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 a target point as arguments. Let us see the Figure1.2. Two rotary drives (situated in O₁ and O₂ 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 OX axe. The distance between O1 and the target point H is, using the Pythagoras' theorem

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

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

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

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

We can use the cosine rule

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

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

$$\beta = \arccos \left((L^{2}+L1^{2}-(L2+Q)^{2})/2LL1\right) \qquad (6)$$

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

For the right elements of FLM, using proportions

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

$$Fy = L1*\sin\phi + (Hy-L1\sin\phi)L2/(L2+Q)$$
(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)
 $\delta = arctg((Fy, d-Fx))$ (11)

$$\delta = ATAN2(Fy, d-Fx)$$
(11)

using the cosine rule

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

$$2LL^{2}\cos\gamma = L12 + L^{2} - L22 \qquad (13)$$

$$\cos\gamma = (L12 + L^{2} - L22)/2L1L^{2} \qquad (14)$$

$$\gamma = \arccos((L12 + L^{2} - L22)/2LL^{2}) \qquad (15)$$

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

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.





3. Application of calculations

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



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.





5.Five Link Mechanism model

We make model with LED display. We use folder tablet for paper as an base, and diagram millimeter paper. Let us see the schematics and the photo of the Model. We use plane We can tune the angles of servos ϕ and ψ by means of multy-turn potenriometers 3 and 4, connected with A0 and A1 Arduino Uno inputs, toggle button 4 for mode switch and one single-turn potentiometer to control the speed in "Auto" mode. Here we use two 4-symbole LED display 7.

VCC - VCC VCC GND - GND GND MAX7219 1 D11 DIN DOUT . Α5 CS LOAD . D13 CLK CLK . • Tx Vin S1 GND VCC • Rx GND • GND RST • RST - RST ^{R3}_{1k}≤← A2 • GND 5V • VCC • D2 R A7 • D2 GND D3 • D3 A6 • NANO • D4 A5 • D4 Α5 VCC VCC D5 • D5 A4 • A4 • D6 RDUINO D6 A3 • A3 A1 – A0 D7 • D7 A2 • A2 • D8 GND GND D8 A1 • A1 D9 • D9 A0 • A0 REF • S0.1 S0.0 VCC /CC D11 ---- D11 C D12 ---- D12 C 3V3 • D2 D3 D13 • - D13 •GND GND

5 LINKAGE MECHNISM TESTER LED 8

Arduino Uno is controller PCB 8, and cable 9 is connected with power supply-USB computer port or power bank.



The program for Arduino Uno is on the Hack-a-Day file store. Science is fun. Sincerely Youth – Robots from ChG.