Experimental Analysis of Soft Vacuum Cups for Automated Mushroom Picking

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Abstract - **In this paper, the use of soft suction cups for automated mushroom picking is studied. The aim is to identify the vacuum level that starts to cause bruising for mushroom cups, in addition to the maximum torque that can be generated at this value to facilitate harvesting via twisting mushrooms. An experimental setup was developed that controls vacuum level, controls rotation of the vacuum gripper, and records resulting torque during picking.**

Keywords - agri-robotics, soft grippers, grasping.

I. Introduction

The agriculture sector nowadays is interested in the use of robotics to automate labour-intensive harvesting tasks. Mushroom harvesting is an example which requires lots of human pickers that are becoming difficult to recruit. Picking involves skilful twisting of the mushrooms to separate them from the compost. Soft robotics offers various grasping technologies that are suited for delicate targets such as elastomer actuators, granular jamming, Gecko adhesion, Electro adhesion, and others. Suction based gripers can be a simple solution for mushroom picking, but vacuum can also bruise picked mushroom surface. This project studies the impact of vacuum on mushroom bruising and the maximum torque that can be generated for picking mushroom without bruising using a soft vacuum cup.

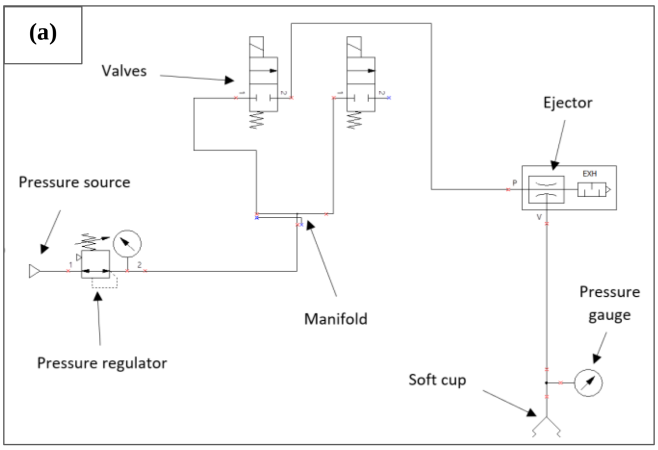
II. Literature review

Soft grippers provide excellent shape adaptation to a wide range of objects compared to conventional rigid grippers. Soft grippers can be categories into three main categories. First by using actuation, which can bend and grasp the objects gently similar to human fingers [1][2]. This approach can easily handle convex and non-convex shapes, but it is difficult for picking a flat and deformable object. Second gripper technique is by controlled stiffness [3]. There are four methods for controlling stiffness; The shape memory polymers [4], low-melting-point alloys [5], granular jamming [6], and electrorheological (ER) and magnetorheological (MR) fluids [8]. The controlled stiffness gripper is not ideal for lifting flat or deformable objects, but is usually combined with actuation to handle convex and non-convex objects. The third soft gripper category is controlled adhesion, which also needs to use the actuation method to grip the objects. There are several examples of this method such as: electro-adhesion [9], Gecko adhesion, or simply using suction cups. Adhesion heavily depends on the surface properties of an object, but can be suitable for handling convex, flat and deformable objects, but not ideal for non-convex objects [3][10]. A soft gripper can also combine two technologies to improve performance. The choice of soft gripper type relies on the properties of the object such as shape, weight, and delicacy, as well as, picking requirements such as speed, force, the power consumption, and biocompatibility.

In this work, soft suction cups are investigated as a simple approach for picking mushroom since they enable picking mushroom cups from the top, which is important since mushrooms grow in dense clusters so there is no space for fingers to reach in between. This makes other actuation based technologies difficult to reach the right position to grasp and twist a mushroom. This paper investigates if the suction cup concept would enable adapting to varying mushroom cup sizes without damaging or bruising. In addition, quantifying the maximum torque that the soft vacuum gripper can generate to harvest by twisting.

III. Experimental setup

The pneumatic circuit and the block diagram in figure 1 demonstrate the working principle of the setup controlling the grasping operation of bellows suction cups (SMC ZP2-B15JS). The circuit is supplied with 4 bar pressure input which is adjusted via a pressure regulator based on a potentiometer reading connected to an Arduino board. The regulated pressure flows through an ejector which generates a negative pressure for the suction cup that is proportional to the set positive pressure. The vacuum cup activation and release are controlled by the valve via an Arduino signal from a push button. The Arduino program sets the duration of suction and the analogue signal to the regulator. The pressure gauge provides a visual display of the negative pressure during the operation.



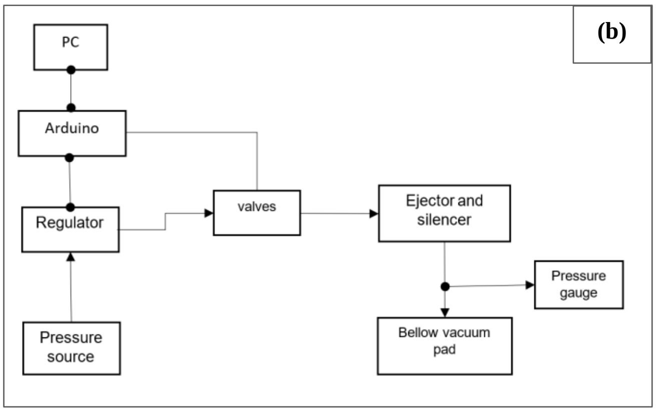


Figure 1: (a) Pneumatic Circuit (b) Block diagram of the system

Figure 2 shows the testing setup with the suction cup connected to the pneumatic circuit. The cup is carried by a stepper motor to enable rotation, which is mounted on a controlled motorized stage that moves the gripper vertically to approach and lift the mushroom. The setup allows mimicking a picking routine that involves lowering the cup until pressing against the mushroom, then activating the rotation motor to twist the suction cup. Sample mushrooms are fixed to a 3D printed piece mounted on a sensitive force-torque sensor (Schunk Mini40) to record the maximum reaction torque that occurs during grasping.

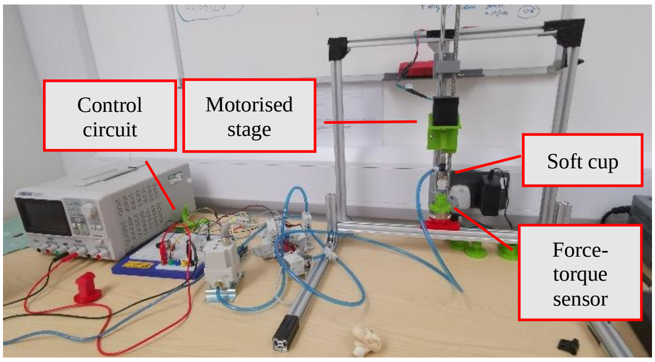


Figure2: The test setup of the vacuum cup gripper

IV. Results

Figure 3 shows the relationship between the resulting negative pressure at the vacuum cup and the supplied voltage to the pressure regulator for small and large mushrooms sizes. The relationship was mostly linear and was not significantly affected by the difference in mushroom size. Hence, the relationship can be used to estimate the voltage value required to achieve a particular negative pressure value.

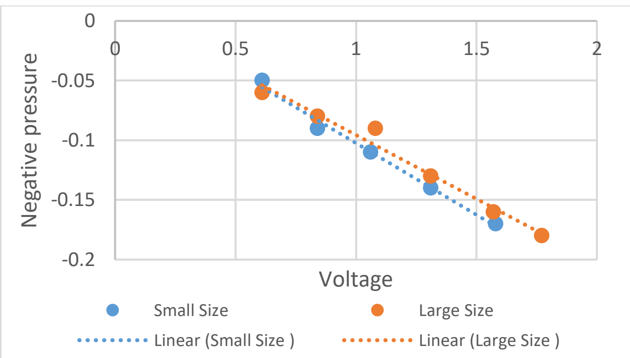


Figure 3: the relationship between the input voltage and the resulting negative pressure at the cup

Moreover, the next stage of the experiment tested thirty mushrooms of different sizes at increasing vacuum levels to find out at what negative pressure the surface bruising starts to occur. The tested mushrooms were monitored over a 24-hour period since bruising may occur later. The results showed that mushrooms suffered no damage up until -0.02 bar at the end of the monitored duration. Figure 4 shows two mushrooms as an example to highlight when bruising occurs. A red circle was drawn around the area where the suction cup touched the mushroom to highlight bruising due to the cup.

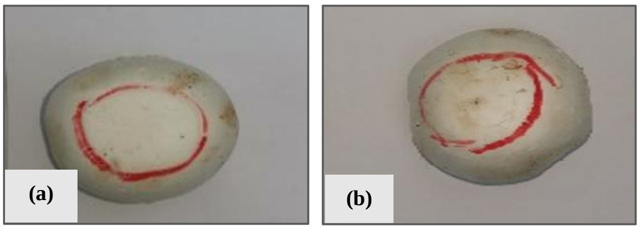


Figure 4: (a) no damage at a negative pressure of -0.02bar (b) visible damage at negative pressure -0.08

Finally, a test was performed at the identified vacuum level of -0.02 bar on three mushrooms to evaluate the maximum torque that can be generated during twisting at this value. The results showed that the maximum resulting torque when no bruising to the cup occurs was on average 0.0038 Nm.

Table1: Torque test values

Pressure in (bar)	Negative pressure (bar)	Voltage (V)	Average Torque (Nm)
1.19	-0.02	0.65	0.0038

V. Conclusions and Future Work

The outcomes of the preliminary work presented here showed that the negative pressure that can lift loose mushrooms using soft suction cups without bruising was -0.02 bar. At this value, the torque generated during twisting fixed mushrooms was on average 0.0038 Nm, which will not always be enough to break the mushroom stalk for automated harvesting tasks. Further investigation into parameters other than size, such as maturity, that could impact the results is still needed. Future work will investigate methods to improve the design of the suction cups to increase the maximum torque without damaging the mushroom for better performance. This could involve combining multiple smaller suction cups or creating custom contact surfaces to better distribute the pressure. Nevertheless, the initial work so far identified an initial benchmark for future development.

VI. Acknowledgement

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VII. References

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