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Development and Application of a Birds Nest Removal Robot for Telecom Towers

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Abstract - This research paper presents the design, development, and application of a bird nest removal robot tailored for telecom tower maintenance. The paper outlines the necessity for such a robotic system, the challenges it addresses, and the technologies used in its construction. The Telcom tower network exists in each corner of the world and is responsible for communications and connectivity. Mobile connectivity is considered one of the most essential services nowadays. Maintenance of such an extensive network is challenging due to technical, environmental, safety and economic issues.Another big problem is the carnivorous birds nest on the tower. The rigger climbs the tower for maintenance and becomes a victim of bird hits and incidents of falls from the tower or injuries. The Telecom tower climbing robot assists the rigger, and a manipulator robot attached to it removes the bird nest at the telecom tower's top. The study also discusses real-world applications of manipulator robots for bird nest removal and highlights its effectiveness in improving the safety and reliability of telecom tower infrastructure.

Keywords: Bird Nest Removal, Telecom Network Tower, Field Maintenance, Automation, Robotic Manipulator.

INTRODUCTION

Telecom tower maintenance can be complex and challenging due to various technical, environmental, and logistical factors. Some common problems in telecom tower maintenance include accessibility, equipment repair or replacement on the top of the tower, safety of riggers, environmental conditions, bird's nests on towers, power supply, and unpredicted failures [1]-[3]. Birds of prey, such as falcons or eagles, often build nests on towers, along with honey bee hives commonly found at many locations on telecom sites. Instances have been frequently reported where these birds strike riggers, causing them to lose balance and sustain injuries or even fatalities [4]-[5]. In response to this issue, the authors proposed a robotic manipulator that can be attached to a climbing robot. This system is designed to remove bird nests from the towers, thereby enhancing safety for riggers [6].

Over the past twenty years, the demands for mobile robots and telecommunication technology has increased a lot. The infrastructure to manage the demands and the subsequent utilization of telecom services also has significantly grown [7]. This growth has led to higher telecom revenues and substantial network expansion. Consequently, the maintenance of this infrastructure has become more complex due to frequent revolutionary changes in technology. The task of maintaining telecom towers is both challenging and risky, with much of the maintenance work requiring operations at the top of the towers [8]-[10]. Telecom operators are under pressure to ensure nearly 100% operational network efficiency to support round-the-clock online connectivity for users. It necessitates robust maintenance network services for quick network recovery, preventive checks and periodic maintenance. In the fiercely competitive telecom industry, having a strong and sufficient network maintenance foundation is crucial, especially given the significant portion of work that involves heights on towers. Prompt restoration of network connectivity is essential but places considerable pressure on maintenance staff [11].

The Telecom field tower's height ranges from 25 to 80 m and is located in each corner of the world [12]–[15]. At such heights in remote areas, carnivorous birds build their nest. Figure 1 shows the bird's nest on the telecom tower, which are build by carnivorous birds. When the rigger accessed the tower for maintenance, these birds hit them, and the rigger's life came into danger. With the growing demand for communication payload, such problems have become more prominent. The riggers must remove the bird's nests that are troubling in connectivity and

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maintenance tasks. Figure 1 (a,b,c,d,e,f) represents the bird and tower environment in which the rigger has to perform maintenance operations. There is no mechanism to remove this automatically and safeguard the rigger.

(a) Carnivorous Bird's Nest

(b) Rigger and Hawk

(c) Bird of prey's nest

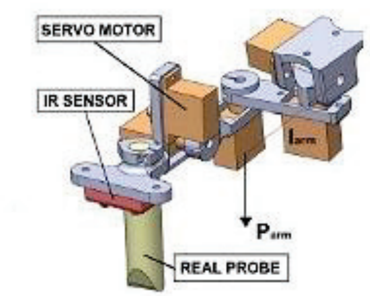
(d) Bird Nest at Riggers Workplace

(e) Nest at the gap between the antenna

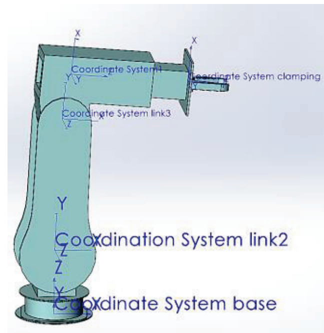
(f) Birds nest on top of the tower

FIGURE 1. Birds nest on the tower

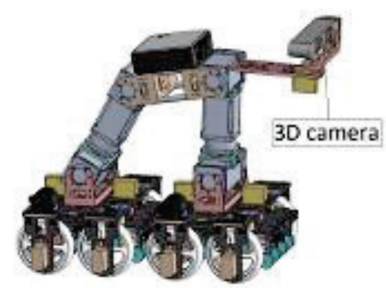
The objectives of the present work are to design, analyze and develop a robotic manipulator that can remove the bird nest on the top of the tower. The designed arm has to be accommodated on the climbing robot. The combined module of the climbing robot and robotic arm can climb the telecom tower's ladders, and the bird nest removal arm operates whenever there is a birdnest on the tower. An exhaustive literature survey is conducted to judge the capabilities of a manipulator on the mobile robot to utilize for maintenance purposes [16]. The manipulator can perform many operations in manufacturing, assembly and in hazardous areas. It can inspect tanks, chemical pipes and performing various underwater applications. The versatile apllicaions of manipulator technology has encourage the engineers to search new application that can be performed by a manipulator. A classifications of manipulator robots and salient features are essential for designing and selecting manipulators for a various operations[17]–[22] Figure 2(a,b,c,d,e,f,g,h,i) represents the robots in the application which are mounted on the other mobile robots



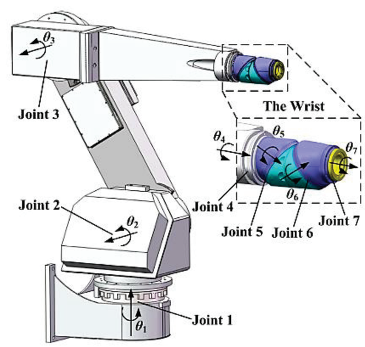
(a) A Climbing robot equipped with a manipulator of 5 DOF for inspection [23]



(b) A spray painting arm mounted on a crane [24]

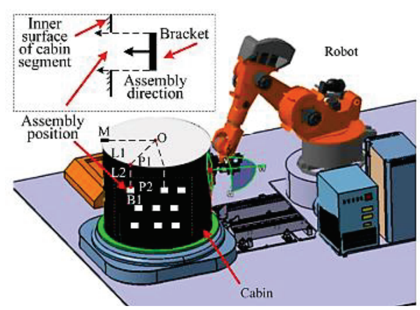


(c) climbing robot with magnetic adhesion for steel bridge inspection[25]



(d) 6-DOF painting robot. [26]


(e) Industrial Painting Robot [27]



(f) Assembly robot [28]


(g) Telescopic Spray painting robot[29]

(h) 6 DOF Industrial Spray painting manipulator [30]

FIGURE 2. Robots mounted on devices for performing tasks.

To safeguard the riggers from the birds, the authors have developed a six-degrees-of-freedom robotic arm that can be mounted on the climbing robot. The design of the manipulator for removing bird nests is included in section 2. Section 3 contains the analysis results and information for the development of the robot, which is presented in section 4. The concluding remarks are given in section 5.

MECHANICAL DESIGN OF A ROBOT

Removing the nest of bird's from the top of the telecom tower is required. Most towers contain predatory birds like eagles or hawk's nest. The weight and size of the nest are the most critical parameters for designing the manipulator. The dimension range is 28 to 70 cm in diameter and 10 to 30 cm deep. The weight of the nest ranges between 2 to 5kgs. Considering the payload as 5 kg, a six-degree-of-freedom (6-DOF) robotic arm is designed.

A Serial manipulator kinematic structural manipulator with an end effector is designed. Figure 3 shows the CAD model of a robotic manipulator designed to remove a bird's nest on the top of the telecom tower. The cross-section of the telecom towers becomes narrow at the tower's top. The links' dimensions of the manipulators' links are decided based on the reachable workspace requirements and the space available at the heights on the tower. The design of the gripper is most important for performing the task. Figure 4 shows the CAD model of the Gripper Design.

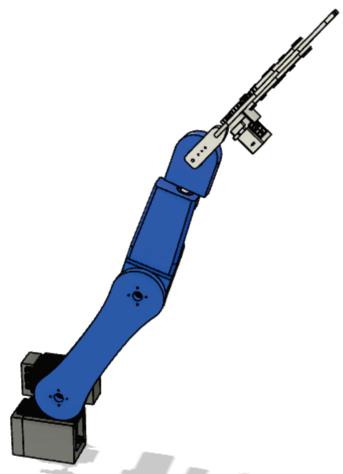


FIGURE 3. Cad model of the Robotic arm

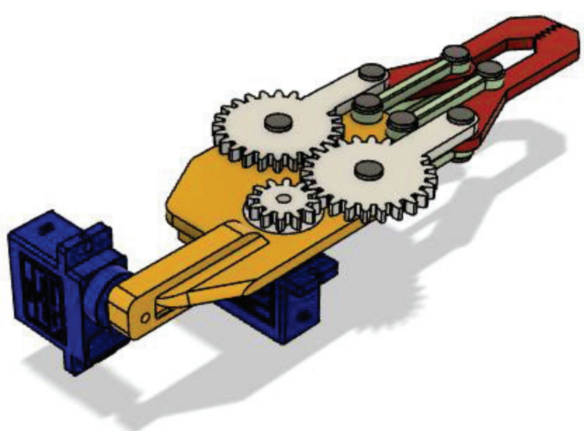


FIGURE 4. CAD model of the gripper

The forward and inverse kinematics of the robotic arm are performed in MATLAB. Its DH parameters matrix and frame assignment are shown in Figures 5 and 6. The forward kinematics link and join parameters are obtained using code, as shown in Figure 7. Appendix 1 contains the generated MATLAB code for the kinematic analysis of a robot.

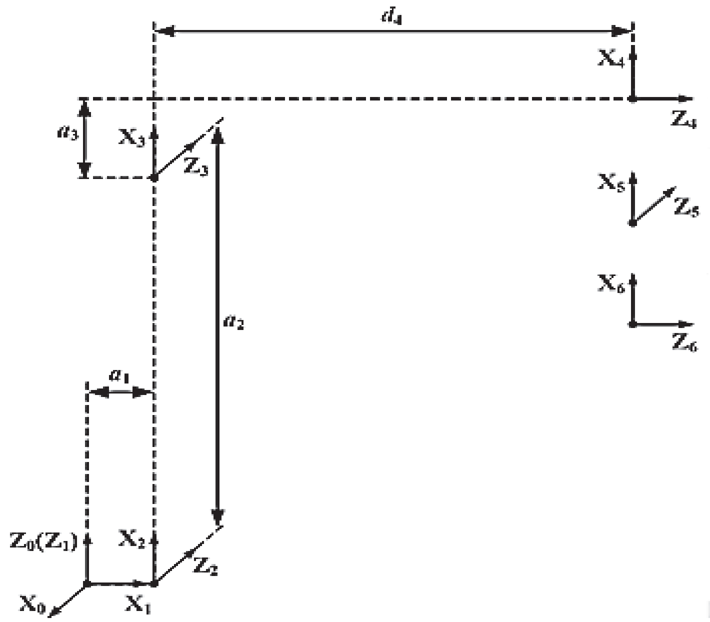


FIGURE 5. Frame assignment

Axis	ai	αi	di	θi	Range(θi)
1	5	90°	0	θ_1	-180 to 180
2	15	0	0	θ_2	-90 to 180
3	10	-90	5	θ_3	-90 to 90
4	7	90	20	θ_4	-90 to 180
5	8	90	5	θ_5	-90 to 90
6	3	0	0	θ_6	-90 to 180

ai = Offset angle

αi = Twist angle

di = Link length unit

θi = Joint angle

FIGURE 6. DH Parameters matrix

The kinematic analysis of the robot is performed using MATLAB code, which is developed using the robotics system toolbox, and a forward kinematic homogeneous transformation matrix is obtained, as indicated in Equation 1.

Homogeneous Transformation matrix for forward kinematics

$$T = T1*T2*T3*T4*T5*T6 \quad (1)$$

Where Ti = Transformation matrix concerning joint (i = 1,2,3,4,5,6)
The results of the above matrix multiplication are shown in Equation 2.

$$Fk = \begin{bmatrix} -c\theta_3\,\sigma_4 - s\theta_3\,\sigma_3 & -s\theta_1 & c\theta_3\,\sigma_3 - s\theta_3\,\sigma_4 & A \\ -c\theta_3\,\sigma_2 - s\theta_3\,\sigma_1 & -c\theta_1 & c\theta_1\,\sigma_3 - s\theta_3\,\sigma_2 & B \\ -c\theta_3\,\sigma_6 - s\theta_3\,\sigma_5 & 0 & c\theta_5\,\sigma_3 - s\theta_3\,\sigma_6 & C \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

Where $c\theta = cos\theta$, $s\theta = sin\theta$, *and*

$$A = c\theta_1 - 2c\theta_1 c\theta_2 + \frac{3c\theta_1 s\theta_2}{2} + \frac{3c\theta_3\sigma_{10}}{2} - 2c\theta_3(\sigma_{11} - \sigma_{12}) - 2s\theta_3\,\sigma_{10} - \frac{3s\theta_3(\sigma_{11} - \sigma_{12})}{2} + \frac{\sigma_{11}}{2} + \frac{\sigma_{12}}{2} + 2c\theta_1 c\theta_2 s\theta_3 + 2c\theta_1 c\theta_3 s\theta_2$$

$$B = s\theta_1 - 2c\theta_2 s\theta_1 + \frac{3s\theta_1 s\theta_2}{2} + \frac{3c\theta_3\sigma_7}{2} - 2c\theta_3(\sigma_8 - \sigma_9) - 2s\theta_3\,\sigma_7 - \frac{3s\theta_3(\sigma_8 - \sigma_9)}{2} + \frac{\sigma_8}{2} - \frac{\sigma_9}{2} + 2c\theta_2 s\theta_1 s\theta_3 + 2c\theta_3 s\theta_1 s\theta_2$$

$$C = \frac{3c\theta_2}{2} + 2s\theta_2 + 2c\theta_2 c\theta_3 + \frac{\sigma_{15}}{2} + \frac{\sigma_{14}}{2} - 2s\theta_2 s\theta_3 - 2c\theta_3(\sigma_{15} + \sigma_{14}) + \frac{3c\theta_3\sigma_{13}}{2} - \frac{3s\theta_3(\sigma_{15} + \sigma_{14})}{2} - 3s\theta_3\sigma_{13} + 2$$

$$\sigma_1 = cos(\theta_3)\,\sigma_7 - sin(\theta_3)\,(\sigma_8 - \sigma_9)$$

$$\sigma_2 = cos(\theta_3)(\sigma_8 - \sigma_9) - sin(\theta_3)\,\sigma_7$$

$$\sigma_3 = cos(\theta_3)\,\sigma_{10} - sin(\theta_3)\,(\sigma_{11} - \sigma_{12})$$

$$\sigma_4 = cos(\theta_3)(\sigma_{11} - \sigma_{12}) - sin(\theta_3)\,\sigma_{10}$$

$$\sigma_5 = cos(\theta_3)\,\sigma_{13} - sin(\theta_3)\,(\sigma_{15} + \sigma_{14})$$

$$\sigma_6 = cos(\theta_3)(\sigma_{15} + \sigma_{14}) - sin(\theta_3)\,\sigma_{13}$$

$$\sigma_7 = cos(\theta_2)sin(\theta_1)sin(\theta_3) - cos(\theta_3)sin(\theta_1)sin(\theta_2)$$

$$\sigma_8 = sin(\theta_1)\,sin(\theta_2)\,sin(\theta_3)$$

$$\sigma_9 = sin(\theta_1)\,cos(\theta_2)\,cos(\theta_3)$$

$$\sigma_{10} = cos(\theta_1)\,cos(\theta_2)\,sin(\theta_3) + cos(\theta_3)\,cos(\theta_1)\,sin(\theta_2)$$

$$\sigma_{11} = cos(\theta_1)\,sin(\theta_2)\,sin(\theta_3)$$

$$\sigma_{12} = cos(\theta_1)\,cos(\theta_2)\,cos(\theta_3)$$

$$\sigma_{13} = cos(\theta_2)cos(\theta_3) - sin(\theta_3)\,sin(\theta_2)$$

$$\sigma_{14} = cos(\theta_3)\,sin(\theta_2)$$

$$\sigma_{15} = cos(\theta_2)\,sin(\theta_3) \quad (3)$$

The final homogeneous transformation matrix for forward kinematics is represented in Equation 4.

$$T = \begin{bmatrix} 0.8517 & -0.342 & 0.3971 & 1.6143 \\ 0.31 & 0.93 & 0.1445 & 0.5876 \\ -0.4226 & 0 & 0.9063 & 6.6113 \\ 0 & 0 & 0 & 1.0 \end{bmatrix} \quad (4)$$

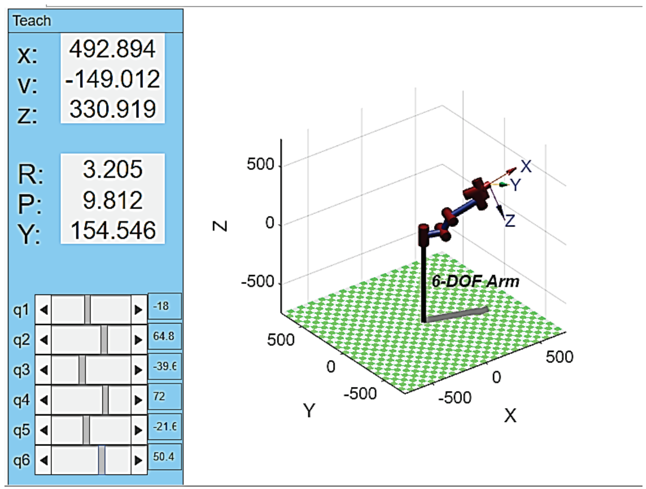
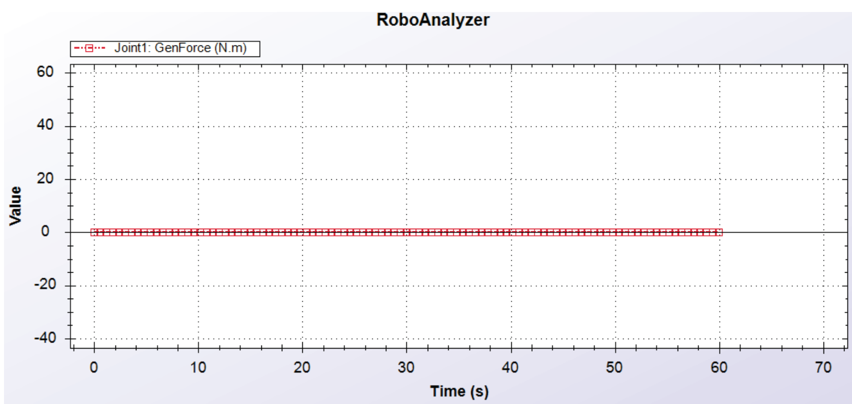


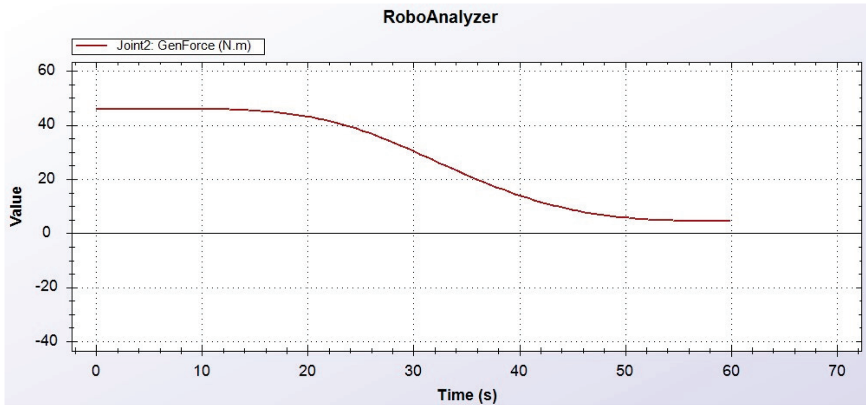
FIGURE 7. Results of kinematic analysis

ANALYSIS OF THE ROBOT

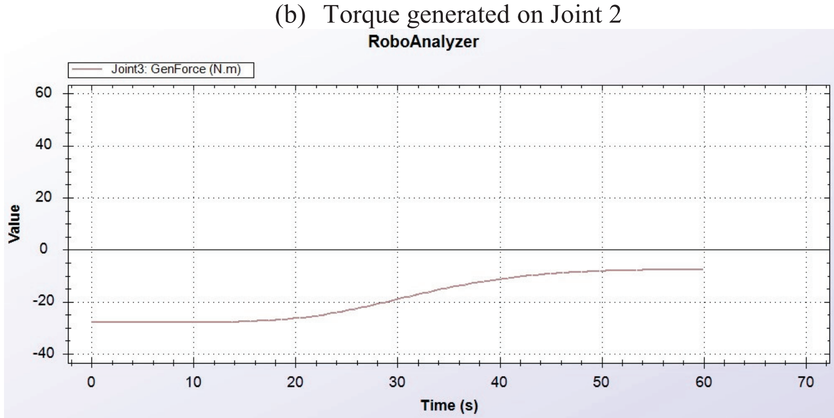
Simulation and analysis of the robot are performed using a Robo Analyzer. It is imperative to perform a dynamic analysis of the robot. The torque requirement at each joint can be judged by the force generated at the joint. The results of the force generated give the required torque, which has helped in selecting the actuators for the joints. Figure 8 shows the force results of all the joints.



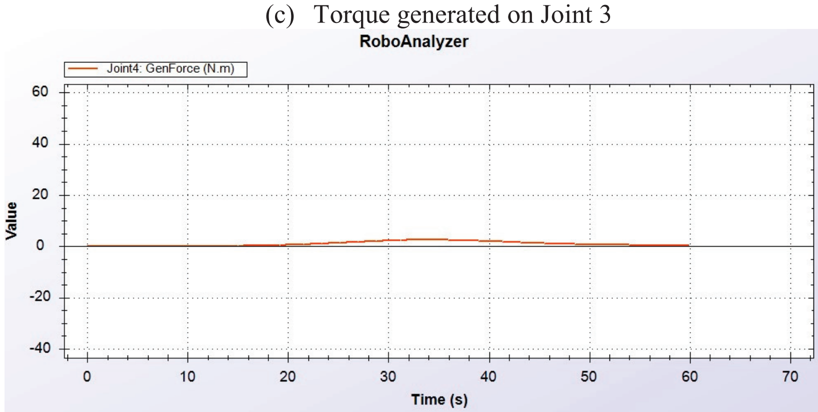
(a) Torque generated on Joint 1



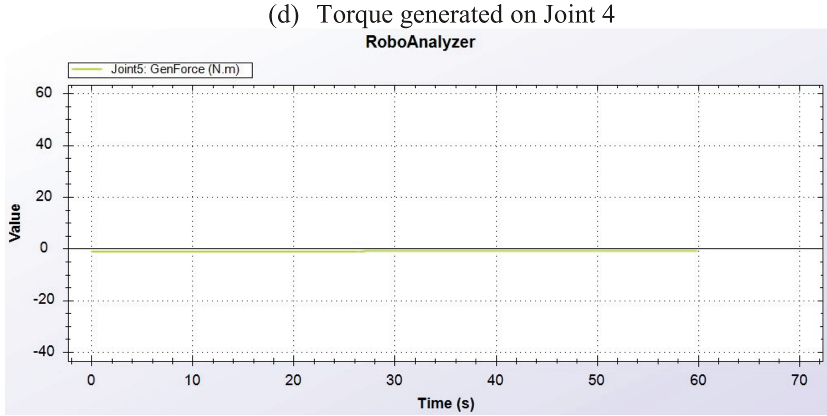
(b) Torque generated on Joint 2



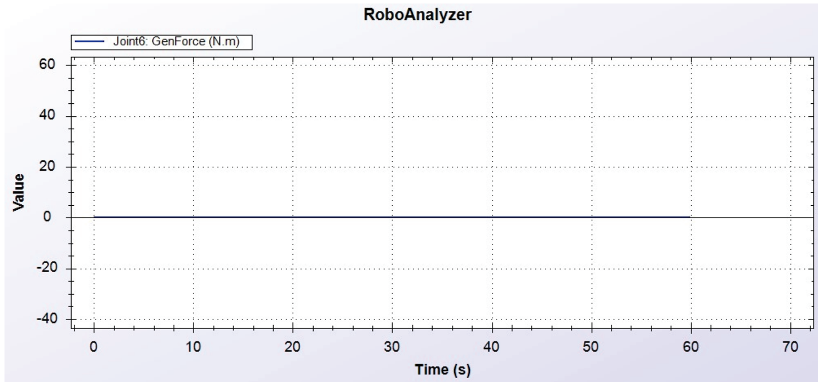
(c) Torque generated on Joint 3



(d) Torque generated on Joint 4



(e) Torque generated on joint 5



(f) Torque generated on joint 6

FIGURE 8. Joint force at all joints

DEVELOPMENT OF ROBOTIC ARM

A bird's nest removal robot prototype is developed with acrylic and plastic materials. Figures 9 and 10 show pictures of the developed prototype. The Arduino controlled six degrees of freedom, and the robot appropriately operated according to the motion sequences coded. Real experimental trials can only be possible once the robot can be mounted on the climbing robot.

FIGURE 9. Prototype developed (Top view)

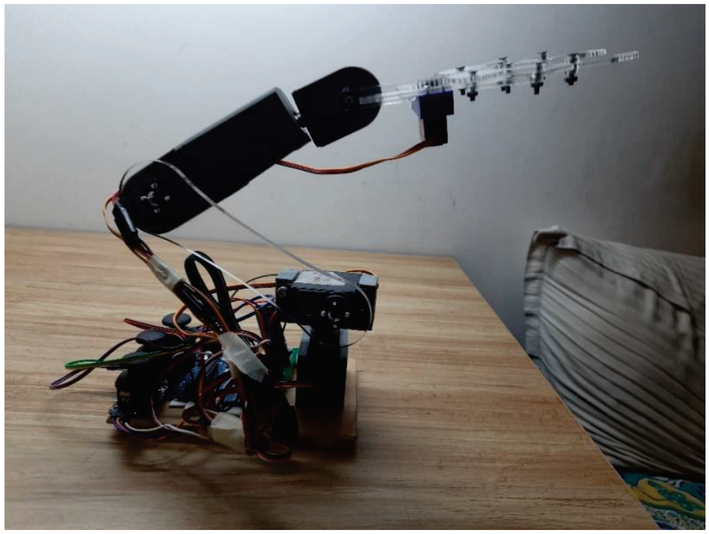


FIGURE 10. Prototype Developed (Side view)

CONCLUSION

The network of telecom towers is spraded worldwide, and with the increasing payload demands, it isn't easy to perform timely maintenance. Carnivorous birds like eagles and hawks have built their nests on the tower. These nests may create connectivity problems if they are situated on the antenna. When riggers access the towers for maintenance, it is sometimes necessary to remove the nest to maintain the network. The riggers may become the victims of birds hit, they lose their balance on the heightened tower, and incidents of fall from towers happen, and riggers may be killed or serious injury happens. A birdnest removal robotic manipulator is designed and developed to resolve the issues and safeguard the riggers from such a dangerous condition. This robotic arm can be mounted on the ladder climbing robot and can remove the bird nest whenever it creates trouble with network connectivity. The design of the manipulator is done considering the workspace required and the available space on the tower top areas. The analysis of the arm was done with satisfactory results, and the developed manipulator also worked well to remove bird nests from the tower.

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APPENDIX 1

MATLAB Code

```
import ETS4.*
L1=150, L2=130, L3=250, L4=80, L5=50, L6=80,
L(1) =Link1('revolute', 'd1', 0, 'a1',L1, 'alpha', pi/2);
L(2) =Link1 ('revolute', 'd1', 0, 'a1', L2, 'alpha', 0);
L(3) =Link1 ('revolute', 'd1', 0, 'a1', L3, 'alpha', -pi/2);
L(4) =Link1 ('revolute', 'd1', L4, 'a1', 0, 'alpha', pi/2);
L(5) =Link1 ('revolute', 'd1', L5, 'a1', 0, 'alpha', pi/2);
L(6) =Link1 ('revolute', 'd1', 0, 'a1', L6, 'alpha', 0);
SixLink=SerialLink (L, 'name', '6-DOF Arm');
```

```
SixLink.fkine([180 180 180 180 180 180], 'deg')
SixLink.teach
syms theta
Xr = [1 0 0; 0 c(theta) -s(theta); 0 s(theta) c(theta)];
Yr = [c(theta) 0 s(theta); 0 1 0; -s(theta) 0 c(theta)];
Zr = [c(theta) -s(theta) 0; s(theta) c(theta) 0; 0 0 1];

syms theta1 theta2 theta3 theta4 theta5 theta6
x1 = 1; x2 = 2; x3 = 0.5; z1 = 2; z2 = 1.5;
H1 = [subs(Zr,theta,theta1) [0;0;0]; 0 0 0 1];
H2 = [subs(Yr,theta,theta2) [x1;0;z1]; 0 0 0 1];
H3 = [subs(Yr,theta,theta3) [-x2;0;z2]; 0 0 0 1];
H4 = [subs(Yr,theta,theta3) [-x3;0;z1]; 0 0 0 1];
H5 = [subs(Yr,theta,theta3) [x2;0;z2]; 0 0 0 1];

FK = H1*H2*H3*H4*H5
t1 = 20/180*pi;
t2 = 10/180*pi;
t3 = 5/180*pi;
t4 = 3;
t5 = 30/180*pi;
t6 = -20/180*pi;
ForwardK_1 = double (sub( ForwardK, {theta1,theta2,theta3,theta4,theta5,theta6} , {t1,t2,t3,t4,t5,t6}))
```

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