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# Design, Analysis and Implementation of a Robotic Arm- The Animator

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***Abstract: -*** A humanoid robotics is a new challenging field. To co-operate with human beings, humanoid robots not only have to feature human like form and structure, but more importantly, they must prepared human like behavior regarding the motion, communication and intelligence. The model number of this beginner is ASR K-250. This paper we consider the mechanism and mechanical structure of ASR K-250 (Beginner) and its implementation.

***Keywords: -*** *Degrees of freedom, kinematic structure, ellipsoid, redundancy, elbow pitch, Hardware interface, joint speed*

## I. SUMMARY

In the field of robotics the beginner can contribute many functional operations in the world. This arm can solve many human's limitations. Many people cannot move from one place to another place for their limitation but they have needed to move for collect something like mug, jog, and so on. For that they require getting help from other persons. When they use this type of robot they can solve their problem easily without help other person for its easy operation system. For an example when a person has needed to carry an object from drawing room to bed room he can use this robot. It can move surround also collect photo and other information. When earthquake will be occurred by using these types of robot people can unseat many weight full objects from destroyed area to a safety place.

**Introduction:**

The application of robotics field is broadly used in the field of research, laboratory based work, industrial work to automate process and reduce the human errors. This paper is describing the design of mechanical structure of a robotic arm. This robotic arm is often indicated to move an object from one place to another place. One kind of example of this application is in an industrial area where need to move a weighable object like tank or container or other object. The advantage of automated process results is faster completion time with lowest errors. This paper also describes the implementation of a robotic arm with switching controlled. The application of the force controlled function can be seen in the industrial/manufacturing environments.

**Overview of the arm:**

Degrees of freedom: 5
Payload capacity: 180gm (Experimentally)
Joint speed (approximate):40-60 rpm
Hardware interface: 2 pin connector
Base spin: 180 degrees
Shoulder base spin: 160 degrees
Elbow pitch: 160 degrees
Finger opening (Max): 10cm

## II. MECHANICAL STRUCTURE

The mechanical design of a robotic arm is based on a robotic manipulator with similar function like a human arm. In order to establish a generalized operating systems and the technological systems for the analysis, design, integration and implementation of a humanoid robotic arm.

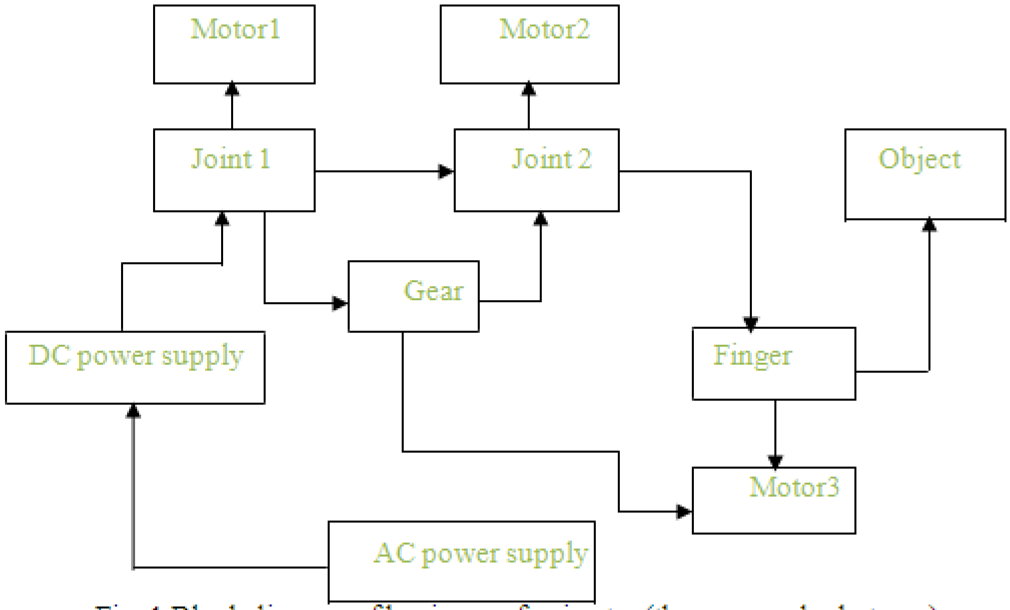


Fig. 1 Block diagram of beginner of animator (the proposed robot arm)

For operating DC motor we need DC power supply that's way we attached an AC to DC converter for getting DC power. This DC power supplies each motor. In this robot arm each and every motor is connected with external gear with external gearbox.

## III. CALCULATED TORQUE

Torque means measure of how much force are acting on an object reasons that object to rotate. Torque is denoted by T. Torque (**T**) is defined as a moving "force" and is calculated using the following equation:

$T=F*L$ …………………………………………………………………………………………….. (1)

Where T is torque F means calculated force and L is denoted the length from a pivot point. The force is accelerating on an object due to gravity (**g** = 9.81m/s$^2$) multiplied by its mass.

$F=M*g$ ……………………………………………………………………………………………. (2)

Mass (M) and gravity (g)

The force (F) is also considered of an object's weight (W)

$W = M*g$…………………………………………………………………………………………….. (3)

The torque required to hold a mass at a given distance from a pivot point is showing therefore

$T = (M*g)*L$…………………………………………………………………………………… (4)

The length L is the perpendicular length from a pivot point to the force. This equation can found by similar doing a torque balance about a point.

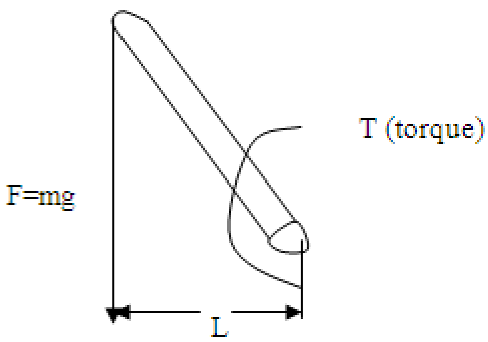


Fig. 2 torque balance

$\sum T = 0 = F*L - T$…………………………………………………………………………………….. (5)
Therefore, replacing the force (F) with mass and gravity (m*g) we can find out the same equation above. This is the more accurate way to find out the torque by using the torque balance.
$M*g*L = T_A$ ........................................................................................................................................ (6)
In order to estimate the torque required at each joint, we can must chose the worst case scenario.

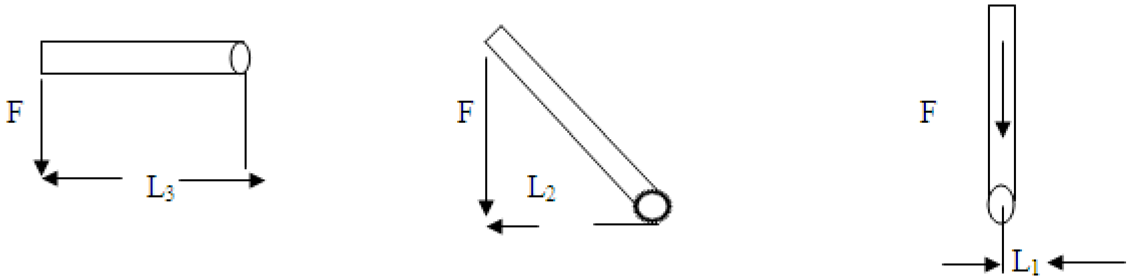


Fig. 3 required torque at each joint

From the above figure we can see a link of required length L is rotate clockwise. Only for perpendicular component of the length (L) between the pivot point and force (F) is taken into account. We can observe that the distance of length (L) is decreasing from length L3 to length L1. Since from the torque equation the length (L) or distance multiplied by the force (F), the greatest value will be obtained by using L3, The force (F) does not change. We can rotate the link counterclockwise similarly and observe the same effect.
The weight of the object (load) being held as Indicated in the Figure 4 by A1, which is multiplied by the distance its center of mass and the pivot point gives the torque required at the pivot. The tool takes into the consideration that the links may have a significant weight (W1, W2……) and its center of mass is located at roughly the center of its length (L).
The torque caused by this difference masses must be added. The torque required at the first joint is therefore.
T1 = L1*A1+L1*W1 (“A” is weight of the actuator or the load.) …………………….................. (7)
We may consider that the actuator weight A2 which is as shown in the diagram below is not included when calculating the torque at that point. This is because by the length (L) between its center of mass and the pivot point is zero. The torque required at the $2^{nd}$ joint must be re-calculated with the new lengths, which is as shown in the following figure. (The applied torque shown in green color like $T_1$ and $T_2$)

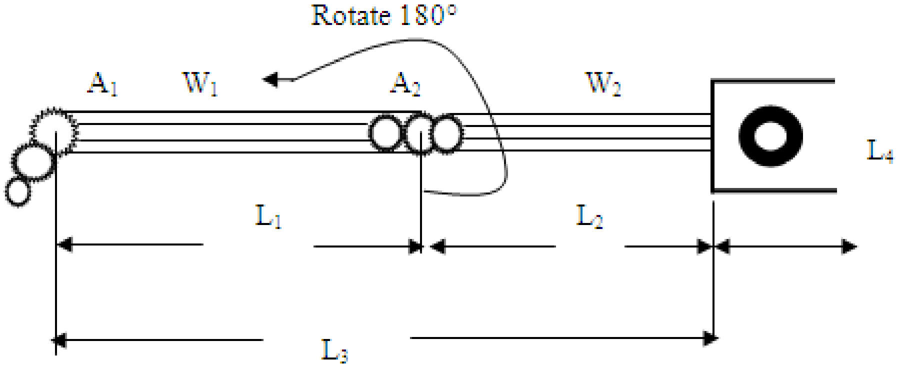


Fig. 4 calculation of applied torque

$T2 = L_3*A_1+ L_1*W_1+ L_2*A_2+L_4*W_2$ ................................................................................................ (8)
Knowing that the link weight (W2, W2) are located in the center point of the lengths, and the distance between the actuators (L1 and L3 shown in the diagram above) we can re-write the equation as follows:
$T2 = (L_1+L_2)*A_1+ (L_1+L_3)*W_1+ (L_2)*A_2+ (L_2)*W_2$ …………………………………………… (9)
Only for the tool requires that the user enter the lengths (L) of the each link, which would be L1 and L3 above so the equation is showing accordingly. The torques at each subsequent of the joint can be found similarly, by re-calculating the lengths between each new pivot point and each weight.

## *IV.* THE KINEMATIC STRUCTURE OF BEGINNER ARM

The following figure shows the reference and link coordinate systems of 5- DOF arm using the first step of the animator. The values of the kinematic parameters are listed below in the table (I). Where $l_{u,}$ $l_s$ and $l_f$ are the link lengths of the shoulder, back arm and forearm respectively.

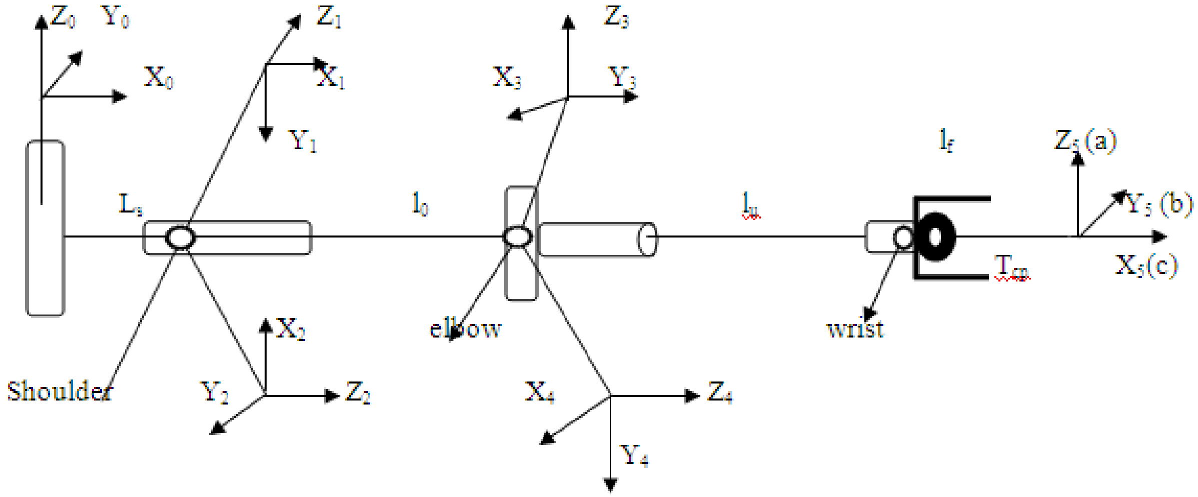


Fig. 5 The coordinate system of the arm

Defined a frame of each link, the coordinate transformation is describing the position and orientation of the end-effectors with respect to (wrt) the base frame is given by

$$T_{tcp}(\vec{\theta}) = \prod_{i=1}^{5} \left[ A_i(\theta_i) \right] = \begin{bmatrix} a\ b\ c\ p \\ 0\ 0\ 0\ 1 \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

Allude the basic construction of the forward kinematics function by composing the coordinate transformations into the one homogeneous transformation matrix. The actual description of the coordinate transformation system between frame i and frame I – 1 is given by homogeneous transformation matrix.

$$A_i = \begin{pmatrix} C\,\theta_i & -\,C\,\alpha_i\,S\,\theta_i & S\alpha_i\,S\theta_i & \alpha_i C\,\theta_i \\ S\,\theta_i & C\,\alpha_i\,C\,\theta_i & -\,S\alpha_i C\,\theta_i & \alpha_i\,S\,\theta_i \\ 0 & S\alpha_i & C\,\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

Where $S\,\theta_i$ and $C\,\theta_i$ are $S\alpha_i$ and $C\,\alpha_i$ , respectively.

Table 1 the parameters of the arm

| i | $\theta_i$ | $\alpha$ | $a_i$(mm) | $d_i$(mm) | range |
|---|---|---|---|---|---|
| 1 | $\theta_1$ | -90° | $l_s$ | 0 | - 90°…….90° |
| 2 | $\theta_2$ - 90° | -90° | 0 | 0 | - 90°…….90° |
| 3 | $\theta_3$+180° | 180° | 0 | $l_u$ | - 180°…...180° |
| 4 | $\theta_4$ | -90° | $l_h$ | 0 | 0………180° |
| 5 | $\theta_5$ | 90° | 0 | $l_f$ | - 45°…….45° |

Where θ is denoted by the vector of the joint variables, a, b and c are the unit vectors of the frame attached to the end- effectors.

## V. CONSIDERATION OF ELBOW POSITION

The main description is the intersection of the ellipsoid and the sphere mentioned above is analytically difficult. To make this task mathematically tractable, firstly we determine the intersection between the ellipsoid and the sphere at Z = ze. The redundancy curve of the arm can eventually be obtained by combining all such intersections for all values of ze in the interval. (Note that $Z_e^{min}$ and $Z_e^{max}$ are the minimal and the maximal values of the Z coordinate of the elbow for a given position and orientation of the end-effectors.)

Let $Z_e \in [Z_e^{min}, Z_e^{max}]$ are be the coordinator of Z of an elbow position of this arm for a given position of the end-effector. The radius $r_1$ and center $C_1$ of this circle are given below:

$$r_1 = l_s + \sqrt{l_u^2 - z_e^2} \quad \text{............} (12)$$

$$C_1 = (0.0.z_e)^T \quad \text{............} (13)$$

The intersection of the sphere with the plane Z = Ze results in a circle. Then the radius $r_2$ and the center $c_2$ of this circle can be determined as follows.

Basically there are two points like $C_1$ and $C_2$ provided by the intersection of the circles represents two possible positions of the elbow. The unit vectors of the frame (x4, y4 and z4) attached to the elbow position must be established.

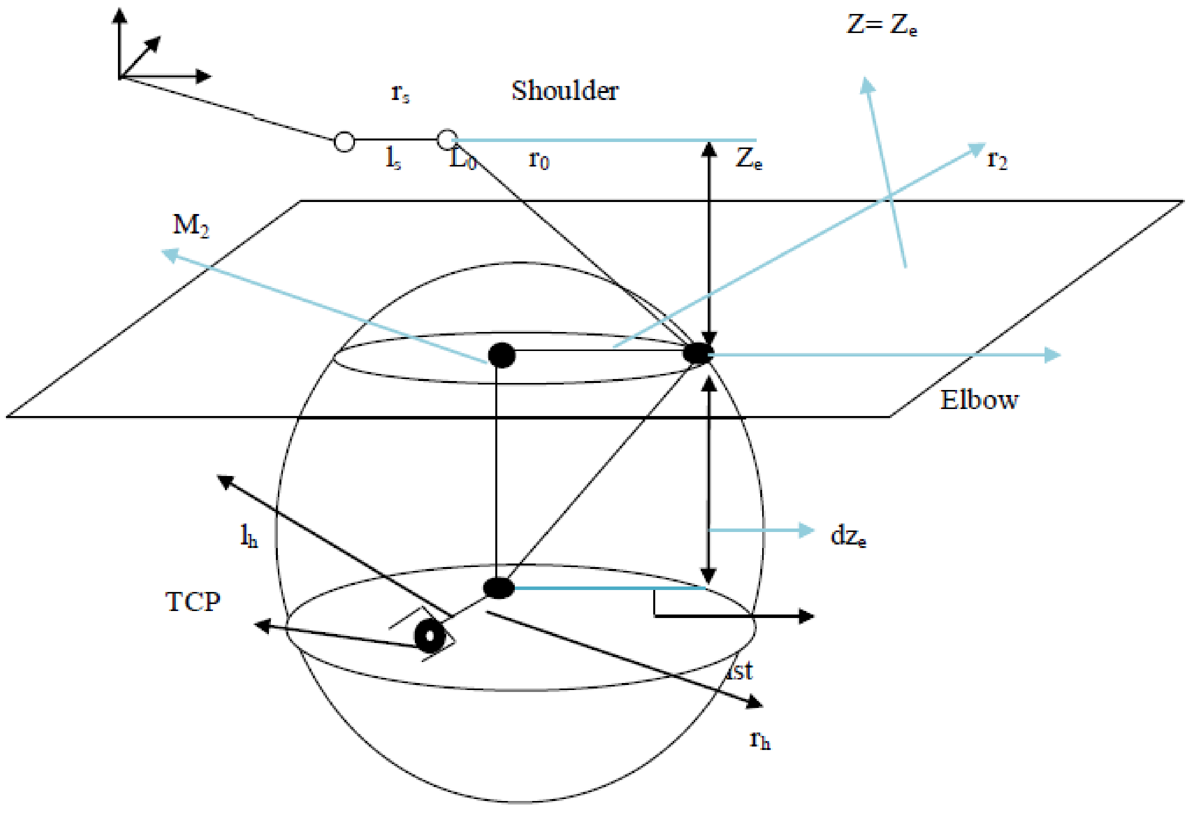


Fig. 6 Plane Z = Ze and ellipsoid

$$r_2 = l_s + \sqrt{l_f^2 - dz_e^2} \quad [dz_e = z_e \text{-} z_w] \quad \text{............} (14)$$

And

$$C_2 = (x_w, y_w, z_e)^T \quad \text{............} (15)$$

The vector z4 lies along the forearm and points to the wrist. The vector y4 is perpendicular to the upper arm ($r_u$) and fore arm ($r_f$). The vector x4 completes the right handed coordinate.

**The redundancy of the arm:**

The redundancy of the animator robots' arm can be described by the rotation of the center of the elbow joint about the axis. The base frame ($x_0$, y0, z0) of the feasible position of the elbow around this axis is defined by the curve. This curve can be described from the ending point of the upper arm which can be describes an ellipsoid. The centered of the origin of the base coordinate system ($x_0$, y0, z0) and that the starting points of the forearm derived a sphere centered on the wrist position ($x_w$, $y_w$, $z_w$) which corresponds to the origin of the coordinating system ($x_s$, $y_s$, $z_s$) which is as shown in the following figure.

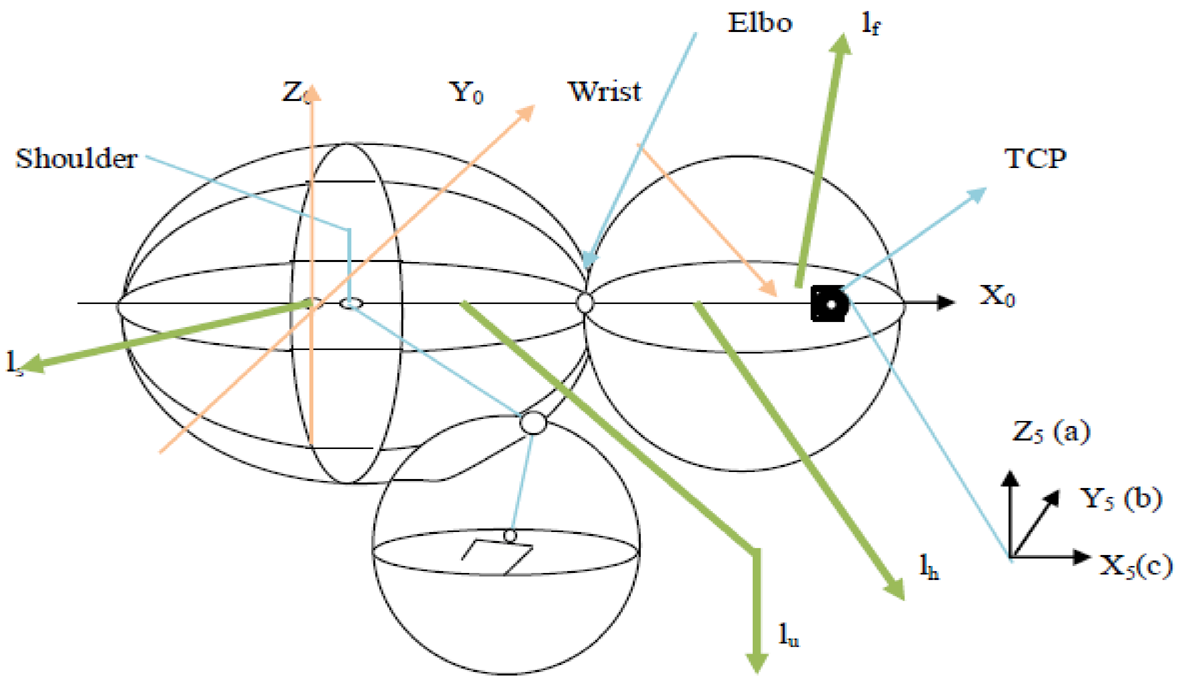


Fig. 7 work space of the upper arm and forearm of this arm

Since this two points have to same to looking the redundancy of the curve results from the intersection of the ellipsoid and the sphere. Mathematical equation is given as follows:

$$\frac{X}{(l_s+l_0)^2} + \frac{y}{(l_s+l_0)^2} + \frac{z}{(l_0)^2} = 1 \quad \ldots\ldots\ldots\ldots\ldots \quad (16)$$

And also

$$W = (x_w, y_w, z_w)^T = p - \vec{i_h} \cdot \vec{c} \quad \ldots\ldots\ldots\ldots\ldots \quad (17)$$

**Gear:**

Gear is a rotating machine part which having cut teeth or cogs, which mesh with another toothed part in order to transmit the torque. A gear can produce a mechanical advantage through a gear ratio and thus may be considered a simple machine. Geared devices can change the speed, torque and direction of a power source.

A particular gear train is made up of two or more gears. Between an input and output shaft; there will be a change in angular velocity and torque. The basic speed relationship of their is given by

**Gearboxes:**

A gear train is made up of 2 or more gears. In these types of robot there will be a change in the angular velocity and torque between an input and output.


Fig. 8 Attached with another teeth or cogs.

The gear is increased by attaching external gearboxes in this robot arm. The mathematical relationship of speed is given below

$$n = \pm \frac{\omega i}{\omega 0} = \pm \frac{N0}{Ni} + \frac{x^3}{3!} \quad \text{......} (18)$$

$$n = \pm \frac{\omega in}{\omega 0ut} = \left(-\frac{N2}{N1}\right)\left(-\frac{N3}{N2}\right) = \left(\frac{N3}{N1}\right) \quad \text{......} (19)$$

Where $N_i$ and $N_0$ are the number of teeth of the input and output gear. $\omega_i$ and $\omega_0$ are the angular velocity of the input and output gear. These types of robot we use spur type gear.

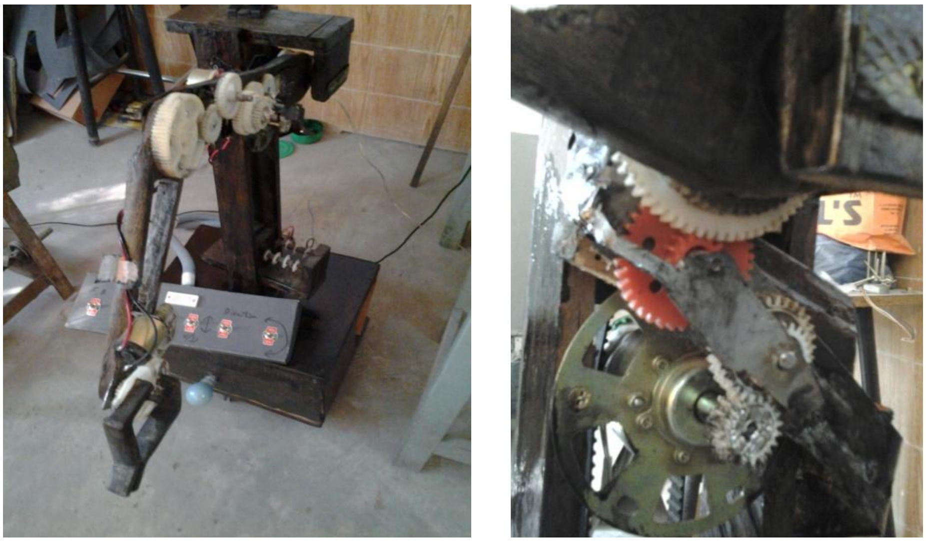

Fig. 9 increasing torque by adding external gear

In general, any two of the three components (like flexspline, circular spline and wave generator) that build up the gearbox can be used as the input to, and also the output from, the gearbox, giving the designer considerable flexibility. The robot need to increasing the gear for his hand work successfully.

This arm the required gear added by using external gear with motor.

**Motor:**

In these types of robot we consider the DC electric gear motor. Actually a DC motor is designed to run on DC electric power. The AC or DC power electric motor is an electromechanical device that can converts electrical energy into mechanical energy. The moving part of the electric motor is called rotor and the stationary part of the electric motor is known as stator.

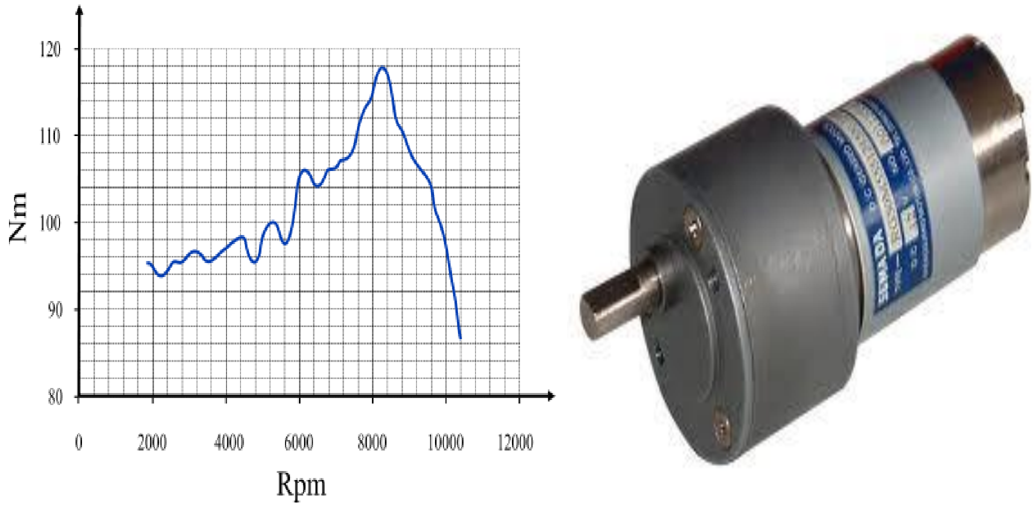


Fig. 10 A DC gear motor and torque related curve.

In order to obtain more torque which is as shown in figure 10? The exact or containing speed of a DC or AC induction motor is influenced by an applied load and the consequences slip. The torque of the motor produces by also a function of the slip. If we can produce more slip ultimately we can produce more torque. Actually a DC electric motor is designed to start on DC electric power.

Series connected and shunt connected DC type motor:

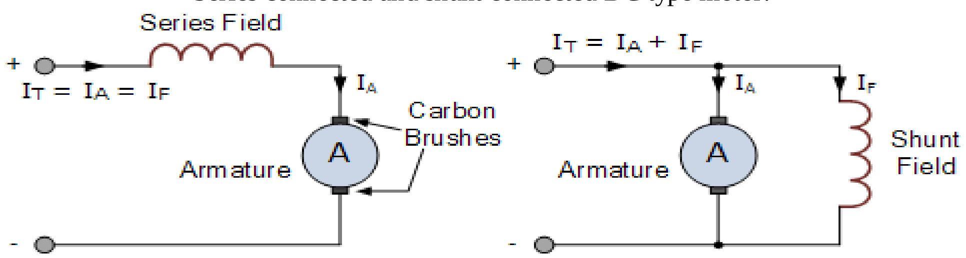


Fig. 11 series and shunt connected DC motor.

Basically there are there basic types of DC motor. Most of them are series motors, shunt motors and compound motors.

**Motor Power Rating:**

How can we apply high voltage to a motor? All motors are operated to a certain rated voltage. The inefficiency of energy conversion is directly related to heat output. When produce too much heat, the coils of a motor melt will be occurred. So it is highly preferred to maintain a sustainable power for usable motor. We can explain the power rating of a motor by a simple equation. The related equation is given below

Power (in watts) = Voltage * Current

**Switch:**

These types of robot arm we bonhomie and adjust DPDT switch. It stands double pole and double through. These types of switch can flow electricity both clockwise and anti clockwise. For continuing the work of this arm we need to rotate both ways. For up and down of this arm need to flow current in both ways so that the DPDT switch attached perfectly.

**Some function of a DPDT switch is given below:**

- A DPDT can be used in any application that requires a NO, that means normally open and NC, that means normally closed wiring system.
- DPDT can be used in such cases for block controlled due to the ease and flexibility of the wiring.

- Block controlled allows the relay coil to be triggered remotely, while another relay is controlling by another block.

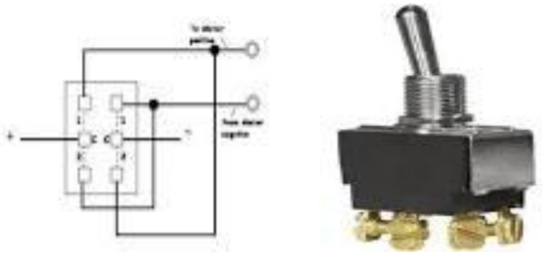

Fig. 12 DPDT switches construction and circuit diagram

Table 2 Switch connection with motor and its mechanism.

| Input A | Input B | Motor Function |
|---|---|---|
| 0 | 0 | Motor Stopped (OFF) |
| 1 | 0 | Motor Rotates Forward |
| 0 | 1 | Motor Rotates Reverse |
| 1 | 1 | Not Allowed |

In the table 2 we describe about the operation system of DPDT switch. When input and output will both 0 then the motor speed 0 that means motor is stopped. When input is 1 and output 0 then motor will rotate with forward kinematics or clockwise direction. On the other hand when input is 0 and output 1 then the motor will rotate inverse kinematics or anticlockwise direction.

## VI. RESULTS AND CONCLUSIONS

The generation of the human-like manipulation motions has been implemented and also tested successfully for the 4 degrees of freedom (DOF) arm of the humanoid robot. The presented approach does not consider the dynamics of the robot arm. This would be necessary to generate realistic velocity distribution for the manipulation motions. In this paper has reviewed the characteristics of the main mechanical structure and construction of a humanoid robotic arm. From this arm the exploration of afterwards will be a full body which is controlled by body switch. The final step of this robot is auto learner, in this stage this robot can learn automatically. The real/exact position and orientation of the arm can be obtained significantly large modifications of the joints $\theta_1$, $\theta_2$ and $\theta_3$. The assistive robotic arm will must be able to contribute most of the challenges in our daily life. However, the resulting configuration is not guaranteed to be human-like.

## VII. ACKNOWLEDGEMENT

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