Design and Implementation of an Electrical Line Inspection Robot

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***Abstract*—This paper presents the design and implementation of an autonomous electrical line inspection robot capable of traversing and inspecting overhead electrical wires. The robot is equipped with a three-arm mechanism and various sensors to detect and navigate wire junctions, ensuring comprehensive inspection while maintaining stability through a dynamic weight adjustment system.**

I. Introduction

The objective of this project is to develop an inspection robot for electrical lines, designed to autonomously navigate and inspect wires using sensors and a mechanical arm mechanism. The robot's capability to handle junctions while maintaining stability sets it apart from existing solutions.

II. System Design

A. Mechanical Design

The robot employs a three-arm configuration, each equipped with wheels that grip the wire. The arms operate sequentially to navigate junctions:

- During junction navigation, one arm is opened at 90 degrees to move forward, followed by repositioning of the center of mass.
- The heaviest component, the battery, is moved along a belt mechanism to maintain balance when only two arms are engaged.

1) Junction Navigation: The center of mass (CoM) position adjustment can be represented as:

$$CoM_{adjust} = \frac{m_{battery} \times x_{battery} + m_{robot} \times x_{robot}}{m_{battery} + m_{robot}} \tag{1}$$

where $m_{battery}$ and m_{robot} are the masses of the battery and the robot respectively, and $x_{battery}$, x_{robot} are their respective positions.

B. Motion Mechanism

Servos are used to control the arms, enabling precise adjustments necessary for navigating junctions. Pulleys and motors provide the primary movement along the wire.

III. Electrical and Control System

A. Microcontroller

An Arduino microcontroller is employed to control the robot's operations, interfacing with sensors and actuators for real-time processing and decision-making.

B. Sensors

Various sensors are integrated into the robot:

- **Camera:** For visual inspection and damage detection.
- **Ultrasonic Sensor:** For detecting junctions and gaps in the wire.
- **Additional Sensors:** For measuring electrical properties like current and voltage.

IV. Operation and Control

A. Control Strategy

The control strategy involves an algorithm that autonomously manages the robot's movement along the wire, its response to junctions, and inspection tasks. The movement dynamics can be modeled as:

$$F = m \cdot a \tag{2}$$

where F is the force applied by the motor, m is the total mass of the robot, and a is the acceleration.

B. Power Management

Power is distributed efficiently among servos, sensors, and motors. The battery position is adjusted dynamically to optimize stability during movement and junction transitions.

V. Software Implementation

The software is designed to process sensor data and control the robot's motion. The control algorithm ensures that the robot maintains its position on the wire and navigates junctions accurately.

VI. Challenges and Solutions

A. Junction Navigation

Balancing on two arms while the third is repositioned requires precise control of the battery's position to maintain stability.

B. Wire Stability

Ensuring the robot does not dislodge from the wire is critical, especially during transitions at junctions.

C. Sensor Accuracy

Calibration of sensors is necessary to achieve accurate detection and inspection of wires.

VII. Testing and Validation

A. Prototype Testing

Initial tests were conducted on a scaled-down wire model, assessing the robot's ability to traverse and inspect while maintaining balance and stability.

VIII. Conclusion

This electrical line inspection robot presents a novel approach to automated wire inspection, offering improved safety and efficiency. Future work will focus on refining its capabilities and conducting extensive field testing.

References

[1] Author, "Title of Paper," *Journal Name*, vol. xx, no. xx, pp. xxx-xxx, Month Year.