Android Based Control of Transmission line Robot for Traversing Through Straight line and Crossing of Tower Junctions

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***Abstract:** The most widely used means to transmit electricity is through transmission lines. These power lines are prone to problems with adverse weather conditions prevailing in different locations. Workers climb the poles and manually check if any faults occur in power lines and this makes their lives riskier. It also interrupts the power supply. A robot based inspection makes this task easier, efficient, foolproof and safe. Android based control is one of the simple and powerful methodologies due to the availability of smart phones. Also android is an open source platform which has software with lot of applications for online and offline operations. This paper mainly concentrates on an Android based control of a dual arm suspended type mobile robot for tension and suspension towers. Methodology of crossing and description of the robot model are also explained in this paper. The communication in android based control of robot is done through a mobile application. Control of the main subsystems such as mobile robot base, pulley system and dual arm is established using the smart phone application named 'Bot Controller' developed using MIT App Inventor which communicates with the Arduino Mega using Bluetooth module. All the tasks are controlled using corresponding buttons in the application interface. The communication between the onboard electronics and the user is taken care by the MIT App Inventor where multiple functions corresponding to various motion of robot are created. Speed and direction of rotation of each and every motor have been given as functions for motions. Complete control flow architecture with all hardware are also depicted.*

I. INTRODUCTION

Electricity has become inevitable in current generation. This has been achieved by innovations in the fields of transmission systems and power grid. Even though there are lots of advances in this area, uninterrupted power supply is not achievable due to the problems associated with transmission lines. These problems can be resolved by appropriate inspection and maintenance of electrical lines.

Traditional ways are inspection by lineman climbing the electric poles, ride in gondolas suspended on the overhead ground wires, monkey patrolling and examining by holding the wires. Major obstacles to be avoided by the robot are suspension towers, tension towers, spacers, dampers and insulators. Crossing from straight line to the jumper cable and vice-versa are the tedious jobs while traversing. Line traversing robots can also be used for crop monitoring, forestry research and surveillance.

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These are not efficient ways to analyze whether the electrical lines are in proper condition because they make linemen's lives riskier. In the above specified method, electricity should be turned off while inspecting or repairing the transmission lines and this results in huge financial loss. This mode of inspection also leads to inconveniences to producers, distributors and consumers of electricity. One of the solutions for solving the above issue is the development of inspection robots for the transmission lines.

II. BACKGROUND

This section covers the important literature closely related to various controls of line inspection robots. Zheng and Ruan designed the robot which uses cameras for capturing the lines and video card for processing the video obtained from them in real time and sends to the computer [1]. The robot is controlled based on the wireless technology. It also has General Packet Radio Service (GPRS) for data connection and Global Positioning System (GPS) for identifying the location. The robot uses sensors for finding obstacles on the wire and thermal cameras for inspection of damages. Jaka *et al.* evaluated the performance of the robot based on various factors among which inspection quality, obstacle avoidance, design, autonomy are the important ones and their problems are outlined [2]. An interactive Graphical User Interface (GUI) is presented by Mostafa *et al*. to control MoboLab via Personal Computer (PC) where the required commands are transferred and appropriate actions are taken by the relay boards [3]. Zhibin and Ruan introduced the control system which is divided into three parts namely supervision layer, robot path layer and action layer [4]. The robot used PC104 in robot path layer and Texas Instruments-Digital Signal Processing (TI-DSP) (TMS320LF2407) in action layer to control the motors. LabView digital interface is used with Programmable Intelligent Computer (PIC) microcontroller by Montambault and Pouliot [5]. The onboard electronics is placed in Electro Magnetic interference (EMI) shield to avoid interferences from transmission lines. Dual architecture is used by Jun *et al.* where one processor is purely responsible for primary tasks such as forward-backward motion [6]. The second processor while being in contact with the first processor also performs secondary tasks such as rotation and balancing. FC-206/B wireless data modems are used along with PC104 by Tang *et al.* to control and give instructions from ground [7]. Gongping *et al.* presented the autonomous motion and detection by integrating various units such as GPS-GIS (Geographic Information System) unit, machine vision unit, multi-electromagnetic sensor unit, hold force sensors, position sensors, visible-infrared imaging system and electromagnetic shield module [8].

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Comprehensive literature review is carried out and research gaps are identified. Most of the work consists of a dedicated computer which is used for control and online inspection of the transmission lines. There are also other controls in which the subsystems are controlled by individual microcontrollers which communicate with each other. Some robots use relay boards and switches to take logic decisions for straight line motion but would not suffice while taking complex decisions like crossing the obstacles. Even though the centralized control of the complete robot offers efficient motion, communication may fail the whole locomotion of the robot. Hence, in the proposed control of robot a "Master-Slave architecture" is used to control the subsystems of robot. Where, the master board controls all the subsystems as well as assigns tasks to the slave board. Android control is implemented due to the major advantage of portability when compared to the remote control systems.

This paper proposes the control of the electrical transmission line robot which can traverse on transmission lines and cross obstacles with a unique and novel mechanism. This robot control system consists of an android mobile phone application which is built in MIT App Inventor. This android application works as an interface between the robot and the manual ground operator. This application includes functions such as: (i) forward and backward motion, (ii) control of crossing operation and (iii) control the speed and direction of the robot which gives more flexibility and freedom to operate. The communication between the robot and the mobile phone application is carried out via a bluetooth module.

III. ROBOT MODEL DESCRIPTION AND METHODOLOGY OF LOCOMOTION

Electrical transmission line traversing robot is developed and the CAD model of the robot is as shown in Fig.1. Important subsystems of the robot are:

1. Robot mobile base and dual arm
2. Pulley mechanism

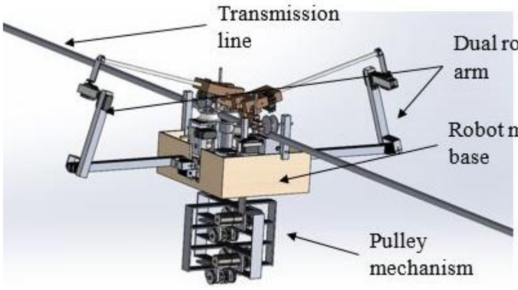

Fig.1. CAD model of the robot

A. Robot mobile base and arm

Robot mobile base is the main body of the robot which has base chassis and dual arm as shown in Fig.2. The base consists of four DC motors in which two DC motors are used for driving wheel mechanism where the robot can move forward and backward according to the user input. The other two DC motors are used for engage-disengage mechanism in order to hold the robot firmly and align to the transmission line. During engaging operation, the actuators rotate to get the driving wheel unit closer. Switches are placed on both sides of the driving wheel units and these switches get pressed automatically if the required distance is attained. This gives a signal to stop the engage-disengage mechanism. To balance and support the robot on electrical transmission line, an additional locking-unlocking mechanism is provided. Locking-unlocking mechanism are placed in the front and rear end of the mobile base which are controlled by two sets of two servo motors. The robot has two arms which has 5 Degrees of Freedom (DoF) each. Servo motors are used at all joints of both arms because of the internal feedback and precise motion. Arduino is used to control the speed and direction of rotation of these motors. But the current ratings of arduino (20mA) is lower compared to that of motors (7.5A). Hence, pololu motor drivers are used to amplify the current. Gripper-hooks are placed at both ends of the arms. Micro-servo motors are used to lock and unlock the fingers of the gripper hook. Gripper-hook helps the robot to cross by holding the transmission line at either sides of the obstacle during crossing operation.

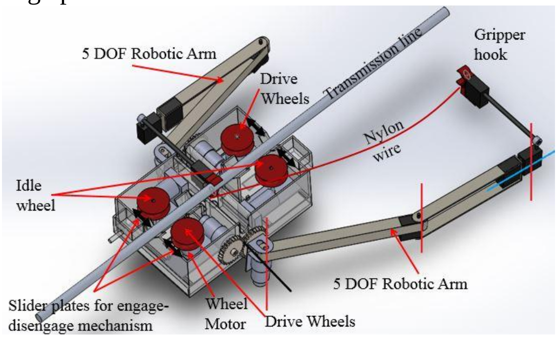

Fig.2. Base and dual arm of the robot

Robot arm dimensions are verified using Virtual robot experimentation platform (V-rep). Arm length and degrees of freedom are selected by checking the end-effector pose whether it reaches the specified goal position or not. V-rep simulation of the robot locomotion at tower junction is as shown in Fig.3.

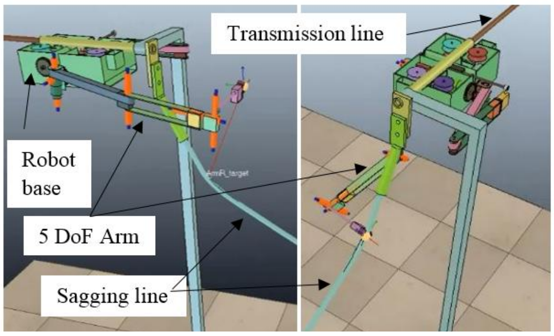

Fig.3. V-rep simulation for grasping the transmission line

B. Pulley mechanism

Pulley mechanism is made up of four individual layer which is placed below the base of the robot. The purpose of this mechanism is to facilitate the robot to cross the tower junction and obstacles. When the robot comes across an obstacle, one gripper-hook of robot holds the transmission line on the other side of the obstacle and the other gripper-hook holds the transmission line at the current position. Now, the robot releases itself from the transmission line by performing unlocking and disengage mechanism. Four layered pulley mechanism is as shown in Fig.4.

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Two nylon wires are attached to each layer of the pulley mechanism and gripper-hooks of the arms. With the help of these nylon wires, the robot crosses the obstacles or tower junctions. Nylon wires are wound inside two sets of spool-pulley operated by single DC motor present in the individual layer help to lift or suspend the robot from the transmission line. During the crossing operation, when the robot suspends and reaches a particular position, the pulley-layer DC motors rotates in such a way that the entire robot gets moved to the other side of the obstacle. The driving wheel engaging mechanism engages and locks the robot on the transmission line and then the gripper-hooks of the arms are taken back to the home position.

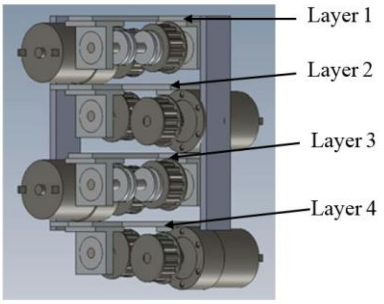

Fig.4. Four layered pulley mechanism

All the subsystems are fabricated and assembled. All the electronic hardware and controller are integrated to the robot mechanism. List of actuators and specification used in various subsystems of robot are given in Table.1. Fabricated robot which is ready for experimentation is as shown in Fig.5.

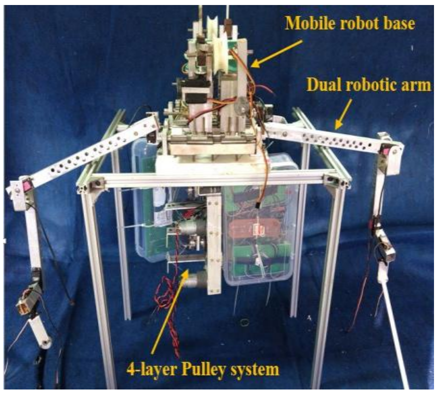

Fig.5. Fabricated electrical line robot

Table.1 List of actuators in various subsystems

Subsystems	Number of motors	Specifications
Robot base chassis	Two DC driving motors	4.58Nm, 5V, 7.5A and 25RPM
	Two DC engaging motors	4.58Nm, 5V, 7.5A and 25RPM
	Two servo motors for supporting wheel	1.67Nm, 6V
	Two servo motors for locking tab	1.6Nm, 6V
Dual arm	Two DC Encoder motors	1.76Nm, 131:1 Metal Gear, 12V, 5A, 80RPM
	Eight servo motors	1.6Nm, 6V
	Two micro-servos for gripper hook	0.15Nm, 6V
Pulley mechanism	Four DC motors	4.58Nm, 5V, 7.5A and 25RPM

C. Methodology of locomotion

The robot has four basic mechanisms such as: (i) driving wheel mechanism performs forward-backward motion of robot, (ii) engage-disengage mechanism helps the robot to attach on transmission lines (iii) locking-unlocking mechanism is used for providing additional safety for robot and (iv) pulley mechanism is useful only during obstacle or tower crossing operation as shown in Fig.6. In addition to these basic mechanisms, the arm has the functionality to reach any point in the 3D plane (Refer Fig.3). This helps during the inspection operation because the robot has to get attached to or remove from any point on the transmission line. Fig.6 shows the block diagram representation of subsystems with various functions of the robot.

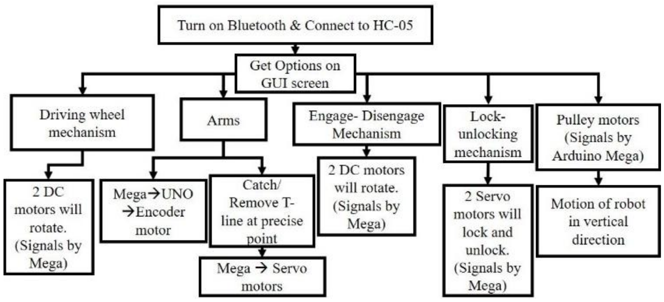

Fig.6.Various mechanisms performed by robot

IV. CONTROL OF THE ROBOT MECHANISM

Control plays a vital role in functioning of robot mechanisms, without which the fabricated robot mechanism cannot be controlled dynamically. Control is required to attain the predefined goals because it provides better performance and decision-making process of the robot. As it is required to control the robot from a distance, android application is integrated along with the onboard electronics to attain the desired motion of the robot on the transmission line. Robot is controlled by using mobile phone application in this work. Decision architecture of robot motion is shown in Fig.7. This figure gives the overall idea about the decisions taken at various levels of implementation of the robot in the transmission line, crossing obstacles and tower junctions.

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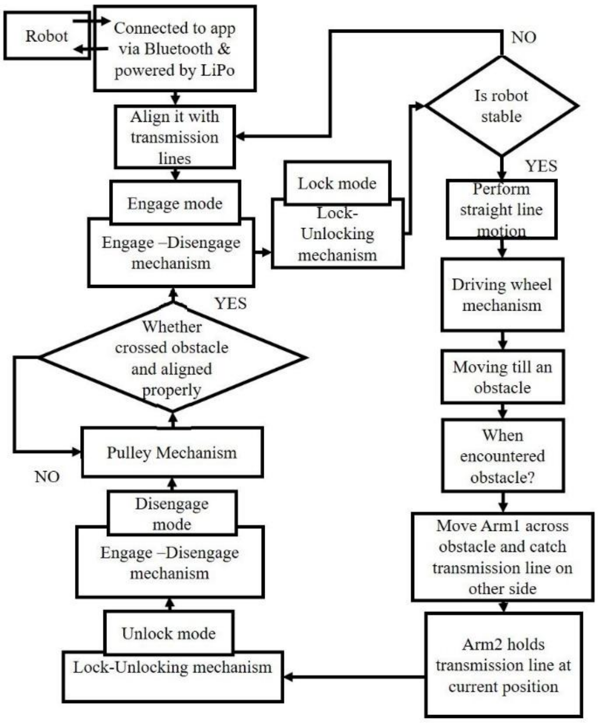


Fig.7. Data flow architecture having various blocks

A. Android Control

The data flow architecture of the robot includes one Arduino Mega 2560 Microcontroller and two Arduino UNOs. Arduino Mega serves as the master controller to Arduino UNOs and each UNO aids the control of individual arms. The data flow architecture is depicted in detail in Fig.8.

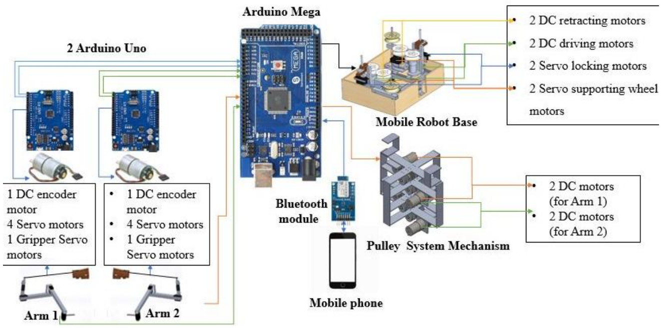


Fig.8. Data flow architecture having various blocks

Relevant circuit boards are designed for this purpose. A bluetooth module is connected to microcontroller and acts as a medium to communicate between the android application and robot so that instructions can be given from the ground by manual operator. The speed of the motors can be controlled to avoid any slippage while the robot is traversing, especially when it is on sagging line. Encoder motor needs to be constantly monitored as it continuously outputs the position of the arm. Hence, two separate Arduino UNOs, are placed which are solely responsible to control both encoder motors. Lithium polymer (LiPo) is used to supply voltage to different components and it is preferred over Nickel Metal Hydride (NiMH) batteries because it is much lighter, holds more power and has much higher discharge rates. LiPo outputs 24V and different electronic components require different voltages/current as shown in Fig.9. Therefore, two power buses, one 12V and the other 5V are made. 24V LiPo output is converted to 12V by a buck-booster operating in buck mode and non-inverting topology. This 12V is given to voltage regulator (7805) for a constant output of 5V. DC motors are connected to the digital pins of arduino. Servo motors and motor drivers are connected to Pulse Width Modulation (PWM) pins of arduino as they require analog voltage for the operation.

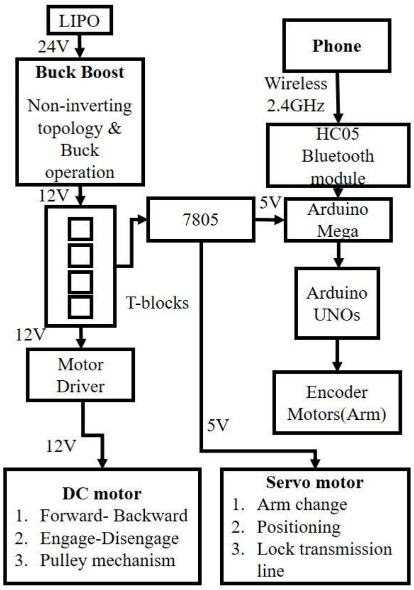
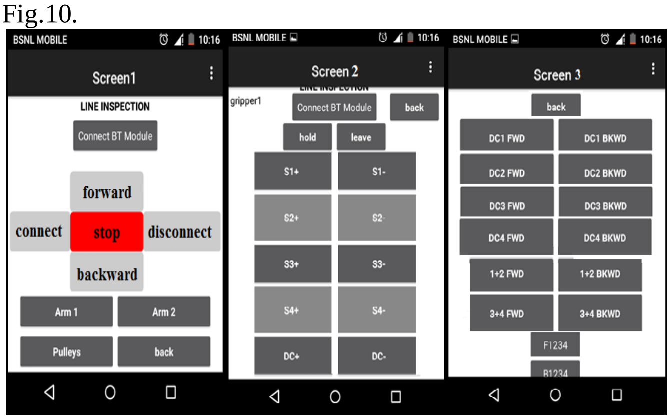


Fig.9. Power supply distribution for onboard electronics

The communication between the onboard electronics and the user is taken care by an android application which is designed in MIT App Inventor where multiple functions corresponding to various motion of robot are created. Speed and direction of rotation of each and every motor have been given as a function and additional functions for motions such as drive wheel mechanism, engage mechanism, lock mechanism, pulley mechanism are created. This application is connected to the onboard electronics via HC-05, a bluetooth module which operates with 2.4GHz and has a range of about 10m. Control of the main subsystems such as mobile robot base, pulley system and dual arm is established using the smart phone application named 'Bot Controller' developed using MIT App Inventor which communicates with the Arduino Mega using Bluetooth module. All the tasks are controlled using corresponding buttons in the application interface. Android application displaying various functions for various motions of the robot is shown in Fig.10.



(a) Home screen 1 (b) Arm1 control screen 2 (c) Pulley system control screen 3

Fig.10. Android application displaying various functions

V. RESULTS AND DISCUSSIONS

A suspension and tension tower setup is constructed for performing experimentations. A1234B represents the straight transmission line motion and C1234D represents jumper cable motion in the experimental setup as shown in Fig.11 and Fig.12 respectively. Point A to point B distance is 10m and velocity of 1m/sec is set for the robot to traverse through straight transmission line. In the figure, the robot is placed on a sagging jumper cable and is made to traverse from point C to D while maintaining a velocity of 0.5m/sec. Successful traversal of the robot on straight as well as the sagging jumper cable of suspension and tension towers is achieved in this paper. Crossing operation is executed slowly compared to the straight line motion as the sagging line is just 1m above the ground level and due to the problem of slipping. Also, robot is touching the ground during the crossing. Hence, experimentation of jumper cable motion is conducted in the indoor laboratory set up. The sagging line slope and span in indoor setup is as same as the outdoor tower setup.

Fig.11. Snapshots taken while testing of robot on the straight transmission line (A-1-2-3-4-B)

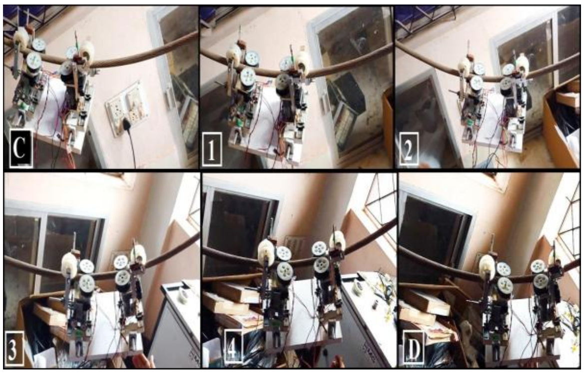


Fig.12. Testing of robot on Sagging line (C-1-2-3-4-D)

The time taken for straight line motion and jumper cable motion are given in detail in Table 2.

Table 2. Time taken for various modes of motion

Sl. No	Time taken (s)		
	Straight transmission line (A1234B)	Indoor Jumper cable (C1234D)	Total time
1	20.40	16.42	36.82
2	21.21	16.35	37.56
3	20.90	16.71	37.61
4	20.61	16.45	37.06
5	20.90	16.32	37.22
Average	**20.80**	**16.45**	**37.25**

Time taken during the experimentation from the point A to D is 37.25s. The sole problem faced during the testing is slipping of the wheel friction pads from the sagging line. Initial phase of the robot development has been completed and various stages of the experimentations are depicted in this work.

VI. CONCLUSION AND FUTURE WORK

A novel robot is fabricated and experiments are conducted using the android based Master-Slave controller. Control circuits are simulated and designed using Proteus. All the subsystems are developed for both straight transmission and sagging line motion. Data flow architecture for various subsystems, power supply distribution for onboard electronics and android application display are explained in detail in this paper. During the experimentation, android based control of robot through straight line motion is simple compared to the sagging line motion. Android based control offers better motion control on these power lines. This work can be extended in the following ways: (i) complete automation where the robot can take decisions while traversing on electrical transmission lines, (ii) performance analysis of robot in real-time, (iii) real-time inspection through integration of components such as cameras, thermal sensors, etc., (iv) Upgrade of control of robot from bluetooth to WiFi or Zigbee modules, (v) Usage of GPS-GSM to get exact location of the robot. This work will be an appropriate solution for the inspection and maintenance of widespread high-voltage electrical transmission lines, inspection of suspension bridge through wire crawling robots, mine inspection, material transport to remote locations via ropes and identification of power theft with suitable procedures.

REFERENCES

1. Zheng Li and Yi Ruan. Autonomous inspection robot for power transmission lines maintenance while operating on the overhead ground wires. *International Journal of Advanced Robotic Systems*, 7(4):25, 2010.
2. Jaka Katrasnik, Franjo Pernus, and Bostjan Likar. New robot for power line inspection. In *2008 IEEE Conference on Robotics, Automation and Mechatronics*, pages 1195–1200. IEEE, 2008.
3. Mostafa Nayyerloo, S Yeganehparast, Alireza Barati, and M Foumani. Mechanical implementation and simulation of monolab, a mobile robot for inspection of power transmission lines. *International Journal of Advanced Robotic Systems*, 4(3):381–386,2007.
4. Zhibin Ren and Yi Ruan. Planning and control in inspection robot for power transmission lines. In *2008 IEEE International Conference on Industrial Technology*, pages 1–5. IEEE, 2008.
5. Serge Montambault and Nicolas Pouliot. Design and validation of a mobile robot for power line inspection and maintenance. In *6th International Conference on Field and Service Robotics-FSR 2007*, volume 42. Springer, 2007.
6. Jun Sawada, Kazuyuki Kusumoto, Yasuhisa Maikawa, Tadashi Munakata, and Yoshinobu Ishikawa. A mobile robot for inspection of power transmission lines. *IEEE Transactions on Power Delivery*, 6(1):309–315, 1991.
7. Tang Li, Fang Lijin, and Wang Hongguang. Development of an inspection robot control system for 500kv extra-high voltage power transmission lines. In *SICE 2004 Annual Conference*, volume 2, pages 1819–1824. IEEE, 2004.
8. Gongping Wu, Heng Cao, Xianjing Xu, Hua Xiao, Shengbang Li, Qingshang Xu, Bin Liu, Qinghong Wang, Zhijun Wang, and Yulin Ma. Design and application of inspection system in a self-governing mobile robot system for high voltage transmission line inspection. In *2009 Asia-Pacific Power and Energy Engineering Conference*, pages 1–4. IEEE, 2009.

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