Touch and Force Reflection for Telepresence Surgery

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Abstract:- This paper describes our on-going work on the development of an advanced telepresence glove, capable of providing touch and force reflection to the human operator. Such a glove will be essential in a telepresence surgery environment. The development of the glove currently constitutes three steps. First, an algorithm is being developed to map human finger motions on to the generally dissimilar robot hands, using the human grasp posture as the reference criteria. Second, a touch reflection system is being built where a set of touch sensors, placed on the robot finger tips, detect touch and activate a set of shape memory alloy based actuators attached to the human finger tips. Third, a force reflection system is being developed where a set of flexible pneumatic tubes, attached to the human fingers, reflect the grasping forces of the remote robot fingers.

1 The Problem

Telesurgery can be performed by creating a telepresence environment where in a surgeon can interact with remotely located patients. For an effective interaction, the surgeon must be provided with an illusive feeling of being present at the surgical site and he must be suitably equipped to perform dextrous telemanipulation of medical equipment and surgical tools.

The feeling of presence can be achieved by providing him with visual display of the surgical site via a head mounted display. To achieve teledexterity - which is the central problem in our work - we need a human hand interface and a suitable robotic end-effector to dexterously manipulate remote objects. Our current work is concerned with designing an advanced hand interface that will enable a human to perform dexterous manipulation of distant objects while receiving the necessary haptic informations in a closed-loop as shown in Figure 1.

The problems that must be addressed in this context are: how do we project the dextrous manipulative ability of a surgeon's hand on to a generally dissimilar multi-fingered slave robotic hand placed at the surgical site? and, how do we make a surgeon's hand feel the touch and the gripping forces experienced by the fingers of the slave robotic hand? As shown in Figure 1, achieving dexterous telemanipulative ability needs exchange of certain informations between the hand of the human operator and the remote robotic hand. Further, the haptic informations (force/touch), fedback to the human hand, must be compatible to the human perceptual requirements in terms of resolution, magnitude, and bandwidth. Building a glove-like device that will provide humans with these capabilities is the primary objective of this work.

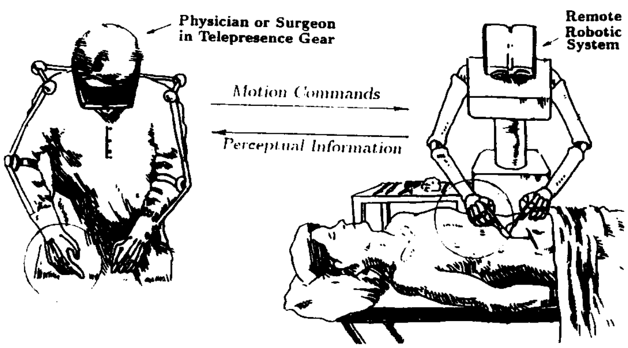

Figure 1: Telepresence Environment for Performing Surgical Procedures.

2 The Approach

2.1 Projecting Finger Movements

Projecting the movements of fingers from the human hand on to an unisometric (kinematically dissimilar) robotic hand is not a trivial task. The human hand has five fingers while the existing gloves can measure motions of 2-5 fingers (Shimoga, 1993a). Further, most existing multi-fingered robot hands have 3-4 fingers. The dissimilarity in the number of fingers complicates the task of motion mapping from human hand to robot hand. The task becomes further complex because of the number of active joints involved in the projection. As shown in Figure 2, the degrees of freedom (DOF) of the human hand is 21, and that of most existing position sensing gloves is less than 21 while the number of joints of most existing robot hands is also less than 21. This inequality in the number of fingers and joints and the possible kinematic (dimensional) dissimilarity makes it a non-trivial task to map motions from human hand to robot hand via glove.

To date, 3 types of algorithms have been developed by researchers for motion transformation: (i) linear joint angle mapping (Hong and Tan, 1989), (ii) finger pose mapping algorithm (Pao and Speeter 1989; Speeter 1992), and (iii) finger tip position mapping (Rohling and Hollerbach, 1993). However, all three methods have their own drawbacks when the remote robot hand is dissimilar to the surgeon's sensorized glove. To address these limitations, we are currently developing an algorithm that takes into account the unisomorphic nature of the gloves, the robot hands and the human hand. Further, the algorithm uses the overall grasp posture as the quality criteria for motion mapping. Therefore, unlike other existing algorithms, the new algorithm is expected to overcome the problem of yielding awkward postures at the robot hand for a reasonably good posture of the human hand.

2.2 Finger Touch Reflection

When using a robot hand as the remote medical end effector, providing the physician with a feedback sensation of touch from the robot fingers will positively enhance the physician's performance. Thereby, the physician will be

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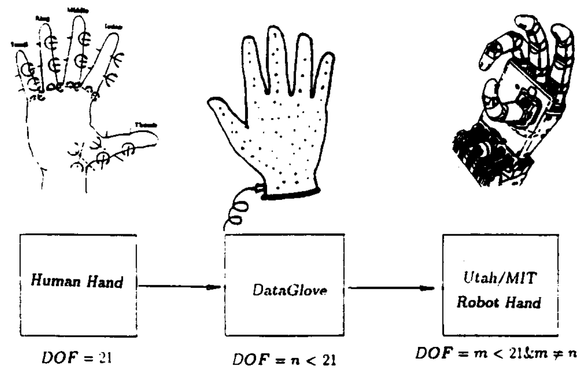

Figure 2: The problem of mapping human hand motions on to a dissimilar robotic hand.

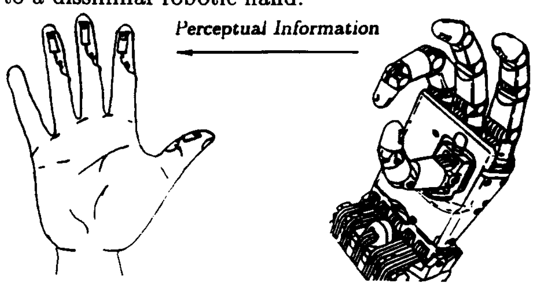

Figure 3: The touch reflection system under development.

able to judge the instance of each finger touching something in its surroundings and to know if the grasped object is slipping. Hence, he/she will be able to perform telepresence tasks in lesser duration of time and with fewer errors (Shimoga, 1993b). Such an ability is not only desirable but will be crucial to tasks involving grasping and manipulation of delicate objects and surgical tools.

The touch reflection system under construction is illustrated in Figure 3. The system performs two tasks: (i) touch sensing at the robot hand fingertips using force sensitive resistor (FSR) type tactile sensors, and (ii) touch reflection to the human hand fingertips via shape memory alloy (SMA) based micro-actuators (TiNi, 1993). The control computer will actuate the tactors as soon as the FSRs sense the touch of an object. The tactors provide a tingling sensation to the pulpy portion of the human fingertips. The tingling sensation is interpreted by the human operator as if the particular finger is in touch with an object. When fully functional, the touch reflection system will be embedded into a position sensing glove.

2.3 Finger Force Reflection

Of the several hand interfaces that currently exist in laboratories around the world (Shimoga, 1993a), very few have force sensing and limited force reflection capabilities. However, many of them are known to be either bulky or unsuitable for handling small objects. Hence, there exists a need for developing a portable force reflecting device capable of handling small objects. Interestingly, no such commercial system exists to date.

The force reflection system that we are developing is illustrated in Figure 4. As shown in the figure, the micro-actuators constructed from tri-segmented pneumatic tubes, similar to that developed by Suzumori (1991), will be attached to the ventral surface of the human fingers. The pneumatic micro-actuators apply reaction forces to the fingers to make the human operator feel as if he is directly manipulating the remote objects.

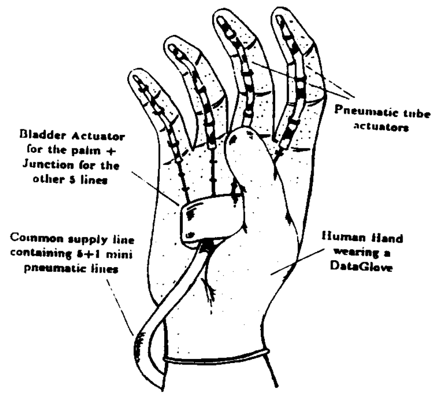

Figure 4: The force-reflection system under development: the arrangement of the pneumatic tubes on the ventral sides of the human operator's fingers.

3 Conclusion

The need for a touch/force reflecting glove-like hand interface, for a surgeon to interact with a remotely located patient within a telepresence surgery environment, has been identified and such a glove is being designed and built. The motion mapping algorithm, currently under development is expected to overcome the problem of "grasp posture distortion" when the human grasp posture is mapped on to a dissimilar robot hand. The FSR-SMA based touch reflection system should prove to be useful for detecting touch while the pneumatic based force reflection system should prove to be useful for sensing the grasping forces. When fully functional, the glove will enable a physician to grasp and manipulate remote surgical equipment with less difficulty in a telepresence surgery environment.

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