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# Towards sensor-based manipulation of flexible objects

Andrea Cherubini\* and Peter I. Corke†

**Abstract**—This paper presents the FLEXBOT project, a joint LIRMM-QUT effort to develop (in the near future) novel methodologies for robotic manipulation of flexible and deformable objects. To tackle this problem, and based on our past experiences, we propose to merge vision and force for manipulation control, and to rely on Model Predictive Control (MPC) and constrained optimization to program the object future shape.

**Index Terms**—Control for object manipulation, learning from human demonstration, sensor fusion based on tactile, force and vision feedback.

## I. CONTEXT

This abstract does not present experimental results, but aims at giving some preliminary hints on how flexible robot manipulation should be realized in the near future, particularly in the context of the FLEXBOT project, jointly submitted to the PHC FASIC Program<sup>1</sup> by LIRMM and QUT researchers.

The objective of FLEXBOT is to solve one of the most challenging open problems in robotics. In fact, we aim at developing novel methodologies enabling robotic manipulation of flexible and deformable objects. The motivation comes from numerous applications, including the domestic, industrial, and medical examples<sup>2</sup> shown in Fig. 1.

Many difficulties emerge when dealing with flexible manipulation. In the first place, the object deformation model (involving elasticity or plasticity) must be known, to derive the robot control inputs required for reconfiguring its shape. Ideally, this model should be derived online, while manipulating, with a simultaneous estimation and control approach, as commonly done in active perception and visual servoing. Hence perception, particularly from vision and force, will be indispensable. This leads to a second major difficulty: deformable object visual tracking. In fact, most current visual object tracking algorithms rely on rigidity, an assumption that is not valid here. A third challenge will consist in generating control inputs that comply with the shape the object is expected to have in the near future.

In the next section, we provide a brief survey of the state of art on flexible object manipulation. We then conclude by proposing some novel methodologies for addressing the problem.



Fig. 1. Examples of flexible object manipulation.

## II. STATE OF ART

One of the first works on flexible object assembly addresses insertion of a beam into a hole [1], by properly designing the robot tool motion trajectory. Planning is also used in [2] to compute paths among minimal energy configurations, for deforming flexible wires, subject to manipulation constraints. More recently [3] targeted the assembly of an o-ring into a cylinder, using a heuristic approach to compute key postures of the robot arms.

While the cited works focus on motion planning, other researchers focused on the sensor feedback required to manipulate deformable objects. In the following paragraphs, we first review works relying on vision, then on force.

In [4], stereovision was exploited, to insert a flexible wire into a hole. Vision is also used in [5] for assembling a rubber belt and fixed pulleys. In the works of David Navarro-Alarcon [6], [7], compliant objects are actively deformed using a novel visual servoing scheme that explicitly deals with elastic deformations, by adapting online the interaction matrix relating tool velocities and optical flow. The controller is model-free, but focuses mainly on shape control, i.e. on manipulating the object to a desired configuration, without dealing with its global deformation over a time window.

Instead of vision, force control is used by the authors of [8] to design a strategy for dual manipulation of a flexible sheet metal. Another approach for modeling the dynamics of manipulators handling flexible objects, is proposed in [9] by dividing the closed chain into two subsystems, one flexible for the object, the other rigid, for the manipulators.

None of the cited works simultaneously exploits vision and force feedback. The only exception is [10], although the authors use the camera as a force sensor by visually tracking object contour changes. Furthermore, no one has combined sensor-based control with constrained optimization or with model predictive control, as we plan to do in FLEXBOT.

## III. PROPOSED METHODS

Within FLEXBOT, we will tackle flexible object manipulation by exploiting the complementary skills of LIRMM and QUT researchers. In particular, we will apply:

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<sup>1</sup><http://www.campusfrance.org/fr/fasic>

<sup>2</sup>Sources: <http://www.scuolanazionalepizza.it> <http://www.connectit-europe.com> and <http://www.kinesiologycollege.edu.au>



Fig. 2. QUT experiments on imaging for deformable object analysis [13].

- Multimodal (vision and force) sensor-based control for manipulation (LIRMM [11], [12]).
- Active perception for deformable object modeling (QUT [13], see Fig. 2).
- Teach-and-repeat generation of object configuration waypoints (LIRMM [14]).
- Robust vision (QUT [15]).
- Constrained quadratic optimization and MPC (LIRMM [16], [17]).

More specifically, FLEXBOT will focus on the four research axes detailed below, in bottom-up order (perception, control and finally planning).

- A1) *Multimodal sensor-based control for deformable object manipulation.* We will draw inspiration from the seminal work of David Navarro-Alarcon [6], [7] on active visual deformation servoing of compliant objects. That work will be extended by relying on admittance control, a scheme that generates compliant motion in response to measured and desired force signals [11], [12]. Another extension will be the use of the optical flow tracking algorithms developed at QUT [13], to replace the fiducial markers used in [6], [7].
- A2) *Constrained optimization for dual arm control.* The addition of a second arm for manipulation introduces new problems, related to the system redundancy. As shown in LIRMM’s works on humanoids [16], constrained optimization is an effective solution for controlling such highly redundant robots. However, the robustness of optimization-based control with respect to inaccurate estimation of the sensor Jacobians has never been explicitly studied. This becomes crucial when dealing with varying objects, such as deformable ones.
- A3) *Teach-and-repeat generation of object configuration waypoints.* In the past, we have designed teach-and-repeat frameworks for visual [14] and lidar-based [18] navigation. A teach-and-repeat approach is very promising for deformable object manipulation, since human teaching could provide a topological representation of the waypoints during reshaping. Again, we could rely on QUT’s recent works on deep learning, for manipulations taught in simulation [15].
- A4) *Model predictive control for reshaping.* MPC is a method for controlling a system so that future states are also taken into account. We have shown its effectiveness in producing walking motions [16], and in avoiding obstacles during navigation [17]. MPC would bridge the gap existing between the local (sensor-based) and

global (planning-based) approaches developed to date. However, prolonging manipulation may jeopardize vision, because of lighting and environment variations. To this end, we will take advantage of QUT’s expertise on robust vision [15].

Note that A4 is alternative to A3: either the plan is taught (A3) or generated automatically by relying on the initial and final object shape (A4).

The methods that will be developed within these axes will be validated on the robots present at QUT and LIRMM. As case studies, we will address linear deformable models, such as flexible cables, including both elasticity and plasticity.

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