ME431-Kinematic Synthesis

Design of One Degree of Freedom Bug Micro Robot

ULAS SUREYYA
BINGOL

2033165

1. INTRODUCTION

In this project my main was to build a robot that walks similar to bugs like robots proposed in the paper that have been studied[1]. This project was helpful in the terms of both understanding some concepts in legged robots and how kinematic synthesis can be helpful in these type of studies. In this project only the bug walking robot was investigated, a similar robot was designed with a different perspective. During my research since kinematic design is an iterative process, I have built some algorithms to explore the coupler curves of 4 bar mechanisms.Dyad equation is used to formulate the problem in a mathematical manner and design made for 3 points on a specified curve which will be discussed in further sections.

2. Design Approach

The bug robot proposed in paper[1] was built in a different way than my design. There were 3 legs on side similar to my design however, only the middle leg was tracing a closed surface and other 2 legs were oscillating about a fixed point. What does that bring is that, there exist leg scuffing at more points and times in the walking gait where the robot only is supported by 2 legs(1 on each side), which could cause unstability. In order to have a more stable walking cycle, I have designed the robot to have 3 point contact(for flat surface) with the ground at all times. Also to not to have opposing forces to the motion, legs that are at swinging should not collide with the ground during swing.To have this kind of motion , coupler link of a four bar mechanism is used.

But in order to design a walking mechanism one has to define how walking should be. I have aimed to have a leg which traces a curve as shown in figure 1.

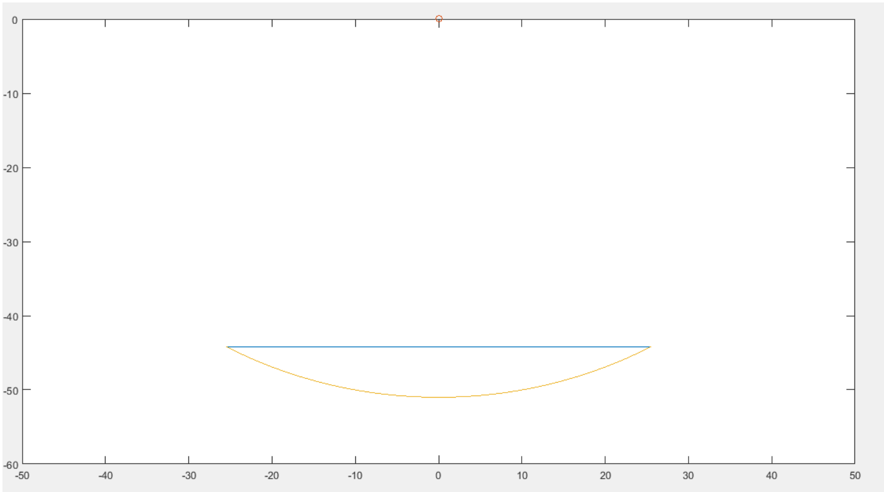


Figure 1-Leg Curve

Red part of the curve is the area where there is ground contact ,and at the straight blue part leg there is no ground contact.Red part of the curve represent 60 degrees swing of a 50 mm link centered at x=0 where a red circle exists. Blue part of the curve is a straight line connecting the start and end positions of moving gait. In my design I wanted to have a straight line retraction of the leg in order to not to work against gravity since coupler curve will be the heaviest. Swing of the leg is chosen arbitrarily, however this phenomenon can be further studied in detail.

3. Mathematical Formulation and Design Constraints

It was very unlikely to find a mechanism that exactly traces the curve however, pretty accurate results can be found with a good formulation, relaxed constraints and good computational power.Dyad formulation for 3 positions are given as:

$$W*\left(e^{i\beta_j}-1\right)+Z*\left(e^{i\alpha_j}-1\right)=\delta_j$$

I wanted to explore if I was able to find a satisfactory result by dyad formulation for 3 positions, and these 3 positions were chosen on red part of the curve since it is more critical. I have chosen 3 positions in order to have a more free parameters and have some space to further introduce constraints to the design. What could have been done that , this curve can be also done with 4 positions, 5 positions and more. Also not only the red part but also the points on the blue part could be chosen to design the mechanism which all of these possibilities are noted and are going to be considered in future.

In 3 position design, 3 positions are chosen I have made my algorithm to choose 3 points randomly on the curve, also in 3 position design rotations of the both crank and follower links are necessary to solve the dyad formulation since I have no specific constraint on those values, I have formulated such that angles are chosen randomly and they are in an increasing manner such that:

$$0<\beta_2<\beta_3<2*\pi$$

Also rotation of the coupler was not a direct constraint in my design, however It should not swing too much to have complicated curves so I have constrained α_j values to be between 0-180 degrees.Still they are chosen randomly since amount is not directly a constraint.

For these generated values, W and Z values are found for both links a2 and a4.Then this generated mechanism is passed through some constraints which are:

- Fixed pivots has to be on the robot (Y values has to be greater than 0 and not too far in x direction)
- Link lengths has to be in reasonable values.
- Input crank has to be fully rotatable, which corresponds to mechanism being double crank or crank-rocker type.
- Mechanism being physical(Solution exists at all points)

Branching problem is handled with plotting with plotting both coupler curves at branches for each mechanism and manually checking if the mechanism passes through 3 design points.

Also one should note that, there is no optimization is done to fit the mechanism curves exactly to the desired curve but rather best curve is chosen manually from a database of mechanism.But this type of coupler curve fitting optimization will be studied in future.

4. Results

From the database of more than generated 500 mechanisms, a mechanism, mechanism 58 came to be a satisfactory approximation to desired curve.

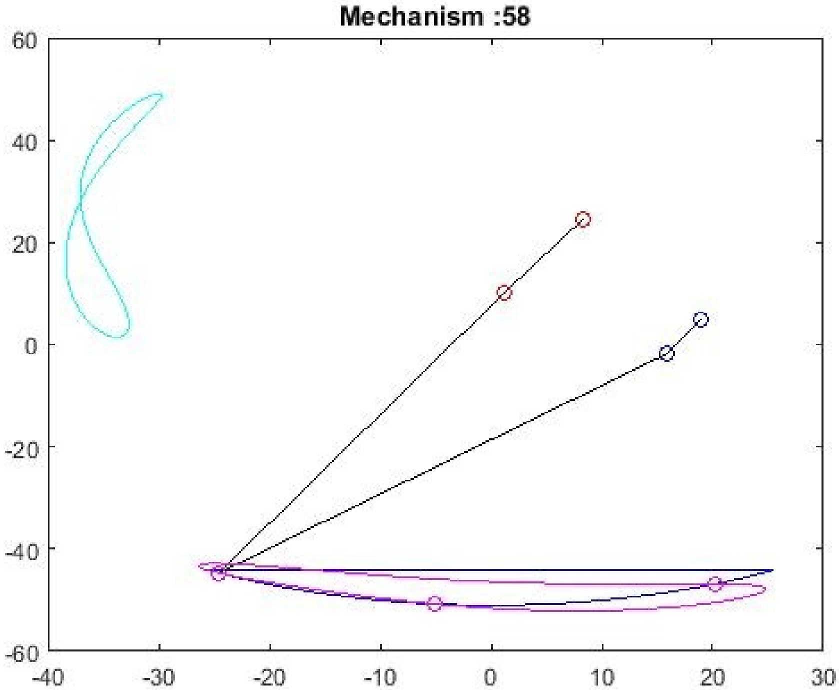


Figure 2-Designed Mechanism and its coupler curve(MAGENTA)

In my algorithm I have drawn coupler curves of both configurations of the mechanism one is Cyan other is magenta, blue curve is desired curve. Blue circles are on the fixed and moving joints of link a2, top blue circle is A0 point. Red circles are on the fixed and moving joints of link a4, top red circle is B0 point. Long lengths are Z links from dyad formulation.

As it can be seen from figure 2 fixed pivots are on the the robot, y values of fixed pivot positions is positive.And the designed curve are not contacting to the ground during swing phase.

With the parameters of this mechanism design is will be done on solidworks.

Parameters:

A0=19.0281+4.89i mm (Position of A0) B0=8.3574+24.6380i mm (Position of B0)

A2=7.3145 mm a3=18.9032 mm a4=16.2290 mm

Gama=274.5941 degrees ➔ Angle of Za measured from a3 link in Cw direction

Za=59.032 mm ➔ Za vector attached to a3 which is the leg in the mechanism.

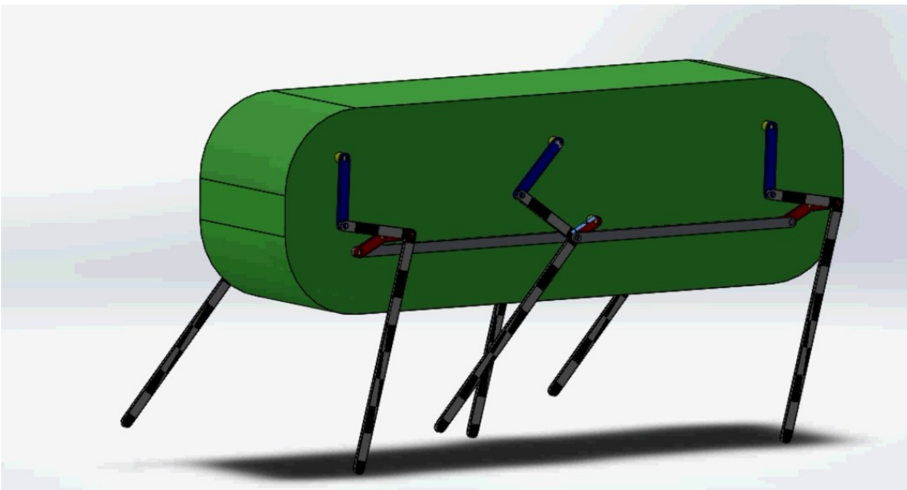
5.Check and Solid Model

Then with these values 2D model of one leg is drawn on Solidworks so that the generated mechanism can be checked. **Animation video is supplied with this report, its name is mechanism 58.** Also in order to coordinate the legs , I have made an approach to use same mechanism but induce a phase difference such that, when 1 leg leaves the ground other one collides at that instant. Then I have connect parallelogram linkage to make them rotate in the same amount but with a phase difference. With this approach, only 1 crank is enough to rotate all the robot. **Animation video is given in the name of mechanism58_2legsCoordination.**Also after this step other leg is also drawn and **another animation video is made in the name of Robot1side.**

Finally after seeing that this mechanism is satisfactory to perform the desired operation, a 3D model representation of a Micro Bug Robot is drawn. 2 sides of the robot are connected in a way such that 3 legs always forms are triangle and move the same. This can be better understood with the **Cad File Assembly** and **video called Assemblyvid**.

All assembly files of each stage of my design also supplied with this report, also mechanisms similar that are proposed in the paper that including bug, crab and spider mechanisms are also supplied.

It should be noted that, I had connected parallelogram linkage in an incorrect manner(it crashes to other mechanisms) however I have drawn them in that way to make main mechanism more visible. Correct way to connect those linkages is to connect on outer side of main



mechanism.

Figure 3-Isometric View of the Robot

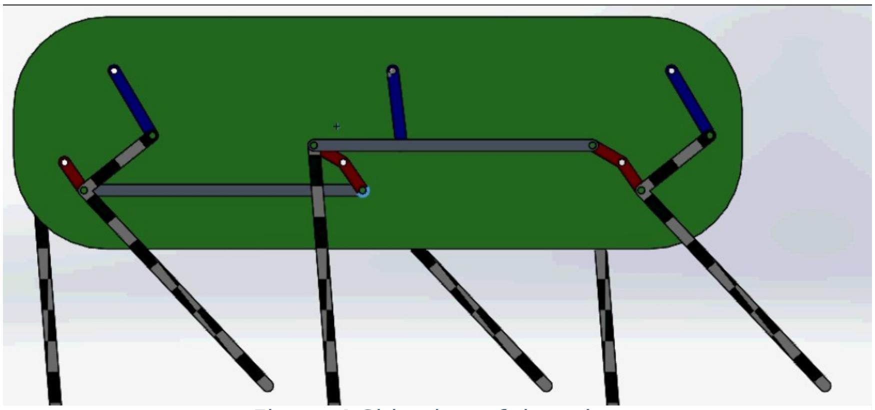


Figure 4-Side view of the robot

6.Conclusion

This project was very helpful in the terms of both understanding how mechanisms can be designed for a specific cause and some practical knowledge like the way to connect 2 same mechanisms with a phase angle but having same rotation. I have faced a good challenge in coding, since the problem was quite different from the problems that we have faced for 3 position dyad equation. I have noticed how the angle of link a1 should be taken in to considerations and how angles in world coordinates have to be transformed to relative angles measured from link a1 to solve the mechanism and have the coupler curve. It was a educating experience I can say since we are not facing that many angle conversions and definitions, I have experienced how important the definition of paramaters can affect the solution of a problem. I had to draw the same mechanism over and over again to check my notation if it is correct both as an idea and in the algorithm.

Algorithm is supplied with the project files, it is called **couplerpointwithcurvesfullrandom** which is a matlab script, but uses subfunctions which checks type of the mechanism and its existence , performs position analysis etc. I would be happy if you run my algorithm once and see the mechanisms being generated, I quite enjoyed watching it happen. Since the algorithm has randomness in it, there could be fascinating curves.

Finally, I want to thank my dear instructors Dr.Ergin Tönük and Prof. Eres Söylemez for their care and their support during the semester.

7.References

[1] Comanescu, A., Dugaesescu, I., & Comanescu, D. (2015). Some Structural and Kinematic Characteristics of Micro Walking Robots.*Mechanisms and Machine Science Microactuators and Micromechanisms,*73-86. doi:10.1007/978-3-319-15862-4_7