Wheel Based Pole Climbing Structure Built for Replacing Manpower in Hazardous Environments and Creating a Platform for Telegraph Pole Deicing and Reconstruction

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Abstract. A common phenomenon in high latitude countries would be a hazardous environment during the winter. Electrical lights and telegraph pole are covered in ice and therefore caused trouble for workers and electrician whose job is to maintain their functions. This climb bot is expected to have various application range, primarily used to replace human workforce and reduce the injuries caused by falling from a considerable height. Scientists have been proposing various ideas of similar robots, such as inspections of vertical pipes in a nuclear power plant, or the funnel for industrial use. The robot I designed will be dealing with the telegraph pole in a metropolitan area, which froze in the winter. Currently, due to the restriction of time and material, the robot is only capable of essential climbing functions, but it is possible to add functions such as deicing and cleaning in the future. This article will further explain the design and function of the robot with statistics while giving examples of how other similar design works.

1. Introduction
Telegraph pole is an essential part in modern society, and most telegraph line requires clean and stable pole in order to communicate with the rest of city. This created many workers who’s job is to ensure the cleanliness and stability of telegraph pole. Current workers use two arc shaped iron to climb up with the help of friction. But in some occasion during the winter, with ice covered at the surface, friction won’t hold the worker and there will be a high risk of injury. There are three potential structures that we could consider to use in the robot.

Figure 1. Workers using classical tool to climb pole.
Wedge based. Two wedge shaped iron would be placed one next to each other, given the fact that only upward motion is allowed in wedge shape, the two wedges would move like a train wheel connected, and step by step the structure would go up. Yet this structure have no way of downward movement.

Wheel based. Use spring or steel wire to attach the robot with the pole tightly, and then with the movement of the rubber wheel, the structure would go upward or downward based on the bluetooth command we send. Students in Nanjing University of Posts and Telecommunications have created a wheel based robot with three wheels supporting the whole structure. It is connected with a spring so that the pressure creates enough friction to keep the robot climbing. However, this example is not suitable for my resining purpose, I need a platform or some space for the robot to carry additional deicing or cleaning functions.

Adhesive belt based. Sticky substance or other materials that is capable of sticking the robot with the

Another example is a 3D robot that Yeoreum Yoon have created. This robot is capable of truss climbing in 3 dimension. Two motor is attached to the end of the robot which enables three motive degrees of freedom to the robot. Though it does not match my requirements, it is still an innovative design of robot moving in complex structures.

2. Modeling
In order for the robot to achieve maximum effect, research on the diameter of common pole must be done. According to China National construction, the most common telegraph pole in Beijing is ranged from 190mm to 390mm. I made a model using SOLIDWORKS, which shows the basic shape of my robot.

The formula calculating relationships between Top diameter and Bottom diameter:

\[
d = D + 4/3 \times L/100
\]

The d is the lowest diameter, the D is the top diameter, the L is the height of the pole.

| Table 1. Common pole diameter in China. |
|----------------------------------------|
| Top diameter | Height of pole | Lowest diameter |
| 190          | 10            | 203.3           |
| 190          | 12            | 350             |
| 190          | 15            | 390             |
| 230          | 10            | 243.3           |
| 230          | 12            | 390             |
| 270          | 10            | 283.3           |
Figure 2. Model 2 showing that the robot is capable of handling both 190mm diameter and 390mm diameter.

3. Structure
Used steel to build an overall structure, a platform to contain the Worm gear and worm reducer motor and circuits. There are two types of steel used, a 20x20mm steel section and a 20x40mm one. The smaller one was used to connect upper layer with the lower layer. I did double layer because one layer can’t ensure the stability of the robot. 2040 section is used to do 4 arms where the motor and wheel will be installed.

Figure 3. Steel structure.

4. Command operation
Code that was finished beforehand would be inputted from the computer to the Arduino Uno board. Then, it will initiate bluetooth receiver and define all port variables. When the robot starts to work, the bluetooth drive will receive signal from a phone. Then the processor would identify the signal through a loop, and finally allowing the robot to act according to command. SPP bluetooth port is one of the best mobil app that allows the user to send and receive bluetooth command. One can customize a control interface to make every signal into visualized button and variables, making the operation easier.
Figure 4. Flowchart of Arduino command.
5. Operation tests

5.1. Pole climbing test
This test aims to evaluate whether climbot is able to climb most telegraph pole with national standard diameter. And by assessing the diameter of poles within its climb range, estimate the climbing function and its practicability in real life.

Place the climbot at the lowest point of given pole. Tighten all four arms around the pole, and begin climbing. During the process, use bluetooth to adjust its arms.

| Pole diameter | Is Climbing possible | Average speed |
|---------------|----------------------|---------------|
| 190mm         | Yes                  | 0.70m/s       |
| 230mm         | Yes                  | 0.68m/s       |
| 270mm         | Yes                  | 0.65m/s       |
| 390mm         | Yes                  | 0.67m/s       |

The test shows that climbot can handle poles with diameter from 190mm ~ 390mm. Through test result, one can conclude that climbot fits most of the national standardized telegraph pole diameter, 190mm ~ 390mm. So this robot can fully meet the climbing function requirement of common telegraph poles.

5.2. Obstacle test
This test aims to evaluate whether climbot is able to go through mini obstacles that is common to occur on telegraph poles. And by assessing the stableness of each climb, estimate its climbing function.

Use the most common 290mm diameter pole for testing. Place the climbot at the lowest point of given pole. Tighten all four arms around the pole, and begin climbing. During the process, use bluetooth to adjust its arms.

Set obstacles of different size, and examine whether climbot is able to go through. Meanwhile observe the stableness of the climbot while it passes through obstacles.
Table 3. Obstacle climbing test result.

| Height of obstacle | Stability |
|--------------------|-----------|
| 10mm               | Yes       |
| 30mm               | Yes       |
| 50mm               | Yes       |
| 70mm               | No        |

Through test result, one can conclude that climbot’s performance is very reliable when encountered with obstacles. Although the speed isn’t outstanding, but later there would be more functions such as deicing and cleaning, so overall it fits most requirement.

6. Conclusion

With the rapid economic development, power and network play increasingly important roles in daily life, while wire and cable erection and maintenance are the most important basis to guarantee power transmission and smooth network connection. With the continuous development of power system, a number of high-pole facilities related to commercial or public works, such as wire pole are found either in rural or urban areas. Basically, the electric wiring could be fixed onto a wire pole, meanwhile, due height of the pole, it normally requires the circuit staff to climb to top of the wire pole for wire installation. This is the traditional way, which brings risks for security and high risk of accident. Our design targeted to solve the above mentioned social issue. The climbing robot can be easily controlled by mobile phone bluetooth. Traditional design of climbing robots is applicable only to the pole with pole rod not being able to cross the clamp, while we have designed two independent climbing layers to enable the robot to climb over obstacles individually. Furthermore, as a climbing platform, the robot has been designed with sufficient loading capacity to be able to carry ice-removal device or cleaning device. This works in various occasions, which can replace manual work in the future.

Through the process, I learned and used many techniques, including:

- Embedded system control and C language programming
- Bluetooth and mobile equipment control
- Mechanical design and 3D model

As for embedded system control, The auto pole-climbing robot platform design is based on the core circuit of embedded system, with an optimization of motor driving and configuration with bluetooth module.

All structure and function is based on mechanical design.

For the future, a better envision to the development of pole-climbing robot can be seen. Current design still requires manual remote-control, which is not sufficient enough. Next step is to involve the automation program.

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