Five Link Mechanism as a part of a Robot.

1. Introduction

We propose very interesting and simple tool to obtain two – dimensional movement using two rotary drives and five-link mechanism (FLM). We made some math model, calculate the relations between angles and the target point coordinates. Rotary drives are servos, dc, brushless or any other motors. We can use the FLM as actuators, levers, plotter arms, pusher and feets in robots and other micromechanics.

2. Mathematical Model and Calculation

Five Link Mechanisms are well known in mechanical engineering, and the calculation in common is very difficult. We introduce simple trigonometric way, without generalized coordinates and matrices. Let us calculate the angles ϕ and ψ, using the Hx and Hy coordinates of an target point as arguments. Let us see the Figure1.2. Two rotary drives (situated in O_1 and O_2 points) rotate the lower levers L1. Two upper levers L2 are connected with flat joints with lower L1 levers, and is connected at a point F. One of lever is longer and it takes L2+Q total length. Let us see leftn elements of a mechanism – O1 joint with the lever L1 at the ϕ angle to the 0X axe. The distance between O1 and the target point H is, using the Pythagoras' theorem

$$L^2 = (Hx-d)^2+Hy^2 \qquad (1)$$

$$\alpha = \mathrm{arctg}\,((Hx+d)/Hy) \qquad (2)$$

or we can use usual for programmer ATAN2(a,b) operator:

$$\alpha = \mathrm{ATAN2}\,(Hx+d,Hy) \qquad (3)$$

We can use the cosine rule

$$(L2+Q)^2 = L^2+L1^2- 2L1L\cos\beta \qquad (4)$$

$$\cos\beta = (L^2+ L1^2- (L2+Q)^2)/2LL1 \qquad (5)$$

$$\beta = \mathrm{arc\,cos}\,((L^2+ L1^2- (L2+Q)^2)/2LL1) \qquad (6)$$

$$\phi = \pi/2- \alpha - \beta \qquad (7)$$

For the right elements of FLM, using proportions

$$Fx = -d-L1\cos\phi + (Hx+d+L1\cos\phi)L2/(L2+Q) \qquad (8)$$

$$Fy = L1*\sin\phi + (Hy-L1\sin\phi)L2/(L2+Q) \qquad (9)$$

Here we use Fx and Fy coordinates to calculate the ψ angle, as in (1) – (7) steps:

$L'^2 = Fy^2 + (d-Fx)^2$ (10)

δ = arctg(((Fy, d- Fx) (11)

δ = ATAN2(Fy, d-Fx) (11)

using the cosine rule

$L2^2 = L'^2 + L1^2 - 2L1L'\cos\gamma$ (12)

$2LL'\cos\gamma = L12 + L'2 - L22$ (13)

$\cos\gamma = (L12 + L'2 - L22)/\ 2L1L'$ (14)

$\gamma = \arccos((L12 + L'2 - L22)/2LL')$ (15)

$\psi = \pi/2 + \gamma - \delta$ (16)

So we can use the values of ϕ and ψ to control the mechanism.

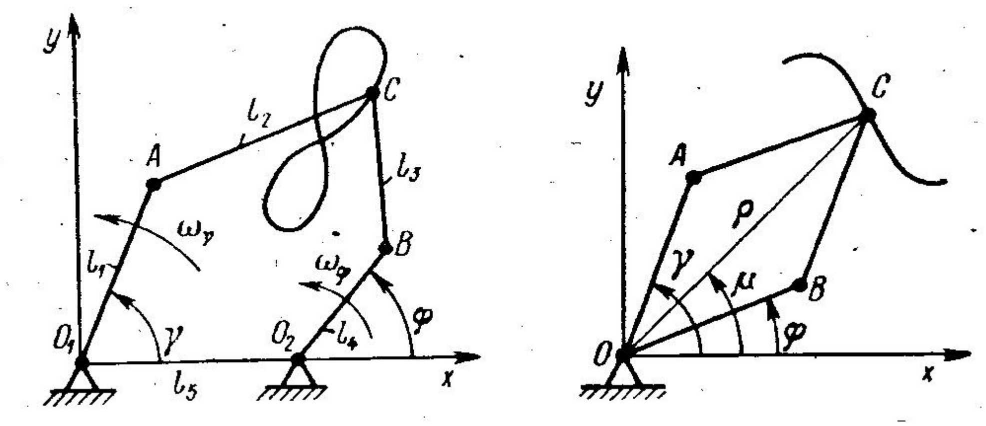


Fig. 01. Five Links Mechanism from old-school college textbook on mechanical engineering.

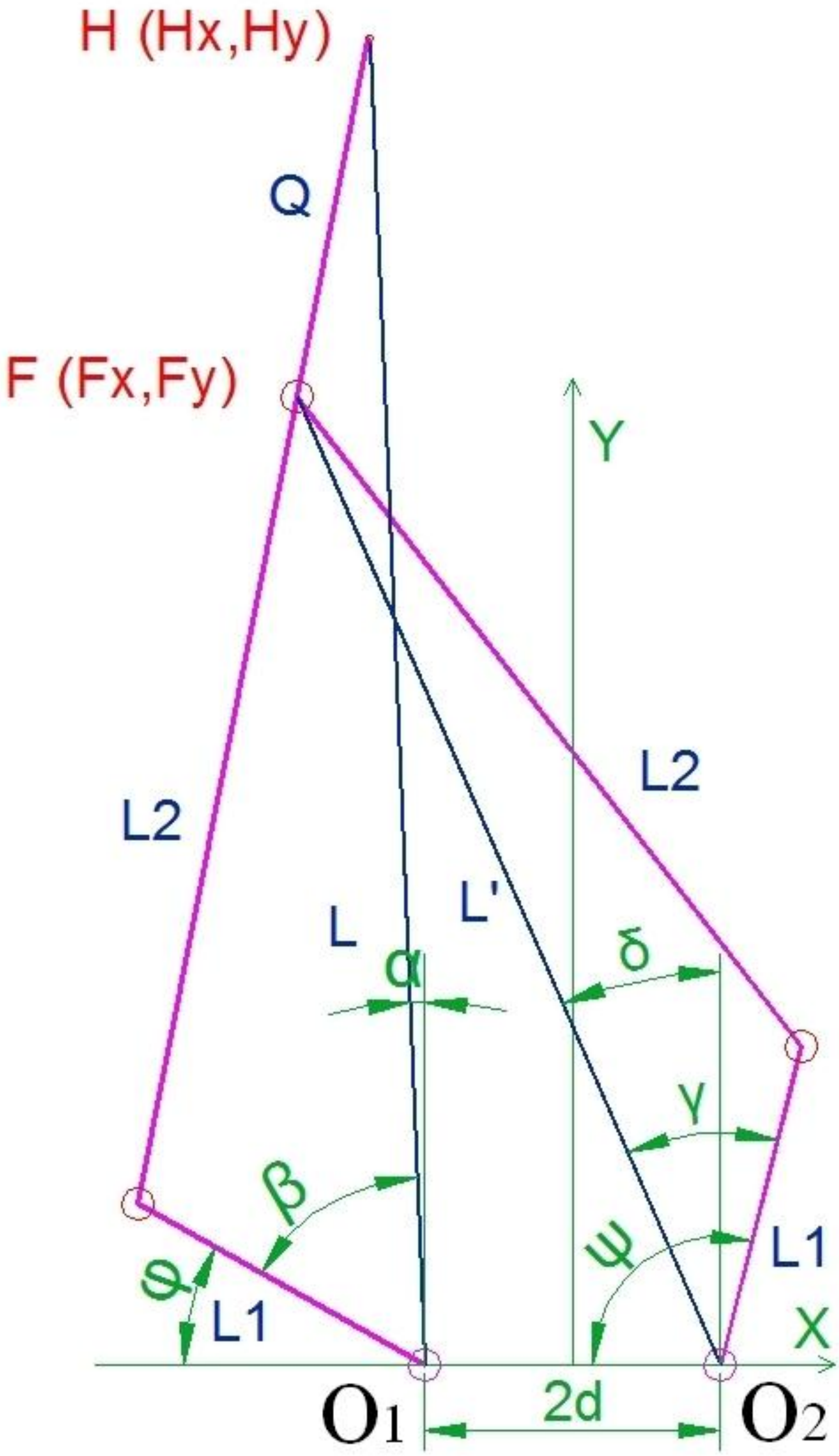
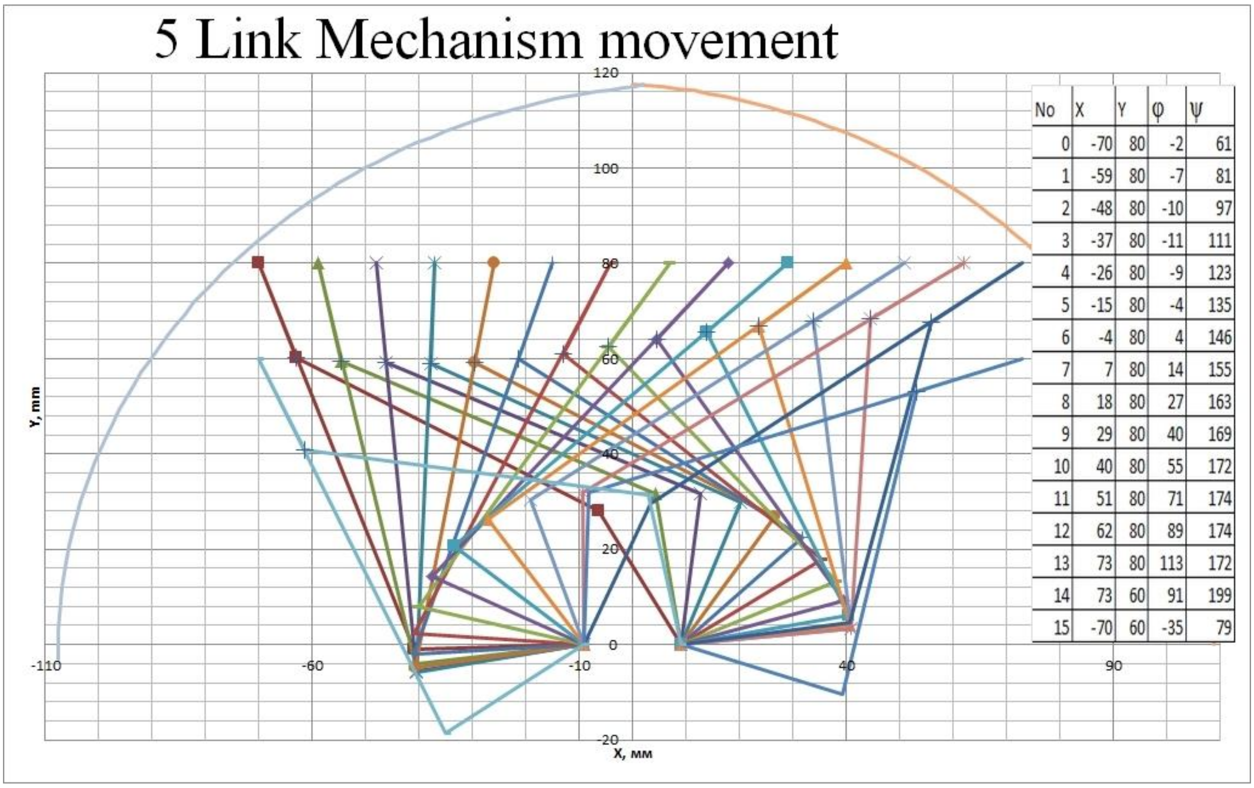


Fig1.2. Sketch of 5-link mechanism.

3. Application of calculations

Let us see some simple example with some sizes of levers.



No	X	Y	φ	ψ
0	-70	80	-2	61
1	-59	80	-7	81
2	-48	80	-10	97
3	-37	80	-11	111
4	-26	80	-9	123
5	-15	80	-4	135
6	-4	80	4	146
7	7	80	14	155
8	18	80	27	163
9	29	80	40	169
10	40	80	55	172
11	51	80	71	174
12	62	80	89	174
13	73	80	113	172
14	73	60	91	199
15	-70	60	-35	79

Fig.1.3. Example of 5-link mechanism path calculation. 16 points of path, angles and arguments of servo() functions are in the table.

Fig.1.3 shows the paths of the FLM with L1 = 32 mm, L2 = 45 mm, d = 9 mm and Q = 20 mm. The table shows the X and Y coordinates of the target points and angles of two servos. The path is some kind of a step with rectangular type. Two quarter of a circle are the range of possible target points, the radius is approximately L1+L2+Q-d. The ranges of the angles ϕ and ψ are drive limited – the ranges are approximately 180° when the simple servos are used, and can be up to 360° when we use brushless of DC motor with encoder.

4. Physical model of FLM.

Some times ago we used FLM with Q=0. The example of the FLM is shown on the Fig. 4.1. Here are:

1, 2 – Servo S9G

3,4 – Servo brackets

5,6 – Low levers of FLM

7,8 – Upper levers of FLM

9 - Central hinge with pusher.

10,11 – Servo brackets holders

And the example of upper lever with Q=20, number 7 right up.