COMMENTS TO SUBMIT – Tablecloth

Details of the setup

Robots

This bi-manual task is executed by two mobile manipulator robots TIAGo (Figure 1). Its specifications can be found at the PAL Robotics website https://tiago.pal-robotics.com/.

Each robot provides a workspace versatility with 12 degrees of freedom, without the end-effector: The base platform has 2 DoF, the torso lift has 1 extra DoF, 2 additional DoFs for the neck to orient the camera, and 7 DoFs for the robotic arm.

The kinematic structure of the arm, shown in Figure 2, consist in 3 DoFs for the shoulder, 1 DoF for the elbow and 3 DoFs for the wrist.

Figure 1. TIAGo robot.

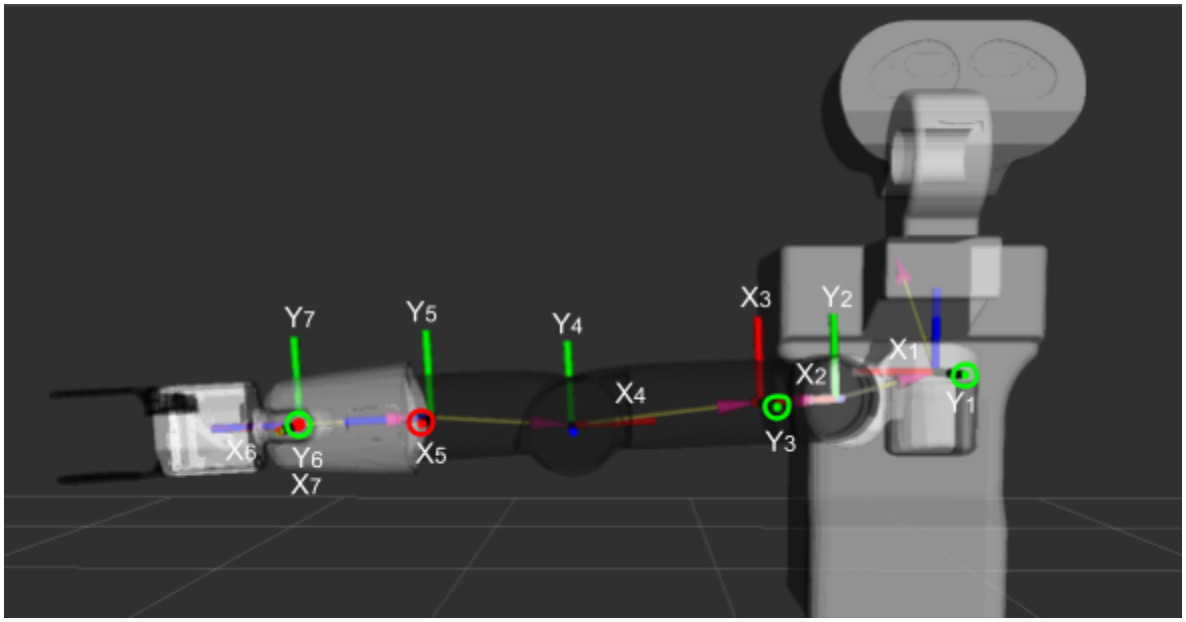

Figure 2. Kinematic chain of TIAGo robot.

Figure 3. Task setup.

End effector

Tiago robots are equipped with a parallel gripper with big highly anti-slippery fingertips. We have modified the gripper to substitute the fingertips with flat and small fingertips that are flexible when they approach the table but rigid when they grab.

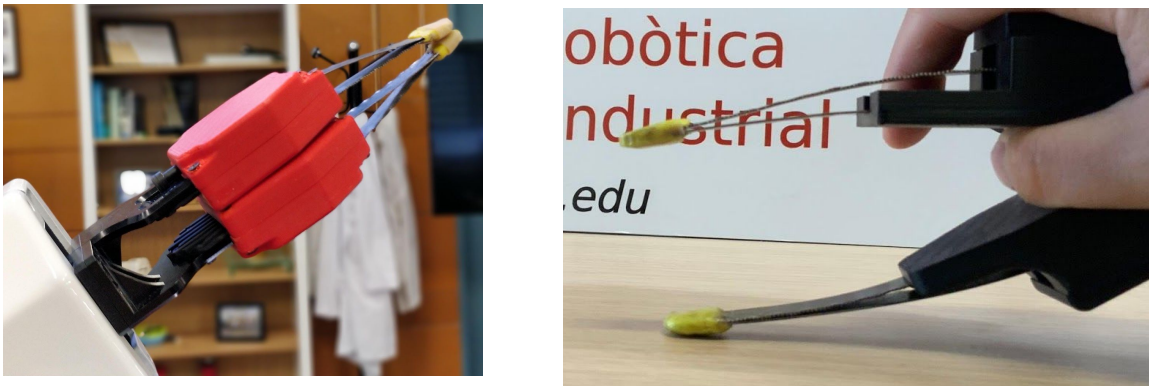

Figure 4. Modified gripper.

Sensors

An RGB-D camera, which is mounted inside TIAGo's head, is used for localizing the first grasping point and for detecting obstacles with which there could be collision, such as the table.

Workstation specifications

Each TIAGo robot has an onboard computer equipped with Intel i7 and 16GB RAM. Two development computers, one for each robot, are used with Ubuntu 16.04 as operative systems.

Software architecture

A ROS-based software architecture is used with ROS Kinetic. At the moment, both robots work independently, each one executing a part of the task. The full process of spreading a tablecloth by the two TIAGo robots is divided into three phases: **[GR1]** grasping the first corner of the tablecloth by the first robot; **[GR2]** grasping the second corner by the second robot; **[MAN]** manipulation of the fabric until covering the top of the table by both robots. Each of these phases are composed of several steps:

[GR1]:

- *Obstacles detection:* First robot executes a scan of the environment to locate obstacles for avoiding subsequent collisions.
- *Localization of the grasping point:* The corner of the tablecloth is located with respect to the robot.
- *Grasping of the corner:* The bottom tip of the end-effector slides under the corner to grasp one layer of the folded garment.
- *Positioning for the next phase:* The grasped garment is brought to a known position close to the second robot to perform the next phase.

[GR2]:

- *Grasping interest point:* The second robot starts its execution by grasping the edge of the tablecloth at a point close to the first hand.
- *Sliding:* An edge-tracing trajectory learnt by demonstration is performed, using the robot's arm and torso, until arriving to the second corner.

[MAN]:

- *Positioning:* Both robots are positioned to be able to execute the manipulation using their mobile platforms.
- *Move platform:* Each robot, placed at different sides of the table, move forward until arriving to the end of the table.
- *Release of garment:* Both corners are released.

Results

What makes the system successful?

The system succeeds when all the phases are executed and completed without incidents and the tablecloth covers the entire top of the table.

The use of our self-design gripper provides successfull grasps of the tablecloth in [GR1] phase with the initial configurations [fd] and [cr]. Its thin fingertips are ideal for inserting between the layers to grasp one single layer of the folded tablecloth. Also, its flexible structure also allows to collide with the table without damaging it in order to place the fingertip underneath the crumpled tablecloth.

After the object is successfully grasped, the strategy of using the mobile platforms to perform manipulations with big pieces of cloth shows to be very successful. We also propose a strategy for grasping that only has to localize the first grasping point and then use a manipulation to get to the second grasp point by sliding the edge of the tablecloth in between the fingertips. This increases the contact with the cloth and therefore, it requires more complex end-effectors that we are developing in our lab but were still not ready to be tested.

What makes the system fail?

The system mostly fails at the grasping action. The main problem is that the first grasp requires a very strong grip, with an anti-slippery surface working better, while the grasp and edge-tracing manipulation to get to the second grasp point requires a more slippery surface but still a strong grasp at the end. This requires a more complex end-effector and with the current version, it makes the system fail during the grasping tasks. Grasping several layers of the folded garment also makes the system fail as it makes the second grasp impossible.

As the gripper has no force sensors, the edge is sometimes lost at the beginning of the sliding movement or sometimes too much cloth is grasped during the edge-tracing motion. In some trials, the wrong edge is grasped, making impossible the manipulation phase. Failures on the second grasp [GR2] are due to this last edge tracing phase.

Regarding the manipulation, the system may fail if the remaining cloth ends up placed in front of the robots, causing the cloth to get tangled with the mobile platform. Therefore, the platform path has to be planned in accordance to this possibility trying to move to leave the cloth behind.

What was improved compared to other methods?

This task, to the best of the authors knowledge, has not been attempted before. However, the phases of grasping a single point of a cloth has been done before and our solution is a baseline approach with simple perception when the grasp points can be relatively easy localized. Using the edge tracing is a novel approach that has not been much explored but is widely used for humans, and we believe it is worth to further explore it.

The fact of using an original strategy with two independent mobile robots for performing a bi-manual task allows it to be applicable to different sized tables and garments. It also can be transferred to solve similar operations, such as making beds or covering actions.

Chosen grasping points and/or grasping strategy

The chosen grasping points are the usual in a rectangular cloth: the corners. What is more original is the strategy to get to the second grasp point by tracing the edge. The system first grasps the top corner, marked on the left image in a red circle, and then lifts the cloth to start the unfolding manipulation. Then with the other gripper grasps the edge at a point close to the first hand, marked on the right image with a circle, and traces the edge until the end to grasp the second corner.

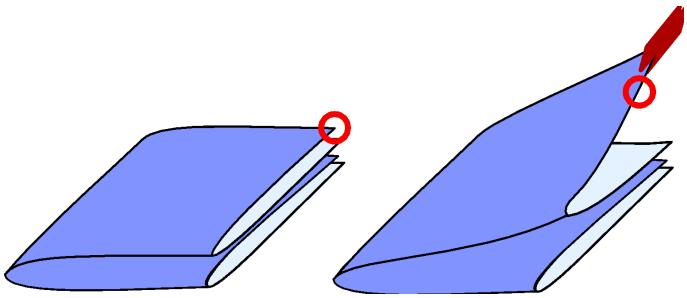

Figure 5. Grasping points.