Collaborative control design strategies for robotic systems at small scales

Laboratory: Institut des Systèmes Intelligents et de Robotique (ISIR)

University: Université Pierre et Marie Curie (Sorbonne Universités)

Thesis supervisor: Stéphane Régnier

Co supervisor: Mokrane Boudaoud and Cédric CLEVY

Email contact: stephane.regnier@upmc.fr
mokrane.boudaoud@isir.upmc.fr
cedric.clevy@femto-st.fr

Doctoral school: SMAER (Sciences Mécaniques, Acoustique, Electronique, Robotique)

summary

Micro-technologies have enabled several technological breakthroughs in electronics and mechanics thanks to the development of the so-called microsystems. For a widespread development and use of microsystems, flexible and accurate robots able to do manipulation, characterization and assembly tasks at the micro-scale (1µm-1mm) are required. Actual robots are flexible and accurate but they are clearly not enough smart for micro-scale purpose, and miniaturization is now limited by human operator’s dexterity and constancy. Collaborative robotics is the key to merge the best capabilities of robot and human in order to pass through the miniaturization limits and to get a productivity improvement. Collaborative robotics requires a high level switching control scheme. The aim of the thesis is the development of new control strategies on a high precision robotic system taking into account the human operator and multiple sensor signals (force, position and velocity) in the control loops. The challenge is to design and to build a set of control schemes with various levels of interactions with the operator. Different control methods may be used in parallel during a single elementary task, e.g. force/position control, velocity/position control, etc. The robotic system along with the proposed control strategies will be tested on concrete industrial cases.
The development of robotic systems able to perform manipulation and assembly tasks at the micro-scale (1µm-1mm) has been a dominant research topic for many years [1]. Achieving efficient and safe assembly tasks at such scales in an automated or a teleoperated way is one of the main challenges. Several robotic systems with a high resolution, precision and flexibility are now available but they are not yet smart enough to deal with complex tasks. For instance, in watch industry, the assembly of micro-mechanical components into a watch is often done by a human operator, which is able to adapt its operating mode when dealing with unpredictable situations. However, the human has not the required capabilities to deal with the physics at the small scales such as sensing forces at the micro-Newton and positioning the manipulation tool with a micrometer resolution. Micro-robotic systems are able to deal with such physical constraints but they are not able to make smart decisions. Collaborative robotics [2][3] is a key technology to improve the productivity of robotic tasks at the micro-scales. It merges the best capabilities of the human operator and the micro-robot to deal with complexes manipulation and assembly tasks of micro-components.

Fig.1 Chronogrip: robotic system dedicated to collaborative tasks at the micrometer scale. (a) Overview of the robotic system. (b) Side view of the robotic system. (c) Enlarged view of the end effector: the microgripper.

The ANR project COLAMIR is devoted to the design and the control of a collaborative robotic platform dedicated to assembly tasks at the micrometer scale. The robotic platform is composed of five main parts (Fig.1):
(i) A manipulation tool: it is a microgripper with 4 DOF force sensing capability. The fingers of the microgripper are able to move in the vertical direction and in the horizontal direction (Fig. 1.c). The force sensor is able to measure the gripping force and the normal force.

(ii) A multi-dof high precision robotic system: it is composed of a 2 dof robotic structure (1 vertical linear motion and 1 horizontal linear motion) and a 3 dof robotic structure (2 linear motions and 1 rotation). The microgripper is the end effector of the 2 dof robotic structure. The microstructures to be manipulated are positioned on the 3 dof robotic structure.

(iii) A haptic interface: it is coupled with the robotic system and the microgripper. It allows the human operator to generate a trajectory for the robotic system and to sense the interaction forces between the fingers of the microgripper and the environment, i.e. gripping force and contact force with the substrate.

(iv) A vision camera: it includes a top view camera and a side view camera.

(v) A platform computer: it is used for the implementation of control algorithms.

The aim of the thesis is the development of new control strategies on the high precision robotic system taking into account the human operator and multiple sensor signals (force, position and velocity) in the control loops. The challenge is to design and to build a set of control schemes with various levels of interactions with the operator (Fig. 2). Two main control levels can be considered: a high level control and a low level control. In the first one, the robot is controlled considering a direct interaction with the human operator through the haptic interface, it is a teleoperated mode. The output feedback signals are the force sensed by the gripper, the position and the velocity of the robotic system and the vision camera. In the second control level, the robotic system and the microgripper are controlled in an automated mode, i.e. without a direct interaction with the human operator. The global control scheme must deal with several switches to manage the operating modes of the system and to deal with priority purposes depending on the working situations.
The robotic system is composed of high precision actuators with a displacement resolution in the nanometer range [4][5].

For each control level, robust control strategies must be defined for position trajectory control, velocity control and force control. The control methods can be based on the robust control theory (H∞ based LMI control, LPV control, gain scheduling control, etc.). Hybrid, force/position and position/velocity control schemes must also be studied.

The robotic system along with the proposed control strategies will be tested on concrete industrial cases as shown in Fig.3. Collaborative robotics will enable to enhance both the quality and the speed of the assembly process. Thanks to the 4 DoF force sensor, the control algorithms and the haptic device, the operator will get force information during manipulation and assembly.

Fig.3 Two of the Percipio Robotics product robotic assembly use cases.

The thesis must include three main contributions:

- Low-level robust control methods for the multi dof robotic structure: position control, velocity control, force control, hybrid position/velocity control and hybrid force/position control.
- High-level control methods taking into account sensor signals from the microgripper, the robotic structure and the haptic interface.
- Experimental demonstrations of robust collaborative tasks for industrial assembly cases.

The thesis will be conducted in Paris at ISIR. Some experimental validations will be performed in Besançon at Femto-ST institute.
The expected candidate must have a multidisciplinary profile with solid theoretical skills on automatic control and robotics as well as a pronounced ambition to experimentations and practical implementations.

To apply for the thesis, send a CV and a cover letter to:

mokrane.boudaoud@isir.upmc.fr
cedric.clevy@femto-st.fr
stephane.regnier@upmc.fr

References


