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QuadraSpider: A Four-Legged Spider Robot Design and Control

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Abstract - *Our paper presents a four-legged spider-inspired robot equipped with various algorithms for versatile locomotion and interactive functionalities, including dancing and greetings. QuadraSpider's movement capabilities extend beyond basic walking to include agile navigation through challenging terrains, such as rough and uneven surfaces. We demonstrate the robot's exceptional agility and stability through extensive testing, ensuring that it can traverse a diverse array of environments with efficiency and reliability.*

Beyond basic locomotion, the robot exhibits additional capabilities such as shaking, forward/backward movement, and lateral navigation. Energy efficiency is a critical consideration in robotic systems. To address this, we conduct comprehensive power consumption tests and incorporate power chargeable silicon batteries into QuadraSpider's design. This feature ensures prolonged operation and minimizes the need for frequent recharging, making the robot practical for extended use in various contexts.

Key Words: Spider Robot, Arduino Nano, Servo Motors, Bluetooth Control, Legged Locomotion, Robotics, Real-time Detection, Terrain Navigation

1.INTRODUCTION

The last few decades have witnessed a significant surge in the interest and development of mobile robots, largely owing to their remarkable ability to function autonomously in diverse environments, including critical applications such as search and rescue missions. These mobile robots span a range of categories, including wheeled robots, tracked robots, and legged robots, each tailored to specific operational demands and environmental challenges.

This paper presents a fundamental implementation of a spider-inspired robot, serving as a foundational model for the integration of more advanced functionalities. The robot's design centers around a robust main frame, featuring four articulated legs, the motion of which is meticulously orchestrated by a total of 12 servo motors. Within the core of the main frame, we have integrated a printed circuit board (PCB) housing an Arduino Nano Microcontroller, alongside necessary voltage regulators, complemented by the utilization of three rechargeable lithium batteries to sustain extended operation.

An essential aspect of our approach lies in the conscious consideration of environmental impact. By selecting reusable electrical components such as servos and microcontrollers, we actively address the ecological footprint of this robot. This conscious design choice aligns with our commitment to sustainable robotics, acknowledging the growing importance of minimizing adverse environmental effects in technology development.

Each system possesses its unique set of advantages and disadvantages. In Table 1, we present a comprehensive comparative analysis between the legged robot and the wheeled robot, outlining their respective strengths and limitations.

Table -1: The comparison of the Legged robot over Wheeled robot

Technical Criteria	**Wheeled Robot**	**Legged Robot**
Maneuverability	no	yes
Navigation over obstacles	no	yes
Transvers ability	no	yes
Controllability	yes	no
Terrain Land	no	yes
Efficiency	no	yes
Stability	yes	no
Cost Effective	yes	no

The Quadruped Robot is a four-legged walking robot that closely resembles spiders, utilizing its legs for locomotion and demonstrating the capability to perform a variety of tasks, both through human interaction and autonomously. Fig -1 illustrates the different views of the robot when operated through a mobile phone.

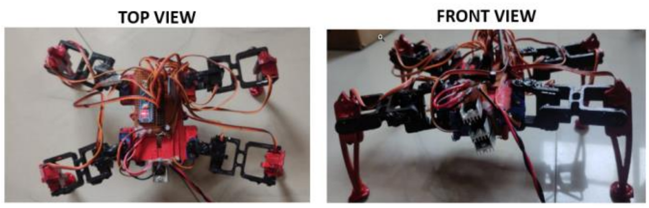

Fig -1: Different views of QuadraSpider

In the subsequent sections, we delve into the intricate design and control aspects of this spider robot, emphasizing its adaptability across various terrains and its potential for diverse applications, including entertainment and human-robot interaction. Additionally, we provide insights into the meticulous testing procedures that validate its performance, showcasing its capacity to navigate challenging environments with precision and efficiency.

2. LITERATURE REVIEW

Prior to this study, numerous scholars have made significant contributions to the fields of robotics and wireless transmission, showcasing remarkable technological advancements.

Traditionally, many robots in our familiar landscape have relied on wheeled mechanisms for their locomotion [1]. This choice offers the advantage of flexibility, enabling the selection of diverse solutions and the ability to regulate the system's center of mass, thereby mitigating issues related to slippage and navigating irregular terrain [2].

However, the advantages of legged locomotion extend beyond the mere number of legs; they encompass posture diversity and leg functionality as well [3]. While wheeled and tracked robots excel in flat terrains, they often falter in cluttered, complex, or hazardous environments. Legged robots, on the other hand, exhibit the potential to traverse a wide spectrum of terrains, from rugged landscapes to intricate and challenging settings [3]. To harness this potential, various walking algorithms have been meticulously designed and rigorously tested to evaluate their performance [4].

This literature review underscores the shift from conventional wheeled robots to the innovative realm of legged locomotion, emphasizing the unique capabilities and adaptability that legged robots bring to navigating diverse and demanding terrains.

3. PRODUCT PERSPECTIVE

The functionality of a 4-legged spider robot is like that of 6-legged or 8-legged spider robots, with the key distinction lying in their mode of rotation. Fig -2 illustrates the pivot turning mechanism employed by the 4-legged spider robot.

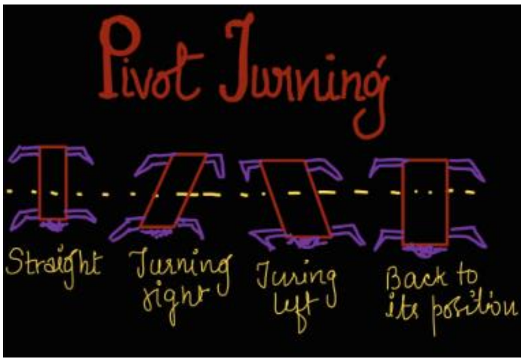

Fig -2: Pivot Turning

The primary components facilitating rotation include servo motors and the Arduino Nano microcontroller. The interconnections between the 12 servo motors and the Arduino are depicted in the circuit diagram provided in Fig -3. Additionally, the data flow diagram in Fig -4 illustrates the fundamental control flow of the spider robot.

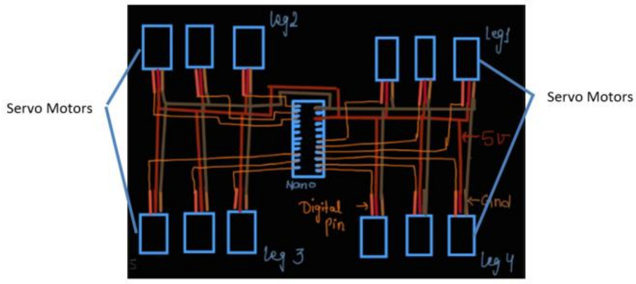

Fig -3: Connection of servo motor with Arduino Nano

All the servo motors are connected to Arduino Nano which is operating its rotation and movement and due to this servo rotation, the actual movement of the robot is carried out.

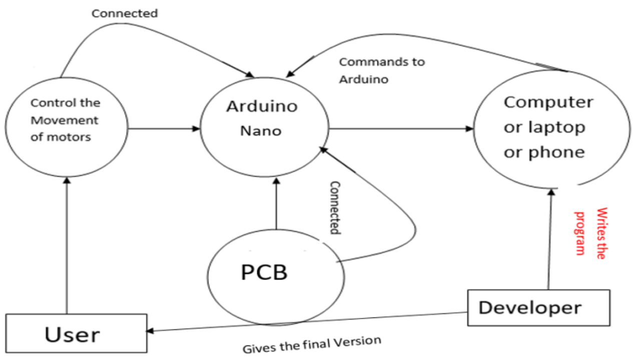

Fig -4: Data flow diagram showing the basic flow of control

In Fig -4, the Flow Diagram explains that the Arduino Nano governs the motor movements, with user commands being transmitted through the RC BLUETOOTH CONTROLLER APP.

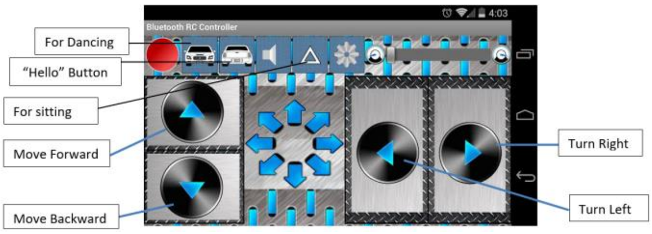

Fig -5: Application Interface

Fig -5 depicts the application interface of the RC Bluetooth Controller App. The user interacts with the robot by simply clicking buttons corresponding to desired actions. For instance, if the user selects the "forward" button, the robot promptly initiates forward movement. Similarly, pressing the "Left" button triggers a leftward turn, while selecting the "backward" button prompts the robot to move in reverse. Furthermore, the robot exhibits its versatility by executing dynamic dance maneuvers, featuring fluid up-and-down motions and even the capability to lift one of its legs. In this interactive process, the user issues commands via button selections, and the robot responds by executing corresponding movements, ensuring a seamless and engaging user experience.

4. METHODOLOGY

In this section, we delineate the key components and technologies employed in the construction of the Spider robot. The pivotal components encompass the Arduino Nano microcontroller, the HC-05 Bluetooth Module, Lithium Rechargeable batteries, and the SG90 Servo Motor.

4.1 Arduino Nano

The Arduino Nano stands as an open-source microcontroller board, designed to fit conveniently onto breadboards. It hinges on the Microchip ATmega328P microcontroller (MCU) and was first introduced by Arduino.cc in 2008. Remarkably, it encapsulates the same connectivity and specifications found in the Arduino Uno board but within a smaller, more compact form factor.

Featuring 30 male I/O headers, configured akin to a DIP-30 setup, the Arduino Nano is programmable using the Arduino Software integrated development environment (IDE), a consistent platform shared among all Arduino boards. This IDE supports both online and offline programming. Powering the board can be accomplished either via a type-B mini-USB cable or a 9 V battery.

4.2 HC-05 Bluetooth Module

The HC-05 Bluetooth Module offers a straightforward solution for establishing a Bluetooth SPP (Serial Port Protocol) connection, tailored for wireless serial communication setups. Its communication protocol is rooted in serial communication, simplifying interfacing with controllers or PCs. Notably, the HC-05 Bluetooth module facilitates seamless switching between master and slave modes, enabling it to receive and transmit data as needed.

4.3 Lithium Rechargeable Batteries

Lithium-ion, or Li-ion, batteries represent a class of rechargeable power storage solutions that harness the reversible reduction of lithium ions to accumulate energy. These batteries feature a negative electrode, conventionally composed of graphite, serving as the anode during discharge. Conversely, the positive electrode typically consists of a metal oxide, functioning as the cathode during discharge. Importantly, the designations of positive and negative electrodes remain consistent during both charging and discharging, rendering them more intuitive terms than the less clear anode and cathode, which can interchange roles during the charging process.

4.4 SG90 Servo Motor

The SG90 Servo Motor is a precision-oriented motor type renowned for its capacity to rotate with remarkable accuracy. Typically, this motor configuration incorporates a control circuit that provides continuous feedback on the current position of the motor shaft. This feedback mechanism empowers servo motors to execute movements with exceptional precision. Servo motors find their ideal application in scenarios requiring precise object rotation at specific angles or distances. Essentially, these motors consist of a basic motor mechanism operating through a servo mechanism, making them versatile tools in various applications.

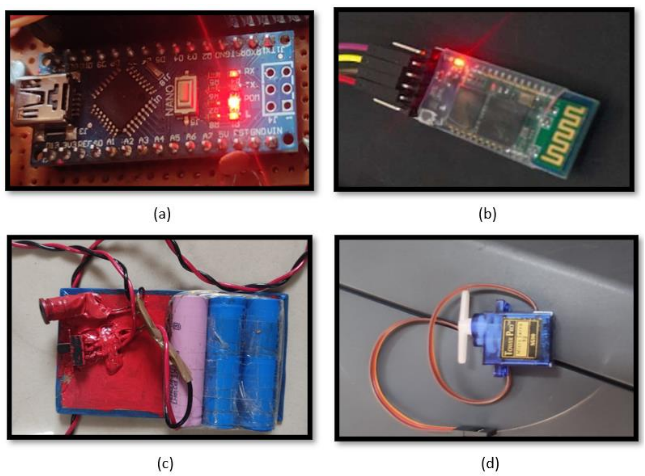

Fig -6: (a) Arduino Nano (b) HG-05 Bluetooth Module (c)Lithium Rechargeable Batteries (d) SG90 Servo Motor

5. ROBOT GEOMETRY

For the robot to achieve proper walking functionality, it necessitates precise geometrical configurations. Each leg is comprised of three servo motors to maintain the curvature of the leg, ensuring flexible and adaptable movements across a wide range of rigid terrain regions. Fig -7 provides a 2D side view of a leg equipped with these three servo motors.

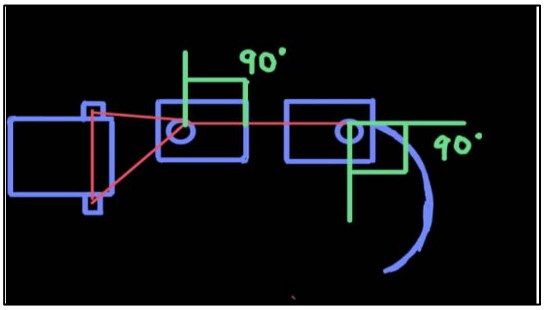

Fig -7: 2D side view of leg

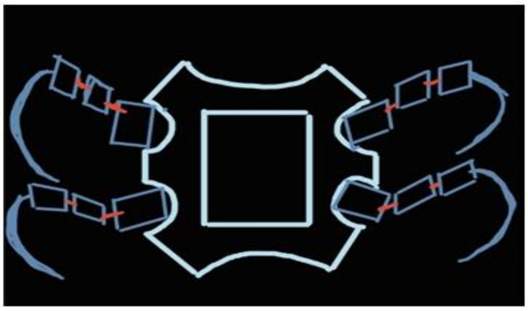

Fig -8: Chassis and the combination of Servo Motors

The servo motors are subsequently affixed to the plastic 3D-printed chassis using screws. Additionally, all other components, including the PCB, Arduino Nano, capacitors, and transistors, are securely fastened to the PCB to ensure uniform energy distribution among the servo motors. Fig -8 illustrates the schematic representation of the motor attachment to the chassis.

6. SOFTWARE REQUIREMENTS

Software plays a pivotal role in any Arduino-based project, and in our case, where we employed an Arduino Nano, it was crucial for uploading the core code to enable the proper execution of the desired functions. To accomplish this, we utilized the Arduino IDE software, within which the program code is referred to as a "sketch." The Arduino IDE encompasses several key elements, including a text editor, a message area, and a console area. This integrated development environment facilitates a streamlined process for transforming user inputs into corresponding signals. Leveraging the Arduino language within this environment simplifies the code-writing process, ensuring ease of development and seamless uploading to the Arduino Nano.

Fig -9: Arduino IDE

7. CONCLUSION

In conclusion, this project revolves around the creation of a quadrupedal Spider Robot, serving as a functional real-time detection prototype. The architectural design employed here exhibits adaptability to a wide spectrum of terrain regions and rugged environments. The utilization of four legs affords the robot an inherent advantage in terms of locomotion and stability. Additionally, wireless control is achieved seamlessly through the integration of a Bluetooth Module. Each module's presence has been meticulously justified and strategically positioned to optimize the unit's overall performance. Furthermore, the project's success can be attributed to the incorporation of advanced hardware and the application of innovative technology, culminating in a fully realized and functional implementation.

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