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Design of a New Type of Eight-bar Walking Mechanism based on Regeneration Kinematic Chain Method and Artas SAM

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Abstract: Legged walking robot can adapt to the change of environment more effectively and provide better mobility on irregular terrain, so it has gradually attracted researchers' attention. When designing the size of leg mechanism, computer aided design provides some advantages for designers to realize competitive products with less error in a short time. The purpose of this article is to use regeneration kinematic chain method to design a new type of eight-bar Walking Mechanism to study the possibility of using this new type of organization construction of walking robot, it also illustrates the advantages of using the SAM software to assist in size synthesis, get the approximate motion curve and the result confirmed that the mechanism type had the ability to walk .

Keywords: regenerated kinematic chain; walking mechanism; eight-bar mechanism; mechanism innovative design; Artas Sam

I. INTRODUCTION

With the change of natural environment, animals and plants in nature have formed their unique physiological structure, movement mode and survival ability in the long process of evolution. Nature always chooses legs as the best mode of motion because of the excellent performance of walking and climbing on uneven terrain and sloping surfaces, so we tried to design the walking mechanism using linkages to imitate nature. Over the past few decades, there has been great interest in this area of research, and many prototypes have been successfully built in university laboratories or in companies [1]。Among the features is Theo Jansen mechanism which can walk smoothly [2]and Klann mechanism similar to crab walking [3]。Since Theo Jansen mechanism was proposed, a large number of scholars have studied this mechanism. Kazuma Komoda et al. [4] changed the leg's trajectory by lifting the center of the connecting linkage, increasing the climbing height of the leg by about 10 times. Shunsuke Nansai et al. [5] combined with software such as ProE and SAM, analyzed the forward kinematics of Theo Jansen mechanism by vector loop method and simple geometry method. In order to optimize Theo Jansen mechanism, Daniel et al. [6] conducted a preliminary dynamic analysis using the superposition method. However, this work is incomplete without a detailed equivalent Lagrange equation. Nansai et al. [7] used the projection method proposed by Blajer to analyze the dynamics of Theo Jansen mechanism, and obtained the binding force and equivalent Lagrange equations of motion. Then, the numerical simulation was carried out by using MaTX, and the study was carried out in combination with the dynamic analysis. The above studies are all based on the existing mechanism for research and improvement, so that it can achieve the expected trajectory, but the linkage itself has limitations. If you just change the size, you can only find a better solution in itself.

The core of pedestrian mechanism design lies in its innovative design. The regenerated kinematic chain method is a common method in innovative design. The regenerated kinematic chain method provides us with more selectivity and provides comparison for future research. The working performance of the mechanism not only depends on the advantages and disadvantages of the mechanism scheme, but also depends on the size of the mechanism. SAM software can select the approximate range of motion of the connecting rod joint by dragging the length of the connecting rod or by using a rectangular box, and obtain a connecting rod size that is close to the expected trajectory through its optimization function. This provides great convenience for designers who do not know how to set the initial value of connecting rod size at the beginning of the design process, which also saves a lot of time for later optimization design.

This paper is divided into four parts: the first part is the introduction; the second part is the innovative design of the one-degree-of-freedom eight-link walking mechanism by using the regenerated kinematic chain method; the third part introduces SAM software and how to design the size of the leg mechanism; the last part is the conclusion.

II. EIGHT -BAR WALKING MECHANISM DESIGN

When designing a new institution, there are often many difficulties in conceiving an institution that meets the expected functional requirements. In the past, designing a good institution depended more on the designer's own conditions. Even if there are designs for new institutions, the number of ideas that can be conceived is extremely limited. However，the regenerative motion chain makes the process of mechanism innovation design have rules to follow.

A. Design Flow of Regenerative Motion Chain Method

Mechanism regenerated kinematic chain method is a creative design method based on the existing design to produce all possible topological structures of mechanical devices, which can invent and create new mechanisms. It is an innovative design method of mechanism by Yan Hongsen [8], which systematically summarizes the theoretical results of mechanism number synthesis and exemplifies, and can be used as a powerful tool for design engineers to generate new design concepts to meet new design requirements and limitations. The design flow of this method is shown in figure 1.

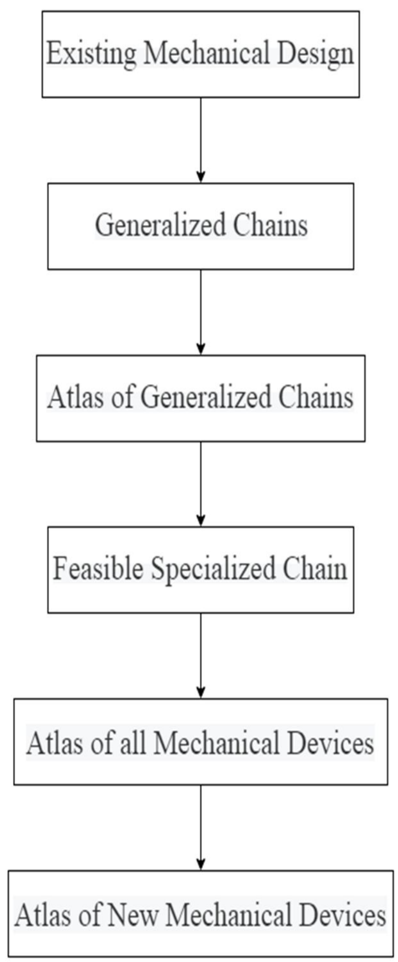


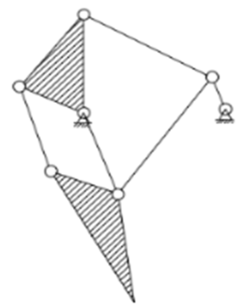
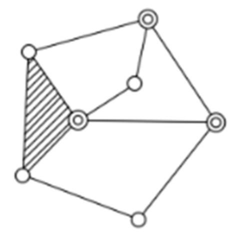
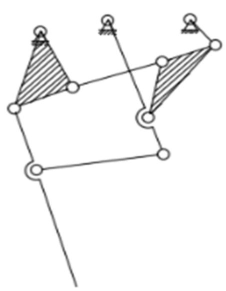
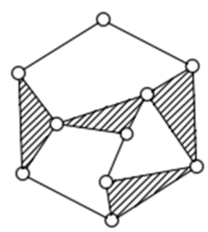
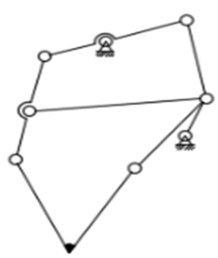
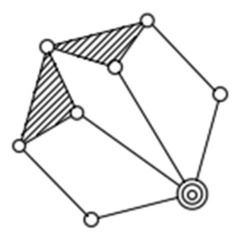
Fig.1 Flow chart of regenerative motion chain design method

B. Existing Eight-bar Walking Robots

Through the analysis of the existing mechanism, they are all eight-bar, ten-joint and one-degree-of-freedom walking mechanisms. The eight-bar walking mechanism is superior to the four-link and six-link, because the more links, the quadruped walking robot can better meet the required movement needs. Based on their motion characteristics, a new eight - link walking mechanism is designed. The table below summarizes the existing eight-link walking robots.

TABLE I

EXISTING EIGHT-BAR WALKING ROBOTS

Type	Schematic Diagram of Mechanism	Generalized Chain
Theo Jansen mchanism		
Muniu Liuma mechanism		
Trot Bot mechanism		

C. Design Requirements and Design Constraints

According to the existing pedestrian design, design requirements and constraints are summarized as follows:

1) Choose a symmetrical chain, not a chain containing four-joint links;
2) The fixed frame is used as the fuselage, and all the linkages are connected by rotating joints;
3) There must be a fixed link as a frame;
4) There must be a crank;
5) Link 1 is the frame, link 2 is the crank, the frame is connected with the crank.
6) Link 1 is a three-joint link, and Link 2 is a two-joint link;
7) The thigh link 6 is a three-joint link, which is not connected to crank 2 but can be connected to fixed frame 1;
8) The crus link 8 is a two-joint link, which is connected to thigh link 6, not to fixed frame 1 and crank 2.

D. Link Assortments

Before determining the atlas of generalized chains, two problems should be solved, that is, to determine the maximum number of motion pairs attached to the joint rod $m_{\max}$ and the number of i-joint link N_{Li}. For the generalized chain, $N_L = 8$, $N_J = 10$, According to the equation $2N_L - 3 = 13$ and $N_L \le N_J \le 13$, $m_{\max}$ is:

$$m_{\max} = N_J - N_L + 2 = 4$$

It is known that there are at most four-joint links in the generalized chain.

Therefore, by solving the equations $N_{L2} + N_{L3} + N_{L4} = 8$ and $2N_{L2} + 3N_{L3} + 4N_{L4} = 20$, the scheme of link assortments in the following table II can be obtained.

Table. II. Link Assortment Scheme

Link Assortments Scheme	N_{L2}	N_{L3}	N_{L3}
一	4	4	0
二	5	2	1
三	6	0	2

If you specify the type of all links in the generalized chain and the movement of a member is constrained after specifying that the member is a fixed link, it becomes a motion chain. According link assortments in table II and eight-bar and ten-joint of 16 kinematic chain in figure 2 can be obtained.

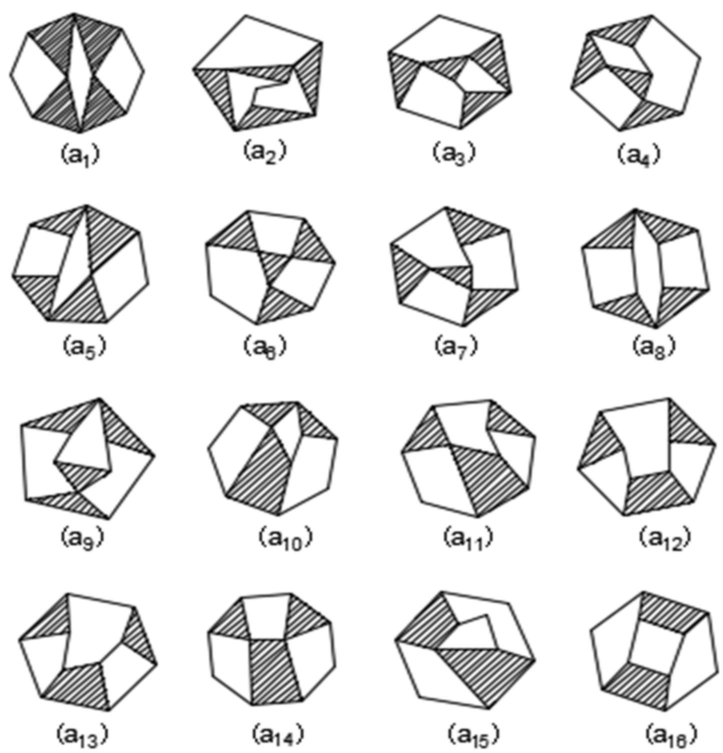


Fig.2 (8,10) Motion chain map

E. Concretization and Specialization

The design requirements are determined according to the topological structure characteristics of the existing design summarized. Therefore, a motion chain is selected from the kinematic chain in figure 2 as the basic design, and the kinematic chain (a_6) is the selected motion chain. According to the requirements and constraints of the design, it can be specialized and concretized into corresponding schematic diagram of the mechanism.

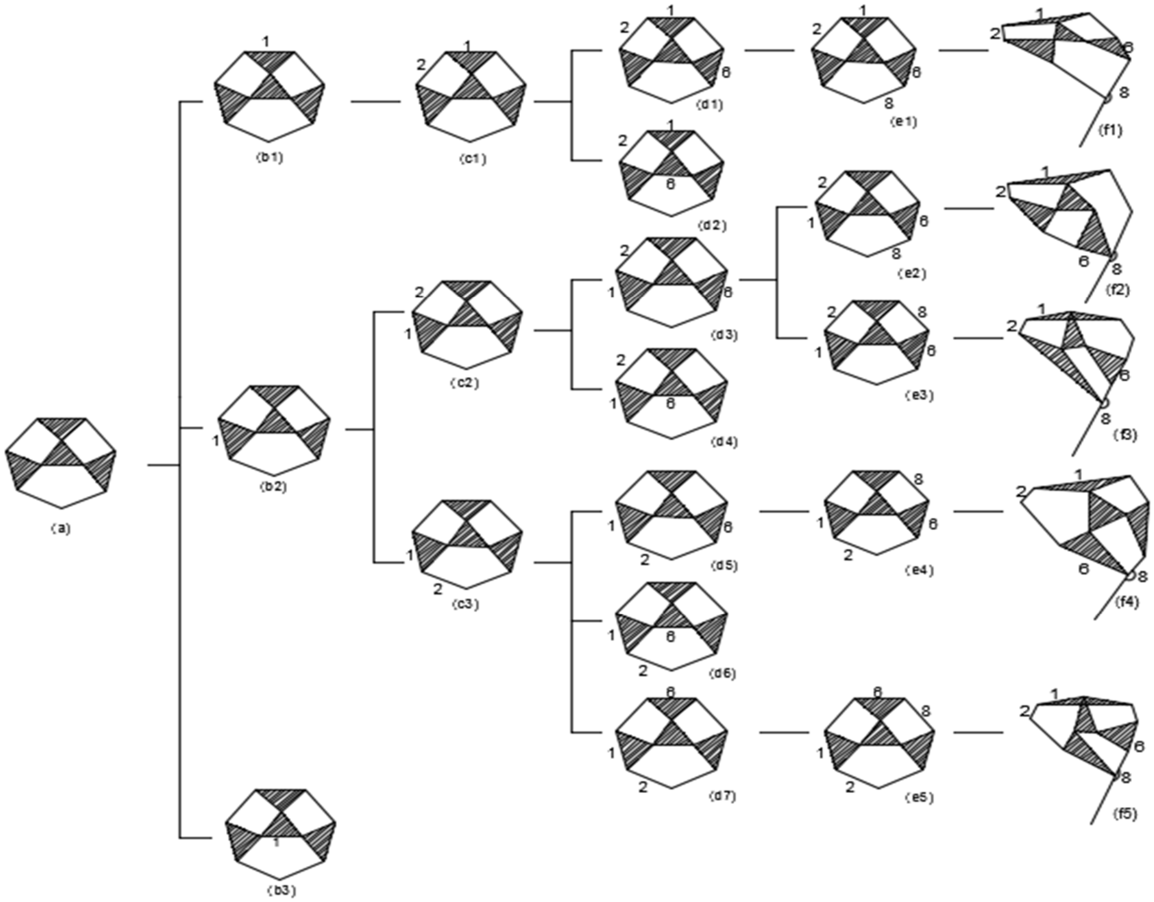


Fig.3 Eight-bar walking mechanism diagram

F. Determination of Feasible Solution

According to the analysis of figure 3, (f4) and (f5) are essentially the same mechanism, and the feasible mechanisms are (f1), (f2), (f3), (f4). In this paper, SAM software is used to synthesize the size of (f3) scheme.

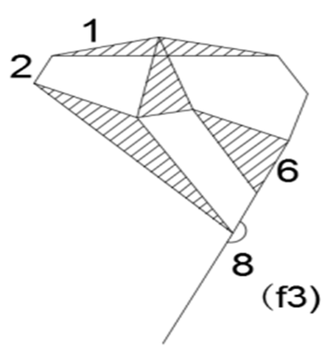


Fig.4 Selected program

III. SYNTHESIS OF DIMENSIONS

Dimensional synthesis has always been a hot topic for researchers, but for designers who have no experience in designing a new mechanism, they do not know how to give an initial value to make it in a reasonable range. In addition to the size of the eight-link parameters, the motion is complex, it is difficult to know which rod to change when there is no clear connection between the links, at this point, computer-aided design to help the designer to shorten the design time.

A. Introduction to SAM Software

SAM's optimization module provides constrained single-function multi-parameter optimization based on evolutionary algorithms and simplex. The trajectory of a given node matches as closely as possible the desired reference trajectory。It calculates the root mean square value of the difference between the actual path and the reference path as the mass number to judge the merits of the candidate scheme. Each node of the designed mechanism can be changed within specific limits.

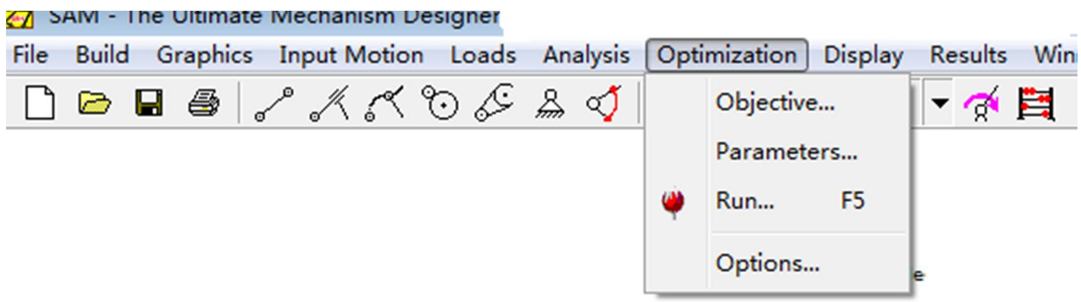


Fig.5 The optimization module of SAM

B. Introduction to SAM Software

1) *Draw Schematic Diagram of Mechanism and Define Optimization Objective:* The design of each part of the new walking mechanism designed in this paper is first drawn in SAM software in the form of 2d sketches, as shown in figure 6 below.

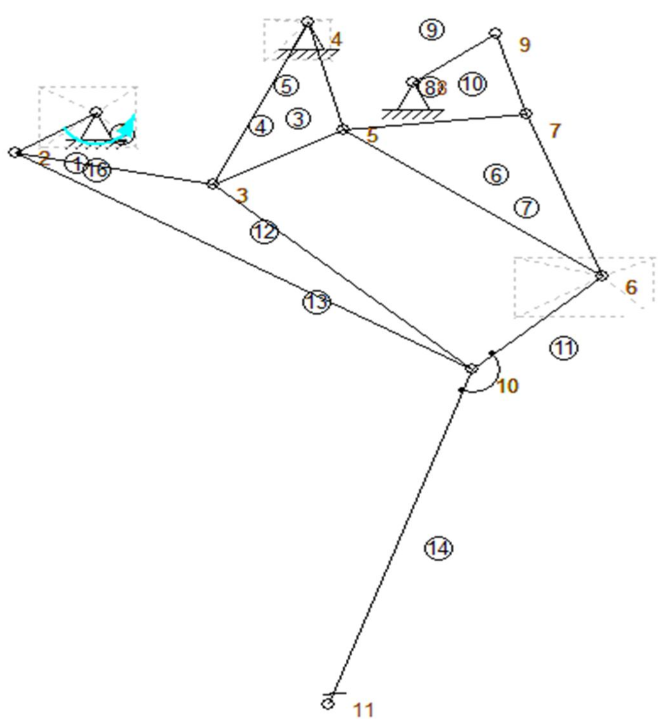


Fig.6 A schematic diagram of the mechanism drawn with Sam and the given trajectory

We defined element 11 in contact with the ground of the crus link ⑭ in the figure 7 above as the objective of optimization.

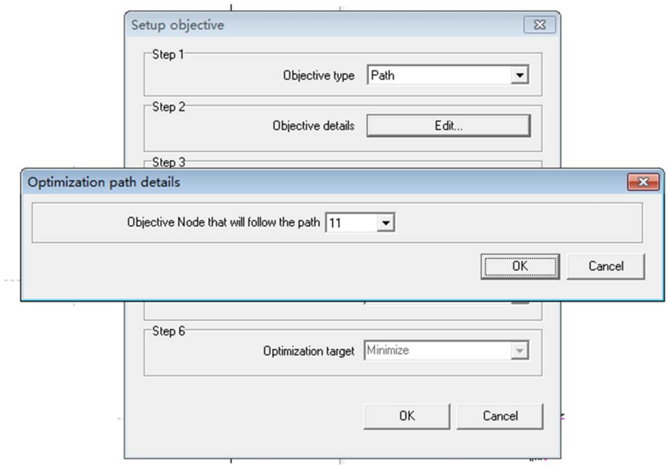


Fig.7 Define element 11 as the optimization target

The reference file for the target trajectory is a simple ANSI text file whose x and y coordinates are in units of m, and the first and last coordinates should be the same in order to generate the closed reference trajectory. The reference data used in this article is shown in figure 8.

文件(F) 编辑(E) 格式(O)

0.29200	0.13161
0.31060	0.18460
0.37983	0.21420
0.46167	0.22710
0.55104	0.23463
0.63826	0.23678
0.73841	0.23356
0.85040	0.22280
0.93439	0.19806
0.90101	0.16472
0.84501	0.13353
0.75241	0.09159
0.66303	0.08299
0.52951	0.08729
0.42865	0.09599
0.33896	0.10363
0.29200	0.13161

Fig.8 Given the coordinates of the target trajectory

2) *Define the Optimization Parameter Range:* Each node of the mechanism can be changed within a specified boundary, or it can be changed without specifying all nodes, only by defining a few nodes that have a greater impact on the trajectory. The range of parameters can be defined in a rectangular box or given a specific range of parameters.

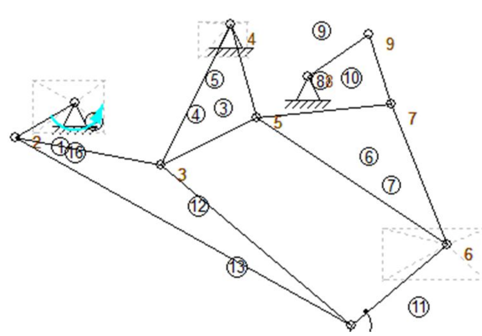


Fig.9 The dotted rectangle is the custom parameter range of the point

3) *Set Optimization Options and Run:* In this paper, the optimization of the mechanism is only to find the initial value of the size of the mechanism faster and save more time for future fine optimization, so the automatic method is chosen.

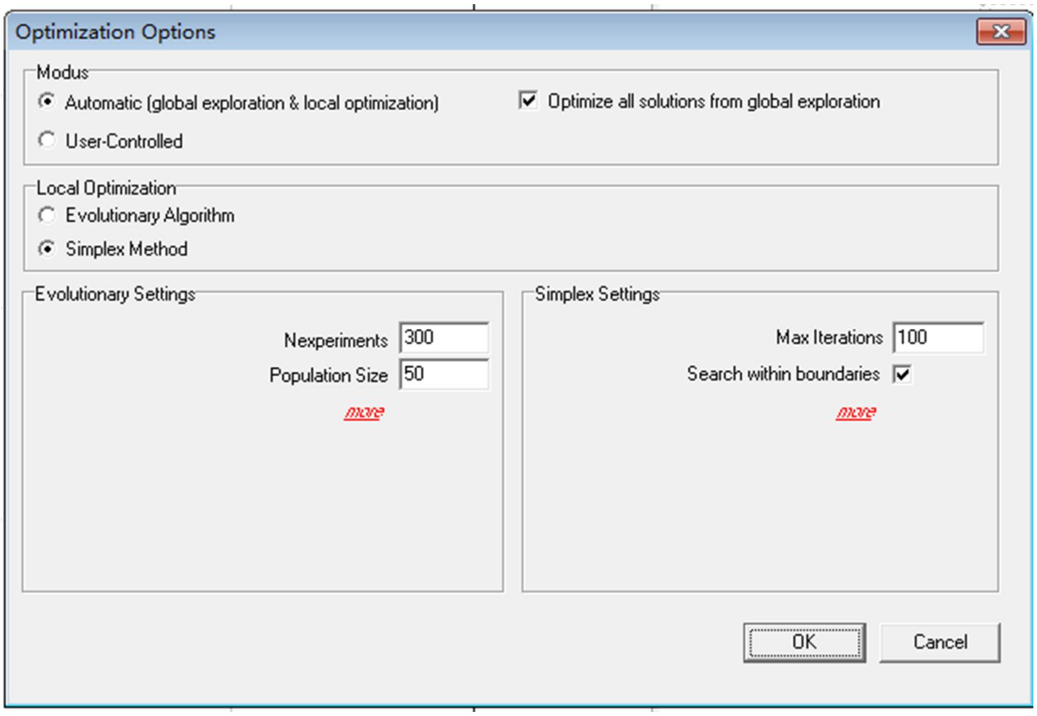


Fig.10 Sam simplex method is used in this paper

The optimized results are shown in figure 11 below.

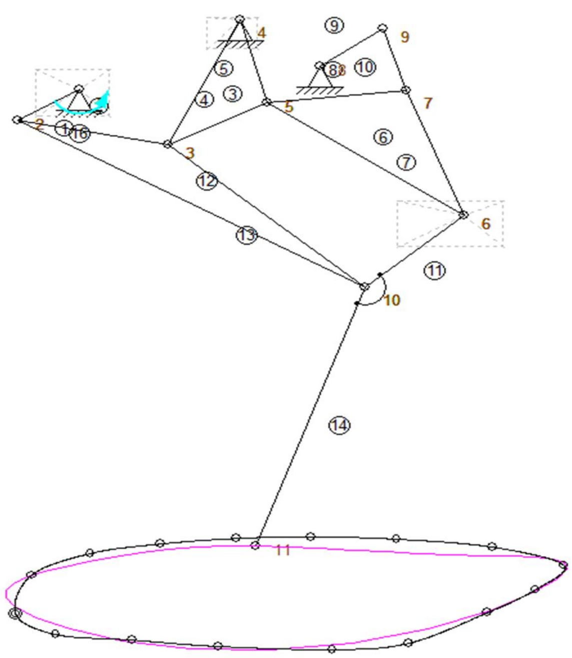
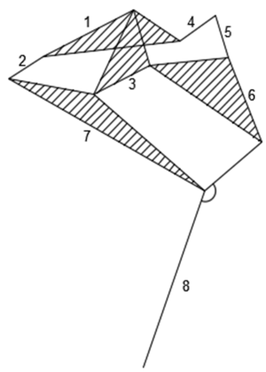


Fig.11 The optimized motion trajectory and target trajectory diagram

Export the graph to AutoCAD and measure its dimensions as shown in the table III below.

TABLE III
THE SIZE OF LINKAGES



Linkage	Link1	Link 2	Link 3	Link 4
Length(mm)	211.25 284.65 113.60	83.44	189.10 128.85 116.86	90.10
Linkage	Link 5	Link 6	Link 7	Link 8
Length(mm)	88.12	163.21 277.41 183.36	465.60 300.93 179.97	152.00 375.66

IV. CONCLUSION

The regenerated kinematic chain method is a set of systematic, efficient and stylized design methods with theoretical support, which will neither omit the scheme due to the multi-solution of the design, nor repeat the scheme due to the multi-solution, which can effectively improve the efficiency of innovative design and reduce the blindness of innovative design. The regenerated kinematic chain method solves the problem of the creative design of eight-link walking mechanism, and obtains all feasible motion chains of eight-link walking mechanism and their corresponding schematic diagram.

After a new mechanism is designed by the method of regenerated kinematic chain, it is a difficult problem for designers to synthesize the dimensions of a new mechanism if the trajectory of the mechanism is similar to the expected trajectory. No matter what optimization method is used to synthesize dimensions, it is necessary to build on a given range of initial values and variables. Due to the large size parameters of eight-bar mechanism, the motion requirements are complex and the design is difficult. However, the aided design of SAM software can determine the initial value and variable range close to the trajectory for the designer in a short time. This software is by dragging connecting rod to change its length in order to change the course of walking mechanism of walking, the designer can clearly see which roots in the process of the connecting rod size changes on the trajectory is larger, the influence of the actual output trajectory is close to the target trajectory, and then with rectangular box according to need to optimize the parameters of the selected node range, thus set a connecting link size and the size is as the optimization of after a reasonable initial value, saved the researchers time and improve the optimization effect of institutions.

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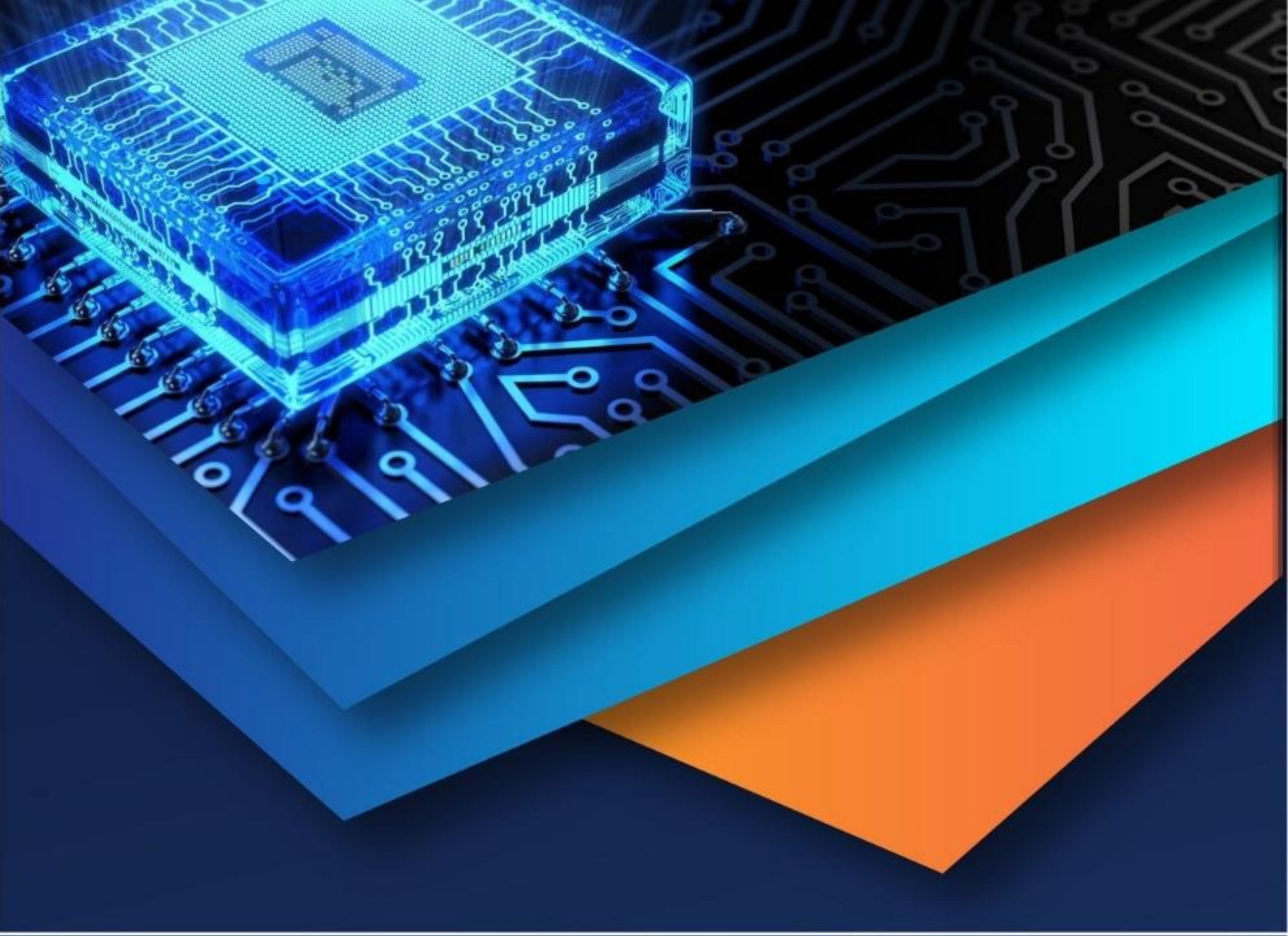

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