient, providing users with an accessible means to navigate the bot's basic movements across various applications, while emphasizing ease of use and reliability for a smooth user experience.

A. Test Scenarios and Performance Metrics

The bot underwent testing across multiple scenarios to evaluate its reliability and performance. These tests encom- passed various terrains, including sand, gravel, and slopes. The primary focus was on the bot's ability to maintain stability on these surfaces, ensuring it could navigate smoothly without wobbling or losing balance. Another key aspect of the experiments was the precision in following commands. The bot's capability to stay on its intended course and ex- ecute tasks accurately was carefully observed. Additionally, the effectiveness of long-range communication was assessed, with tests measuring the speed at which the bot responded to commands from the mobile application. Overall, these evaluations were structured to assess the bot's functionality in real-world agricultural settings, with an emphasis on stability, accuracy, and responsiveness

VII. DISCUSSIONS

The emergence of mobile farm bots represents a significant advancement in the field of agricultural robotics, bringing improved efficiency and accuracy to farming operations. By leveraging the DE10 Nano FPGA board, these bots can process data effectively and make real-time decisions, which are crucial for navigating the complex and diverse agricultural landscapes. This capability allows the bots to quickly adapt to changing conditions, such as uneven ground or obstacles encountered in the field.

The implementation of the UART protocol plays a vital role in facilitating seamless communication between the bot's various systems. This dependable communication is essential for maintaining the bot's operational reliability and ensuring its precise execution of commands. By combining real-time processing with sophisticated communication techniques, the bot significantly boosts operational efficiency, positioning it as an essential tool in contemporary agricultural practices. Its mobile and user-friendly design allows for deployment across different sections of the field, providing substantial versatility. This adaptability makes the bot an invaluable component of a mobile workflow, minimizing the reliance on manual labor and fostering more efficient and sustainable farming methods.

A. Advantages and Limitations

Mobile farm robots provide substantial advantages, espe- cially due to their ability to adapt to various geographic conditions and their enhanced functionalities. Their profi- ciency in navigating different terrains makes them applicable in a wide array of agricultural settings, positioning them as essential tools for farmers. Moreover, the capacity to control these robots in real time significantly improves operational efficiency and supports energy conservation during various farming activities. Nevertheless, several challenges must be addressed. A major concern is the requirement for extensive testing in different environments. While initial trials have produced positive results, it is imperative to evaluate the robots' performance in diverse climates and soil types to ensure their effectiveness across all agricultural scenarios. As technology advances, these robots may need future updates or modifications to maintain their performance and reliability. Certain design aspects may also require adjustments to keep pace with evolving technological standards. In summary, while these robots possess remarkable potential, ongoing evaluation and refinement are crucial to ensure they meet the demands of contemporary agriculture and continue to enhance their capabilities.

VIII. CONCLUSION

The mobile agricultural bot created in this project represents a significant leap forward in the field of agricultural robotics. Leveraging the DE10 Nano FPGA board and a robust UART connection, the bot adeptly maneuvers through challenging and uneven landscapes. It offers precise control via a mobile interface, showcasing how technology can transform modern farming practices.

Several exciting possibilities exist for advancing agricultural bots in the future: 1. Environmental Integration: One of the primary focuses for future enhancements is the integration of environmental

monitoring. By equipping the bot with sensors to track essential parameters such as nutrient levels (NPK), temperature, and moisture, it can deliver critical insights that help optimize agricultural methods. This data will empower farmers to make informed decisions regarding crop manage- ment and soil health, ultimately leading to improved yields and resource efficiency.
2. Enhanced Autonomy: Future iterations of the Agri-Bot may investigate autonomous functionalities that minimize the need for human intervention. For instance, integrating GPS navigation will enable the bot to traverse extensive areas by adhering to pre-set routes. Additionally, incorporating obstacle avoidance technology will allow the bot to navigate around barriers and adapt to varying conditions, enhancing its versatility and reliability across diverse environ- ments.
3. Broadened communication options: Implementing new communication channels can greatly improve the efficiency and flexibility of the bot's operations. By incorporating tech- nologies such as RF (Radio Frequency) or Bluetooth, the control range of the bot can be extended. This enhancement allows the bot to operate more effectively over larger expanses, making it suitable for extensive agricultural settings. The augmented communication features ensure that the bot remains dependable and operational, even in remote locations.

References
[1] Ramesh Kruthika et al., ”Design and development of of an Agri-bot for Automatic Seeding and Watering Applications”, 2020 2nd Interna- tional Conference on Innovative Mechanisms for Industrial Applications (ICIMIA), 2020.
[2] S. Bhargavi, ”Design of an Intelligent Combat Robot for War Field”, International Journal of Advance Computer Science and Application, vol. 2, no. 8, 2011.
[3] Muhammad Hamza Ali and Muhammad Salman Kabir, ”Design and Development of an Unmanned Ground Vehicle with Serial Manipulator and its Control Mechanism”, 2021 International Conference on Electrical Communication and Computer Engineering (ICECCE).
[4] Anmol Singh Shekhawat and Yogesh Rohilla, ”Design and Control of Two-wheeled Self-Balancing Robot using Arduino”, 2020 International Conference on Smart Electronics and Communication(ICOSEC), 10-12 September, 2020.
[5] S. Mandapati, S. Pamidi and S. Ambati, ”A mobile based women safety application (I Safe Apps)”, IOSR Journal of Computer Engineering, vol. 17, no. 1, pp. 29-34, 2015.
[6] P. A S, N. B S, N. Noushad, M. A. S, S. S and D. L. M, ”Automatic Agricultural Robot - Agrobot”, 2020 IEEE Bangalore Humanitarian Technology Conference (B-HTC), 2020**.**
[7] G Megarajan, ”Mega Bot - The Healthcare Chatbot”, Second Inter- national Conference on Electronics and Sustainable Communication Systems, 2021.
[8] Lia Kamelia, S.R Alfin Noor hassan, Mada Sanjaya and W.S. Edi Mulyana, ”Door-Automation System Using Bluetooth-Based Android For Mobile Phone”, ARPN Journal of Engineering and Applied Sci- ences, vol. 9, no. 10, October 2014, ISSN 1819–6608.
[9] N. Maher, G.A Elsheikh, A.N Ouda, W.R Anis and T. Emara, ”Design and implementation of a wireless medical robot for communication within hazardous environments”, Wireless Personal Communications, vol. 122, no. 2, pp. 1391-1412, 2022.
[10] S. Madhura, ”IoT Based Monitoring and Control System using Sensors”, Journal of IoT in Social Mobile Analytics and Cloud 3, no. 2, pp. 111- 120, 2021.
[11] Mr. R. Vinothkanna, ”A Survey on Novel Estimation Approach of Motion Controllers for Self-Driving Cars”, Journal of Electronics 2, no. 04, pp. 211-219, 2020.
[12] Gayatri Joshi and Prof. Mr. Prashant Kolhe, ”Intelligence Spy Robot with wireless night vision camera using Wi-Fi”, 2021 International Research Journal of Engineering and Technology.
[13] D. Inamdar et al., ”Automated Drip Irrigation System based on Em- bedded System and GSM Network”, International Journal of Innovative Research in Computer and Communication Engineering (An ISO 3297: 2007 Certified Organization), vol. 4, no. 5, May 2016.