Gesture controlled robotic surgical arm (GCRSA)

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Abstract

This research paper primarily focuses on Arduino controlled Humanoid arm which transform's the current surgical process operated by a Surgeon. With exponential population growth and a hand full of medical experts at corners of the world, this Humanoid arm will be a substitute for those experts at their proximity. Albeit this modern tech-savvy world needs an expertized touch without distance being a major constraint. The fine precision in the finger movements are sensed by the Accelerometric sensor and flex sensor whose actions are replicated by servos. Myriad evolution in robotic surgery succeeding the pioneer PUMA 360, Medical assistance would be of user friendly robot with force prediction algorithm. Thus the implementation of this paper may push the boundaries of technologies still wider and bigger.

Keywords: Humanoid Arm, Accelerometric Sensor, Flex Sensor, Force Prediction Algorithm.

1. Introduction

This paper deals with controlling and automation of a humanoid arm (artificial human arm) from a remote distance. The process makes use of devices such as IMU 6DOF, Robotic humanoid arm. Robotic humanoid arm replicates the gestures done by the surgeon. Critically intensive operations involving highly experienced Doctors can be accomplished effectively without physical presence of them. A Doctor needs to wrap a socket consisting of IMU 6DOF accelerometer around his arm so that actions made by arm are recorded. This process is also aided with the software simulation involving surgeon to operate on a communicative screen in which the surgeon can sketch or spot the co-ordinates to mark operation spots for fine precision. The robotic arm will infer the co-ordinate points from this spots and does the operation. This process involves in getting the inputs in two forms (i) Analog input through hand positioning using IMU 6DOF, (ii) A specialized software which predicts the co-ordinates of the live camera for fine precision in the operation. This paper is organized as follows: Section (1) presents compliance control strategy. Section (1) describes sensors used. Section (3) describes arm model and mechanics analysis. Section (4) describes the function

of the microcontroller. Section (5) Software prediction in the co-ordinate system. Section (6) provides the experiment result and follows the conclusion in Section (7).

2. Force Predition Algorithm

The flexibility of the humanoid arm motion is a fundamental requirement for human-robot interaction. The force/torque of the end-effector is measured by a 6-axis force sensor located at the wrist. Using the proposed method, it is possible for the humanoid arm to grasp the surgical instruments with a small interference force and keeping the desired hand's posture. Because of the influence of many factors (control algorithm, precision of the sensor, D/A conversion precision and mechanical drive error etc.), there are always some deviations in the real position and posture of the hand when the humanoid arm works. So a kind of compliance control strategy is needed to reduce the interference. In order to realize compliance control, a six-axis force-torque sensor is needed to install between wrist and palm. When hand touches the goal object, it can measure 3 dimension force and 3 dimension torque. The idea of compliance control is when physical

interference happens, the six-axis force-torque sensor feedbacks the size and direction of the interference force in the wrist Six-axis force-torque sensor in the wrist.
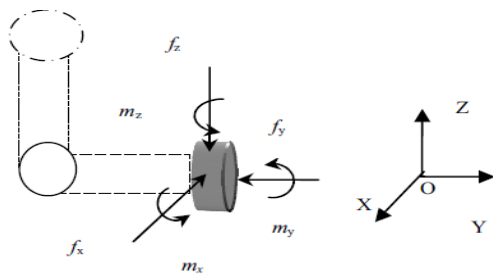

Fig. 1 Six-axis force-torque sensor in the wrist

The idea of compliance control is:[1]

1) When physical interference happens, the six-axis force-torque sensor feedbacks the size and direction of the interference force in the wrist.
2) Following the force can reduce the interference
3) By keeping several parameters (three-dimensional coordinate and three-dimensional posture) of the hand precision movement can be ensured to finish.

For different interference force in direction and size, we take different measures according to the influence of robot stability and the task:[9] If the control error is small, the force between humanoid arm and goal object approach zero at this moment, it can be ignored, now only the basic control algorithm is used. When the mutual force can't be neglected, namely interference force impacting on robot arm makes position posture and planning value of hand relatively heavy difference, which lead to the robot be unable to grasp surgical instrument and enable fluent movements, compliance control takes effect at this moment. The size and direction of force which acts on the humanoid arm can be gotten according to the information (3 direction force, 3 direction moment) of six-axis force-torque sensor in the wrist, and then the arm moves along the direction of the force can weaken the interference force.[3] When the mutual effort is heavy, only by moving the arm is not enough, the arm and the whole body are adopted to take compliance control at the same time. Albeit the set task will be very difficult to continue to finish in case of moving large range, once interference force goes beyond threshold value, the adjustment step must be executed to reduce the interference force, for not causing the hardware to damage. Whereas the last two situations need to rely on motion plan and the stability control, this paper mainly discusses the force and movement control of arm.
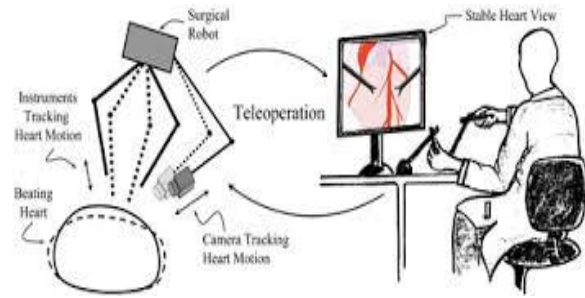
3. Degree of freedom (DOF) of Robotic arm

The robotic arm must be capable of replicating all the movement done by the surgeon. here the surgeon has to wear a hand glows embedded with the sensors. Thus force and inertia of the humanoid arm can be detected by using IMU 6DOF sensors. These IMU sensor have three accelerometers and three gyroscopic sensors in order to find the position and orientation of the hand. The 6DOF makes use of ST's LPR530AL (pitch and roll) and LY530ALH (yaw) gyros, as well as the popular ADXL335 triple-axis accelerometer[3], to give you six degrees of measurement on a single, flat board. The robotic arm imitates a human arm and able to grasp surgical instrument of different shapes and sizes ranging from a small razors to bowls. The robotic arm consists of a shoulder, an elbow, a wrist and five fingers and each finger is designed with three moveable sections except only two for the thumb. The sections in each finger will either be pushed or pulled synchronously using internal linkages and controlled by an 18F4431 microcontroller. Basic movement is pre-programmed to ensure that all the movement is within the allowable constrains, and can be controlled by human operator or automatically controlled by a computer. The 6 DOFs humanoid robotic arm provides wide trajectory coverage over the three-dimensional space around the base. The specified trajectory of each finger, wrist and arm are bio-inspired[4] and carefully designed to resemble the human arm movement.
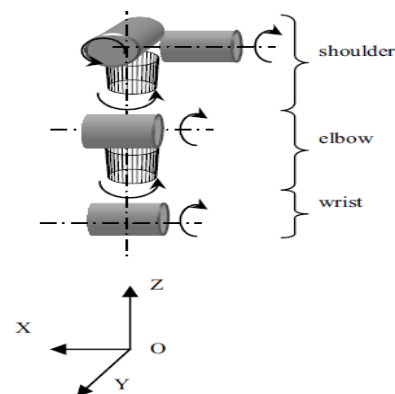

Fig. 2 The model of humanoid robot arm

4. Arm kinematic model and mechanics analysis

A]. *Kinematics model of the robot arm:* The initial posture of the robot arm is assumed: The upper arm is downwards vertical from the shoulder, the cubits is forward stretch and vertical to the upper arm. The reference system of coordinates[1] (the system of the laboratory coordinates) is as follows: X axle : Regard right of initial (state) position of the robot as X axle of the system of the laboratory coordinates; Y axle : Assume y axles according to right hand system of coordinates, namely the front just be y axle; Z axle : Take initial above the position as Z axle of system of laboratory coordinates; The right arm has 6 DOF , 3 in the shoulder, 2 in the elbow, one in the wrist.

B]. *Mechanics Analysis:* The compliance control criterion is gotten by deriving of kinematics formula, analysis force under the typical arm state, imitating passive movement of arm under one dimension force effect. Firstly we discuss the hand is only affected by y axial force in initial state. Following force can be realized only moving the first and the fourth joint by theoretical [5] mechanics analysis, the proportion of angle change is$\Delta\Theta1:\Delta\ \Theta4=1:(-1)$. At this course the hand displaces in the y axial, and do in the Z axial: $\Delta h=(1-\cos\ \Theta1)L1$.But in this paper the interference force is little, so $\Delta\ \Theta1$ is very little, here $\Delta h=(1-\cos\ \Theta1)L1$ can be ignored, following movement is in y direction basically, and the other location and posture of arm keeps mainly. And then we discuss the typical situation of grasping surgical instruments is the typical posture of grasping object, the arm stretches forward, the wrist joint $\Theta_6 \neq 0$ keeps the posture to grasp object such as the control lever, the cup or the torch, etc. There must be the first and the fourth joint movement According to the theoretical mechanics analysis, the proportion of the angle change is:

$$\Delta\Theta1:\Delta\ \Theta4:\Delta\ \Theta6=1:(-2):1$$

Similarly, the simple model by the other one-dimension force can be gotten, and the proportion of the angle change of the corresponding joint can be gotten. These proportionate relationships will be as the foundation of the compliance control regular storehouse in the next section.
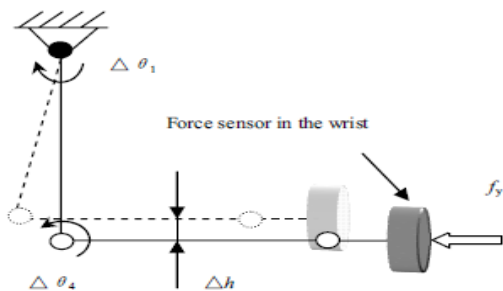

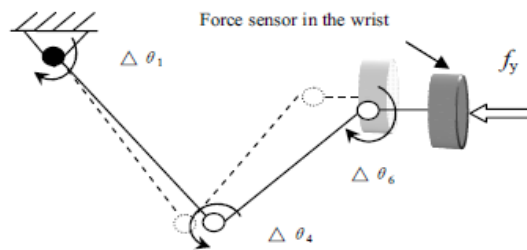Fig. 3 The simple model of the arm by y axial force

Fig. 4 The representative moving model

The 6DOF sensor inputs are feed to the micro controller to analyze the co-ordinates and the gyroscopic angles. And these data's are manipulated and transmitted via computers. This data's are transmitted through remote receiving end computers. The pre-defined algorithm activates the servo motor according to the co-ordinates received. By this way the surgeons hand is replicated using actuators in the humanoid arm.
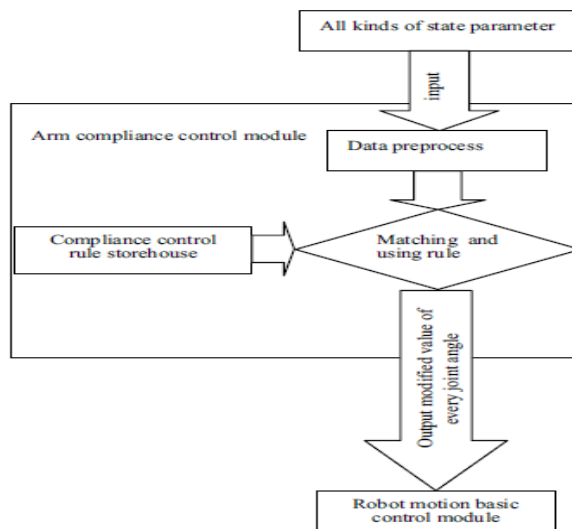

Fig. 5 The flow chat of the compliance control module

5. Communicative Screen

A].*Transformation between frames of reference:* We use specialized software that eradicates the human hand shivering errors. This software provides fine precision over the surgery process. [12]we know that human hands are prone to shakes and vibrations and such vibrations are vulnerable and may produce mishaps during the operation. In order to eliminate such vibrations, software is designed that uses a communicative screen. This screen is touch sensitive and the surgeon needs to place marks or points of where the cut has to be made. The robotic arm will diagnose the coordinates of these spots and makes the cut accordingly. Thus with the help of the software, even small dia cuts can be made with absolute precision and this eliminates human errors.

In three dimensional space, we can define a frame of reference using three perpendicular axes normally labeled x, y and z. A transformation between two such frames involves specifying the location of the origin of one frame relative to the other and the

relative orientation of the three axes. Fortunately for us, this problem was solved centuries ago and we can just write down the transformation equations without having to derive them from scratch.[2] If we are given the angles of the various joints in an arm—robotic or biological—together with the lengths of the segments between joints, it is a simple matter of geometry to compute the location of the hand in three dimensional space. This problem is called the forward kinematics of the arm. On the other hand (so to speak), if we are only given a desired position of the hand in space and asked to compute the angles of the joints that will put it there, we face the harder problem of computing the inverse kinematics of the arm.[8] The reason this problem is hard is that the forward transformation defines a non-linear system of equations [2]. While linear systems are generally straightforward to solve, non-linear systems often require figuring out a different solution at each point along the arm's trajectory. Furthermore, depending upon the number of joints in the arm, also known as its degrees of freedom, there may be one solution, no solutions or an infinite number of solutions for positioning the joints to get the end effector to the target location.

B. *Degree of freedom:* The numbers of degrees of freedom of a mechanism are defined as the number of independent variables that are required to completely identify its configuration in space [3]. The number of degrees of freedom for a manipulator can be calculated as

$$n_{dof} = \lambda(n-1) - \sum_{i=1}^{k} (\lambda - f_i)$$

where n is the number of links (this includes the ground link), k is the number of joints,f_i is the number of degrees of freedom of the ith joint and λ is for planar mechanisms and for 6 spatial mechanisms.

We transform the coordinates of the surgeon into a reference frame attached to the robotic arm. Once we know where the target is relative to the arm, we can compute the joint angles necessary to have the arm point to this location in space.

In addition to replicate the finger's orientation and movement special flex sensors have been incorporated in the glow for each finger. These enables the humanoid fingers to be more specific in their movement, thus aiding fine movement prediction in the surgical operation.

6. Experimental Results

A humanoid arm having 12 DOF and a six-axis force-torque sensor in the wrist designed by[1]. As tested in the first prototype of humanoid robot BHR-01, the following response graph is obtained. Control the robot to grasp an object fixed on tablet at

first. In case of not adopting compliance control, [1] the physical interference between the robot and object will make the robot overbalance, body inclination changes the posture of hand, so the arm can't finish to grasp surgical instruments smoothly[1]. The arm can grasp object successfully after using our compliance control method.
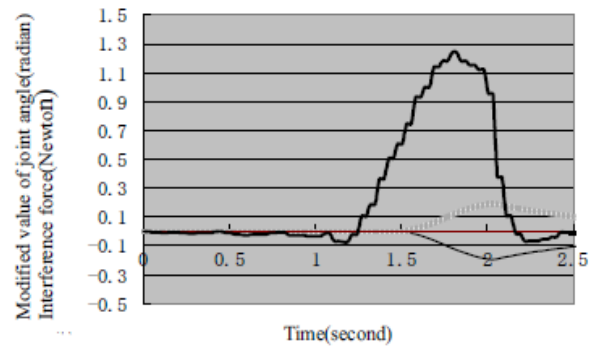

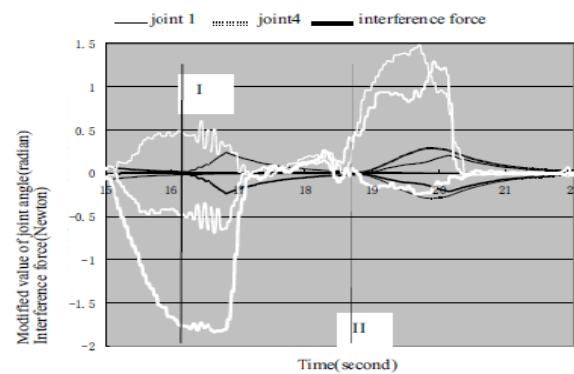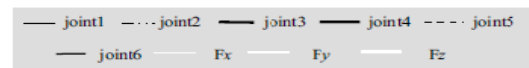Fig. 7 Change of every joint angle under y-axis interference force

Fig. 8 Change of all joints angle under random force

There has been variation in the actual and reciprocated movement of the humanoid arm which is overcame by using an communicative screen and a force prediction algorithm. This communicative screen is incorporated with pressure detection while marking the spots for the operation. Depending on the pressure given the humanoid arm applies force with the razor. This enables the surgeon to operate with ease.

7. Conclusions

The flexibility of the humanoid motion is an important issue for human-robot interaction. This paper focused on the arm's compliance motion for a humanoid remote surgical operation.
The results of the paper are concluded as follows:
(1) A compliance control strategy based on force sensor is presented.
(2) The algorithm of arm compliance control is derived.
(3) Interactive Software for fine precision in surgery.

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