Modular Design and Control of Humanoid Robot Arm

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Abstract— Humanoid robots are used to mimic the human movement in human oriented environment. They are designed and built to work autonomously with no harm to human. In this paper design, and control of humanoid robot arm is concentrated. Modular design of humanoid robot arm extended more flexibility and variety in use of arm.The modular arm resembles actual human arm in movement and appearance, is built using PMDC motors, gear trams, breaks and motor drives. The modular design of humanoid arm is having 7-Dof similar to human arm. The mechanical modular design made it sufficiently small and compact compared to currently available Humanoid robot arm. The developed arm is controlled using the PIC 18F4580 microcontroller. The multi finger gripper is capable of grasping any shape object very precisely. For getting the amount of force applied on object while grasping, flexi force sensor strip is attached to each finger in contrast to previously used pressure pads. The developed modular arm is more suitable for human interactive task. Arm is composed of links and modular joints so that arm can handle 3kg payload even with full arm extension.

Index Terms— End effector, Harmonic drives, Inverse kinematics, Modular humanoid arm, Motor driver, Multi finger gripper, PMDC

1 INTRODUCTION

Robotic arms are widely used in industrial automation for material handling tasks.These arms cannot be used in daily life because the motions they serve are restricted by their structure. In order to behave in anthropomorphic way the humanoid robots should have modular design and efficient degree of freedom so that they can mimic human motions. Further to perform motions like human arm the robotic arm should have 7-Dof and the 5 to 24 Dof for hand.

NASA's Robonaut humanoid robot comes with total of 19-Dof, particularly 5-Dof for arm and 14-Dof for hand. It has sensing abilities; can perform fine motions, included redundancy and safety features [2]. Robonant's hand is explicitly developed for EVA [3]. The first articulated hand with complete integration of electronics and actuators is DLR hand I. It included 6-Dof newly designed force sensors and hence simple communication architecture [1]. The vision sensing based, fast robotic arm developed by University of Tokyo has very high bandwidth for grasping object [6]. The reason behind the fast operation of arm is artificial muscle actuator.

The developed modular design is having 7-Dof for arm and 8-Dof for multi finger gripper hand. The arm together with hand is capable of sensing force applied by hand on object while grasping. These arms can be used for grasping even delicate material such as glass.

2 MECHANICAL DESIGN

The modeled structure of arm has 7-Dof from shoulder to wrist. It helps to perform fine motions just like human arm. In shoulder three motors are placed in such way that shoulder can moves in 3-Dof.The elbow moves in 1-Dof and wrist in 3-Dof. The design is compact hence the application need harmonic drives which give large gear ratio with very small size and it helps to reduce the backlash. The shoulder provides free movements 270 pitch, 120 yaw and 180 roll. While elbow provides 90 pitch motion. The wrist is somewhat difficult to design as the size of wrist is very compact. Wrist provides 180 roll, 180 pitch and 120 yaw capability to hand. For ease in electrical wiring the joint centers are made hollow.

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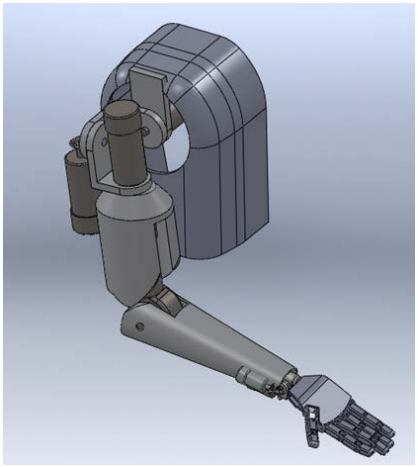

Fig. 1 Modular Robotic arm with multi finger hand having 3 Dof at shoulder, 1 Dof at Elbow and 3 Dof at Wrist.

TABLE 1
COMPARISON BETWEEN MODULAR ARM AND HUMAN ARM

Sr.No.	Parameter	Modular Arm	Human Arm
1	Length	Shoulder to Elbow: 180mm Elbow to Wrist: 220mm	Shoulder to Elbow: 210mm Elbow to Wrist: 240mm
2	Weight	4.2 Kg	5.3 Kg
3	Dof	7	9 and 5 to 24
4	Type of Joint	Revolute Joint	Ball Socket Joint

3 KINEMATICS AND CONTROL

Kinematics is very important aspect in robotics for finding position of joint at end effect. Analytical solution can be classified into different geometry based closed loop solutions. For less than 7- Dof the closed loop solution can be obtained easily [8].

The general structure of robot is highly dependent on the utility and the purpose for which they are built. A robotic arm with 7 Dof shows have potential because, it can perform the motion that mimic most of human hand motions. The kinematic structure of robotic arm is shown in fig 2.

A D-H coordinate system of the humanoid robot arm is found in Fig 3. The parameters of link are shown in Table 2.Where the four parameters are respectively the rotary joint angle θi, sliding joint variable di, joint offset distance ai, and the angle between the two neighboring z axes αi [9].

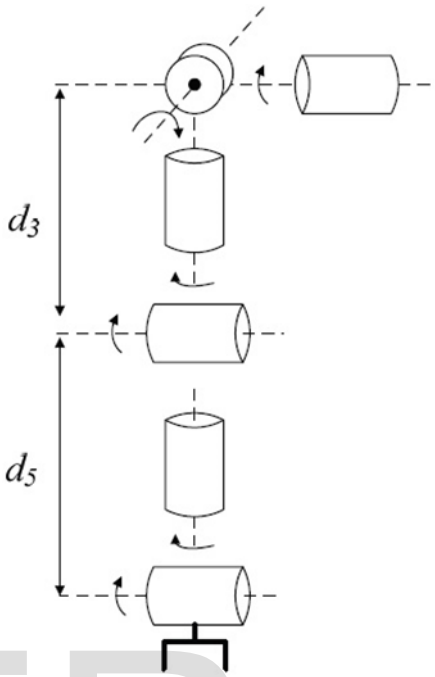

Fig. 2 Kinematic model for Arm helps to get the trajectory.

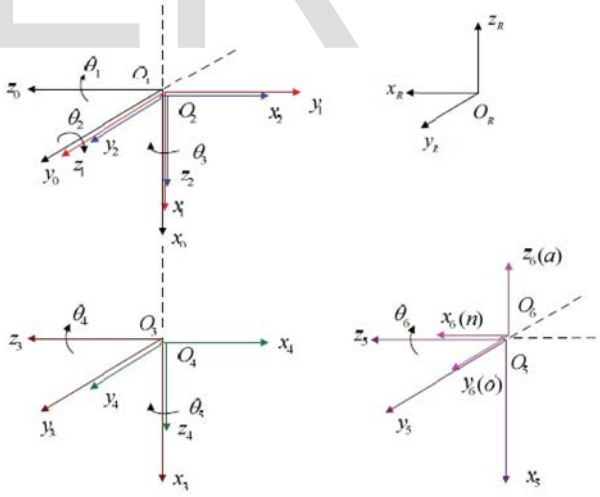

Fig. 3 DH Coordinate system for calculating DH parameters.

For humanoid robot arm, each joint must be compact in structure with high accuracy and necessary torque for actuator [11]. By calculating torque required, PMDC servomotor is used for each degree of freedom. For controlling the 7 motors at a time PIC 18F4580 microcontroller is used having CCP/ECCP module for DC motor control.

The advantage of CCP/ECCP module is, using library files the motors can be controlled easily without disturbing the PIC processor; hence the speed of communication is increased by interfacing through RS232 interface.

TABLE 2
DH PARAMETERS OF THE ARM

Joint	θ_i	α_i	a_i	d_i	*Joint range*
1	θ_1	−90°	0	0	−90° ~ 180°
2	θ_2	90°	0	0	−180° ~ −70°
3	θ_3	−90°	0	d_3	−90° ~ 0°
4	θ_4	90°	0	0	−180° ~ −70°
5	θ_5	−90°	0	d_5	90° ~ 180°
6	θ_6	0°	0	0	0° ~ 90°

4 EXPERIMENT

There are total 7Dof servomotors drivers for driving each motor, consisting PIC18F4580 micro controller. The L2980chip is used as motor driver having an internally H- bridge circuit to drive DC servomotor and provides required current flow.

5 CONCLUSION

This paper presents a robotic arm with 7Dof with modular wrist for interactive humanoid applications. The mechanical design is compact and modular so by attaching pneumatic suction cup or multifinger gripper arm at wrist end, applications such as assistance to physically handicapped persons.By adding the visual algorithm to give environmental information, useful for obstacle avoidance.

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