The Mag-Gripper: A Soft-Rigid Gripper Augmented with an Electromagnet to Precisely Handle Clothes

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***Abstract*— In this work, we briefly present Mag-Gripper, a novel robotic gripper specifically designed for autonomous clothing manipulation. It is capable of improving the grasp repeatability and precision, compensating uncertainties in the desired grasping locations by exploiting a proper magnetic force. It is an augmented jaw gripper, equipped with an electromagnet capable of attracting small metal parts suitably placed on the garment to be grasped. Mag-Gripper can find applications either in research labs investigating Machine Learning-based clothing manipulation, either in companies having to manage a large amount of returns, either in home setting scenarios.**

I. Introduction

A. Motivations

Continuously evolving robot generations are spreading out in factories and in home settings as Service Robots. Adapting robots to perform tasks requiring complex dexterity (*e.g.*, to manipulate deformable objects) poses new challenges. Garments are extremely challenging objects, because of their difficult perceivability and manipulation, due to the potentially infinite configurations they can assume. To bring clothes in a desired configuration, the sequence of the intermediate movements is paramount: Each sub-movement causes a cloth configuration which, in turn, depends on the points where the cloth is grasped. Due to the deformable nature of the fabric, relatively small changes in the grasping points location can produce a significant change in the final configuration taken by the grasped garment, potentially causing a failure in the task accomplishment. On the contrary, grasping the garment in proper locations leads to a fast and effective task accomplishment, as shown in the video reported in [1] by a popular garment producer. Moreover, in the next future, assistant robots can help in our houses nicely folding our garments. As reported in the accurate taxonomy in [2], grippers usually involved in autonomous garments manipulation are not specifically thought for interacting with clothes, which are extremely deformable objects. We propose a novel approach to the problem, exploiting both grippers and garments specifically designed to be autonomously manipulated by robots. According to our vision, we developed Mag-Gripper, a novel type of jaw gripper augmented with an electromagnet (Fig. 1). Small metal parts embedded in the garment as ornamental or brand elements such as buttons, studs or small plates are involved in the attractive gripper-clothing approach.

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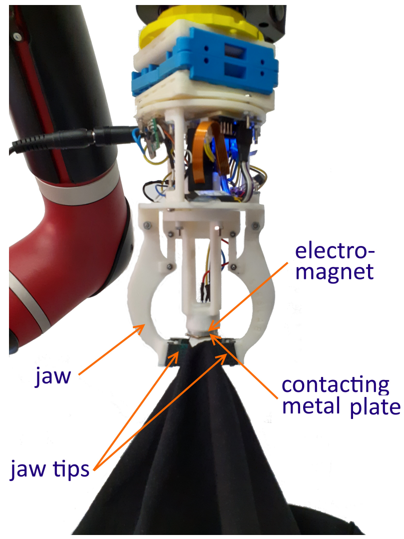

Fig. 1: Mag-Gripper: a novel gripper to manipulate clothes

Our long-term vision is a cooperation between researchers in robotics and producer of garment to realize clothes that can be easily manipulated by our gripper. In the meanwhile, Mag-Gripper can have an immediate field of application in the robotic community: It is meant to be a support tool for the research in Machine Learning-based garment manipulation, where high repeatability in grasp location is a paramount issue during data collection [3], [4].

B. Related works on Cloth Manipulation

In the last decade, research on autonomous cloth manipulation has received great boost. To retrieve proper grasping points on the object, different approaches have been proposed, accounting also for the unfolding and folding subtasks (where the former aims at bringing the cloth from a random configuration to a known one, while the latter aims to actually accomplish the required manipulation starting from the known configuration). Regarding the unfolding task, the most popular approach consists in re-grasping the object until the target configuration is reached. To cite some works, geometry-based shape analysis techniques [5], Hidden Markov Model [4], Support Vector Machines and greedy policies [6], Random and Hough forests [7] have been investigated, and the main experienced difficulties are: *i)* the time required to accomplish the task; *ii)* the uncertainties on the estimate of the final grasping point; *iii)* the risk of loosing the object during multiple re-grasping. In a more recent work [8], a hierarchical structure of Convolutional Neural Networks is used to recognize the garment category and grasp it directly in two points, avoiding multiple grasps and decreasing the task completion time. Concerning the folding task, early works relied on geometric approaches[9], [10], [11]. More recent contributions arise from the synergy between Machine Learning and Robotics, and are based on Deep Learning, Learning from Demonstration (LfD) and Reinforcement Learning. In these works, the robot is taught to learn the folding task by means of a set of demonstrations provided by a human operator. In [12], a deep convolutional autoencoder joint with a deep time delay neural network is used to process data acquired via teleoperation. In [13], a LfD with Deep P-Network is used to learn a T-shirt folding. In [3], Dynamic Motion Primitives are exploited with LfD and RL. When dealing with Machine Learning techniques, it is well-known that to achieve a good learning process (*i.e.*, good generalization capabilities), a large and consistent dataset has to be provided to the machine. In particular, when a given cloth manipulation task has to be learnt by means of human demonstrations, the multiple demonstrations have to start all with the same initial garment configuration [3]. To this aim, grasping the cloth always in the same points is fundamental, since clothes are extremely deformable objects and relatively small changes in the grasping points can cause significant errors in the initial configuration.

II. THE MAG-GRIPPER

Mag-Gripper [14] has been designed to be a possible solution to cope with the issues mentioned in Sec. I-B, *i.e.*, to allow a repeatable extended point-like grasp. Since the location where a clothing is grasped causes its configuration after the grasp has occurred, having a repeatable grasping capability results in having repeatable clothing configuration.

By design, Mag-Gripper is lightweight, modular and with a limited encumbrance. The prototype has been designed via CAD and realized with additive manufacturing techniques (material used is ABS M30), which allowed small production cost and short production time. The gripper is similar to a jaw gripper, but the novelty we propose consists in having realized an *augmented* jaw gripper: in its central part, there is an electromagnet mounted on the top of a linear actuator. By activating the electromagnet, a magnetic field is generated, which causes a magnetic force attracting the metal part attached to the cloth. Due to the attractive motion of the metal part, a collision between the end-effector and the cloth occurs, and is detected by a small resistive force sensor (FSR), which is located near to the electromagnet. The contact is deemed to be occurred when the force measured by the sensor exceeds a given threshold, triggering the closing motion of the jaws. The proposed gripper exploits the advantages of both the electromagnet and the jaws: the former allows to grasp the cloth in the desired point, while the latter allows a secure grasp maintenance during the cloth manipulation. In other words, the uncertainty brought by the soft fingertips of the jaws is tamed by the action of the electromagnet.

Differently from simpler, commercially available grippers exploiting the presence of a magnet [15], we exploit the magnetic force only to establish the contact between the gripper and the garment: After the extended point-like grasp has occurred, the magnetic force is no more needed, the electromagnet is deactivated to avoid overheating and a secure grasp maintenance is achieved by exploiting the gripper jaws. In this way, we also reduce disturbances due to undesired magnetic interactions between object and environment.

In the central part of Mag-Gripper, between the jaws, there is a linear actuator (PQ12-30-12-P by Actuonix), at the top of which the electromagnet (KS0320 by Keyestudio) is mounted. Thanks to a set of pin joints and connecting links, the motion of the actuator allows both to approach the electromagnet to the cloth, and to open/close the jaws. Thus, the proposed gripper has one degree of actuation, which allows the gripper to be lightweight (181 g) and with limited encumbrance, taking into account the considerations in [2].

The closed structure width is 9 cm. The maximum opening size of the jaws is 13 cm. When the jaws are at the maximum opening distance allowed by design, the most prominent part is the electromagnet. When the jaws are completely closed, the most prominent part is given by the jaw tips, and the distance between the tips and the base is 15.5 cm. The circular base have 5 cm diameter, and the links connecting the two circular surfaces enclosing the electronics are 5 cm height. To have a robust structure, the gripper base, the jaws and the locations assigned to the actuator and the electromagnet are 3D-printed in ABS. Conversely, the jaw-tips are hollow and realized in TPU, to have a more compliant interaction with the cloth. The tips are designed with suitable grooves to increase the friction during the contact with garments, thus reducing undesired slippage.

The gripper microcontroller is an Arduino Pro Mini with an ATmega328P (running at 16MHz, 5V input voltage). Gripper control is achieved via position control, by exploiting the actuator feedback position and the polarity inversion through the L293B motor-drive. The electromagnet is activated or deactivated through a logic input (H/L), which is a function of the actuator position and sensor measurements. The gripper-pc communication runs via bluetooth (RN42 module by Microchip) and the gripper working voltage is 12 V.

III. EXPERIMENTS

Experiments with a Sawyer collaborative robotic arm (by Rethink Robotics) were performed to test the actual capabilities of the proposed gripper. To this aim, we investigated: *i)* how the performance are related to the size of the metal plate and the cloth weight; *ii)* which is the role played by the electromagnet on the configuration taken by the cloth after the grasp has occurred; and *iii)* how to compensate possible uncertainties on the estimate of the grasping points.

For the sake of simplicity, we assumed the desired location of the grasping point to be fixed on the garment (*i.e.*, on a shoulder), and a fiducial marker located in that position had been used to retrieve an estimate of the desired pose with respect to the robot base. The trajectory planning was implemented in the *MoveIt* framework and was decomposed

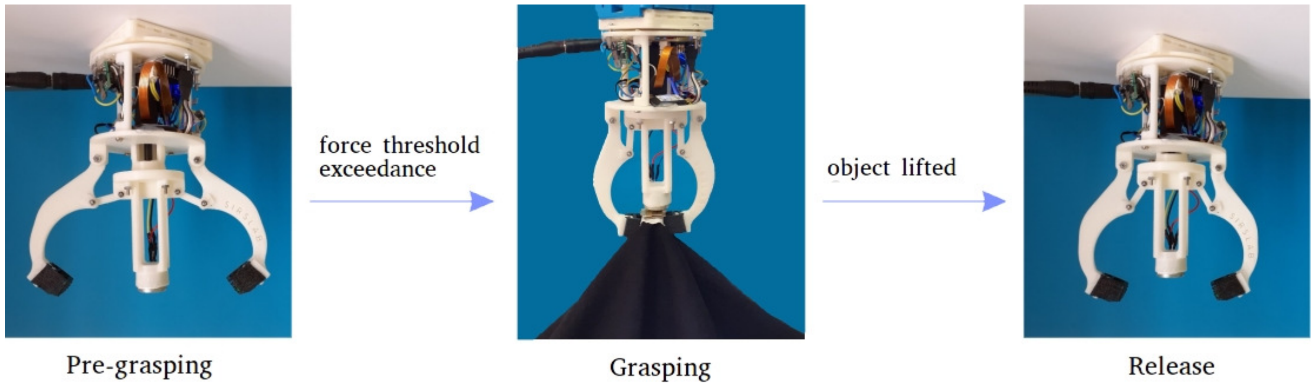

Fig. 2: Mag-Gripper working configurations. During the pre-grasping, the electromagnet slot is the most prominent part of the structure, to allow the attractive motion of the metal plate without undesired collisions between the jaws and the cloth.

in three different steps: *a)* go 4 cm over the estimated location; *b)* go down until the contact between the gripper and the metal part has been detected; and *c)* lift the garment for 20 cm.

Concerning the aim of *i)*, three different squared metal plates (of side 0.8, 1.8, 2.5 cm) were used. Moreover, 4 different garments were involved in the experiments (a YCB T-shirt, a mid-season pullover, an old bib and a terry guest towel). As it can be easily envisaged, the larger is the plate, the larger is the potential contacting area and the capability of compensating undesired uncertainties on the grasp location, thus increasing the grasp success rate. Experiments revealed also that the garment thickness is more relevant than the overall object weight: changing the thickness results in varying the local mass the electromagnet has to attract.

Regarding *ii)*, E and WE experiments were conducted, activating and not activating the electromagnet, respectively. 10 grasping attempts were performed for each condition. What happens is that when the grasp execution relies on the presence of the electromagnet (E experiments), the distance between the jaws tips during the grasp execution is smaller than in the case where the electromagnet is not exploited (WE experiments). Moreover, from a qualitative point of view, the part of the cloth located between the jaws was significantly crinkled during WE experiments. Hence, the electromagnet exploitation allows a sort of extended point-like contact resulting in a more predictable configuration of the clothing, which is an high deformable object with potentially infinite ways of being deformed.

Concerning *iii)*, an error of 1 cm on the x and y coordinates of the estimated grasping point was introduced by purpose, and 10 grasping attempts were performed. 7 grasps resulted to be successful. To increase the grasp success rate, the presence of the electromagnet suggested the possibility of performing a sort of *partially-blind* grasp, as a strategy to be applied when the vision system is not particularly reliable. According to this strategy, the robot is first commanded to reach the estimated grasping point and, if the contact between the object and the gripper is not detected, the robot starts spanning a small area around the estimated grasping point to exploit the magnetic attraction. However, the success of the blind grasping is highly dependent on the distance between electromagnet and garment which, in turn, depends on the thickness of the cloth. To get a more generalized planning strategy, further investigations are needed. Magnetic parts on the garments are not limited to be a mere escamotage, since they play the role of magnetic markers for the grasping system: Once the grasping locations will be identified by proper algorithm and the magnetic parts will be located in those locations, garment-agnostic grasping systems will be capable of successfully grasp the object.

IV. Conclusions

In this extended abstract, we presented Mag-Gripper, a novel augmented jaw designed for autonomous clothes manipulation. The only working assumption is to deal with garments provided with small magnetic parts. In our vision, these parts are properly-located ornamental or brand elements (such as buttons, studs or small plates). Mag-Gripper is equipped with an electromagnet: The electromagnet is exploited to establish an extended point-like contact with the garment, while the jaws allow a secure grasp maintenance during the manipulative motion. Experiments performed with a collaborative robotic arm showed that the exploitation of the magnetic force allows to perform a repeatable grasp execution and to compensate vision-based planar uncertainties on the estimation pose of the desired grasping point. Moreover, the extended point-like contact caused by the electromagnet allow to perform grasp without unnecessary wrinkles, achieving clothing configurations more suitable to vision-based Machine Learning techniques for autonomous manipulation. Although this work is focused on the manipulation of garments, the approach underlying Mag-Gripper can be adapted for manipulating different types of deformable objects (ongoing work). Future work will focus on testing the gripper in robotic setups for bimanual autonomous clothes manipulation. Moreover, the proposed *blind grasp* strategy will be further investigated, as a method to be applied when the vision system is not sufficiently reliable. The magnetic-based technique illustrated in this work is currently patent pending.

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