Arm Exoskeleton to Control Industrial Robot

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Introduction

Tele-operation is the process of operating a machine at a distance. In situations like space applications or disasters we encounter situations where the environment is hazardous to human health. It is expedient to deploy robots in such locations. Their motion is controlled by human operators positioned at a safe distance from hazard centers with radiation and chemicals.

In space programs, the rovers on other planets are controlled remotely from earth. Recently in Japan, after the damage caused by the tsunami and the earthquake, robots were deployed for shutting down the nuclear plants and carrying out rescue missions.

However, even for seemingly innocuous tasks like inserting a peg in a hole, it is difficult to provide instructions in the form of a predefined algorithm. Currently, we are to go a long way before we can make task planning systems matching the human brain, telepresence provides us with a convenient approach to deal with certain class of applications. There have been successful implementations of human arm exoskeleton [1, 2, 3, and 4].

The controlling device may be a mouse, a joystick or a steering wheel. To make the interface more intuitive, it can be a wearable robot or exoskeleton as shown in Figure 1. Although there have been attempts to track arm movements without exoskeleton, such an approach fails to provide for a feedback system [5].

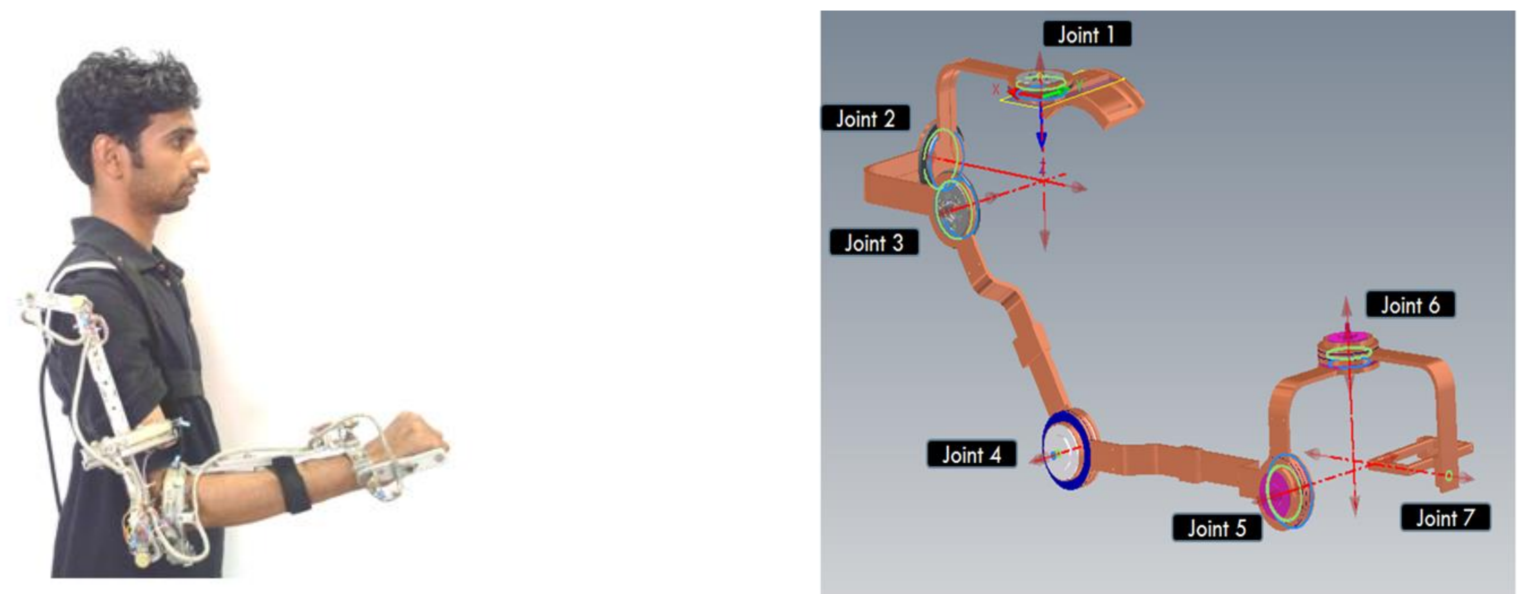

Figure 1: Exoskeleton for teleoperation of industrial robot

Methods and Materials

KINEMATICS DESIGN

Our work focuses on an exoskeleton which has been developed (Figure 1) to be worn on a human arm, and provide the necessary information for effectively controlling an industrial robot through hand motion. The application targeted is a peg in a hole insertion, which is to be carried out by a KUKA KR5 ARC manipulator. For effective functioning, the end-effector's motion of the master device, in this case the exoskeleton, is reproduced in the slave device, in this case the KUKA robot, with power amplification as desired. This type of control is called position-position tele-operation. The KUKA KR5 is a six degree of freedom (DOF) manipulator, whereas the human arm, and correspondingly the anthropometric exoskeleton (shown schematically in Figure1), has seven DOFs. There are three degree of freedom at the shoulder joint, two at the elbow joint and two at the wrist. Sensors are mounted on seven different places on the exoskeleton in order to sense the variations of the joint angles. Tekscan's FlexiPot Potentiometers are used for shoulder joint and pronation–supination (twisting) of the elbow joint. Rotary Potentiometers are used for the measurement of angle of rotation of flexion–extension (forward-backwards) and abduction–adduction (inside-outside) motions.

The Brakes, each of which weighs at 400gm can exert considerable strain on the wearer upon prolonged exposure. Spring based gravity balancing techniques [6] can counter gravity loading without compromising dynamic performance. Points of attachment of the springs are selected so that the energy variation with change in the mechanism configuration is zero. The minimum number of springs depends on the number of independent potential energy variation terms in the energy equation. Gravity balancing for the exoskeleton with 2 brakes at the wrist has been done. Four possible configurations where investigated for the system modeled as two link planar problem.

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GRAVITY BALANCING

Matching the net potential energy of the Mechanism to that of the springs yields the following constraints were evaluated:

Since we are at liberty to select d1 and d2, we assume d1 = d2, thus we will need to find springs with similar spring constant, which is easier than finding two different types of springs.

M = mass of two brakes at the wrist (0.8kg) +half the mass of exoskeleton without the brakes (0.6kg) thus M = 1.4kg.

The primary criteria for selecting a spring has been the available extension which is of the order of 0.5m

One such spring is LEM080BB05 (highlighted in the document named catalog1) whose natural length is 290mm, max extended length is 515mm and spring constant is 110N/m.

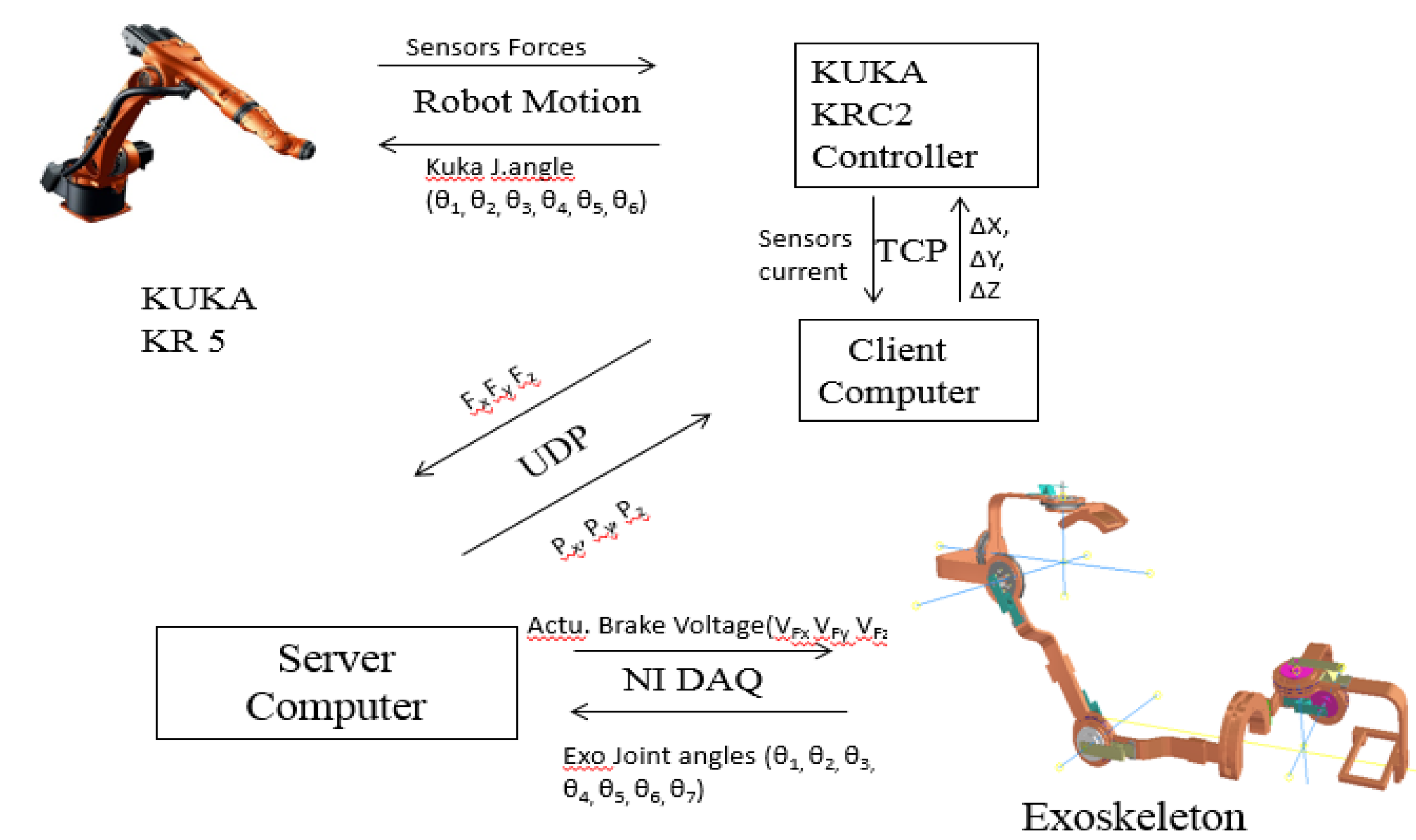

Figure 2: Algorithm to control the industrial robot

Figure 3: Controlling an Industrial robot by an arm Exoskeleton in the PAR Lab, IITDelhi

Conclusions

Human arm measurements vary to a substantial extent and we have had considerable difficulties in fitting the exoskeleton to personnel outside our lab. Misalignment between the Human and exoskeleton axes strains the wearer. It has come to our attention that certain consecutive links no longer stay in plane as desired as an immediate consequence of such strain. Also the current potentiometers fitted on the exoskeleton provide mediocre repeatability which at times causes discrepancy between the exoskeleton and the Manipulator position. To account for these shortcomings a new design of the exoskeleton is being drafted. Haptic feedback provides the operator with a better understanding of the remote environment, especially in situations where visual feedback does not have sufficient resolution. For enhanced telepresence, the new design of exoskeleton is to include three axis haptic feedback, and more compact electronics. The reaction forces sensed by the robot during the insertion procedure will be used to drive magnetic particle brakes to let the operator to feel the reaction seen by the industrial manipulator.