Software Architecture for Haptic Integration 6 DOF Articulated Manipulator

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ABSTRACT

The development of a general software for haptic integration of 6 degrees of freedom articulated robot through C language is discussed in the paper. The paper mainly focusses on development of the basic software architecture along with its algorithm. The software along with its graphical user interface has been developed and tested.

KEYWORDS: *Articulated Robots, Haptics Technology, Virtual Reality*

I. INTRODUCTION

Design and development of the slave manipulator i.e. articulated robotwhich is to be fitted in dangerous environment, unsuitable for humans, is crucial when it comes to remote actuation and hazardous situation response management. Control scheme for slave manipulator, installed in hazardous environment requires, as inputs, the desired position, velocity, and acceleration of each joint of the manipulator. Scope of this paper is to briefly discuss the development of acontrol software which acts like interface between master-controller board and slave manipulator.

It is most natural to specify the desired trajectory of the end effecter in Cartesian coordinates. Therefore, it is desirable to have a command generator which has, as input, a desired Cartesian trajectory (time series of data points x, y, z, roll, pitch and yaw), and as output a series of data points that would serve as a joint space command for the manipulator. The proposed Command Generator would generate a series of data points which are derived from Haptic device state, that consists of joint positions corresponding to Cartesian trajectory. [1]

Based on the above description the important task areas are:

- Kinematic modelling of the robotic manipulator
- Handling and interpreting input data that facilitates natural operation of the manipulator
- Choosing most advantageous Mapping Technique for mapping between two workspaces (Haptic device and Manipulator),as link dimensions of Haptic device and manipulator are not in proportion
- Sending Joint space parameters to controller residing at manipulator
- MonitorSafety of the system

The paper is divided into 5 sections as follows

1) Kinematic Modelling of Articulated Manipulator
2) Haptic Devices
3) Workspace Mapping Techniques
4) Motion designing
5) Safety of Instruments

II. KINEMATIC MODELLING OF MANIPULATOR: GEOMETRIC SOLUTION

Kinematics is the study of motion without regard to the forces that cause it. Hence the study of kinematics of the manipulators refers to all the geometrical and time based properties of motion. Manipulators consist of nearly rigid (ideally perfectly rigid) links which are connected with joints which allow relative motion of neighboring links. For this case all joints are rotary or revolute, hence joint parameters are the angles with respect to other links. End effector co-ordinates are taken as final solution for the angles in between joints. Knowing the robot link lengths and orientation, DH (Denavit–Hartenberg) parameters can be estimated for each joint. As given by following equation, transformation matrix for converting from n^{th} frame to $(n+1)^{th}$frame is

$$^{n-1}T_n = \begin{bmatrix} \cos\theta_n & -\sin\theta_n & 0 & a_{n-1} \\ \sin\theta_n \cos\alpha_{n-1} & \cos\theta_n \cos\alpha_{n-1} & -\sin\alpha_{n-1} & -d_n \sin\alpha_{n-1} \\ \sin\theta_n \sin\alpha_{n-1} & \cos\theta_n \sin\alpha_{n-1} & \cos\alpha_{n-1} & d_n \cos\alpha_{n-1} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Here,variables used in the equation can be easily understood by the following figure. Combining all the joints matrices and solving for **Θ**, joint angles can be found out. As shown in figure 2 both elbow up & elbow down solutions are available for usage, depending upon the type of the robot.The figure shows robot interface available through OpenGl software interface.

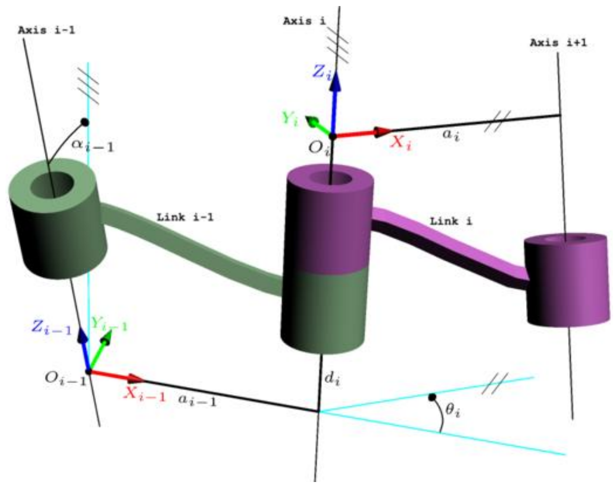

Figure 1 DH parameters

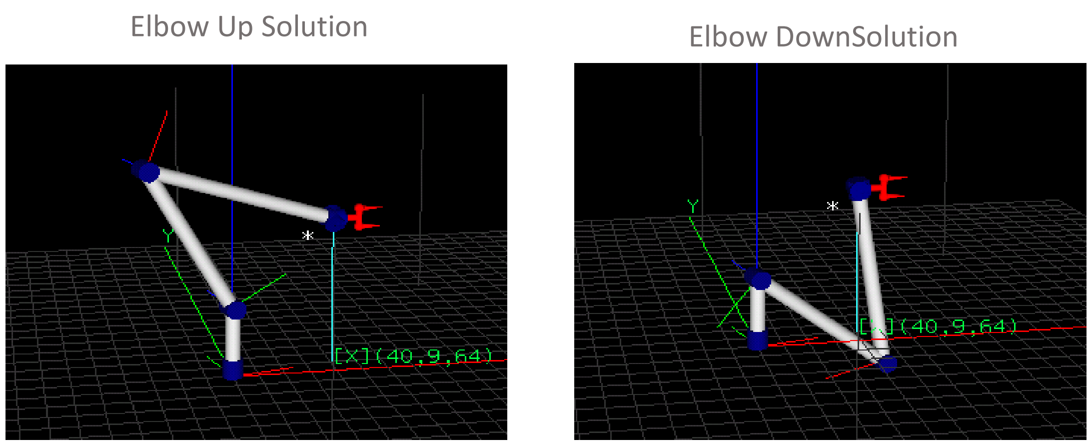

Figure 2 Two different solutions

III. HAPTIC DEVICES

Haptics is the technology of adding the sensation of touch and feeling to computers. A haptic device gives people a sense of touch with computer-generated environments, so that when virtual objects are touched, they seem real and tangible. This mechanical stimulation may be used to assist in the creation of virtual objects for control of such virtual objects, and for the enhancement of the remote control of machines and devices (tele-operators). Most haptic devices use torque feedback which restricts the haptic device motion according to the boundary conditions defined in the virtual world.

As haptic devices directly give the feeling of an object theyare very intuitive to use. Thus, can be used tocontrol remote machines easily.It takes a lot of time to train operators to operate bigger machines such as robot arm placed on the vehicle or snake robot. If haptic devices are used for controlling the machines, being intuitive, machines are easily controlled without any prior knowledge of the system. For system discussed in the paper,haptic device is similar to a robotic arm in elbow down position. Here encoder values are taken as an input for the program which are then mapped via workspace mapping technique asdiscussed in section 3

Figure 3 Haptic Device

IV. WORKSPACE MAPPING

The mapping of actual workspace to the haptic workspace is a tedious task as the size of workspace have a many fold difference. Directly giving the co-ordinates or directly feeding angles won't give the accuracy and precision required by the system. Also, it will be susceptible to human hand vibrations & jittery movement. Even the link lengths of the manipulator are not in proportion to the haptic device dimensions.[3]

Every point in manipulator workspace needs to be accessible individually through the haptic workspace. According to need, different mapping techniques were tested. Direct mapping- directly puts the haptic end-effector coordinates to the target manipulator workspace. The workspace themselves don't match in proportion and small movements in haptic space did cause large movements in actual workspace. Up scaling: In this type of mapping, co-ordinates of manipulator are directly multiplied with a constant which is suitable andthen values are directly fed to Inverse kinematics code. Here if proportionality constant is large enough then entire workspace will be mapped.But because of simple scaling the workspace motions would be violent as humans move their hands with high speeds and this speed when multiplied with proportionality constant, will increase velocity of slave arm to a very high value. Also if manipulator is to be kept constant, haptic device should be kept constant which is impossible to execute with a human hand.

In Differential mapping technique, as shown in figure4, if the haptic device is pointing in one direction then it starts moving the slave in that direction. One small safety cube/sphere around the origin can be added if necessary. This ensures that manipulator will not oscillate about itself when haptic device is pointing to origin, due to human hand oscillations.But here feel of haptic device is not achieved since the same operation can be achieved with the help of keyboard or a joystick. Also the speed with which the workspace is to move should be perfect otherwise the workspace would either move very fast or very slow.

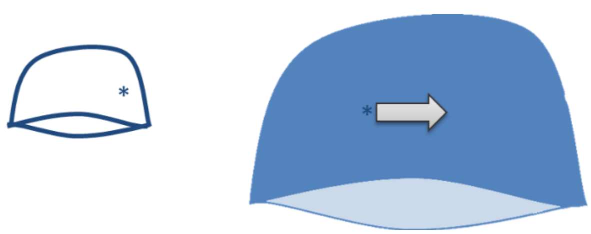

Figure 4 Differential mapping

Workspace shifting is the workspace mapping technique which is used in the present system and almost all the problems which are stated above are solved by this mapping technique. As shown in figure 5, haptic device is pointing in middle of the haptic workspace the points are directly mapped or may be down scaled if much higher precision is needed. And as soon as haptic device pointer starts pointing to the area which is near to the edges it starts shifting the slave manipulator in the direction in which manipulator is pointing. Thus this method is combination of Direct mapping technique and Differential mapping technique. Since one can set the velocity, manipulator is safe to operate and also it is directly mapped so precision is also maintained. In fact this precision can be increased to a very high value by using down scaling.

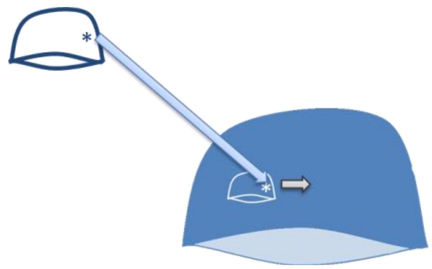

Figure 5 Workspace Shifting Mapping

V. MOTION DESIGNING

Any trajectory i.e. end effector movement can be generated with linear combination of movements in X/Y/Z directions, and any orientation at an optimal velocity can be limited by hardware constraints. For line fitting between data points, spline fitting is used.[2]

VI. SAFETY OF INSTRUMENTS

Heart Beat

When a motion controller is started on,motion controller starts listening to commands from PC and executes it. But if there is communication loss or power failure from the command center itmust be shut down properly because there is danger of unexpected movement or manipulator will be locked in that position.Hence a method is used for overcoming such situation. In simple words 'If there is no command from the operator, assume that there is a communication lapse& shut down the system'.

Here, a variable (Heart-Beat-Variable) is constantly reset to a particular & pre-set value by the command center in each loop.This variable is decremented bymotion controller every loop. If value of Heart-Beat-Variableis not reset tooriginal value within some duration, controller will assume thatcommunication with command center is lost and it must bring manipulator back to its home position and shut down the entire system.

Torque Management

Articulated robots work usinghigh load motors which require continuous monitoring of torque values. If the load on any motor is higher than its limiting capacity, that motor will fail & will bring down the whole system, risking safety of people around it & itself. Hence if the loads on motors are higher controller brings back the manipulator to home position & sends system message to the controlling PC.

VII. CONCLUSION

The software discussed in the paper is for articulated manipulators & can be modified according to specific needs. Steps detailing the operation are tabulatedbelow.

- Accept the Encoder values of each joint from the haptic device i.e. get end effector pose and position of the haptic device
- Map the workspace, as dimensions of slave manipulator and haptic device are not in proportion
- Perform inverse kinematics operation on these values to get Joint space angles
- Send these values to Motion Controller
- Monitor important parameters such as torques on each motor and frequency of operation

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