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The Jansen Walking Robot

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Abstract. The main purpose of this project is to make a versatile robot that can run-over any solid surfaces no matter the condition of surface. We are archiving this benefit by using Theo Jansen Mechanism. This is popular among legged robotics researchers due to its scalable design, energy efficiency, and low payload to machine load ratio, bio-inspired locomotion, and deterministic foot trajectory among others. It is an eight-legged robot which can walk in wet and dry soil, sand, any type of slope (up to 45^{o}) and also climb stairs. It is using simple mechanism to overcome obstacles, which height is below the maximum height of the leg path by our Theo robot. This mechanism is able to carry loads without any high forces applied to it. By including IOT to our project, we can archive more.

Keywords. The Jansen walking Robot; Walking Mechanism; Jansen Mechanism; Stair Climb

1. Introduction

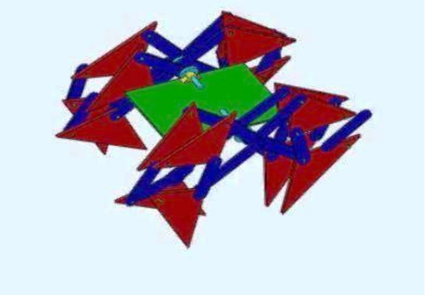

Figure 1. Theo Jansen assemble in solid works 2014

Theo Jansen mechanism as shown in Figure 1, is designed by Theodorus Gerardus Jozef. Because of its scalable architecture, energy efficiency, bio-inspired locomotion, low payload to machine load ratio, and deterministic foot trajectory, this is popular among legged robotics researchers. In this work, we present Theo Jansen's mechanism design in a novel approach. It is an 8 legged robot which can walk in wet soil, dry soil, sand any type of slope (up to 45 degree). It is using simple mechanism to make a path and the obstacle which height is below the maximum height of the path is overcome by our Theo robot. It has 8 legs for maintaining the CG. This gives the smoothest motion and is able to carry loads

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without any high forces requirement. Scientist Theo Jansen made this mechanism as an Engineering Art piece and we are converting this art piece into real world working robot with Motor Power and Torque Calculation. Our robot’s structure is made out of Acrylic sheet. Our design has a lot of applications such as – Walk on any uneven surfaces easily and smoothly, climb stairs,remotely controllable. Our goal is to develop this mechanism into a proper robot which can carry weights, Replace wheels to move smoother and reliable, climb stairs, military uses, rescue operations, autonomous robot for fireextinguisher, space missions etc.

2. Review of Literature

2.1. History

Theodorus Gerardus Jozef is a Dutch artist who was born on March 14, 1948. He began making gigantic PVC systems that can move on their own in 1990, and they are collectively known as Strandbeest [7].

2.2. The Strandbeest

It is depicted in Figure 2. Since 1990, Jansen has been making strandbeesten, that are moving kinetic structures that mimic walking creatures and are occasionally pushed by wind. Jansen refers to them as "artificial life" [7].

Figure 2. A strandbeest, exhibited by Jansen on the Linz city square during Ars Electronica, 2005 [6]

3. Mechanism

Theo Jansen, a kinetic artist, created Jansen's linkage, a planar leg mechanism that generates a smooth walking motion. Jansen's mechanism has been employed in a number of kinetic sculptures known as Strandbeesten. Jansen's linkage is notable both for its artistic and mechanical merits in simulating organic walking motion with a single rotational input. Mobile robots and gait analysis both benefit from these leg processes [4].

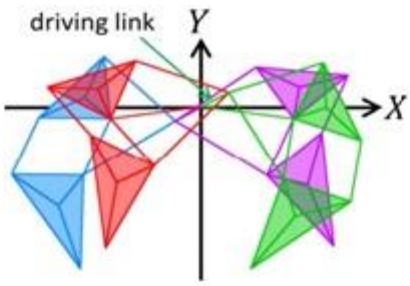

Figure 3. Schematic Figure of a four legged jansen linkage mechanism.

The central 'crank' link is moved in circles by a rotary actuator, such as an electric motor. Because of the motion given by the crank, all other links and pin joints are punctured and move. The mechanism

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has just one degree of freedom since its locations and orientations are governed solely by the crank angle (1-DoF). Using the circle intersection method and bond graphs (Newton–Euler mechanics), the kinematics and dynamics of the Jansen mechanism have been thoroughly characterized. These models may be used to calculate actuator torque and to build the system's hardware and controller [3]. Figure 3 shows the schematic figure of a four legged jansen linkage mechanism.

4. Methodology

Any point of normal wheel makes a cycloid shaped curve (as shown in the Figure 4) but in the case of theo Jansen mechanism it use a special curve. The curve iscalled locus.

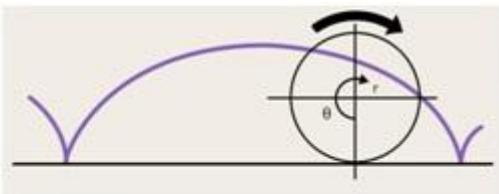

Figure 4. Cycloidal motion.

Locus has four parts i.e. drive, lift, return and lower. The foot is ideally in contact with the ground throughout the support phase. During the lift process the foot will move toward its maximum height in the locus. The foot achieves its greatest height off the ground and goes in the same direction as the walker's body, throughout the return phase. Finally, at the lowest position, reduce its height until it touches the ground. While a wheel travels, each point on the circle has the same velocity, and when the wheelmoves, each point encounters some resistance, resulting in energy loss [5].

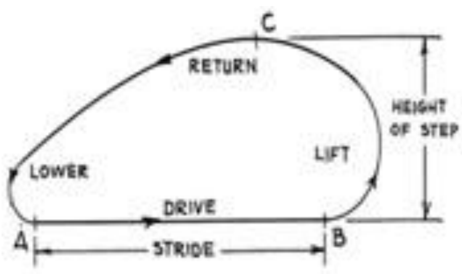

Figure 5. Graphical output of our leg mechanism [1].

But in case of theo jansen Local maxima and minima may be completely avoided by simply stepping over them. This results in less loss of energy during locomotion and allows the vehicle to maintain a constant velocity and height over variable surface. Figure 5 depicts the graphical output of leg mechanism, whereas Figure 6 depicts small prototype.

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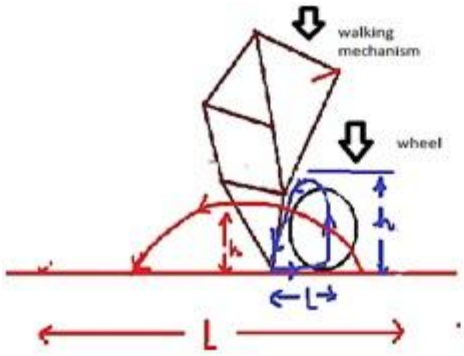

Figure 6. Small Prototype.

4.1. Figures and Photographs

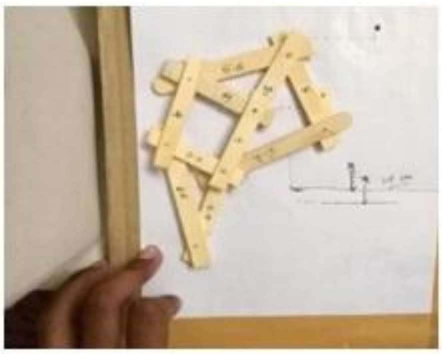

Figure 7. Theo Jansen curve during walking.

This is the prototype of a single leg of the robot in Solid works. There will be 7 more legs to be made forour project as shown in Figure 7.

We will then add two motors with this all legs and will add a controlling device such as microcontroller (i.e. Arduino or Raspberry pi) with wireless module to run. Figure 8 depicts solidworks drawing for a single leg. Figure 9.1 and 9.2 are representing the solid works assembly of the robot.

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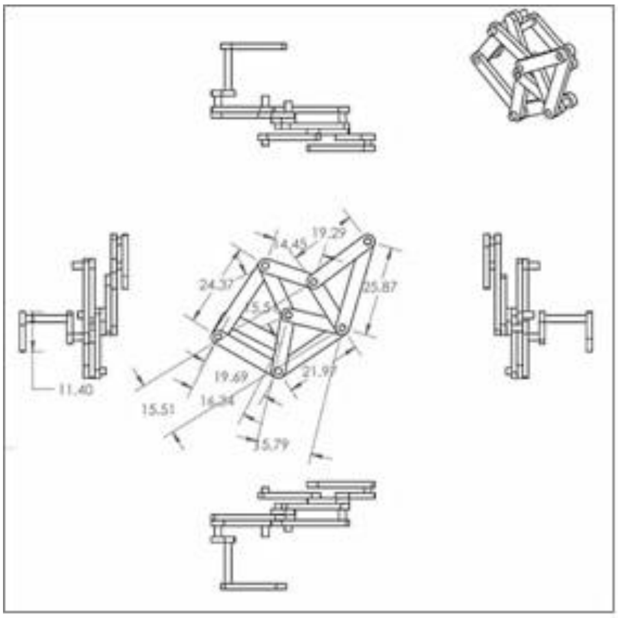
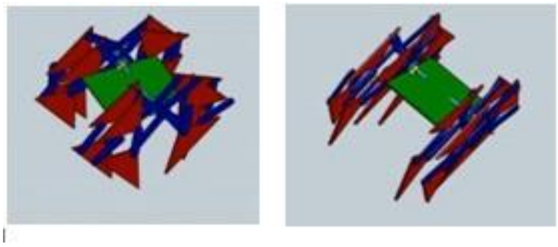


Figure 8. Solidworks Drawing for a single leg.



(1) (2)

Figure 9. The Solidworks assembly of the robot

5. Calculations and Equations

We are using two motors in both sides to control 4+4=8 legs. Each motor is operating 4 legs respectively.

5.1. Linear Torque and Power Calculation for Area of Segments

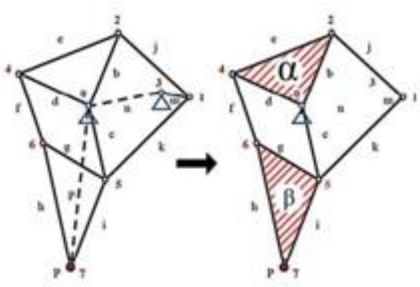


Figure 10. Theo Jansen single leg analysis [1].

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We can find from our solidworks design:

$$\alpha + \beta + j + k + f + c$$

$$= 0.1661 + 0.1831 + 0.06 + 0.072 + 0.0493 + 0.0394$$

$$= \mathbf{0.5699m^2}$$

We know that the density of our acrylic sheet is $= 1051.1\ kg/cm^3$

Mass of segments:

$$\left(4 \times 0.5699 \times \frac{5}{1000}\right) \times 1051.1 = \mathbf{11.98kg}$$

5.2. Mass of Cranks

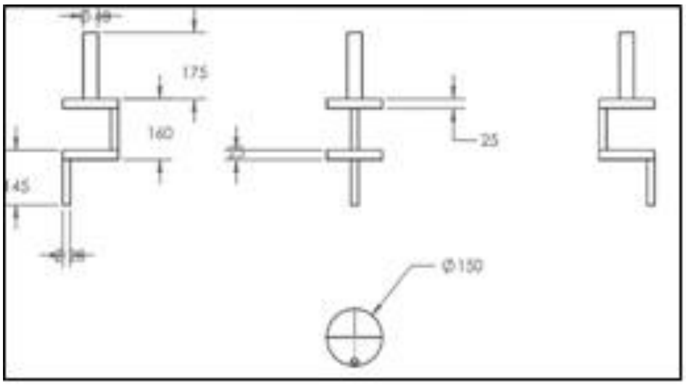

Figure 11. Theo Jansen rotating crank.

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Volume

$$\left[2 \times \left\{\pi \times \left(\frac{150}{1000}\right)^2 \times \frac{5}{1000} \times\right\} + \left\{\pi \times \left(\frac{20}{1000}\right)^2 \times \frac{140}{1000}\right\} + \left\{\pi \times \left(\frac{10}{1000}\right) \times \left(\frac{150+140}{1000}\right)\right\}\right]$$

$$= 9.73 \times 10^{-4}$$

$\text{Mass} = 9.73 \times 10^{-4} \times 1051.1 = 1.02kg$

$\text{Total Mass (m)} = 11.98 + 1.02 = 13kg$ (for 4 legs in one side)

Force calculation

$$F = ma$$
$$or, F = 13 \times 0.\frac{1m}{s^2}$$
$$or, F = 1.3N$$

The value of **acceleration and the angle** is taken from ""KINEMATIC ANALYSIS AND SIMULATION OF THEO JANSEN MECHANISM by Mehrdad Mohsenizadeh, Jenny Zhou Department of Mechanical Engineering Lamar University Beaumont, Texas, USA"

Torque

$$\tau = F \times r \times cos\theta$$
$$= 1.3 \times \frac{150}{1000} \times cos180°$$

$= 0.116\ N - m$ [As we are just taking the magnitude of this value, not the directional value]

Power

Assuming the rpm of the motor, N = 50

$$P = \frac{2\pi N\tau}{60}$$
$$= \frac{2\pi \times 50 \times 0.116}{60}$$
$$= 0.60773kw$$
$$or, 607.71\ watt$$

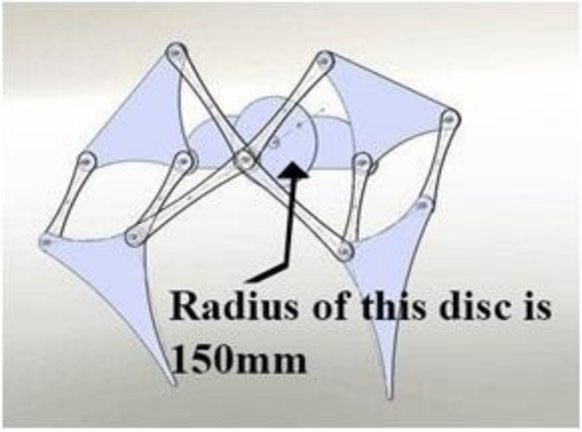

Figure 12. Theo Jansen rotating disc diameter.

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Total mass (M) = 13kg

Mass of the Disc:

Volume $= \pi \times 0.150^2 \times 2.5 \times 10^{-3}$
$= 0.1767 \times 10^{-3}\ m$
Mass $= 1051.1 \times 0.1767 \times 10^{-3} = 0.1857$

Total mass of one side $= 2 \times 0.1857 = 0.3715\ kg$

Moment of inertia

$$I = \frac{1}{2} m r^2\ [where\ r = 0.075m]$$
$$= \frac{1}{2} \times (13 + 0.3715) \times 0.150^2$$
$$= 0.1504 \text{ kg-m}^2$$

We know that Angular Torque

$$\tau = I\alpha$$

Now, $\alpha = \frac{\omega}{t}$

$$= \frac{\pi N}{t \times 30} = \frac{\pi \times 50}{3.15 \text{x} 30} = 1.6622$$

The value of "t" is taken from "KINEMATIC ANALYSIS AND SIMULATION OF THEO JANSEN MECHANISM by Mehrdad Mohsenizadeh, Jenny Zhou Department of Mechanical Engineering Lamar University Beaumont, Texas, USA"

Angular torque

$$\tau = 0.1504 \times 1.6622 = 0.2499\ N - m$$

Power required by the motor

$$P = \frac{2\pi N \tau}{60}$$
$$= \frac{2\pi \times 50 \times 0.2499}{60}$$
$$= 1.309\ kw$$

or, 1309 ***watt***

6. Conclusion

Scientist Theo Jansen made this mechanism as an Engineering art piece and we are converting this art piece into real world working robot. This mechanism has a lot of applications such as it can run over any obstacles smoothly (i.e. sand or rocky surfaces)

The major things which we can archive:

- We can carry heavy weights very easily [8].
- Overcome the limitations of wheels.
- Climbing stairs for various rescue missions.
- Military uses.
- Adding Advance robotics and IOT andmany more…

The minor things which we can archive:

- Developing our project can lead to open a new field of Mechatronics R&D and applications.
- By adding advance technologies like Machine Learning (M.L.) and Artificial Intelligence (A.I.) these robots can handle complex tasks very quickly and these robots can analyze and find the most optimum solution of any chaotic scenario. Etc.

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This mechanism has a lot of applications in the field and by further developing this mechanism we can archive more opportunities and innovativeness in the Engineering world.

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