Intelligent Perception and Dexterous Manipulation for Fine Robotic Assembly

Principal Investigator: **Professor Pham Quang Cuong**
Email: cuong@ntu.edu.sg
Office: N3.2-02-37
Tel: (65) 6790 5597 (Office)

PROJECT DESCRIPTION:

Motivation & Objectives

Fine assembly tasks (e.g. in the electronics, shoes, food industries) are still out of the reach of today's industrial robots. The main challenges lie in the unstructured environments, the soft/fragile materials of the parts to be assembled and the difficulty in controlling contact interactions.

This project aims at tackling these challenges in order to make robots capable of handling those fine assembly tasks in industrial contexts. In particular, researchers are developing the theoretical and technological framework to (i) integrate 3D perception, tactile perception and compliant control using cheap, off-the-shelf components combined with usual position-controlled industrial manipulators, (ii) plan dexterous bi-manual manipulation based on motion planning with dynamics. Researchers will evaluate the manipulation capabilities of the robotic system obtained at the end of the project on the task of autonomously assembling an IKEA chair.

Methodology

Researchers will integrate 3D perception with force/torque sensing: F/T sensor placed at the robot end effector can detect contacts, and via the robot kinematics, give information about the position and orientation of the contact points. 3D perception gives a rough description of the environment and guides the exploration while contact interactions refine environment description to a level suitable for fine manipulation.

The main difficulty here lies in the integration of different modes of perception and their respective uncertainties. The theory of optimal multi-modal sensor fusion in the case of visual and force perceptions will be leveraged on and further developed.

Results / Progress

Researchers have developed a hardware and software framework tailored for robotic assembly. The hardware comprises of a 3D stereoscopic camera and two industrial position-controlled manipulators, each equipped with a force/torque (F/T) sensor at the wrist and a parallel-jaw gripper. The two manipulators are necessary since most assembly tasks require two hands to complete. On the software side, issues arising from fine assembly have been addressed, such as workspace optimization, external wrench compensation, position-based force control, etc.

These issues have often been discussed in the literature, but researchers addressed them in an integrated way and on a single software platform built on top of the Robot Operating System (ROS).

To illustrate the above developments, a highly dexterous task was considered: bimanual pin insertion. This task requires most of the capabilities just mentioned, such as bimanual motion planning, object localization, control of contact interactions, etc. It also constitutes one of the key steps in our long term project, the autonomous assembly of an IKEA chair. Figure 1 shows snapshots of the bimanual pin insertion.

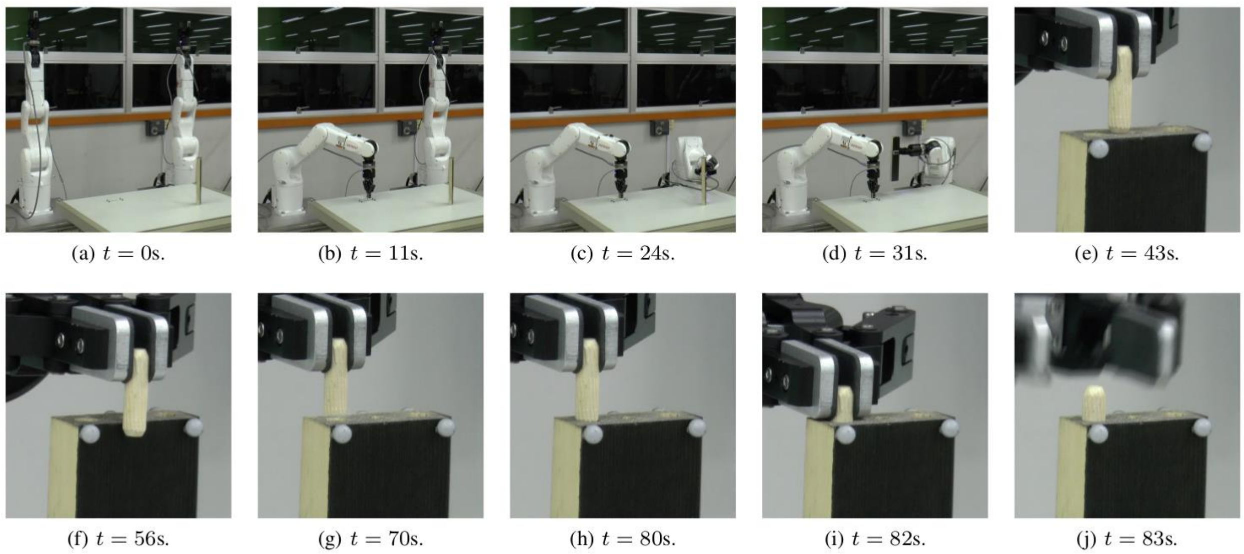

Figure 1: *Snapshots of the bimanual pin insertion.* ***a)*** *The initial position. The positions of the table, stick and pin are determined using Optitrack.* ***b)*** *The left arm performs the compliant grasping of the pin.* ***c)*** *The right arm grasps the stick.* ***d)*** *The right arm 'places' the stick in a position where the insertion can take place.* ***e)*** *The left arm moves above the stick and detects the contact with the pin.* ***f)*** *Through force exploration, the left arm finds the first edge of the stick.* ***g)*** *The left arm finds the second edge of the stick.* ***h)*** *Using the refined position of the two edges, the system knows where the middle axis is and can find the hole.* ***i)*** *Once the hole is found, the left arm inserts the pin.* ***j)*** *Finally, the left arm releases the pin and moves back to its home position. The complete video can be found at http://goo.gl/cYl9sq.*

GRANT:
$211,017.35, MOE AcRF Tier 1(Call 1/2014), 1 Nov 2014 –31 Oct 2016

PERSONNEL:

Name	Title	E-mail
Prof Pham Quang Cuong	Assistant Professor, School of Mechanical & Aerospace Engineering, NTU	cuong@ntu.edu.sg
Dr Francisco Suárez-Ruiz	Research Fellow	fsuarez.suarez@pmail.ntu.edu.sg
Puttichai Lertkultanon	PhD Student	M130039@e.ntu.edu.sg
Nguyen Dinh Huy	PhD Student	M140018@e.ntu.edu.sg

PUBLICATIONS

Refereed Journal (Published/In Press)

H. Nguyen, Q.-C. Pham. Time-optimal path parameterization of rigid-body motions: applications to spacecraft reorientation. *Journal of Guidance, Control, and Dynamics*, vol. 39(7), pp. 1665-1669, 2016

P. Lertkultanon, Q.-C. Pham. A single-query manipulation planner. *IEEE Robotics and Automation Letters*, vol. 1(1), pp. 198-205, 2016

P. Lertkultanon, Q.-C. Pham. Time-optimal parabolic interpolation with velocity, acceleration, and minimum-switch-time constraints. *Advanced Robotics*, vol. 30(17), pp. 1095-1110, 2016

Q.-C. Pham, S. Caron, P. Lertkultanon, Y. Nakamura. Admissible Velocity Propagation: beyond quasi-static path planning for high-dimensional robots. *International Journal of Robotics Research*, 2016

Refereed Conference (Published/In Press)

F. Suárez-Ruiz, Q.-C. Pham. A framework for fine robotic assembly. ICRA 2016, Stockholm, Sweden, May 2016

P. Lertkultanon, Q.-C. Pham. A single-query manipulation planner. ICRA 2016, Stockholm, Sweden, May 2016