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Design and Synthesis of Eight-Legged Spider Robot

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***Abstract:** Less than half the world's landmass is accessible to existing wheeled and tracked vehicles. But people and animals using their legs can go almost anywhere. Our aim is to develop a new type of rough-terrain robots that capture the mobility, autonomy and speed of living creatures. Such robots will travel in outdoor terrain that is too steep, rutted, rocky, wet, muddy, and snowy for conventional wheeled vehicles. They will travel in cities as well as in our homes, doing chores and providing care, where steps, stairways and household clutter limit the utility of wheeled vehicles. Robots meeting these goals will have various sensors, sophisticated computing and power systems, advanced actuators and dynamic controls.*

It is marvellous that creatures can go over a rough terrain at speeds which are remarkably higher than practically possible with wheeled vehicles. Indeed, even an individual, by getting down on each of the eight legs if necessary, can travel or climb over terrain which is unreachable for a wheeled or followed vehicle. It is therefore of immense eagerness to realize what machines for land locomotion can do if they are intended to imitate nature. Legged robots can be used for space missions on extraterrestrial planets and in risky places, for example, within an atomic reactor, giving independent legged robots a great potential. less power consumption and weight are further advantages of walking robots, so it is important to use the minimum number of actuators. In this context, the objective of this project is to learn and design a prototype of the Theo-Jansen eight leg strolling robot. The goal is to develop a new mechanical automated walker utilizing eight bar link mechanism. The essential Theo Jansen device is a 13 bar framework that strolls when a crank is rotated. So, utilizing linkages we attempted to imitate nature and put together certain strolling robot which will suite off-road.

I. INTRODUCTION

The rise of new high-speed technology and the growing computer Capacity provided realistic opportunity for new robot controls and understanding of new methods of control theory. This technical upgrade together with the need for high performance robots created faster, more accurate and more brilliant robots using new robots control devices, new drivers and advanced control algorithms. This project describes a new low-cost solution of robot control systems. The presented robot control system can be used for different advanced robotic applications. The objective of this project is to build a new mechanical robotic walker using 8 bar link mechanism. The system uses a Robot which is Capable of walking towards the object according to the user remote control and avoid it with help of ultrasonic sensor. The main aim of this project is to fabricate a Mechanical walker robot using Arduino. As it is a wireless Robot it can be easily mobilized and can be controlled.

An eight-bar linkage is a one degree-of-freedom mechanism that is made from eight links and 10 joints. These linkages are infrequent compared to four-bar and six-bar linkages, but two well-known examples are the Peaucellier mechanism and the linkage designed by Theo Jansen for his walking machines. This project makes use of an on-board computer, which is commonly termed as micro controller. It acts as heart of the project. This on-board computer can efficiently communicate with the output and input modules which are being used. The controller is provided with some internal memory to hold the code. This memory is used to dump some set of assembly instructions into the controller. And the functioning of the controller is dependent on these assembly instructions. In this project we use micro controller, which is programmed to control the input and output modules interfaced to it. The controller makes use of a remote, which is used to control the robot. The project consists of micro controller based motherboard is present with the Robot itself. It is interfaced with some DC motors for moving the robot.

A leg mechanism (walking mechanism) is an assembly of links and joints intended to simulate the walking motion of humans or animals. Mechanical legs can have more than one actuators, and can perform simple planar or complex motion. Compared to a wheel, a leg mechanism is capably better fitted to uneven terrain, as it can step over obstacles.

Jansen linkage is a planar leg mechanism designed by the kinetic sculptor Theo Jansen to simulate a smooth walking motion. Jansen has used his mechanism in a variety of kinetic sculptures which are known as strand bees ten Jansen's linkage bears artistic as well as mechanical merit for its simulation of real walking motion using a simple rotary input.

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These leg mechanisms have applications in moving robotics and in gait analysis. When two Jansen linkages are joined to each other by a rotating horizontal shaft, both the legs help the machine to move forward or backward depending on the clockwise or anticlockwise rotation of the shaft.

II. THEO JANSEN MECHANISM

Legged autonomous robots are a type of mobile robot which use mechanical arm for movement. These type of robots are more versatile than wheeled robots. It is known that animals can travel over uneven surface at speeds much greater than wheeled or tracked vehicles. Wheeled vehicles are not suitable for uneven surface due to some reasons. It is also practically not possible for most automobiles to move over vertical surfaces. Even on more sandy and circular edge surfaces most automobiles slip frequently. The facts are that, there is still a lot of scope left for changing the way in which vehicles exchange in the 21st century.

The new invention of modifying an existing mechanism can enable various applications of the science and technology. One of the most useful applications for these new mechanisms could be easy movement of a vehicle over roads destroyed because of earthquake, tsunami or any other natural disaster. Another application is use of locomotive mechanism of vehicle used for mining.

Mining site are extreme bumpy and rough, so roads have to be made for it but it will cost more to mining industry and also increases emission level but making road separately enable simple and smooth mining operation.

The problem can be easily solved with mechanisms that can help the vehicle to move easily over any type of surface. The main advantage of Theo Jansen mechanism robots is their capability to access places impossible for wheeled robots. Copying the real structure of legged animals, it may be possible to improve the performance of mobile robots. To provide more stable and faster walking, scientists and engineers can utilize the relevant biological concepts in their design.

The most forceful motivation for studying Theo Jansen mechanism robots is

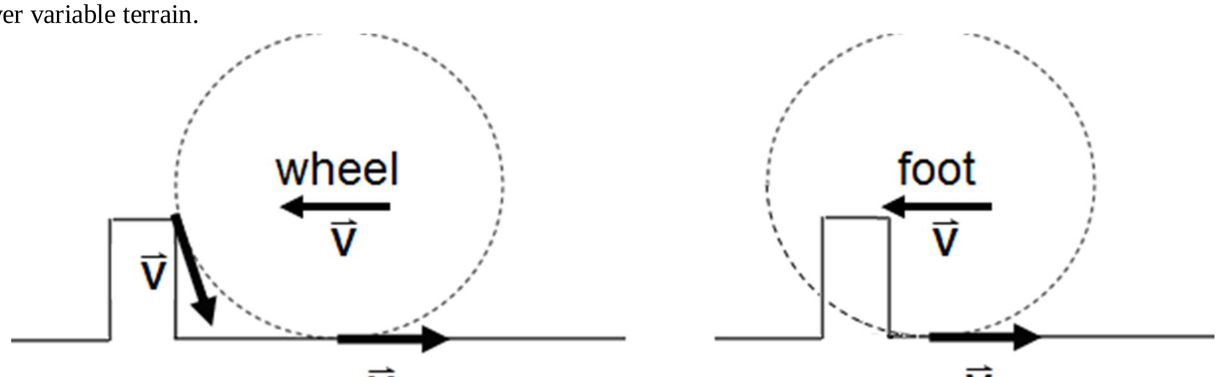
1.To give access to places which are dirty and

2. To give access to places those are dangerous. Highly difficult jobs can be easily done by legged robots used for rescue work after earthquakes and in dangerous places such as the inside of a nuclear reactor, giving biologically inspired autonomous legged robots great potential. Low power consumption and weight are further advantages of walking robots, so it is important to use the less number of actuators.

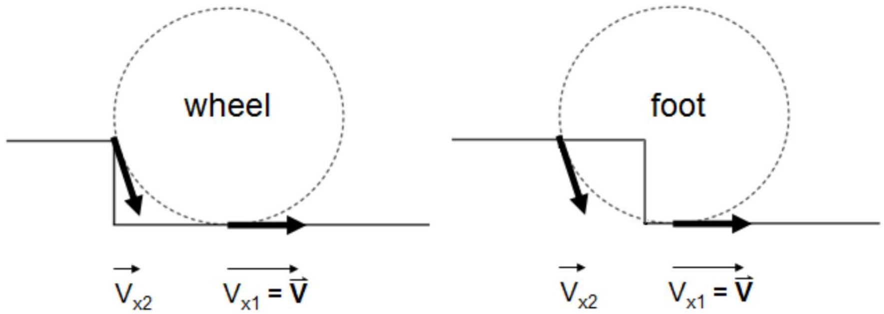
III. ADVANTAGES OF WALKING

Walking robots possess several advantages over wheeled robots in areas of variable terrain. Consider a wheel moving a constant velocity V; every point on its perimeter is moving at a constant velocity V tangent to the curve of the wheel.

A comparable walking mechanism would be one which moves at a constant velocity V, and where the “foot” of the walker traces out a similar circular path with a constant velocity V at all points on the path. The most obvious advantage of the foot over the wheel is that the foot may step over inconsistencies in the terrain. Local maxima and minima may be completely avoided by simply stepping over them. This results in less loss of energy during motion and allows the vehicle to maintain a constant velocity and height over variable terrain.



Comparison of wheel and foot reaction to a local maximum in the terrain. The dotted lines indicate the perimeter of the wheel or the pathway of the foot. The arrows indicate’s the direction of movement. The foot may step over the obstacle where the wheel must move over the obstacle. Now assume a case where the comparable foot and wheeled systems approach an obstacle that cannot be avoided, as shown in Figure.



When the edge of the wheel makes contact with the higher ground, it forces the velocity of the vehicle to immediately slow. This edge has a total velocity V, but only a fraction of that velocity is in the x direction, so the vehicle quickly slows from V to Vx2. The foot encounters a similar change in velocity, but it has the advantage of being able to slide along the ground. Although this scenario is not ideal, dragging the front foot across the raised terrain reduces change of velocity in the x direction. Both models must still overcome the potential energy barrier posed by the increased height of the terrain. A comparison of a wheel and a foot (moving in a wheel-like path) approaching an inconsistency in the terrain. The x component of the velocity of the edge of the wheel and the foot's path are indicated. Furthermore, the wheel causes a great deal of environmental harm . Its inability to avoid obstacles means that it erodes more terrain than a foot when moving comparable 3 vehicles. Additionally, wheeled vehicles work best on terrain with no inconsistencies; this has led to paving of many permanent roadways, another form of environmental degradation. The benefits of walking over rolling on rough terrain are summed up in the following: x Higher energy efficiency, better fuel economy x Increased speed x Greater mobility x Improved isolation from terrain inconsistencies x Less environmental damage.

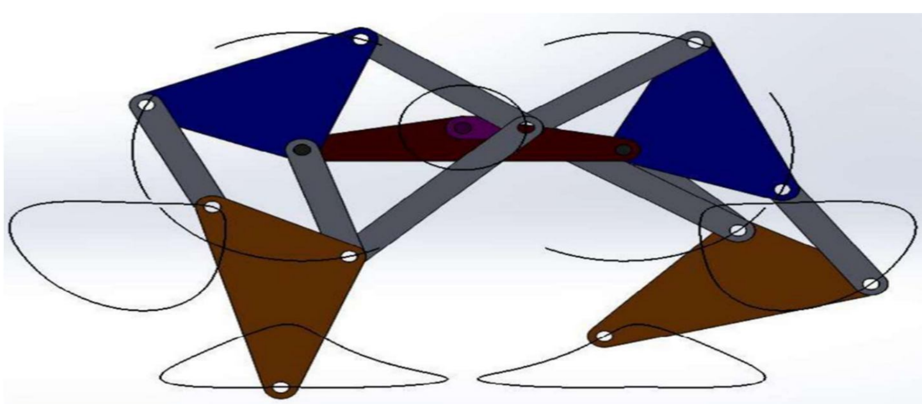
IV. SOFTWARE REQUIREMENTS

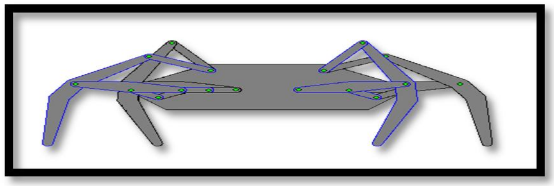
Arduino IDE: The open-source Arduino Software (IDE) makes it easy to write code and upload it to the board. It operates on Windows, Mac OS X, and Linux. The environment is written in Java and based on Processing and other open-source software. This is where you can type the code you want to compile and send to the arduino board. The Intial Setup: We need to setup the environment to the Tools menu and select Board Then select the type of Arduino you want to program,in our case it's Atmega Arduino The code you write for your Arduino are known as sketches. They are written in c++.

V. DESIGN AND METHODOLOGY

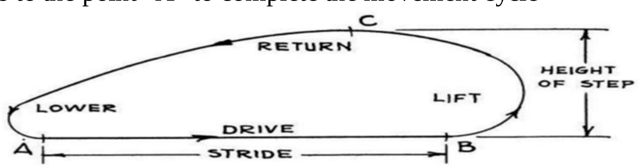
A. Solidworks Simulation

In order to measure the precision of the analytical results, we simulated the motion of the Theo Jansen mechanism using SolidWorks Motion Study package. The position (loci), velocity and acceleration results for the points 1, 2, 4, 5, 6 and 7 are represented in Fig. 11, Fig. 12 and Fig. 13, respectively. The linear velocities and the linear accelerations plots acquired from SolidWorks are shown for the time of 6.28 seconds which is equal to one full rotation of the crank at constant angular velocity of 1 rad/s.



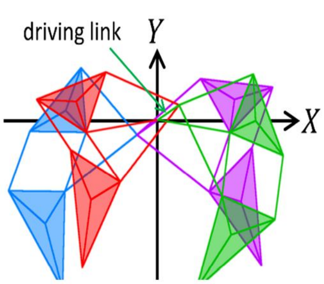


The length of each link in the mechanism is defined to make the foot movement (approximately) linear for one-half of the rotation of the crank. The remaining rotation of the crank allows the foot to raise to a predetermined height, which is called the height of step (see Fig) before returning to the starting position, which is the beginning of the next cycle. During each movement cycle of the Theo Jansen mechanism, each leg experiences four different movement phases which make a closed curve. These phases are called stride phase, lift phase, return phase and lower phase as shown in Fig. The straight line "AB" the stride phase in which the leg is in touch with the ground where it should move at a constant velocity. A consists of two portions "BC" and "CA" . The first portion "BC" is called the lift phase. During this phase the leg moves toward its maximum height. As the leg passes the it enters into the second portion of the "BCA" which is called the return Phase. During the return phase, the leg moves in the same direction as the whole mechanism. The shape of this phase affects the highest acceleration of the leg. Any attempts to make the curve "CA" as a straight line will ideally minimize the acceleration of the leg. Lastly, the leg descends to the ground until it reaches to the point "A" to complete the movement cycle



B. Kinematic Analysis

In this section we studied the kinematics of one leg of the Theo Jansen mechanism. For this kinematic analysis, we are interested in the position, velocity and acceleration of points 1, 2, 4, 5, 6 and 7 which are shown in Fig. 4. We obtained the general equations of motion for the linkages - - - (see Fig. 2) using the loop closure method, in which links are represented as position vectors (see Fig. 5), and then we solved these analytical equations for one full rotation of the crank, by numerical analysis at each degree of rotation. The upper and lower linkages are categorized as crankrocker mechanisms because of conforming to the Grashof condition [11]. As in the kinematic analysis we need the dimensions of the links, we used the dimensions that are provided in Theo Jansen book [12]. To write the equations of motion for each linkage, we used complex numbers and the Euler identity in polar coordinates, which simplifies the calculations.



POSITION ANALYSIS

Fig.11

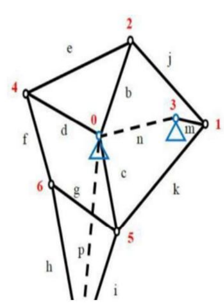


Fig.12

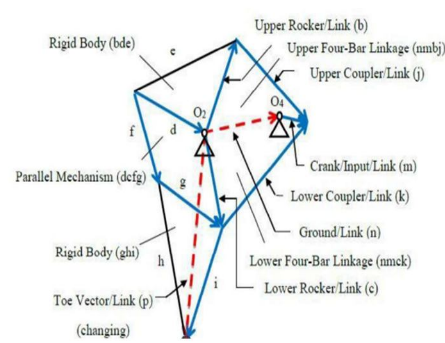


Fig.13

For position analysis we put the origin of the general coordinate system (GCS) at point O2 as illustrated in Fig. 5. The vector loop equation for a general four-bar linkage dc-ab as shown in Fig. 6 will be:

$$\vec{d} + \vec{c} - \vec{a} - \vec{b} = 0 \quad ....(1)$$

$$de^{j\theta d} + ce^{j\theta c} - ae^{j\theta a} - be^{j\theta b} = 0$$

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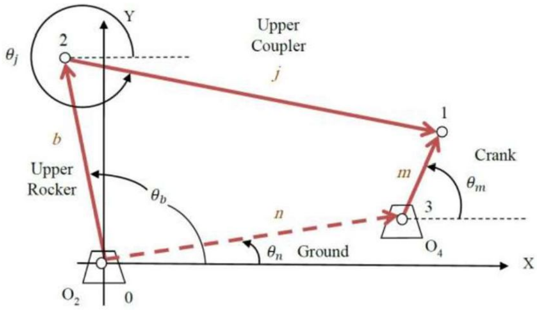
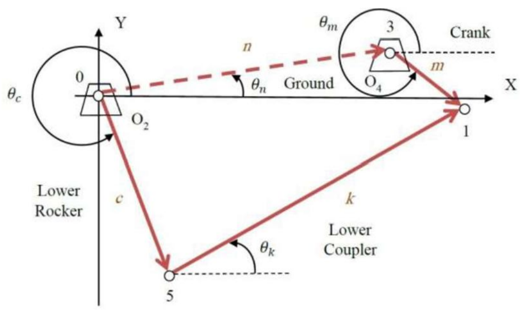
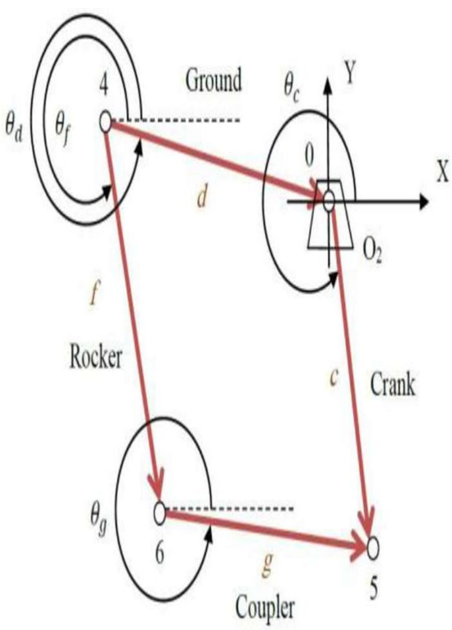
using complex numbers Eq. 1 can be rewritten as:
where {a,b,c,d} present the link lengths. Equation 2 can be solved for two unknown parameters,the angular positions of the rocker and coupler . These unknowns are functions of the links length {a,b,c,d} and the angle of the crank θc : ....(2)

$$\theta_{\{a,b\}} = u_{\{a,b\}}(a, b, c, d, \theta_c)$$

Where $\theta_{\{a,b\}}$ means either or . θ_a θ_b
As the parameters and represent the parameters {a,b,c,d}and of the $\{\theta_a, \theta_b, \theta_c, \theta_d\}$ represents the param







general linkage "dc-ab", they should be replaced by the corresponding parameters in the linkages under study.

$$Upper: \{a, b, c, d\} \triangleq \{b, j, m, n\} \quad (4)$$

$$\{\theta_a, \theta_b, \theta_c, \theta_d\} \triangleq \{\theta_b, \theta_j, \theta_m, \theta_n\} \quad (5)$$

$$Lower: \{a, b, c, d\} \triangleq \{c, k, m, n\} \quad (6)$$

$$\{\theta_a, \theta_b, \theta_c, \theta_d\} \triangleq \{\theta_c, \theta_k, \theta_m, \theta_n\} \quad (7)$$

$$PARL: \{a, b, c, d\} \triangleq \{f, g, c, d\} \quad (8)$$

$$\{\theta_a, \theta_b, \theta_c, \theta_d\} \triangleq \{\theta_f, \theta_g, \theta_c, \theta_d\} \quad (9)$$

for example, Eq. 2 can be written in terms of the real and imaginary parts for the upper linkage:

$$n\cos\theta_n + m\cos\theta_m - b\cos\theta_b - j\cos\theta_j = 0 \quad (10)$$

$$n\sin\theta_n + m\sin\theta_m - b\sin\theta_b - j\sin\theta_j = 0 \quad (11)$$

for the set of Eq. 10 and Eq. 11, the unknowns are $\{\theta_j, \theta_b\}$. From the Eq. 10 and Eq. 11 one can find:

$$x\cos\theta_{\{j,b\}} + y\sin\theta_{\{j,b\}} \triangleq R\cos(\theta_{\{j,b\}} - \alpha) = A \quad (12)$$

where the constants "x", "y", "R", "α" and "A" are:

$$x = n\cos\theta_n + m\cos\theta_m, \quad y = n\sin\theta_n + m\sin\theta_m \quad (13)$$

$$R = \sqrt{x^2 + y^2}, \quad \alpha = \tan^{-1}\left(\frac{y}{x}\right) \quad (14)$$

$$A_{\{j,b\}} = \frac{\{j,b\}^2 - \{b,j\}^2 + x^2 + y^2}{2\{j,b\}} \quad (15)$$

In Eq. 12 and Eq. 15, only one subscript inside the curly brackets will be considered at a time. Solving Eq. 12 will determine the angular position of the coupler and rocker of the upper linkage. A similar approach can be used to find the unknown parameters $\{\theta_k, \theta_c\}$ for the lower linkage.

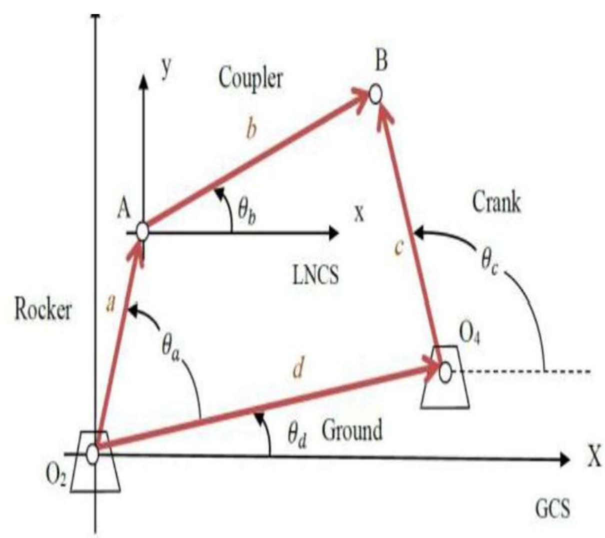


Figure 6. Vector loop of a four-bar linkage

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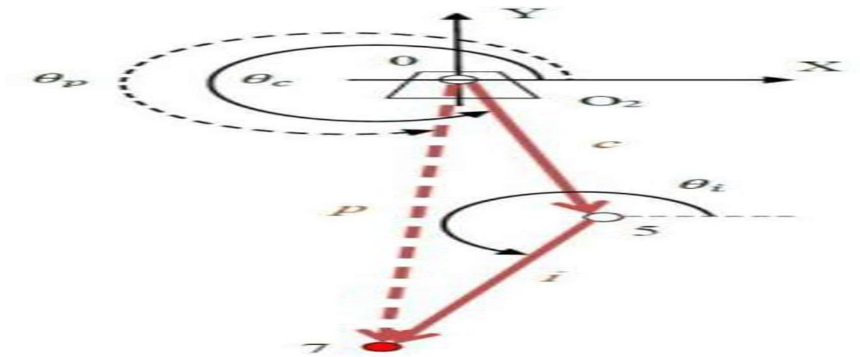
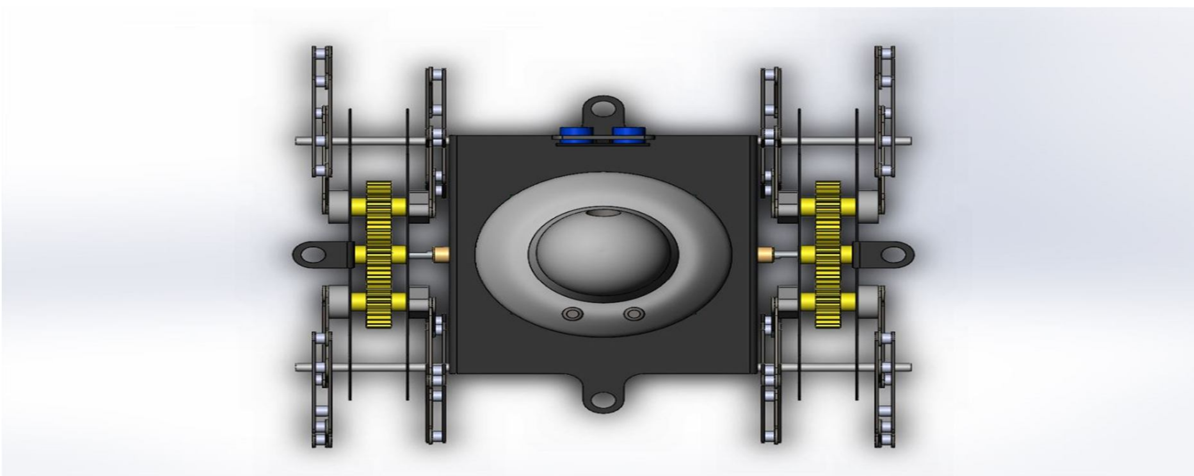
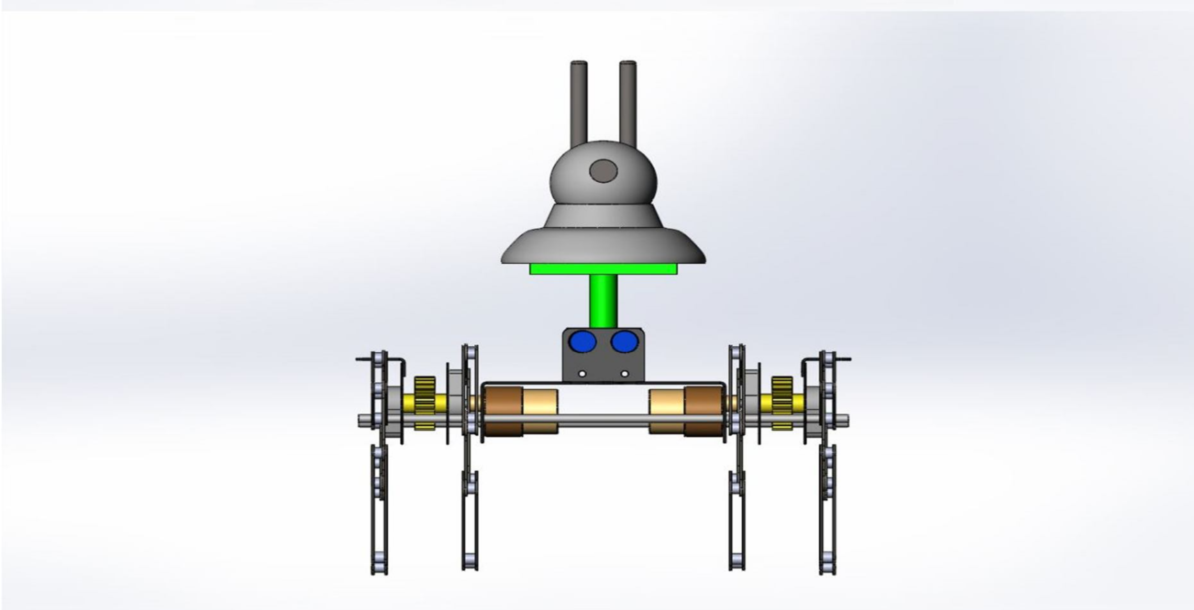
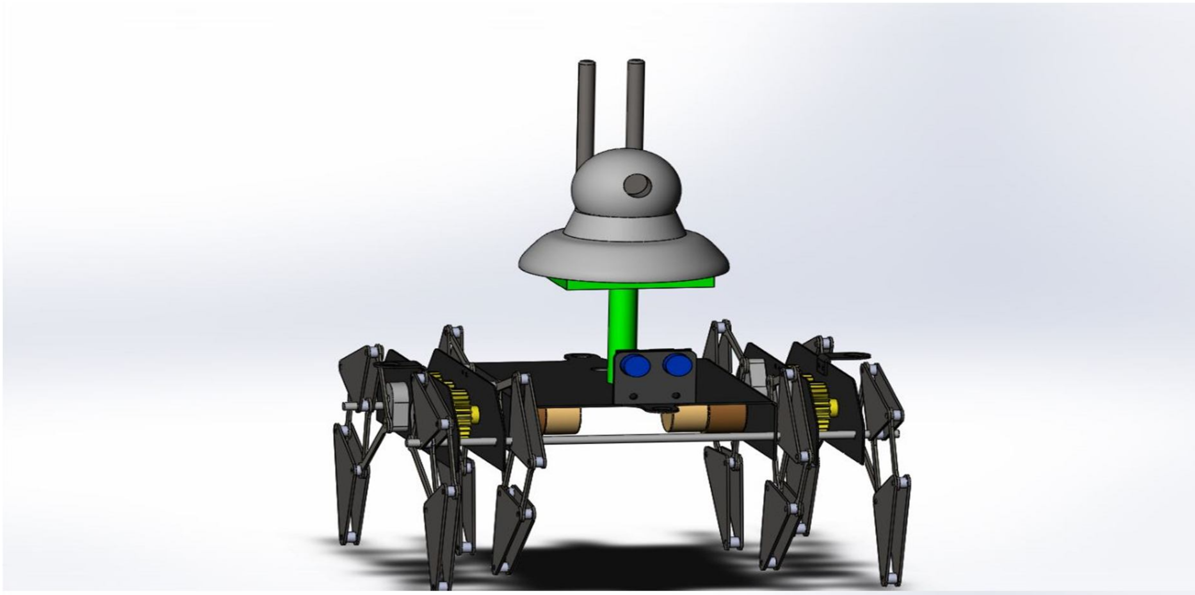


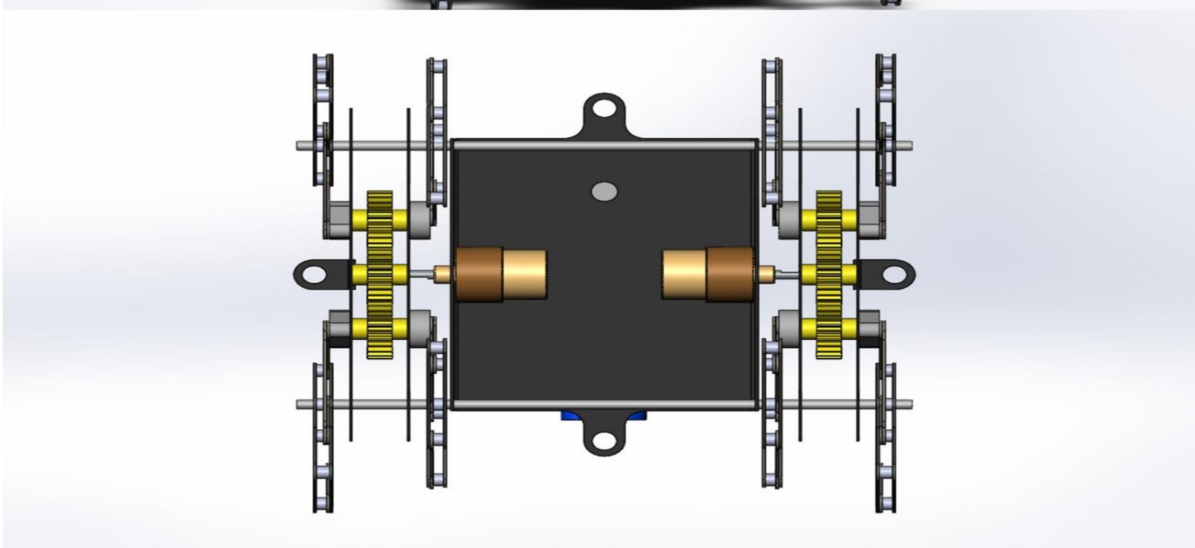
Figure 5. Vector loops of the Theo Jansen mechanism;
(a) nm-bj (b) nm-ck (c) dc-fg (d) cip

C. CAD Model

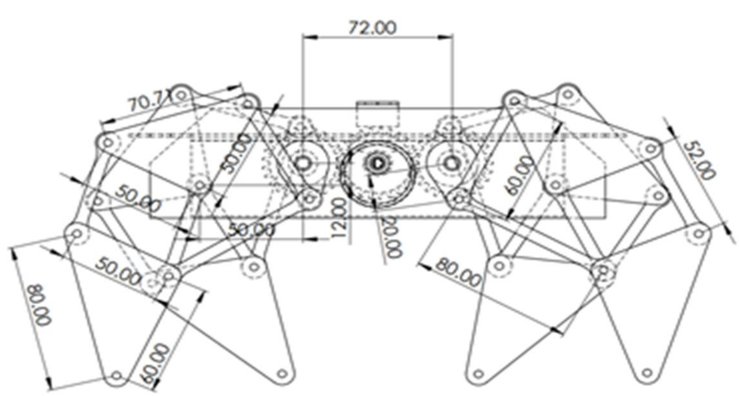








D. Dimensions



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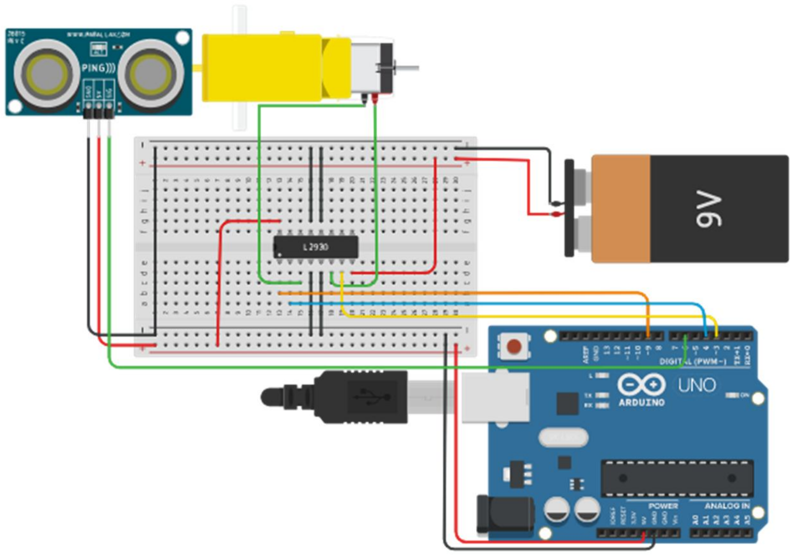
E. Virtual Electronic Circuit



F. CODE

```
int motorpin1 = 10 , motorpin2 = 11;
int trig = 12;
int echo = 9;
float distance;
float time;
void setup()
{
 pinMode (motorpin1, OUTPUT);
 //yellow wire
 pinMode (motorpin2, OUTPUT);
 //blue wire
   pinMode (trig, OUTPUT);
 pinMode (echo, INPUT);
 Serial.begin (9600);
}
void loop()
{
 // setup ultrasonic sensor to control
 //motor
 digitalWrite(trig, LOW);
 delayMicroseconds(2);
 digitalWrite(trig, HIGH);
 delayMicroseconds(10);
 digitalWrite(trig, LOW);
 time = pulseIn(echo, HIGH);
 distance = time/148.1;
 Serial.println(distance);
    if distance <5,digitalWrite (motorpin1, LOW);
 digitalWrite (motorpin2, LOW);
if distance >=5, digitalWrite (motorpin1, HIGH);
 digitalWrite (motorpin2, LOW);
 delay (1000);
```

VI. CONCLUSION

Our investigation showed that different elliptic circles were formed for strolling, climbing, venturing into a place, and moving back by utilising the cyclic movement of the linkage center. The purpose of this paper is to contemplate about the Theo-Jansen eight leg strolling robot.

The goal is to assemble a new mechanically automated walker utilising an eight bar interface system. In future we need to utilize this robot to perform diverse kind of activities consequently by utilizing sensors. If the robot is made of a high-heat-resistance material, we can use it in an atomic power plant or set up a high radiation level. Also, in our robot DC motors are used instead of servomotors to reduce the cost of our project, as servomotors are more costly than DC motors, and the load on the microcontroller will also be increased due to lots of servomotors. That's why we are going to use only two DC motors to run the entire mechanism. That will permit us to use a less-costly Atmega microcontroller, which is cheaper and less complicated than the Raspberry Pi Mini Computer, which is being used in modern spider robots. As a low-cost and less complicated microcontroller is being used in our project, less complicated programming is required for operation. In the other types of spider bots, they can only move forward and backward, but in our case, we are using two DC motors that can let him move forward and backward and also turn in the desired direction. Also, based on the design aspects studied and simulated in Solidworks software, our robot will be more balanced with 8 legs.

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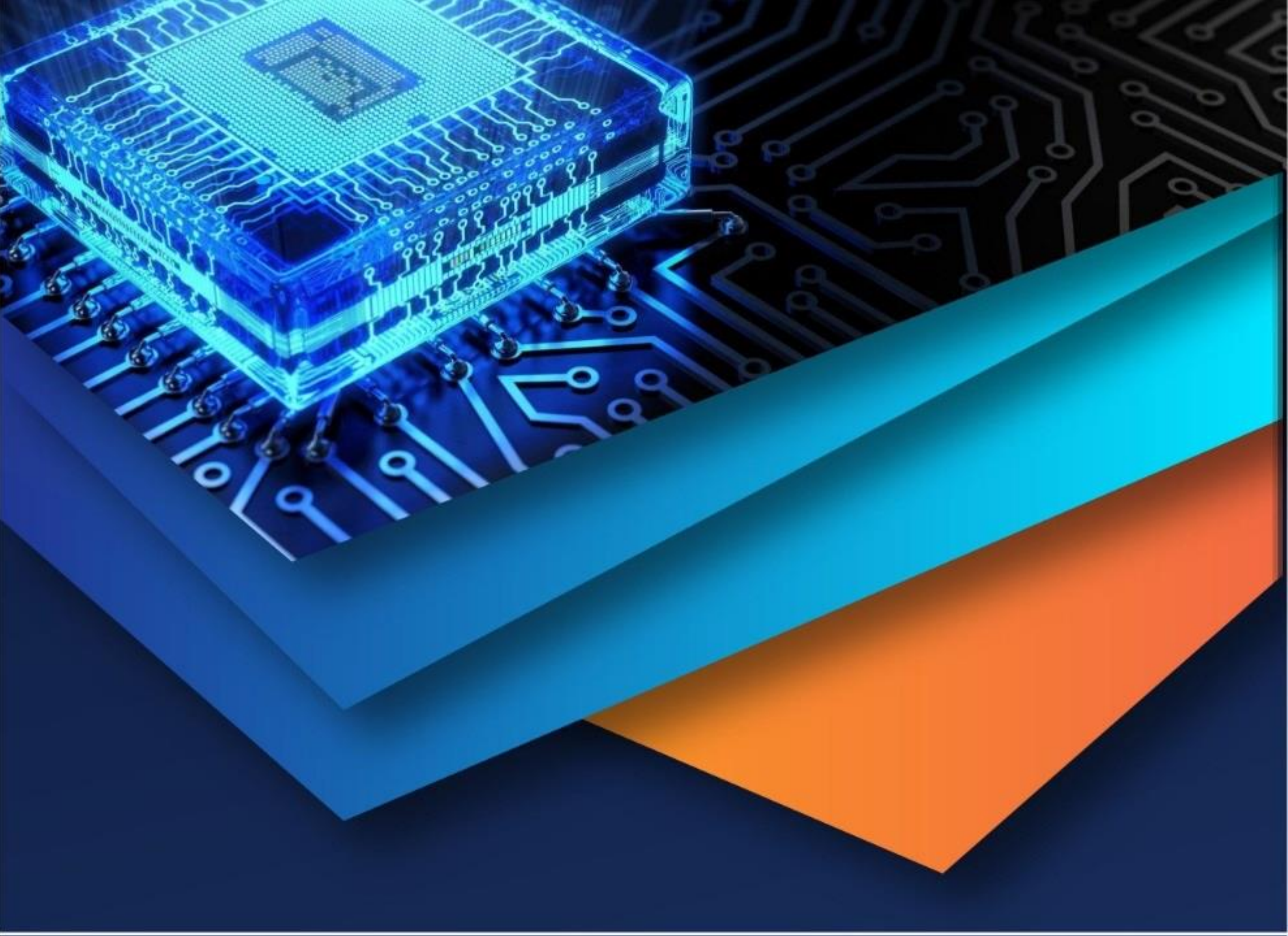
[14] Control of an 8-Legged, 24 DOF, Mechatronic Robot Submitted by Brian Lim Youliang Kuvesvaran s/o Paramasivan National Junior College Assoc. Prof. Dr. Francis Malcolm John Nickols



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