A Cable-based Manipulator for Chemistry Labs

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***Abstract*—This paper presents the design of an end-effector for handling of supplies commonly found in chemistry labs. The system uses a cable loop capable of providing an effective grasp of any prismatic or cylindrical object, making it ideal for handling vials and other containers commonly used in laboratories. When compared to the more common parallel jaw gripper design, the proposed cable based end-effector is able to handle a larger variety of objects without interfering with the surrounding objects even in a crowded environment (minimal footprint). The payload capability of the gripper has been tested on a load test apparatus with different materials, demonstrating its effectiveness.**

***Keywords*—Robotic Gripper, Cable-based Manipulator, Chemistry Automation**

I. INTRODUCTION

The current trend in industry and research is pursuing effective human-robot interaction and cooperation, where the two would participate to the same workflow both efficiently and safely. This would make for easier set up and inspection of automated plants, since the safety features and procedures would be embedded in the robotic system. Currently, robot manufacturers provide cooperative robots in the form of low-power robotic arms (<35kg max payload), sometimes mounted on mobile bases. These systems come equipped with collision detection and avoidance and compliance features to avoid harming humans or damaging themselves or the surrounding environment [4].

Chemistry research, and more specifically material discovery, relies on exploring a large number of chemical combinations. Artificial intelligence trained for the task can skim most combinations through simulation and narrow down the possible solutions to a few hundred composites. This software combined with a robotic system makes a robotic scientist that can run the reactions in a lab and has provided some great results [1]. Current systems require a highly controlled environment and can only perform specific tasks[2]. As a result, a significant amount of resources goes into the design and possible modifications of a physical system. The creation of a robot that can work in any chemistry lab with the available supplies is extremely appealing to reduce the set-up costs of chemistry automation and improve its accessibility.

In order to be effective in an environment with variable features, like position of supplies or layout of the lab benches, the robotic system needs to be extremely robust. Specifically, when it comes to manipulation, a balance needs to be struck between computation (the software) and embodiment (the hardware). Computation has traditionally been the main focus for manipulation task because of the quicker turnaround when compared to mechanical design. However, thanks to the advance in rapid manufacturing technology, the hardware can nowadays be updated at similar pace to the software [5]. This has led to further exploration of potential mechanical designs in an effort to find the right tool for the job instead of finding a workaround for sub-optimal equipment. This is particularly true for the development of end-effectors, where many of the newer designs have become better adapted for their work environment [3]. The end-effector proposed in this paper aims to outperform current designs in their flexibility, footprint and ease of grasping. The use of a cable loop mechanism allows for all of these requirements while also keeping costs low.

II. PROPOSED DESIGN

The proposed design, shown in Fig. 1, consists of a main body containing the drive components and a vertical beam (finger) with a cable loop at its end. A 0.5 mm polyamide cable is used to envelop objects and pull them against the finger. To keep the object aligned to the end-effector, the contact surface on the finger is concave. One end of the cable is fixed at the end of the finger while the other can be pushed or pulled by a two wheel arrangement, shown in Fig. 2, with wheel 1 driven by a geared DC motor and wheel 2 used to keep the wire in contact with wheel 1. Both wheels use a 3D printed flexible material (Ninjaflex^{TM}) external cover with a V groove to better grip and feed the cable. The cable is fed into a channel that drives it to the desired position.

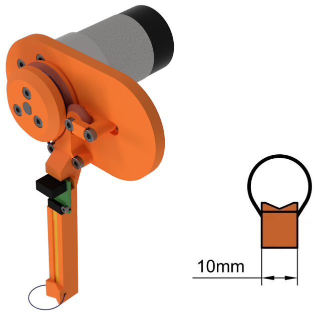

Figure 1: Proposed end-effector (left) and a bottom view of the grasping mechanism (right).

All the mechanical components for the design have been 3D printed using PolyLactic Acid (PLA) for rigid components

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and Ninjaflex™for the flexible ones. This made it possible to create channels for the cable to go through inside the structural components.

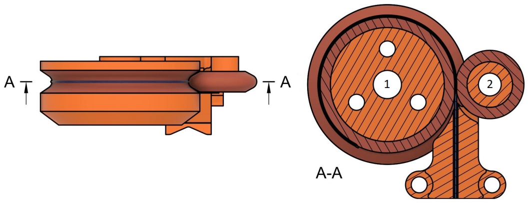
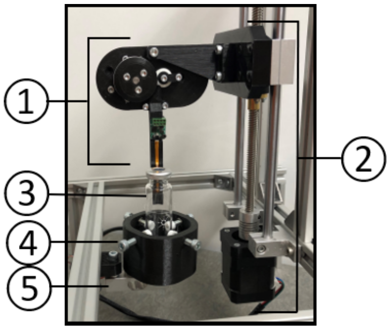


Figure 2: Cable drive mechanism top view and section. Drive wheel (1), idler (2) and cable in blue in the section view.

An embedded capacitive force sensor (SingleTact™10N) mounted behind the contact surface collects information about the grasping force, and a rotary encoder mounted to the motor shaft is used to estimate the radius of the cable loop. Two PI closed-loop control systems, implemented on an Arduino™Mega board, are used to control position and torque of the motor connected to the cable loop.

III. TESTING

The system has been tested by grasping cylindrical objects of different diameters attached to a load cell to check the maximum payload weight, see Fig. 3.



1	Manipulator
2	Linear Axis
3	Vial
4	Clamp
5	Load Cell

Figure 3: Assembled test rig.

The tests were conducted with both glass and plastic cylindrical objects of different diameters and materials clamped to the load cell, performing 5 runs for each test sample to insure reliability. For each test, the cable loop was tightened around the cylinder until a grasping force of 5N was registered by the sensor in the end-effector. The drive wheel was then locked in place and the end-effector was slowly lifted using the linear actuator of the load test apparatus shown on the right of Fig. 3.

The results of these tests are summarised in Fig. 4. The end-effector could lift more weight with plastic specimens because of their higher surface roughness and therefore extra friction. In spite of the lower friction of glass, the end-effector was still able to reliably lift 400g of payload. Tests with both materials show no significant direct correlation between diameter of the object and weight lifted, which suggests that the design could prove to be highly versatile. The maximum load exceeds the requirements for use in a chemistry lab where most vials will weigh less than 100g.

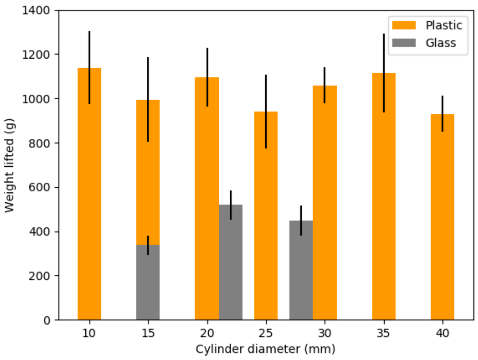


Figure 4: Maximum weight lifted as the diameter of the samples increases. Error Bars represent one standard deviation.

IV. CONCLUSIONS

The proposed end-effector design provides a small footprint and can handle variable payload sizes, thanks to an unconventional grasping mechanism. The cable loop design compromises on the type of shape the system can grasp but has potentially unprecedented flexibility for payload size. Thanks to its small dimension the mechanism could be easily fitted to existing 6 DoF Robotic arms with good reach and dexterity.

To improve its reliability, the prototype will require better materials and electromechanical components and more thorough testing. Moreover, software integration with a robotic manipulator can be developed to allow for testing in a realistic environment.

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