New Solution for Telescopic Robotic Arm

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Abstract. This paper deals with a Robotic arm actuated by a monomobil telescopic planetary gear and servo DC motor. Experimental model of robot was designed and manufactured at the Faculty of Engineering from Sibiu, (Patent no. 112418 Cl6.B25J 18/02). The Servo DC as actuator drives a reel. Wires on the reel will produce displacement of telescopic modules from robotic arm structure. The reference as a voltage for future arm displacement is provided by a PWM generator. The rotation of the reel in one way or another has the effect of lengthening or shortening robotic arm. Robotic arm length is directly related to the PWM signal. Control of robotic arm positioning is done with a linear transducer.

Introduction

In a robot manipulator, there are commonly two types of joints: revolute and prismatic. The revolute joint allows for rotation between two links about an axis, and the prismatic joint allows for translation (sliding) motion along an axis. In a revolute joint, the link offset d is a constant while the joint angle \( \theta \) is a variable, and in a prismatic joint, the link offset d is variable and the joint angle \( \theta \) is normally zero [1].

At “Lucian Blaga” University of Sibiu, in field of robots, there is experience in cinematic structure of robots, work space, as well as in terms of programming and control movements. The model presented in this work, that is the programming and control of movements using PWM techniques, is the result of a patent of invention. Experimental robot model is manufactured using a structure with cylindrical coordinates (Fig. 2). Cylindrical coordinates allow robot arm to move in space under coordinates. The robot is relying on cinematic structure with three movements: Rotation-Translation-Translation. Experimental model of robot was designed and manufactured at the Faculty of Engineering, (Patent no. 112418 Cl6.B25J 18/02), (Fig.1) [2].

Appropriate architecture variant shown in the figure below (Fig. 2) Uses serial interconnect couplings of rotation and translation.
Structural analysis and determination of the transmission function for the planetary gears of the movement of the telescopic monomobil telescopic mechanism is shown in Fig. 3. The translation module is made up from two telescopic elements. It has degree of freedom: $M = 1$. Degree of freedom correspond to an independence movement $S_A$ and $LM = 2 - 1 = 1$.

$S_A$ represents input of mechanism, $F_A$ represents mechanical force. Number of external links is equal to 2: an input $S_A$ and an output $S_B$. The function of transmitting forces depends of $S_B$ and $F_B$. $S_B$ depends of $S_A$. To determine the movement’s velocity of the robot arm, we have two situations, when the $C$ is fixed, respectively when the $D$ is fixed. Due to construction, module translation movements are fine and can reach high speeds. Because of the elastic structure of movement’s transmission, telescopic modules are recommended to be used at works that do not exceed 30N.

$L = 2$ is the number of external connections: input $(S_A)$ and output $(S_B)$.

$$S_B = f(S_A). \quad (1)$$

The mechanism has $M = 1$ of Force Transmission Functions:

$$F_A = f(S_A, F_B). \quad (2)$$

Determination of the transfer function of the movement will be done by applying superposition principle because the functions are linear. Friction and inertia were considered negligible.

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Corresponding figures 3 and 4 will be obtained:

\[
S_{B} = S_{B}^{C} + S_{B}^{D}.
\]

(3)

Where \( S_{B}^{i} \) is the speed of B element when i element is fixed; \( i \in \{C, D\} \).

For calculus of \( S_{B}^{C} \) (Fig. 4) we consider the mechanism having pulleys fixed axis:

\[
S_{B}^{C} = i_{BA}^{C} \cdot S_{A}.
\]

(4)

\[
i_{BA}^{C} = i_{ab}^{C} \cdot i_{bc}^{C} \cdot i_{cd}^{C} = -1.
\]

(5)

\[
S_{B}^{C} = -S_{A}.
\]

(6)

Where \( i_{BA}^{C} \) is the ratio of transmission from “B” element to “A” element, when “C” element is fixed. For the determination of the mobile pulley mechanism we will use Figure 5 and we will obtain:

\[
S_{B}^{D} = i_{BA}^{D} \cdot S_{A}.
\]

(7)

\[
i_{BA}^{D} = i_{AB}^{D} = (-1) 1/2 = -1/2.
\]

(8)

\[
S_{B}^{D} = -S_{A}.
\]

(9)

From the relations (3), (4), (5), (6), (7), (8) and (9) we get: \( S_{B} = -3/2S_{A} \), this relationship representing the transfer function of the gear transmission.

The Robot can make a rotation and two translations (rotation, translation and translation - RPP). Mathematical matrix of reference transformation \([A]_{0,n}\) is \((OZYX)0\) in reference system \((OZYX)n\), results three operators \([P]_{x,r}, [R]_{z_0,\alpha}\) and \([P]_{x,r}::\)

\[
[A]_{0,n} = [P]_{x,0,z} [R]_{z_0,\alpha} [P]_{x,r}.
\]

(10)

The robot is based on a modular structure. Making movements by elastic elements: belts with cable, allows displacement on distance with high dynamic performance. The kinematics structure allows the robot to realize movements based on wire mechanism. For each axis movement is necessary a DC servomotors.

The displacement of the robotic arm, can be achieved independently or simultaneously depending on software and hardware used. Telescopic mechanism of the translation module has degree of freedom equal to 1 (Fig. 3).

The Experimental Set

The experimental set consists of: DC motor with gear ratio fixed transfer, a cable drum, an analogical rotational encoder, robotic arm and a system for verifying accurate of displacement, (Fig. 6). The Cable drum transmits movement to the robotic arm. The value of speed “v” is depending of rotational speed of cable drum “3” or speed of DC motor. The speed of DC motor will be constant. The diameter of cable drum is equal to 30 mm and speed of robotic arm is 0.9 m/min.
1-DC Motor, 2-Gear ratio fixed transfer, 3-Cable drum, 4-Encoder, 5-robot arm, 6-Displacement verification system

The displacement verification system consists of a linear incremental encoder which provides two digital electrical pulses for each millimeter. The value of displacement as digital pulses will be displayed on the screen and will be used to compare with programmed displacement to see accurate of robotic arm displacement.

The DC motor is part of servo system (Fig. 7). From microcontroller is provided PWM signal as a value corresponding to the future value of displacement. This value will be reference signal [3].

**PWM signals and tests**

The value of PWM is generated by a microcontroller under specific software. The experiments are based to applying different value of PWM and controlling real displacement of robotic arm.

Simulated PWM and voltage values are presented in Fig. 8. The value of PWM voltage, increase from 0% to 100%. Some values were selected as shown in figure.

The value of PWM voltage can be realized in any order using a program dependent on the type of microcontroller. For experiments were used MEGA 2560 R3 microcontroller.
Linear displacement of robotic arm will follow a speed diagram, acceleration, and space as shown in Fig. 9. The time for speed increase and decrease may be established by software. It depends on the weight of the object to be transported by the robotic arm. For practical applications, an established speed diagram is used. From speed law, a resulting acceleration and space profile is obtained. Speed, acceleration, and space are very important in designing and selecting a DC motor. The power of the DC motor depends on gear ratio, cable drum, and friction in telescopic guidance. High mechanical torque supposes a high ratio transfer of gear. Finally, user requirements of the robotic arm will determine the design conditions.

In time of experiments, the value of PWM voltage was evaluated for different positioning desired. Normally for PWM signal, any value between 0% and 100% can be set. The values of PWM signal evaluated were: 5%, 20%, 50%, 90%, and 95%. From simulated values of PWM voltage, the correspondence of voltage value from experiments is known.

Analogical encoder can realize ten turns. Analogical encoder is axial fixed to cable drum. For ten turns, a linear displacement of 900mm is similar. In this paper, experiments will use minimal position of encoder to 5% PWM and maximal position to 95%. The start position of the robotic arm will be 5% PWM. Protection of encoder to mechanical damage is realized by establishing PWM voltage values: minimal (5%) and maximal (95%) (Fig. 10).
The Monomobil planetary telescopic gear can be a solution for implementing a robotic arm as a module from complex structure of robots. This solution have advantage of simple linear telescopic and translation movement. The final dimension of robotic arm will be supple. For transmitting torque and mechanical force may be used steel wire and other materials. The new solution, have advantage of elasticity transmitting movements and disadvantage of precision for positioning. The evaluation of accuracy of positioning used was 0.5mm. The servo DC and PWM technique have advantage of a simple and easy programming and control by using a microcontroller. For feedback voltage signal may be used analogical encoder, a multiturn precision potentiometer.

Summary

The displacement verification system provides pulses corresponding to displacement value, Fig. 11. The number of pulses from displacement verification system shows the true value of displacement.

References


