LASER BASED TELEROBOTIC CONTROL FOR ASSISTING PERSONS WITH DISABILITIES PERFORM ACTIVITIES OF DAILY LIVING

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Abstract: In this paper we demonstrate an innovative use of range information from a laser sensor mounted on the end- effector of a remote robot manipulator to assist persons with disabilities carry out ADL (Activities of Daily Living) tasks in unstructured environments. Laser range data is used to determine goals, identify targets and via points to enable autonomous execution of trajectories. The human operator performs minimal teleoperation and is primarily involved in higher level decision making. We hypothesize that laser based assistance improves task performance in terms of time and accuracy and also reduces the cognitive load on the user executing the task. Tests on ten healthy human subjects in executing a remote manipulation task conform the hypothesis.

1 INTRODUCTION

Robotic devices have thus been used to enable physically disabled individuals to execute ADL tasks (Bolmsjo, Neveryd and Eftring, 1995). However, teleoperation of a remote manipulator puts a lot of cognitive load on the operator (Bolmsjo et al., 1995). Our previous work at the Rehabilitation Robotics Laboratory at University of South Florida has focused on augmenting the performance of motion-impaired users in job-related tasks using scaled teleoperation and haptics (Pernalete, Yu, Dubey and Moreno, 2002) and assistance based on real-time environmental information and user intention (Yu, Alqasemi ,Dubey and Pernalete, 2005). In this work the laser data is used to determine goal points, identify targets and via points in unstructured environments that enables autonomous execution of certain sub tasks under human supervisory control thus providing assistance to the human. The human is still in the loop to make high level decisions like pointing the laser to critical points in the remote environment by teleoperating the arm.

Hasegawa, Suehiro and Takase (1991) made use of the laser range information to compute and record 3D co-ordinates of points on objects in the environment, to enable autonomous task execution. Takahashi and Yashige (2000) presented a simple and easy to use laser based robot positioning system to assist the elderly in doing daily pick-and-place activities. Nguyen, Anderson, Trevor, Jain, Xu and Kemp (2008) made use of an arrangement consisting of a laser pointer, a monochrome camera, a color filter and a stereo camera pair to estimate the 3D co-ordinates of a point in the environment and thereby fetch objects in the environment designated with the laser pointer.

2 LASER ASSISTED CONTROL

We have used PUMA560 as the remote manipulator and Phantom Omni haptic device as the master. The human user by means of teleoperation points the laser to critical points in the environment. These critical points could be goal points, objects or planar surfaces of interest. The laser sensor is mounted on the end-effector of PUMA and has the same orientation as the end-effector. The laser beam direction thus will always be parallel to the z axis of the end-effector.

2.1 Laser Assisted Target Position Determination and Autonomous Trajectory Execution

The user points the laser to a specific target and

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locks the target by ceasing to teleoperate. Then as the user commands by pressing a keyboard key, the machine generates a linear trajectory from the current PUMA end effector location to the target point determined by the laser and also executes the trajectory.

For generating a linear trajectory, the initial and final transformation matrices are required. The initial point transformation matrix is determined from PUMA forward kinematics and that for the final point is determined using laser range data and (1) (ref Fig. 1).

$$T_O^B = T_E^B * T_L^E * T_O^L \qquad (1)$$

2.2 Laser Assisted Autonomous Surface Alignment

For certain ADL tasks determination of orientation of the planar surface associated with the target is necessary to orient the end-effector in such a way that it is aligned with the perpendicular to the surface. This alignment has been implemented as an autonomous function using laser data and it helps the user to manipulate a target from a convenient angle in teleoperation.

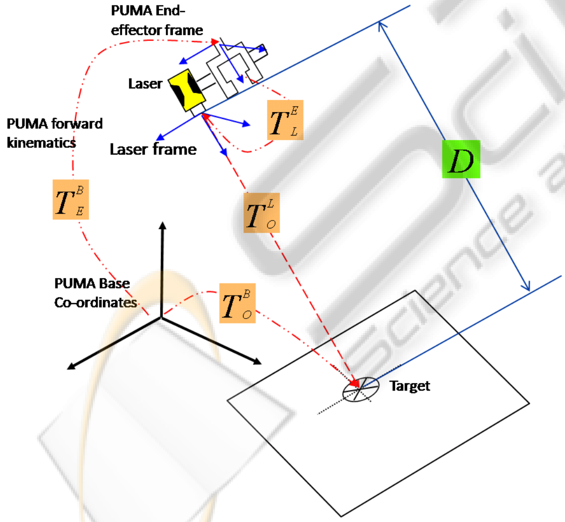

Figure 1: Autonomous trajectory generation concept.

The user points the laser to three distinct points on the planar surface to record their co-ordinates. When the user activates autonomous alignment algorithm, the transformation matrix required for end-effector alignment is computed online and the end-effector aligns with the surface. The z-component of the rotation component of the transformation matrix is the same as the unit vector along normal to the surface which is computed by the cross product of the vectors connecting the three points P1, P2 and P3. The x and y-components are then obtained using the right-hand rule.

3 APPLICATION OF LASER BASED CONCEPT IN TASK EXECUTION

Fig. 2 shows the sequence of steps in executing a pick and place task using laser assistance. The user starts with locating the destination point by pointing the laser in teleoperation and commanding the system to record the co-ordinates of that point (Fig. 2(a)). Next the user identifies three random points on the planar surface with the laser (Fig. 2(b)). After this the user locates the target object with the laser and commands the execution of the autonomous trajectory (Fig. 2(c)). When the arm stops near the target (Fig. 2(d)) the user commands autonomous alignment with the planar surface (Fig. 2(e)). Now as the arm is in a convenient configuration for grasping the user makes fine adjustment in teleoperation to locate the gripper exactly over the target to grasp it.

Next the user commands the system to autonomously execute a path from the current location to the destination point while avoiding the obstacle. The path is executed in three linear segments. , the first being from the current PUMA location to a point vertically above it so that the arm is clear of the tallest obstacle (Fig. 2(e) and 2(f)), the second being in the horizontal plane from this point to a point vertically above the destination (Fig. 2(f) and 2(g)) and the third is to a point just above the destination (Fig. 2(g) and 2(h)). The initial and final transformation matrices for each segment are computed by the system from forward kinematics, the heeight of the tallest obstacle and the destination point coordinates. The height of the tallest obstacle is determined by pointing the laser to the top of the obstacle and recording the co-ordinates.

After the arm has traversed the path, the user makes fine movements to precisely locate the target over the destination by teleoperation and places the target. Thus we see that the human is only a supervisor and is involved in minimum teleoperation. The trajectories and generated online and executed autonomously. Moreover the interface consisting of pointing with laser and pressing

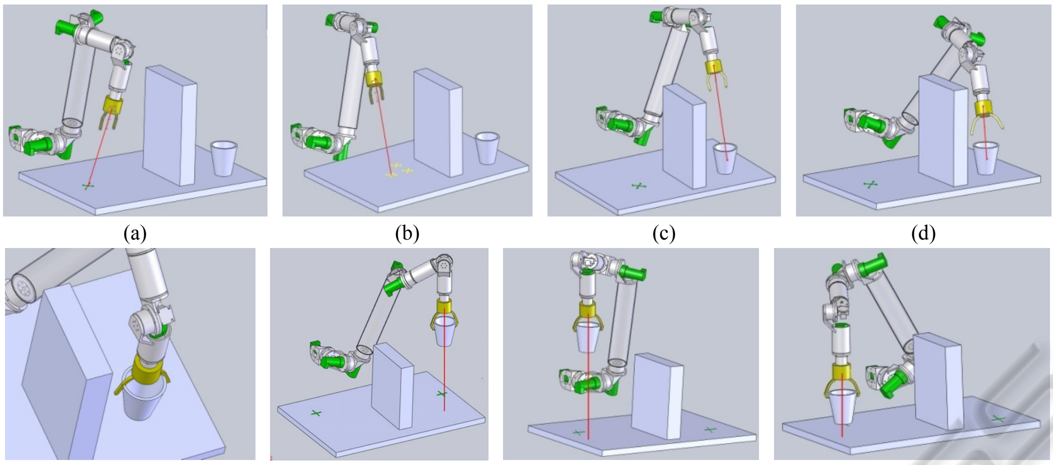
(a) (b) (c) (d)
(e) (f) (g) (h)

Figure 2: Laser based features in pick and place task execution: (a) Pointing to destination point for path planning (b) Pointing to platform points for planar surface orientation determination (c) Pointing to target (cup) for autonomous trajectory generation (d) End of autonomous trajectory (e) Autonomous end-effector alignment (f) Autonomous path – end of first segment (g) Autonomous path – end of second segment (h) Autonomous path – end of third segment.

keyboard keys is simple to use. This way we aim at relieving the human from much cognitive load in task execution. The destination point, target and surface could be located anywhere in the environment and thus the method can be used for manipulating in unstructured environments.

4 TESTS AND RESULTS

The test bed consists of PUMA and Omni manipulators (Fig. 3). A SICK DT60 laser range finder and a Logitech MT Orbit CCD Camera were mounted on the PUMA end effector.

For testing, 10 healthy subjects were asked to perform a pick and place task thrice in each of the two modes, one is the unassisted teleoperation mode and the other is the laser assisted mode. For each run the time taken to complete the task, the end effector Cartesian co-ordinates and the user experience were recorded. Before starting the tests the subjects were given sufficient time to acclimatize with the system. In general each subject was given 5 to 6 trials before testing.

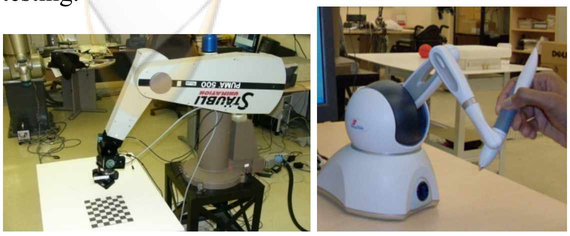

Figure 3: Test bed of PUMA and Omni manipulators.

The experimental set up is shown in Fig. 4. The cup is the target which is to be picked up from the location shown, and placed on the orange sticky shown to the left. The folder simulates an obstacle. The task here is to command the arm from a ‘ready’ position towards the target, grasp the target and place it over the destination point while avoiding the obstacle.

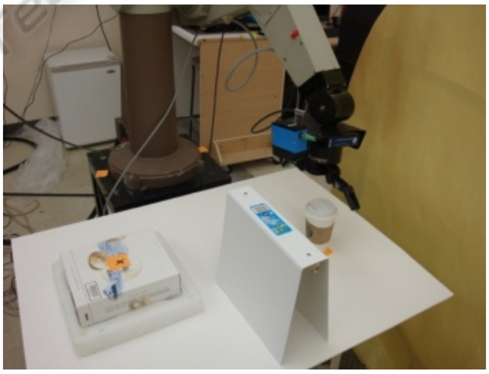

Figure 4: Experimental set-up for pick and place task.

The task performance is compared between the two modes in terms of accuracy and time. Accuracy is presented in the form of the path traversed by the end effector in the two modes.. Plot for only one subject is shown in Fig. 5. We observe that the motion generated by laser assisted mode was, continuous and accurate. On the other hand the motion in the unassisted mode was discontinuous and the arm often deviated from the path. The subjects had tremendous difficulties in teleoperating the PUMA without any assistance. The loops around the pick-up point are due to subjects repeatedly trying to orient the gripper properly so that it is in a convenient configuration for grasping. Orienting the arm properly was one of the most challenging activities the subjects faced.

Figure 5: Accuracy in path traversal for laser assisted and unassisted modes.

The average time per subject per mode was computed and is presented in the form of plots in Fig. 6. We observe that each subject spent more time to complete the task in the unassisted mode than in the laser assisted mode.

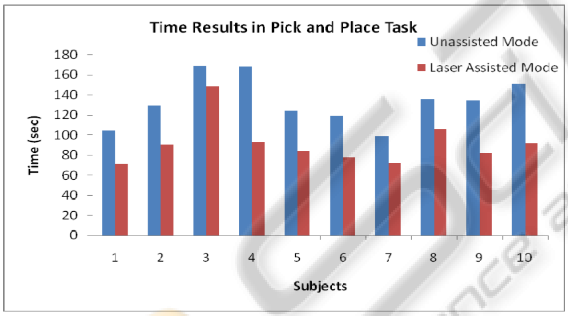

Figure 6: Time plots in executing pick and place task.

The user experience in executing the task in the two modes was also noted. The users preferred the laser assisted mode as generating task plans by picking up points with the laser was easier for them and the robot executed the task. In teleoperating without assistance they experienced a lot of mental load.

5 CONCLUSIONS

Our hypothesis that the laser assisted telerobotic control methodology of task execution would improve the task performance and reduce the mental load on the users has been validated by tests on healthy subjects on a pick and place task. The task performance in terms of time and accuracy improved and the subjects were overwhelmingly in favour of using the laser assisted mode in executing the task as they experienced less cognitive load. With the results obtained we believe that this telerobotic system would make it possible for persons with disabilities to execute ADL tasks with much greater ease. Next we intend to test the method on persons with disabilities and for a variety of ADLs.

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