'95 KACC (1995. 10. 23 ~ 25)

RESEARCH AND SIMULATION OF THREE LIMBS ROBOT

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Abstract The closed loop robots have the advantage of higher velocity capability and often higher precision in comparison to the open loop robots. We have simulated the kinematic analysis of three limbs robot (T-L robot),which is one of the closed loop robots. After then, we have designed experimental T-L robots with 3 different kind of actuators. In this paper, we described the experimental results, and the problems in its applications.

Keywords Robot, Manipulator, Simulation.

1. INTRODUCTION

In recent years, the high accuracy techniqes of position control have been required for insertion tasks such as electronic parts assembly. The most of conventional robotic manipulators are modeled by open loop (serial kinematic) chains. The serial manipulator has some advantages, that is, a kinematic analysis is easy and the reachable area is wide. However, its cantilever structure is a serious drawback because of the low rigidity. Due to the reason above, attention has been given to the closed loop (parallel kinematic) chains, such as the three limbs robots with improved rigidity, even though the reachable area is restricted. Advantages in designing and using T-L robots are considered as follows;

1) The kinematic rigidity/precision of T-L robot is higher than the open loop robots, because the out put link is coupled to a fixed base by three binary links.

2) Owing to this structure, all the actuators can be installed on the fixed base, which enables to reduce the weight of moving output link and to increase the velocity of end effector.

3) The out put link is driven by three binary links, thus its center position is possible to operate the tracking and rotating motion, without the base rotation.

4) Same conventional and maintenance easy parts (bearing, links, actuators, etc.) can be used for each symmetrical three limbs, and the thermal expansion errors will be corrected alternately.

For these reasons, the T-L robot is expected to be applied to many future tasks requring the very higher precision and higher velocity capability.

2. CONSTRUCTION

The configration of T-L robot is shown in fig.1. Three pairs of binary links (5) connects the stationary base (3) to the output links (1), which is an equilateral triangle. Input links (2) are nearly same length to the coupler links (4).

A sliding elbow with a gripper is added to the output links for manipulation of small objects. The geometric configuration of T-L robot have a four degree of freedom, and it is called Planar Manipulator [4], Lobster Arm Robot [8],Oklahoma Crawdad Robot [7] etc.

2.1 Mechanical Design

The mechanical design of T-L robot is evaluated by The needs of applications.

The design requirements of our prottype T-L robot is the high accuracy of position control, including joint design, joint layout, transfer speed, easy maintenance, etc.

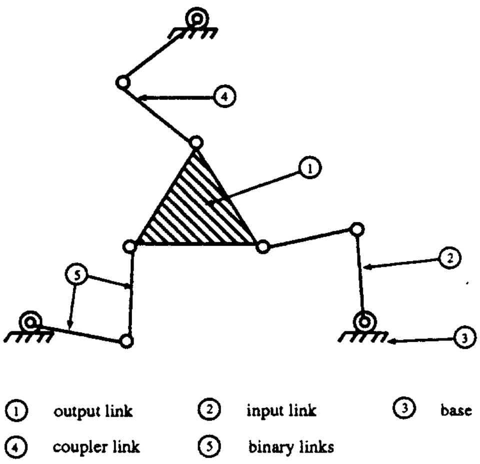


Fig. 1: T-L robot Mechanism

2.2 Bases

Steel sheets are used to construct the bases. Each motor is mounted on this base directly.

2.3 Gear

In order to gear down the motors, we must use the precision gears, sprockets and special constructed chains, which produced a zero backlash geardrive. When using open loop control devices such as stepping motors, it is critical condition. In the case of stepping motor and piezo motor, we had selected direct drive system without gears.

2.4 Links

Three pairs of binary links connect the tenary link to the three actuators. All links have " I " beam type cross section of the same size. Double ball bearings are used at each end to insure rigidity of the mechanism.

3. ACUTUATOR

We have designed the 3 types of experimental T-L robots with 3 different kind of actuators.

3.1 DC Servo Motors

DC Servo Motor System is accomplished using a closed loop position control system, which is fast and accurate control of the rotational position of the motor shaft. It is given using a shaft encorder and a angular velocity meter (tachometer). The T-L robot has considerable inertia. Therefore some means of velocity feed back must be employed to obtain sufficient damping and fast response. The block diagram of a position control system is shown in fig.2

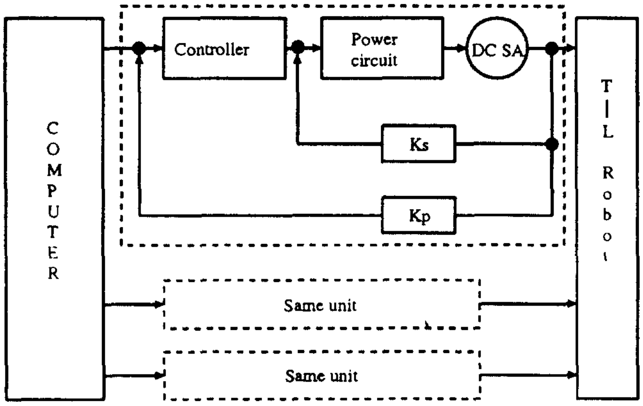


Fig. 2: Control circuit of T-L Robot with DC Servo Actuator

3.2 Stepping Motors

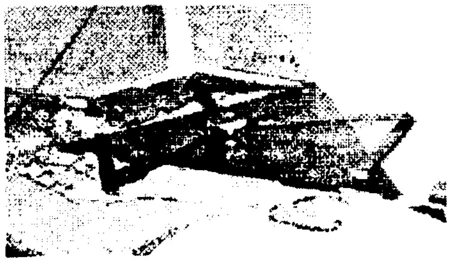
Stepping Motor provids precisely controllable speed or position. Since the motor increments a precise amount with each control pulse, it easily converts digital information to exact incremental rotation without the need for any feedback device such as a shaft encorder or potentiometer. Each motor has four phases which must be turned on and off in a determined pattern in order to rotate the motor shaft in CW or CCW direction.

3.3 Piezo Motors

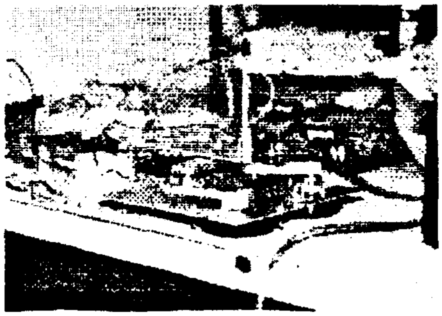
An ultrasonic Piezoelectric actuator has the advantages of large torque in low speed range, compact structure and standstill force without excitation. The rotating type of piezo motor are already used for industrial applications as Camera automation. These motors are drived by ultrasonic frequency, generating a wave forme deformation, creating a movement by friction. Such motors have an asynchronous behaviour at low speed and with a high torque. Three motors are not justified in the T-L robot because of asynchronous torque characteristics. If a synchronous execution could be realized at low price, a wide range of robotic applications would be possible.

These 3types of experimental T-L robots are shown in phot 1 ~ 3.

Phot. 1: DC Servo Motor Type T-L Robot



Phot. 2: Stepping Motor Type T-L Robot



Phot. 3: Piezo Motor Type T-L Robot

4. SIMULATION

The details of kinematic Analysis is reported in refferences [1] and [2].

According to the above analysis, we simulate the circular motion program about T-L robot. Standard dimension of T-L robot are as follow.

length of binary link L_1, L_2 = 0.5[m]
length of output link L_a = 0.3[m]
length of stationary link L_s = 1.0[m]
standard velocity of output link v_a = 1.0[m/sec]
radius of circular locus with uniform velocity
circular movement r = 0.1[m]
sampling time t_s = 10[msec]
position angle of output link α = 30[deg]

One example data of simulation is shown as followoing.

```
Sampling Time  = .01[sec]
Velocity \quad =   1[m/s]

Joint Angle = θ
   Joint(1) = 5.783[rad]
   Joint(2) = 1.003[rad]
   Joint(3) = 3.488[rad]

Inverse Jacobian = J^-1
   1.00000     0.31218     2.12722
   0.86416    -2.44569    -0.13854
  -2.21730     3.14019    -0.99564

Desired Angular Velocity = θ̇
   2.08966    -1.79331    -0.29635
  -1.04289    -1.36898     2.41186
   0.25062     1.94273    -2.19335

Desired Angular Acceleration = θ̈
   3.42957    13.20570   -16.63520
  28.52080   -21.45550    -7.06540
 -25.00530     6.61922    18.38600
```

Table. 1: Simulation Condition

	L_1, L_2 [m]	L_a [m]	L_s [m]	t_s [msec]	v_a [m/sec]	r [m]	α [deg]
straight motion	0.5	0.3	1.0	100	1.0	0.1	0
	0.5	0.3	1.0	100	1.0	0.1	30
circular motion	0.5	0.3	1.0	10	1.0	0.1	30
	0.7	0.3	1.0	10	1.0	0.1	30
	0.5	0.05	1.0	10	1.0	0.1	60
	0.5	0.9	1.0	10	1.0	0.1	60
	0.5	0.3	1.0	10	1.0	0.1	-30
	0.5	0.3	1.25	10	1.0	0.1	-30
	0.5	0.3	1.0	10	1.0	0.1	0
	0.5	0.3	1.0	100	1.0	0.1	0
	0.5	0.3	1.0	10	0.5	0.1	45
	0.5	0.3	1.0	10	2.0	0.1	45
	0.5	0.3	1.0	10	1.0	0.1	30
	0.5	0.3	1.0	10	1.0	0.2	30

Also we simulate about another dimension and t_s, v_e, r, α. Table.1 shows the simulation of various condition.

The best arrangement is searched for straight motion and circular motion by these simulation table.

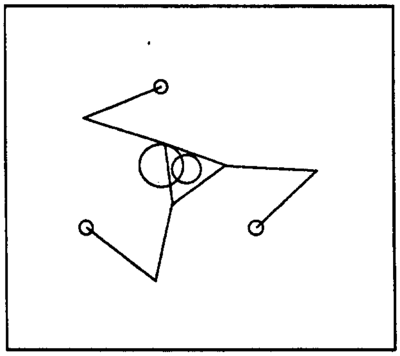


Fig. 3: Simulation

We represent a simulation graph as shown in fig.3.

The rotating angles, angular velocities, angular accerelations of each driving motor are shown in fig.4.

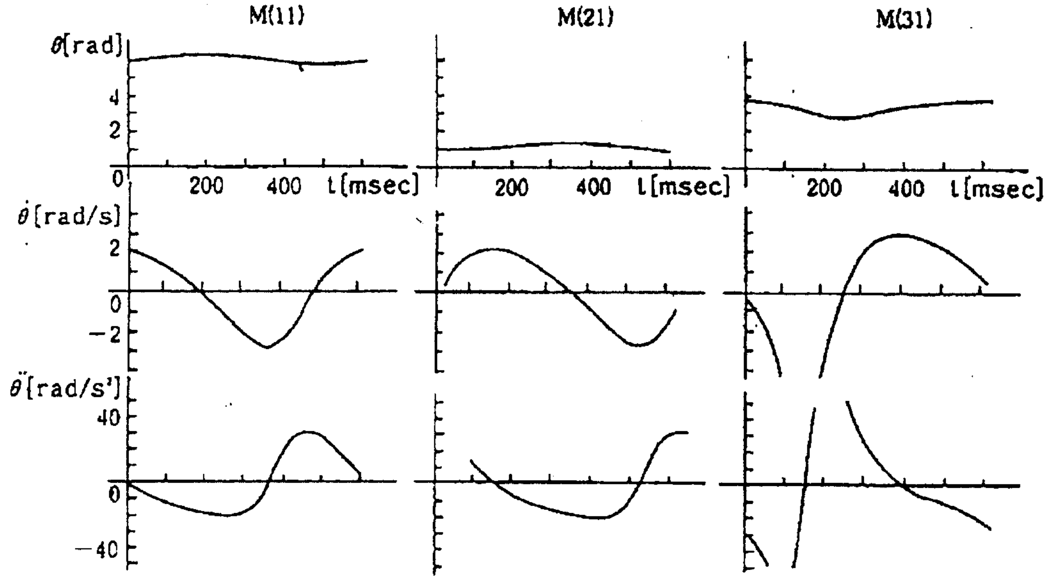


Fig. 4: Simulation Data

5. EXPERIMENTAL DATA

The comparison of performances in real model had been done about dynamic analysis.

Three kinds of servo motor are selected for the T-L robot.

The experimental data by DC servo motor is shown in fig.5, and fig.6, fig.7 are the results for stepping motor and Piezo motor.

These data are mesured by X-Y Tracker (vision sensor).

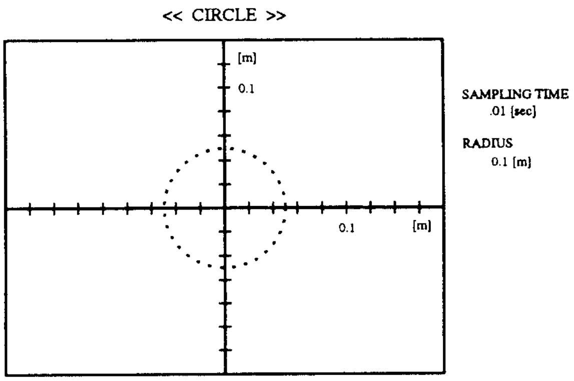


Fig. 5: Exp. Data by DC Servo Motor

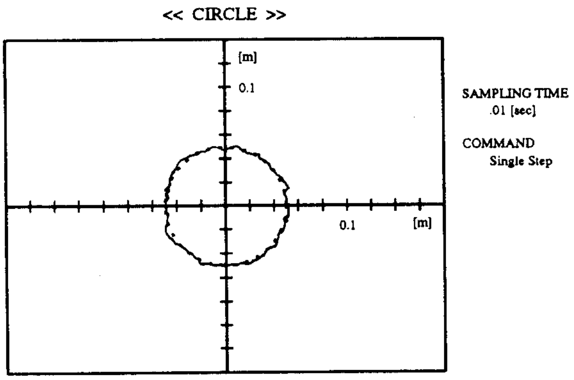


Fig. 6: Exp. Data by Stepping Motor

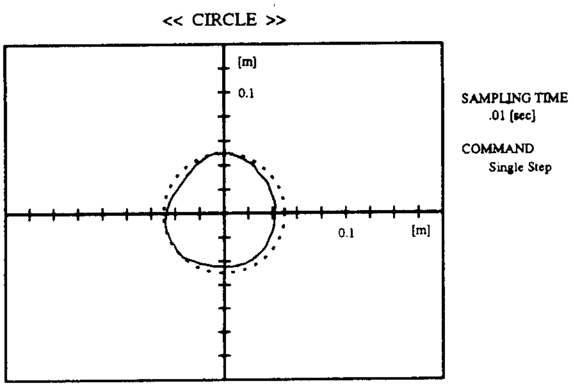


Fig. 7: Exp. Data by Piezo Motor

6. CONCLUSION

In this paper, we described the development of T-L robots, which is one of the closed loop robots.

In fundamental phases, we had simulated the dimension of each link length, and culculated the rotating angle, angular velocity, angular acceleration of each joint operating motors independently.

In second phases, we had designed and developed the 3 kind of plottype T-L robots, with different actuators. The DC servo motor and Stepping motor are successful and efficient actuators. The Piezo motor has a sutable torque-speed characteristics, but it is not justified in this T-L robot because of torque errors in each motor based on production quality.

In third phases, evaluation and application plans in future work are discused. The mechanism of T-L robot is a simple construction that incorporates only rotational freedom, which is suitable to the sealed construction using a ferro-fludic seal. The application to clean room robot for semi-conductor process will increase due to preventes the contaminant [9]. Typically T-L robots have the advantage of higher precision, which is required for insertion tasks such as electronic parts assembly [6]. In this cases, over head types of T-L robot will be successful system.

Further study will be developed about the ajustable compliance Mechanism [4].

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