Soft-rigid Grippers to Exploit Environmental and Embedded Constraints in Food Handling

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Abstract— **Food handling is a complicated task to be perform by a robot since the handled objects are delicate in nature. It is important to design end-effectors that can be versatile and reliable yet limiting damage on the manipulated items. We present a novel family of soft-rigid grippers that exploit the combination of specialised fingers or fingertips with a passively compliant structure. The proposed devices can gently grasp objects of different shape by exploiting rigid inserts that can slide below the object. This solution allows both the forces applied directly onto an object during handling and the precision needed to identify object position for grasp planning to be reduced, while increasing the grasping success rate compared to a classical gripper. We have tested the prototypes in a real experimental setups using real ingredients. The encouraging results suggest that this approach to food manipulation may be especially useful when delicate objects need to be handled in the context of an automated production line.**

I. Introduction

This extended abstract proposes our recent works on a novel design for a soft robotic hand combining soft fingers and flat surfaces. The concept is much deeper than it appears. The main idea behind is a novel approach to the design of soft hands which includes not only the soft fingers but also the constraints, such as flat surfaces. In soft manipulation, robotic hands are compliant to adapt to the shape of the object to grasp [1], [2]. Soft hands are largely underactuated and do not usually have enough dexterity to execute a precision grasp. Most of the grasps are of power grasp type [3] and the grasp planner is enriched with the exploitation of the environmental constraints to adjust the object position and then grasp it [4]. The environment, such as a planar surface, represents a constraint able to reduce the uncertainties that can be exploited by the robotic hand [5]. This concept is in contrast with classic grasp planning for rigid hands where the environment is treated as a disturbance to avoid. Such enabling constraints are typically considered as part of the environment and to the best of our knowledge, no one proposed to include a constraint, such a planar surface, into the design of the gripper to grasp object in combination with the soft fingers. Embodying the constraint in the design of the hand is novel and allows to design primitives of soft manipulation that are independent of the environmental constraints, at least to a certain extent, since the constraint is available and does not need to be detected in the environment. In the following, we introduce two examples of soft-rigid grippers that exploits this idea for the manipulation of food, in particular fruits and ingredients for the preparation of hamburgers.

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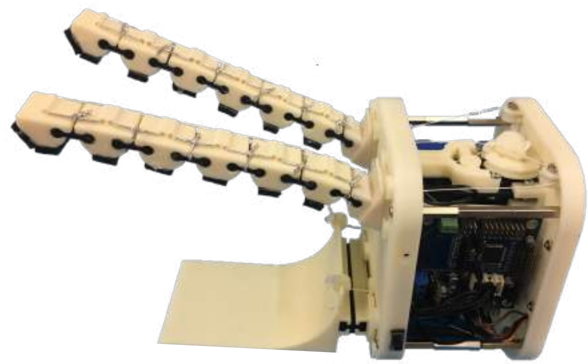

Fig. 1. The Soft ScoopGripper.

II. The ScoopGripper

In [6], we proposed a novel design of a robotic hand with two soft fingers and a flat surface (Fig. 1).

One of the main issue of soft hands as designed up to now is that the enabling environmental constraints not always are reachable or detectable by the grasp planning system making difficult to exploit the primitives of grasping developed for soft hands [7].

We have included the environment by design in the robotic hand. The constraint is embedded in the robotic hand. The Soft ScoopGripper is composed of two soft modular fingers actuated by a single tendon through a differential system, similarly to the fingers designed for the gripper proposed in [8]. Flexible joints connects rigid links so to build a deformable structure able to adapt to the shape of the grasped object. The scoop, representing the constraint, is connected through a flexible hinge to the hand palm. This allows to easily adapt the scoop orientation to the surface where it slides. The soft hinge also allows to actuate the scoop so to move toward the fingers increasing grasp stability. The solution proposed with the Soft Scoop Gripper may outperform classical soft grippers when dealing with uncertain contacts, complex shape, grasping flat object without exploiting edges or flip motion, soft deformable objects, objects that can be damaged and slippery objects.

We demonstrated that in several grasping problems, the presence of the scoop allows to reduce the squeezing force required to grasp increasing the grasp robustness. The capability of soft grippers, and more in general of soft hands,

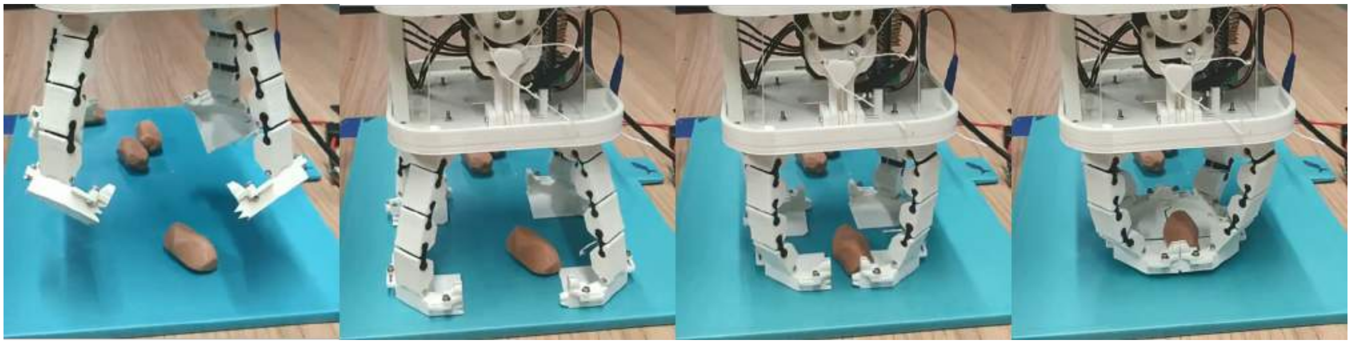

Fig. 2. The QuadSpatula Gripper.

to comply with the environment so to achieve stable grasps using a reduced set of control inputs was fully exploited also when the constraint was not available in the environment. The Soft ScoopGripper itself contains the environmental constrain. Advantages of this solution may be: i) large contact area, ii) compensate uncertainties in contact, iii) lower grip force necessary to maintain the grasp and iv) the possibility to achieve grasp not possible from the top, due to object dimensions or position in the environment.

III. The Quad-Spatula Gripper

The gripper presented in [9], called Quad-Spatula Gripper (QS Gripper) introduced a novel approach to food handling. The main idea is that part of the fingertips can slide below the object to be grasped and form a rigid surface that can carry the desired item. The obtained strategy can be defined as a *scraping* strategy. There are three main features that characterise the device. Firstly, the fingers have a compliant structure obtained by using soft joints that connects rigid links. This increase the robustness of the system and allows to interact with the environment where the object to grasp is placed. Exploiting compliance with underactuated compliant hands is an active research branch for the design of novel robotic end-effectors [10]. Different soft grippers examples are available in literature, see e.g., the Yale OpenHand Project [11], the 3-Finger Adaptive Robot Gripper [12] and the Jamming Gripper [13]. Secondly, we have designed specialized fingertips for food handling. Such fingertips are designed as a part of a larger spatula so to be able to slide below the object when fingers are close. A locking system including a mechanical and magnetic part is used to keep together the spatula sub-parts during object transportation. This solution allows to practically not consider forces applied to the object during transportation. In fact, once the spatula is locked below the object, no forces are exerted on it and the weigh of the object is compensated by the locking system, see Fig. 2. Application using only a classic spatula may results more prone to possible object lost during arm motion, while enclosing gripper may not be usable with delicate ingredients. Finally we have introduced a magnetic guidance to align the quad spatula parts. The magnetic guidance is used to cope with the low repeatability and precision proper of soft systems.

We have tested our QS-Gripper against a classic two-finger gripper using real ingredients. We have demonstrated a higher grasping success rate and a higher robustness to uncertainty to object positioning. We have also demonstrated that magnetic guidance can help to improve precision in quad spatula interlocking.

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