Design of a Low-Cost Prosthetic Hand: Utilising the Jamming of Coffee Granules

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Background and Motivation

The need for a low cost upper limb prosthesis is a prevalent problem the world over, more so in developing countries where sufferers of limb deficiency do not have the access to a suitable prosthesis. Due to the remarkable and complex nature and function of the human hand, the design of an upper limb prosthesis can be challenging. Considerations that need to be made include the actuation, aesthetics, functionality and cost of the device.

Recently in robotics a manipulator utilising the jamming phase transition of granular materials was proposed and tested. When loosely packed in an elastic membrane, granular materials possess fluid like properties allowing them to conform to an objects shape. When a vacuum is applied to the granular material, it contracts and becomes rigid, the granules are then unable to move past each other. This operation of the adaptive gripper can be seen in Figure 1. The possible gripping mechanisms in effect are friction, suction and the interlocking of the manipulator around the object. The result of this application is a manipulator that is extremely adaptable and exhibits infinite degrees of freedom.

Aim and Objectives

- To build a low-cost (less than $30) jamming phase transition manipulator as a prototype for a prosthetic hand.
- Assess the relationship between:
  - The volume of the granular material (instant coffee) on the gripping process.
  - The applied vacuum and resulting grip force.

Methodology

- A successful prototype was developed where ground coffee was placed into a large (40cm) balloon and sealed using two 1mm thick discs of stainless steel (Figure 2).
- The percentage volume of coffee was varied and the force input required to securely hold a range of objects was measured along with the holding force and torque it produced.
- A secure grip was considered achieved when the manipulator fully encompassed the sides of the object.
- A constant force of 50 Newtons (N) was then applied to a screw driver and the percentage volume of coffee kept at 95%.
- The vacuum applied to the terminal device was varied from 40-90 kilopascals (kPa) and the related grip force measured.

Results and Discussion

- As the percentage of volume of coffee increases, the greater the input force required for a complete grip (Figure 3a).
- Below 45 kPa the gripper is unable to manipulate the screw driver and at 45 kPa a grip is not always achievable.
- An increase in vacuum between 45-75 kPa equates to an increase in grip strength (Figure 3b).
- An upper limit may exist for the grip strength which can be seen around the 80-90 kPa range where the grip strength starts to plateau at an average of 13 N. This could be confirmed by testing higher pressures however these pressures were not achievable during these experiments.
- For the size of the manipulator it would be expected that a grip force in the 5-10 N range would be sufficient for the manipulation of every day objects and competitive in the market.
- The relationship between the volume of coffee and the resulting grip strength produced complex results due to the variety of mechanisms in action and will require further investigation.
- From a qualitative view the device is easier to position and control with higher amounts of coffee.
- The highest forces required are easily achievable for an amputee.
- The vacuum required is achievable with a simple piston mechanism.

Conclusion

A low-cost prototype for a jamming phase transition prosthesis has been developed and tested. Initial results show a strong relationship between the applied vacuum and the grip force with an upper limit average of 13 N, giving a promising performance for what could be considered an extremely adaptable prosthesis. It is proposed that the terminal device could be combined to a piston mechanism (Figure 4). This design would be able to draw a sufficient vacuum and make the prosthesis operable via the body power of the amputee.

Further investigation into higher vacuum pressures, the classification of the grip force on different objects and the testing of different membrane and granular materials could further the effectiveness and usefulness of the prosthesis.

Proposed Prosthetic Design

Figure 4: A possible assembly of the prosthetic using a simple piston mechanism to draw the required vacuum.