

Modeling and Design of Two Link Robotic Manipulator for grading and Sorting of Rotationally Symmetric Products

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ABSTRACT

This paper present a design and modeling for a two link robotic manipulator for grading and sorting system. The mechanical design calculation of the robotic manipulator is accomplished firstly to estimate the torques and positions of manipulator that are required to move a certain payloads from one to another position, which is resulted by choosing of the right electrical motors. The mechanical design drawings for this manipulator system are fully done using Autodesk Inventor Software which concerns the real joint of the robotic manipulator. The dynamic equation of the robotic manipulator system is derived using the Lagrange equation which is then represented in the state space method to make simple for utilization in Simulation and real-time systems.

Keywords: Robotic manipulator, two link manipulator, design and modeling

1. INTRODUCTION

The design and modeling of a robotic manipulator has attracted the interests of some researchers over the world for many purposes and reasons. This is due to that the robotic manipulators have the capability to perform the handling tasks with high efficiency and safety such as assembly, grading and transportation, which can be performed by either one manipulator or many manipulators in free or constrain spaces.

The computed torque control system of a robot is usually used to decouple the control loops for the position and force when the robot manipulator is working in free space [1], where there are no forces or other disturbance applied to the system. A simulation study with accurate calculation has been developed for trajectory tracking task of the robotic manipulator to transfer the payload using PID controller where it shows good robustness of the controller [2]. To cooperate with the uncertainties of the parameter in the control system and external disturbance, the Active Force Control schemes were introduced [3-6]. The reason is to make the system robust enough for interruption by outside disturbance.

The optimization algorithm is usually used to solve a complex system where to exchange data efficiency of the controller [7], where the suggested control system is a robust and able to achieve the desired output.

The robotic manipulators are well known as expensive device since they requires a high precision sensors and actuators, strong material and a customizing machining part. A low cost robotic manipulator will make the user of the robotic manipulator increase due to its application is worldwide issue [8]. A chosen of the actuator are based on the calculation and function of the robotic manipulator. Different part of the manipulator will cause different size and specification of the actuator [9]. The end effector in the gripper will be the parts that make the process depend on the application. The design of the gripper should be the main concern where it needs to be suitable when been applied [10].

2. MECHANICAL DESIGN OF THE ROBOTIC MANIPULATOR

The design of robotics manipulators has been developed based on two aspects; namely are mechanical design calculation and drawings as follows:

2.1 MECHANICAL DESIGN CALCULATION

The robotic manipulators are driven by three motors to move the robotic manipulator links and a gripper for grasping objects. One additional motor is required to move the base of the robot manipulator to rotate the whole links of manipulators. The movement and rotation of the manipulator are shown in Fig.1.

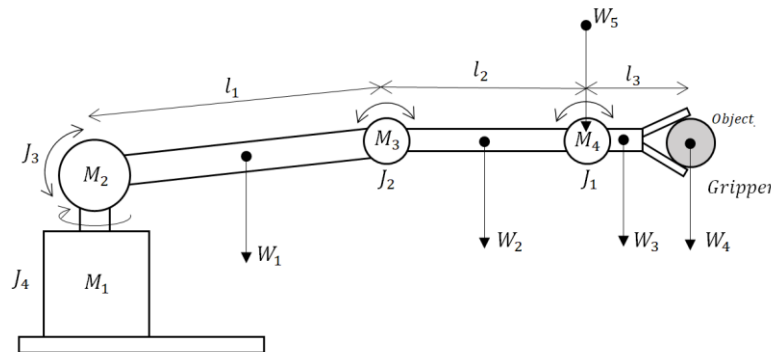


Fig.1: Free body diagram of the robotic arm

For choosing the electrical motors, a lot of parameters are considered to determine the maximum torque require. The motors are chosen by considering the following parameters:

- Total mass of the robotic link without electrical motor
- Length (m) of each link
- Distance from the joint of link to its center of gravity
- Acceleration due to gravity
- Electrical motor
- Robotic arm materials
- Maximum acceleration
- Working environment

The F_g is the total force needed to move the robotic gripper for maximum acceleration. The F_g can be computed by Eq. 1 as follows:

$$m(g + a) = 2\mu F_g \quad (1)$$

m is the payload mass, g is the gravity acceleration, a is the normal acceleration, μ is coefficient of friction.

The gripper device was arranged with a two parallel finger for its wide applications despite its exact control require as shown in Fig. 2. The fingers are moved in two directions to do grasping process, in which, two geared servo motors are used to accomplish the movement. The cover of the gripper and fingers will be made of aluminum sheet for light weight without lifting a finger the machining and openings cut through edges. These design gives straightforward and an easy upkeep procedure to the system. The movable finger is driven by a lead screw and guided by a linear bearing system with the advantage of self-locking capacity, ease and simplicity of fabrications.

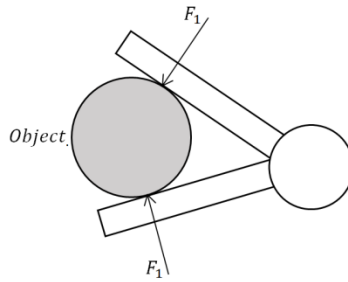


Fig. 2: Free body diagram for the gripper

For the links movement, the torque required to move the links as in Fig. 3 can be written as Eq. 2:

$$\tau = Fd \quad (2)$$

Where F is the weight of the links and joint, d is the diameter of the joint that is connected to motor shaft

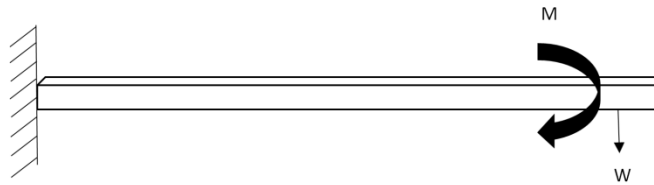


Fig. 3: Free body diagram of the arm joint

After calculation of the gripper as in Eq. 1 and other links by Eq. 2, four VEXTA brushless DC motor with a torque of 6.3Nm, 10Nm (two) and 16Nm are chosen. The motors are geared with a gearbox ratio of 30:1.

2.2 MECHANICAL DESIGN DRAWINGS

The fabrication of the robotic arm is almost similar to the human arm where there have the same function [8]. The links of a manipulator are connected by joints that are allowing for rotational motion. The end

effector used in this project is robotic gripper with two jaws that can move to grasp the object. Once the initial dimension of the robotic arm and the motor are defined, the designs were carried out. The design is carried out carefully taking into account the thickness of the platform, position of motor, and the way in which the link of robotic arm is attached to each other's. Autodesk Inventor has been used to design the robotic manipulator, which enable to produce accurate 3D models with aiding in designing, visualizing and simulating products. Figs. 4 and 5 shows the mechanical design of the robotic manipulator, where the robotic arm system design is shown in Fig. 4 and robotic gripper system design is shown in Fig. 5.

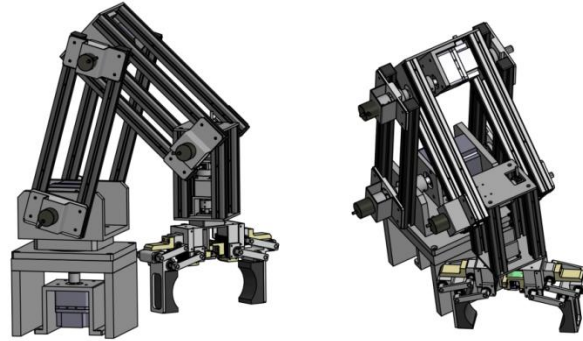


Fig. 4: robotic arm system design

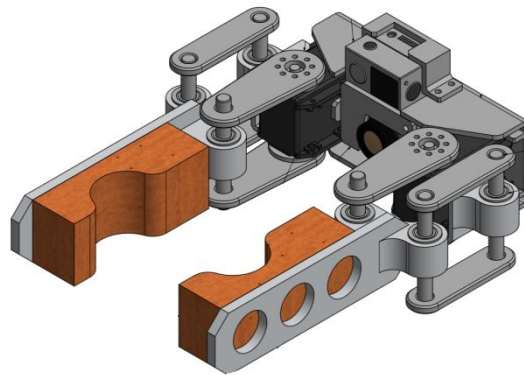


Fig. 5: robotic arm gripper system design

3. ROBOTIC MANIPULATOR DYNAMICS

The robotic manipulator dynamics of both gripper and robotic manipulator are demonstrated as inflexible connections joined by joints as represents in Fig. 6. The two link robotic manipulator model is confined along the sagittal plane by accepting, in which the frictional components following up on both the robotic arm and gripper joints and others modeled elements are disregarded.

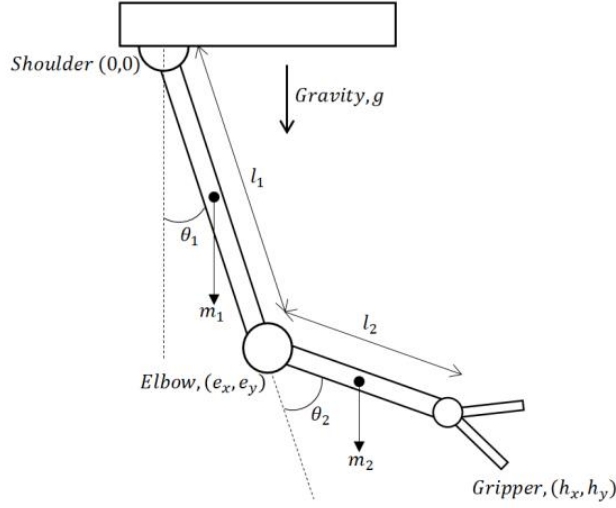


Fig. 6: Dynamic model of the robotic arm

The model is assumed to be free from any frictional elements and it is attach on the horizontal plane. Fig. 5 has described the parameters of the robotic manipulator links where the first link is joined with the second link and together are linked to gripper as in Fig. 5. L_1 and L_2 are the length of the link, M_1 and M_2 are the central of gravity between the links. To derive the equation of the robotic arm dynamic system, Euler-Lagrange formulation is used as in Eq. 3.

$$Q_j = \frac{d}{dt} \left(\frac{\partial L}{\partial \dot{q}_j} \right) - \left(\frac{\partial L}{\partial q_j} \right) \quad (3)$$

J indexes of coordinate system where

$$L = T - U$$

T = kinetic energy

U = potential energy

The Linear kinetic energy can be calculated using Eq. 4

$$\begin{aligned} T_{lin} &= \frac{1}{2} m v^2 \\ T_{lin_1} &= \frac{1}{2} m_1 (\dot{x}^2 + \dot{y}^2) \\ T_{lin_2} &= \frac{1}{2} m_2 (\dot{x}^2 + \dot{y}^2) \end{aligned} \quad (4)$$

The Rotational kinetic energy is calculated using Eq. 5

$$\begin{aligned} T_{rot_1} &= \frac{1}{2} I_1 \Theta_1^2 \\ T_{rot_2} &= \frac{1}{2} I_2 (\Theta_1^2 + \Theta_2^2) \end{aligned} \quad (5)$$

I = moment of inertia

θ = angular velocity

The coordinate of the (x,y) (location of centre of mass) can be transformed into intrinsic θ using Eq. 6

$$\begin{aligned}x_1 &= r \sin \theta \\y_1 &= -r \cos \theta \\x_2 &= l_1 \sin \theta_1 + r_2 \sin (\theta_1 + \theta_2) \\y_2 &= -l_1 \cos \theta_1 - r_2 \cos (\theta_1 + \theta_2)\end{aligned}\quad (6)$$

Total kinetic energy is given in Eq. 7

$$T = T_{lin_1} + T_{lin_2} + T_{rot_1} + T_{rot_2} \quad (7)$$

Potential energy is calculated using Eq. 7

$$\begin{aligned}U_1 &= m_1 g r_1 (1 - \cos \theta_1) \\U_2 &= m_2 g (l_1 (1 - \cos \theta_1) + r_2 (1 - \cos (\theta_1 + \theta_2)))\end{aligned}\quad (8)$$

The total energy can be written in Eq. 9:

$$\begin{aligned}L &= T - U \\L &= T_{lin_1} + T_{lin_2} + T_{rot_1} + T_{rot_2} - U_1 - U_2\end{aligned}\quad (9)$$

The general equation motion or the dynamic model of the robotic manipulator can be described as in Eq. 10:

$$\tau = H(\theta) \ddot{\theta} + h(\theta, \dot{\theta}) + G(\theta) + \tau_d \quad (10)$$

Where Q is the actuated torque vector, N is the $N \times N$ inertia matrix of the manipulator, h is the Coriolis and centripetal torque vector, G is the gravitational torque vector, whilst τ_d is the external disturbance torque vector. Since the manipulator is consider to move in vertical plane, the gravity terms can be assumed ignored.

The equations of dynamic are further rearranged in a state space representation. The advantage of this representation is that the non-linear systems can be represented by linear simple equations. It's also easy to deal with state space equations in the simulation since they are just first order equations [7]. The state space equation for the dynamic system of robotic manipulator is described as Eq. 11.

$$\begin{bmatrix} \frac{d\theta}{dt} \\ \frac{d^2\theta}{dt^2} \\ \frac{dx}{dt} \\ \frac{d^2x}{dt^2} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ \frac{N(\theta)(\ddot{\theta})}{h(\theta)(\dot{\theta})} & 0 & 0 & \frac{G(\theta)}{h(\theta)(\dot{\theta})} \\ 0 & 0 & 0 & 1 \\ \frac{\theta}{N} & 0 & 0 & \frac{G(\theta)}{n(\theta)(\ddot{\theta})} \end{bmatrix} \begin{bmatrix} \theta \\ \dot{\theta} \\ x \\ \dot{x} \end{bmatrix} + \begin{bmatrix} 0 \\ -Qv \\ 0 \\ \frac{QV}{N(\theta)\ddot{\theta}} \end{bmatrix} \quad (11)$$

$$Y = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} \theta \\ \frac{d\theta}{dt} \\ x \\ \frac{dx}{dt} \end{bmatrix}$$

4. CONCLUSION

In this paper a design and modeling of the robotic system has been discussed. A Dynamic model has been developed for two links and one gripper using Lagrange equation which has been converted later into state space equation. The design is created in the Autodesk software which concern on showing the best dimensions of manipulator and simulate the movement of joint. A material required for the fabrication of the robotic manipulator has been chosen based on the calculation of torque and suitability of the material. The future work is to develop simulation work to control the manipulator in MATLAB/SIMULINK, fabrication of the robotic manipulator and real-time control of the robotics manipulator.

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