CHAPTER-4

DESIGN OF LOW-COST SIX-WHEEL ROCKER–BOGIE ROBOT FOR SMALL-SCALE AGRICULTURAL SPRAYING

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Abstract

Agricultural automation plays an important role in improving farming efficiency, reducing labour dependency, and supporting sustainable agricultural practices. This chapter presents the design, fabrication, and experimental investigation of a low-cost six-wheel rocker–bogie robotic vehicle developed for small-scale agricultural spraying applications. The robotic platform was fabricated using lightweight materials integrated with a rocker–bogie suspension mechanism to improve mobility, stability, and terrain adaptability on uneven agricultural land. A spraying assembly consisting of a PVC spray pipe, water pump, flexible tubing, and nozzles was incorporated for effective spraying operations. The robot was initially tested under laboratory conditions to evaluate wheel movement, spray performance, pump operation, and suspension stability before being investigated under real agricultural field conditions. Experimental results showed that the rocker–bogie mechanism provided satisfactory terrain adaptability, wheel traction, manoeuvrability, and uniform spray distribution during operation. The lightweight and modular design of the robot makes it suitable for educational research, prototype development, and small-scale farming applications, while future improvements may include autonomous navigation and intelligent agricultural automation technologies.

Keywords: Agricultural Robot, Rocker–Bogie Mechanism, Precision Agriculture, Spraying Robot, Terrain Mobility

1. Introduction

Agriculture is one of the oldest and most essential human activities that supports global food production and economic development. Traditional agricultural practices have evolved significantly over the years due to increasing technological advancements and growing demand for efficient farming systems. However, many farming operations in developing regions still rely heavily on manual labour and conventional equipment. Such methods often lead to reduced productivity, increased operational costs, and excessive physical effort. In addition, agricultural labour shortages and rising costs of farming operations have created an urgent need for automated and intelligent agricultural systems (Bechar & Vigneault, 2016).

Agricultural automation has emerged as a promising solution for improving farming efficiency and reducing dependence on manual labor. Modern agricultural robots are capable of performing several important farming operations such as irrigation, harvesting, crop monitoring, spraying, and seed planting. These robotic systems help farmers increase productivity while minimizing resource wastage and operational cost (Jin et al., 2021). Among different agricultural operations, spraying is one of the most important and frequently performed activities. Proper spraying ensures effective pest control, nutrient distribution, and crop protection. However, manual spraying exposes farmers to harmful chemicals and often results in uneven distribution of pesticides and fertilizers (Oliveira et al., 2021).

Robotic spraying systems have therefore attracted significant research attention in recent years. Mobile robotic platforms integrated with spraying assemblies can improve operational safety and spraying accuracy while reducing human effort. Artificial intelligence and Internet of Things (IoT)-based agricultural robots are increasingly being developed for smart farming applications and precision agriculture practices (Astuti et al., 2024). For agricultural applications, mobility over rough and uneven terrain is an important design requirement because farmland surfaces are generally irregular and difficult to navigate using conventional wheel arrangements.

The rocker–bogie suspension mechanism is one of the most effective mobility systems developed for rough terrain robotic applications. Originally designed for planetary exploration rovers, the rocker–bogie mechanism provides excellent stability and obstacle-climbing capability. The mechanism maintains continuous wheel contact with the ground surface, thereby improving traction and minimizing excessive chassis tilting (Kim et al., 2012). Due to these advantages, rocker–bogie systems are increasingly being investigated for agricultural robots, surveillance vehicles, rescue robots, and exploration platforms (Patel et al., 2022).

This chapter focuses on the development of a low-cost six-wheel rocker–bogie robotic vehicle specifically designed for small-scale agricultural spraying operations. The developed robotic system integrates a lightweight chassis, six-wheel rocker–bogie suspension mechanism, and spraying assembly to achieve stable and efficient spraying operations on uneven agricultural terrain.

2. Rocker–Bogie Suspension Mechanism

The rocker–bogie mechanism is a passive suspension system widely used in mobile robotic applications requiring terrain adaptability and obstacle-climbing capability. The system consists of rocker arms, bogie links, wheel assemblies, and pivot joints connected in such a way that the wheels can move independently while maintaining chassis stability. The primary objective of the rocker–bogie mechanism is to ensure continuous wheel contact with uneven surfaces and improve load distribution during motion (Kim et al., 2012). The mechanism is composed of two rocker arms connected to the main chassis through pivot joints. Each rocker arm supports a bogie linkage connected to two rear wheels. The front wheel is directly attached to the rocker arm. When the robot encounters an obstacle, the articulated linkage system allows the wheels to adjust according to terrain irregularities without significantly disturbing the chassis orientation. Unlike conventional suspension systems that rely on springs and dampers, the rocker–bogie mechanism utilizes geometric articulation to absorb terrain variations. This feature simplifies the mechanical structure while improving reliability and terrain adaptability. The six-wheel arrangement further enhances traction and stability by distributing the load uniformly across the wheels (Patel et al., 2022). The rocker–bogie mechanism provides several advantages including improved terrain adaptability, better obstacle-climbing capability, reduced wheel slippage, and enhanced stability on rough surfaces. These characteristics make the system highly suitable for agricultural environments where uneven soil conditions, small obstacles, and rough terrain are common (Mohan et al., 2023).

3. Design and Fabrication of the Robot

The robotic platform was designed with the objective of developing a low-cost and lightweight agricultural spraying system suitable for small-scale farming applications. The robot consists of a rectangular chassis integrated with a six-wheel rocker–bogie suspension mechanism and spraying assembly as shown in Fig.1. The chassis was fabricated using plywood and lightweight support members to reduce overall system weight while maintaining sufficient structural rigidity. The approximate dimensions of the robot were selected to ensure stability and manoeuvrability during field operation. The six-wheel arrangement was designed to distribute load effectively and improve terrain adaptability. Each wheel was driven using DC geared motors mounted on rocker and bogie links connected through pivot joints. The wheel assemblies were designed to provide sufficient traction on uneven terrain while minimizing wheel slippage. Rubber wheels were selected to improve ground grip and mobility performance.

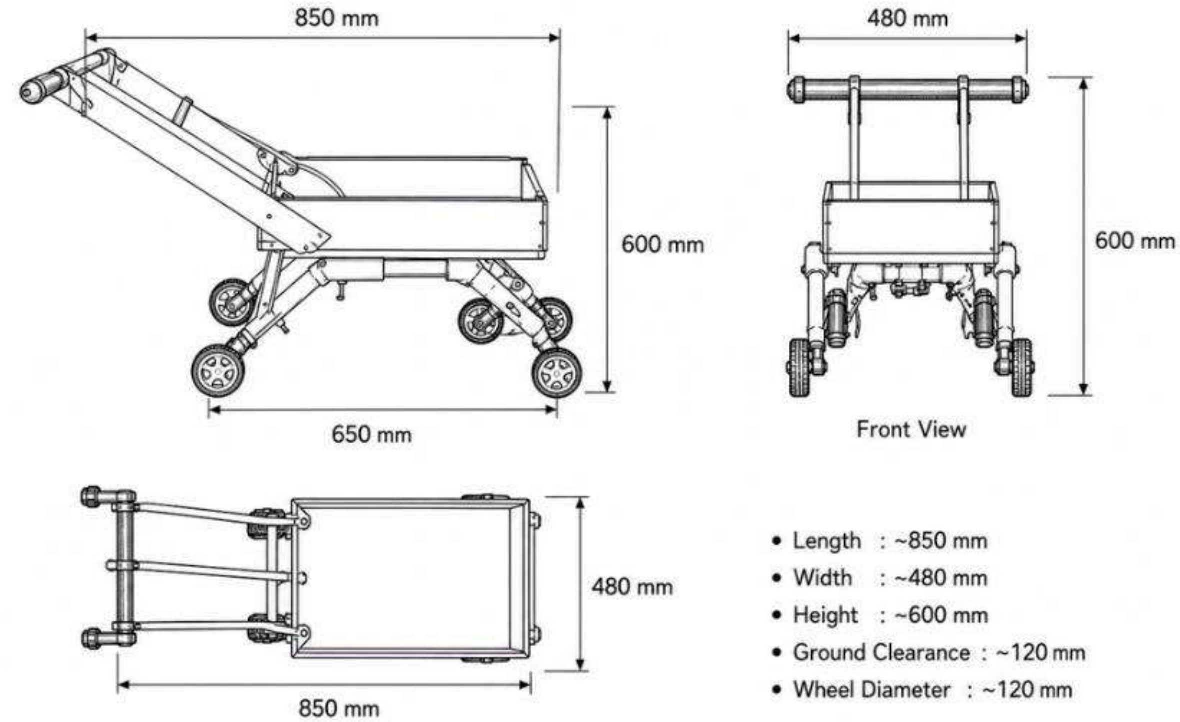

Figure 1: Dimensional drawing and overall structure of the six-wheel rocker–bogie robot

The spraying assembly consisted of a PVC spray pipe fitted with multiple nozzles to ensure uniform spray distribution. Flexible tubing connected the spray pipe to a water reservoir and pumping system mounted inside the chassis. A compact water pump was used to supply pressurized water to the nozzle arrangement during spraying operations. Similar spraying arrangements have been widely adopted in precision agriculture systems to improve spray efficiency and reduce chemical wastage. The electrical system included rechargeable batteries, motor driver circuits, electrical wiring, and control switches. The battery pack supplied electrical power to both the wheel motors and water pump system. Proper insulation and wiring arrangements were implemented to protect the electrical components from water exposure and mechanical damage. The fabrication process involved cutting and assembling structural components, mounting the wheel assemblies, integrating the spraying system and establishing electrical connections as in Fig.2.

(a) (b)

(c) (d)

(E)

Figure 2 Sequential Fabrication Images of the Chassis Assembly, Rocker–Bogie Linkage Construction, Wheel Mounting and Spray Pipe Integration

4. Experimental Investigation

The experimental investigation of the robotic spraying vehicle was performed under both laboratory and agricultural field conditions. The primary objective of the experiments was to evaluate wheel movement, terrain adaptability, spray distribution, pump performance, and suspension stability. Initially, laboratory testing was conducted to examine the mechanical and electrical performance of the robot. The spray assembly was operated continuously to evaluate nozzle performance, spray coverage, and water flow rate. Minor leakage points were identified near pipe joints and corrected using sealing materials. The rocker–bogie suspension system was tested by operating the robot over small obstacles and uneven blocks placed on the laboratory floor. The wheel assemblies maintained continuous contact with the ground surface, and the chassis demonstrated satisfactory stability during movement. The articulated wheel arrangement successfully minimized excessive vibration and tilting. Previous studies have also reported that rocker–bogie systems improve robotic mobility over rough terrain and maintain stable wheel-ground interaction during obstacle traversal (Patel et al., 2022). Electrical testing was also performed to verify battery performance, motor operation, and wiring reliability. The wheel motors demonstrated smooth operation and satisfactory torque during motion. The battery system provided sufficient backup time for continuous operation during testing.

Fig. 3 and 4 shows the robot undergoing testing on a rough terrain simulator. To replicate uneven ground conditions, a 5-ft pathway composed of an acrylonitrile–butadiene copolymer (NBR) sheet as containing regularly spaced octagonal cuts was constructed shown in Fig.3. The robot advanced over this surfaces displaying smooth forward motion. Small and periodic vertical oscillations were observed during its motion. These oscillations correspond to the depth and spacing of the rectangular openings in the sheet. The robot's demonstrated sequential vertical displacement as each wheel entered and exited the gaps in the sheet. The robot body maintained coherent and unified motion throughout the traversal.

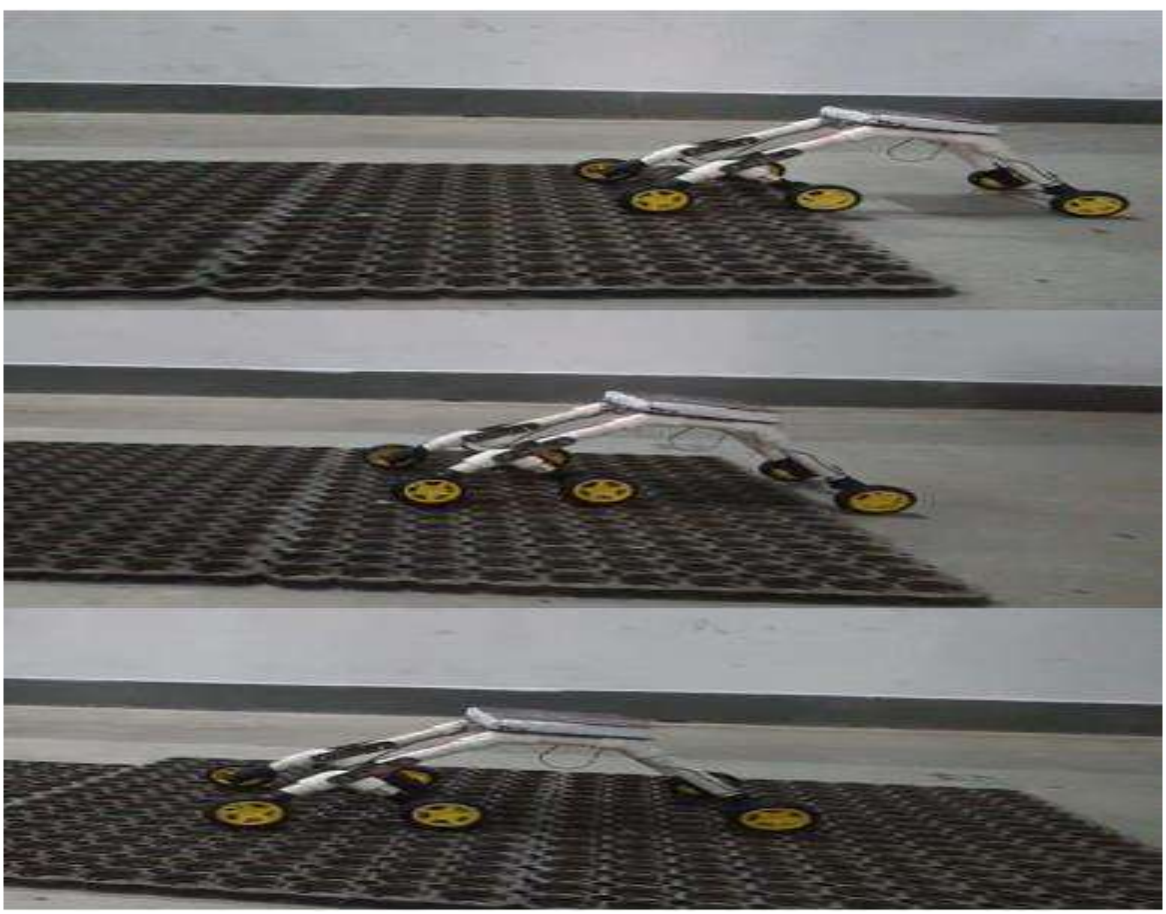

Figure 3: Images robot under rough terrain test on acrylonitrile–butadiene copolymer (NBR) sheet

Fig.4 shows the robot crossing over a wooden cylindrical obstacle. During the obstacle-course evaluation the front wheel required additional mechanical support to initiate the climb due to the relatively large diameter of the cylinder. The rocker–bogie suspension system oriented itself nearly perpendicular (≈90°) to the cylinder's surface ensuring continuous wheel surface contact throughout the maneuver. The revolute joint located at the rocker bogie junction played a critical role in enabling smooth ascent and descent of the wheels. Furthermore, the increased ground clearance because of larger height of the robot assisted in overcoming the cylindrical barrier.

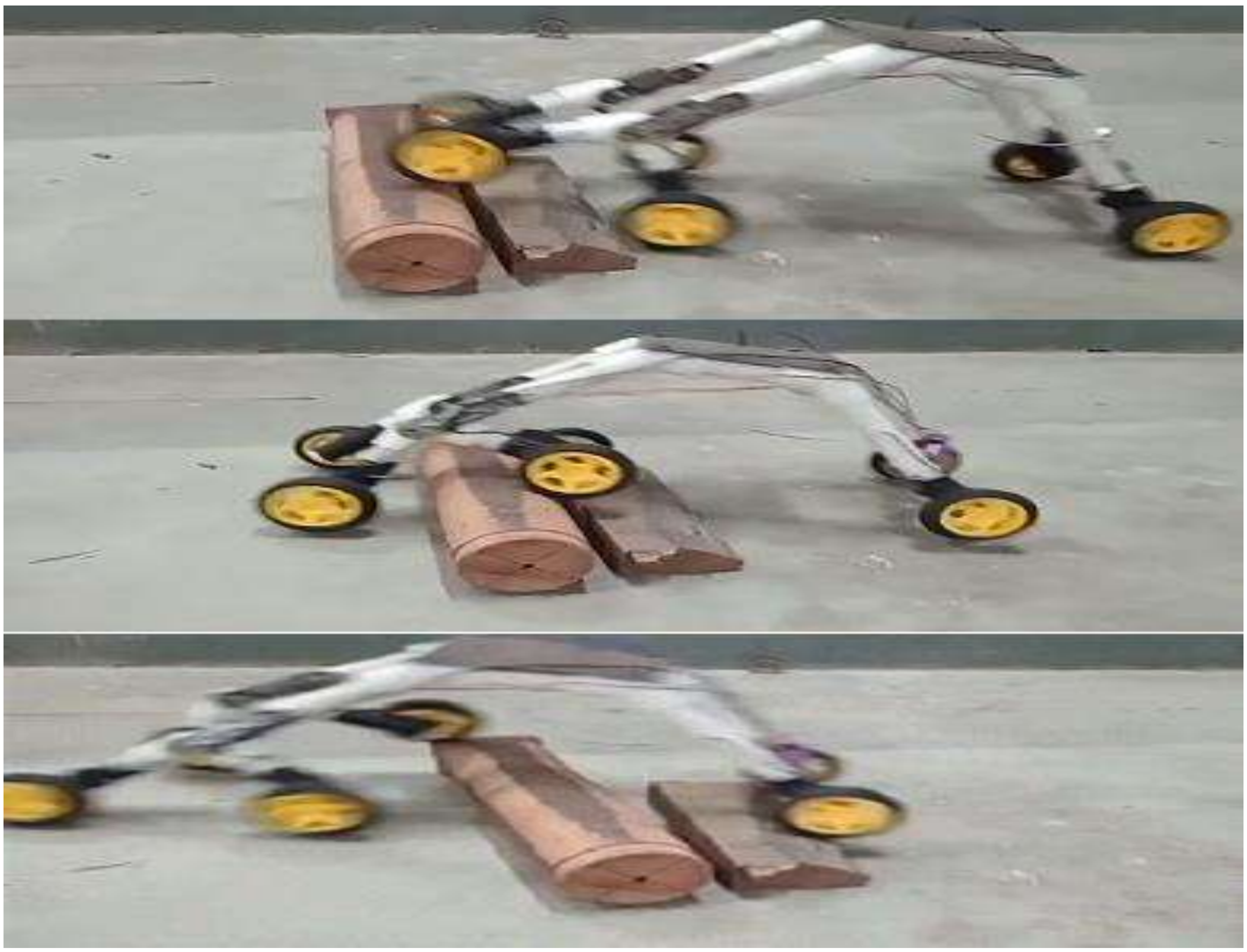

Figure 4: Captured frames from robot clearing cylindrical obstacle larger than size of its wheel with assistance from rectangular block

Fig.5 shows the initial testing of the robotic spraying vehicle conducted inside the laboratory environment. The purpose of laboratory testing was to evaluate spray assembly, wheel movement, suspension flexibility and electrical performance. The spray system was operated continuously to examine the water flow rate, spray coverage, and nozzle performance. Minor leakage points were identified near pipe joints during preliminary testing and corrected using sealing materials.

Figure 5. Images Showing the Pump Assembly, Water Pray Testing and Wheel Mobility Experiments Conducted Inside the Laboratory

After successful laboratory testing, the robot was experimentally evaluated under actual agricultural field conditions. The field investigation involved operating the robot on uneven farmland surfaces containing soil irregularities, small obstacles, and grassy regions.

The rocker–bogie mechanism demonstrated excellent terrain adaptability during field operation. The wheel assemblies maintained stable traction and smooth articulation while moving over rough terrain. Similar findings have been reported in agricultural robotic studies where rocker–bogie systems provided improved field mobility and stability (Mohan et al., 2023). The spray assembly effectively distributed water across the target area, and the pumping system maintained continuous water flow throughout the experiment. The field experiments confirmed that the developed robotic platform is capable of performing agricultural spraying operations with satisfactory stability and manoeuvrability.

5 Conclusion

The experimental results demonstrated that the developed robotic platform successfully performed agricultural spraying operations under laboratory and field conditions. The rocker–bogie suspension mechanism significantly improved wheel traction and terrain adaptability while reducing excessive chassis vibration. The six-wheel arrangement distributed the load effectively across the terrain surface and maintained continuous wheel contact during movement. The articulated rocker and bogie links enabled smooth wheel articulation over uneven terrain and improved obstacle-climbing capability (Kim et al., 2012). The spray assembly successfully distributed water uniformly across the target area. The integrated water pump maintained continuous flow during operation, and the nozzle arrangement provided satisfactory spray coverage. Laboratory testing helped optimize nozzle alignment and improve spray efficiency before outdoor deployment.

The lightweight structure improved manoeuvrability and reduced power consumption during operation. The modular design simplified maintenance and allowed easy replacement of mechanical and electrical components. Similar low-cost agricultural robotic systems have been recognized as suitable solutions for small-scale farming and educational research applications (Bechar & Vigneault, 2016). The developed robotic platform can therefore serve as an effective low-cost solution for small-scale agricultural spraying applications. The system also provides a useful platform for educational research and prototype development in agricultural robotics.

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