Air-Powered Soft Robotic Gripper Using Lego Bricks and Jamming of Granular Material: An Initial Approach

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***Abstract* - Gripping and holding delicate objects is a definitive challenge for any robotic arm. Simple tasks that human can do can be very stimulating for robots to conduct. More precisely, in the realm of human robot interaction, surgery, medical intervention etc. soft robotic gripper can pose a great benefit for delicate biological tissue manipulation. In this paper, we demonstrate an ingenuous approach to use air-powered soft robotic gripper using Lego bricks as the basic building block for fabrication. This is an initial prototype which needs no 3D printing sophistication and can be used for multiple gripping applications. Along with this, we have used granular jamming mechanism for stiffness control and manipulation for future biomedical applications.**

Keywords- Soft gripper, Lego bricks, particle jamming.

I. Introduction

Modern biomedical applications especially surgeries demonstrates a great need for soft, adaptable, customized stiffness manipulator for clutching the soft tissues, manipulating cellular aggregate in human body, optimal drug delivery and many others. In this regard, we demonstrate initial trials of a soft, flexible yet resilient, robust, adaptable gripper by granular jamming technique. Miniaturization of the current prototype can promise an *in vivo* human delicate tissue manipulations for critical surgeries with less complications. More so, while we are considering using robots for biomedical subtle surgeries. In this paper, we have demonstrated the initial experiments which are conducted for a robotic gripper fabrication with granular jamming in consideration.

The flow of this paper can be categorize into two parts. Firstly, we will demonstrate the soft robotic gripper made by using silicone gel, paper and non-elastic ropes. Even though the final prototype can bend its four arms simultaneously, there are still many open-ended design, optimization challenges for independent control of each finger. Towards the end, we will describe some initial research on particle jamming with granular materials [1] [2]. Granular materials we used here are a type of material which can be made from using particles such as pulses and coffee grain etc. [3] [4] [5]. This jamming mechanism enhances gripping strength and helps to prevent unwanted deformations of fingers when pneumatic actuation is applied.

II. Soft Robotic Gripper: Fabrication Procedure & Forthcoming Challenges

In this section, we will describe an initial prototype of four-finger(s) gripper by using Lego bricks to make the mold. For our design, we plan to build gripper which can be controlled by varying its motion by providing the source of air pressure. The presence of the air will cause the elastomers to inflate like balloons for pneumatic actuation. The four fingers gripper will be able to pick, bend, grip and lift things. For our model, it is completely made up of silicone materials, which use of its intrinsic compliance to achieve shape matches. For our soft robotic gripper, we require four fingers to be able to bend in longitudinal direction by supplying optimal air pressure. Thus, we design air channels to construct pneumatic compression force in transversal direction. All bending motions are designed to generate by supplying air into air chambers inside the model. Following fabrication methods will be our first attempt in building the four- finger soft robotic gripper.

Following sections will represent a step by step procedure to establish different parts of the arm.

A. Using Lego bricks to build shape of four fingers soft robotic gripper and seal the gaps between Lego bricks and Lego boards.

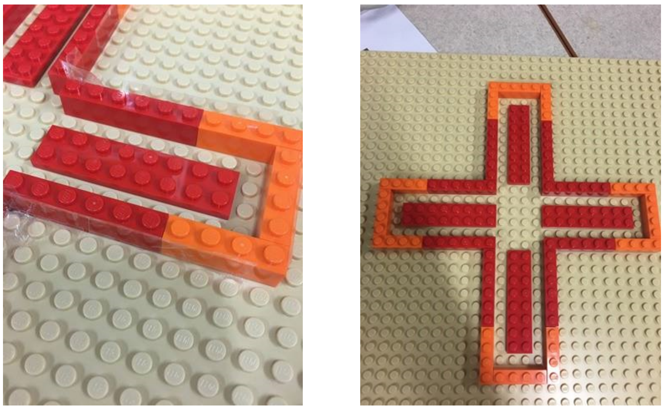


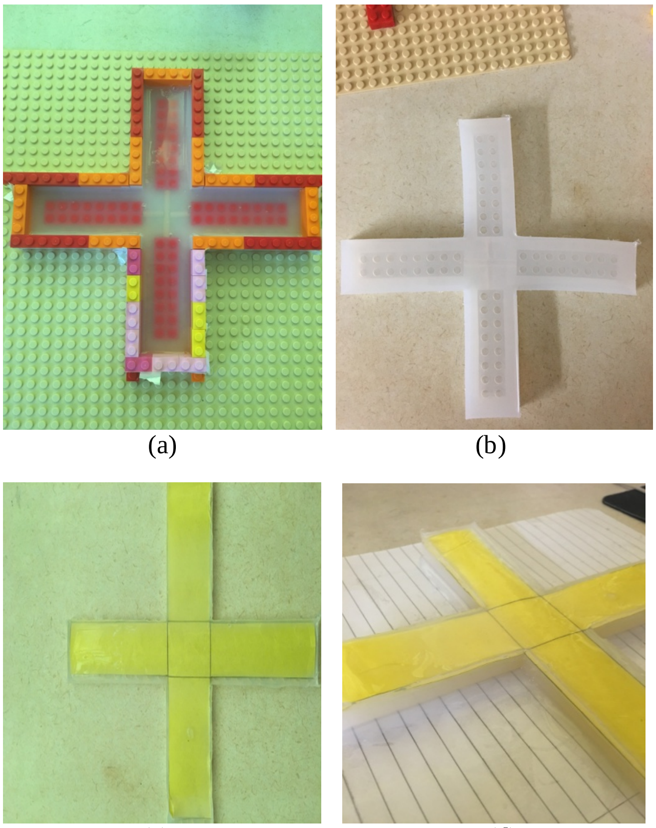
Figure 1. Lego bricks to make the mold.

B. Mixing Ecoflex A and Ecoflex B in ratio (W/W) 1:1 and keep the mixture inside a vacuum desiccator to prevent air bubbles in the silicone gel.

(a) (b)

Figure 2. (a) Show the amount of Ecoflex A. (b) Show the amount of Ecoflex B.

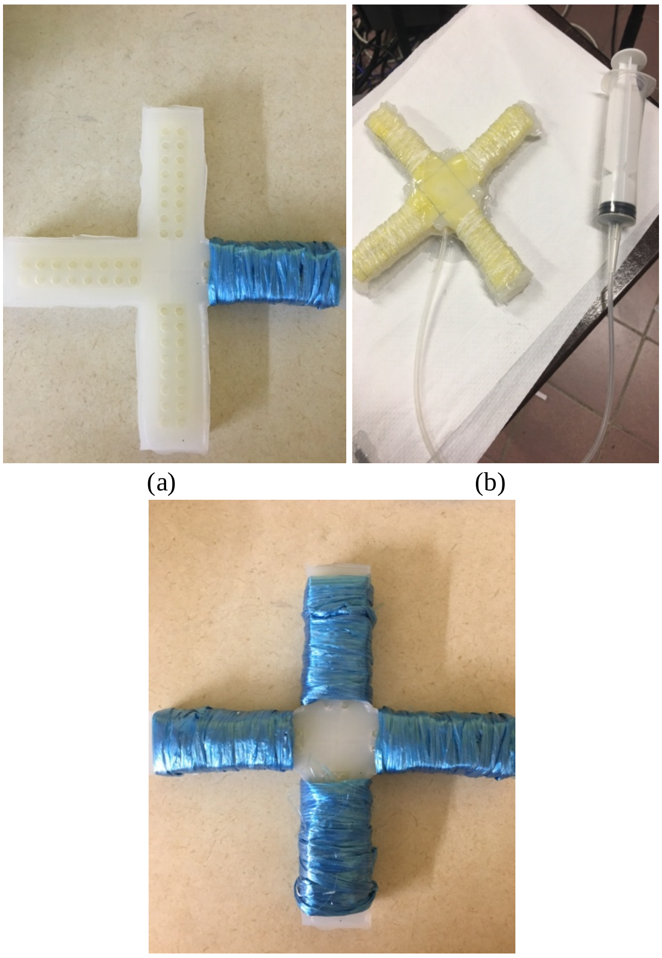
C. Pouring mixture onto the mold and wait for at least four hours for silicone rubber to cure. After making the first layer, by repeating the process to making the second layer which will serve as bottom section of the soft robotic gripper.



(a) (b) (c) (d)

Figure 3. (a) Poured Ecoflex into the Lego mold. (b) Cured layer of four arm gripper. (c) Paper cutting for air ventilation in between two layers (d) First layer and paper attachment embedded together.

D. Wrapping four arms with non-stretching ropes. The non-stretching rope wrapping is slippery so that we will need to cover the bottom of the gripper with a thin layer of Ecoflex and wait for at least four hours for it to cure. We will pump the air by connecting a tube with the middle of the air chamber and supply the air by using a syringe.



(a) (b) (c)

Figure 4. (a) Combined two layers wrapping (b) Pneumatic actuation to the soft robotic gripper (c) Final Prototype.

E. Challenges Faced

In our fabrication process, we have used chopsticks to be used as the air channels. The size of the fabrication and final prototype are also in bigger dimension and heavy for delicate medical applications. This introduces insufficient pneumatic force to be able to provide enough actuation pressure/weight to make the gripper fully expand/contract. In our future experiments, we plan to use motorized air compressor to provide sufficient pressure to make the four fingers to expand optimally. In addition, due to the different kind of ribbon materials that we used, this may cause uneven compression force applied for each arms. In order to solve this problem, we plan to wrap each arms with equal concentrations. Our plan is to achieve that all the arms will be able to expand at the same time by roughly same extent. Other than this, there is also paper ripping constraints on the bottom layer to overcome. Even though it will not affect the robot's performance much, we will try to tape around the paper and make it more durable with changing pneumatic pressure.

F. *Conclusion Drawn*

Our near term goal is to make sure that our custom made soft robotic gripper can grab different objects with different size, shape and weights. In addition, we are also trying to make the cost of making the robotic gripper optimized so that these robots can be used in different biomedical intervention areas. Most importantly, placement, speed and precision are key challenges to overcome before this technology can be used further in soft tissue manipulation and surgery therein. In this stage, we are preliminary focusing on design and fabrication and in the future works we try to make the complex pick and place movements mechanically.

III. Particle Jamming: Initial Trial

In order to increase the ability for four fingers soft robotic gripper to grab different shapes of objectives, we have decided to look into the particle jamming so that it allows gripper to pick up huge range of delicate, unfamiliar objects. In present studies, there are different kinds of particle jamming grippers which are ranged from vacuum-based suction grippers to multi fingered hands. The main working principle is due to the particulate materials have a property called jamming transition. This property will allow the particles to behave like from a fluid like to solid like when the particles can no longer slide past each other. For most of the earlier reports, coffee grains were used for jamming because the vacuum-packed coffee is as hard as a brick until the package is unsealed.

A. *Fabrication Procedure*

When the gripper approaches the objectives in soft state, it will deform around the object. Then the air is evacuated from gripper and the soft robotic gripper will have enough force to grab the objects. In current scenario, most of the active commercialized robotic grippers have multi fingers which can be actuated independently. However, these products engender extensive physical and computational complexity which includes the higher costs and thus limits their adoption among large range of biomedical industries. For pick-and-place performance evaluation we plan to use UR5 robotic arm, which includes high-pressure air lines, controlled by an embedded solenoid valve. Pasar Barley and Pasar Green Beans were chosen as the granular materials for these tests because of its superior performance in jamming hardness trials tests. Relatively low density of Pasar Barley and Pasar Green Beans are also advantageous, as it can be used to fill relatively large areas of a robotic gripper without increasing much of total weight and straining the membrane.

B. *Challenges and Future Scope*

In our fabrication processes, granular beans slide over each other and it is increasingly difficult to use the Oppo rubber bands to wrap around the silicone elastomer. The silicone rubber cannot fix in its position and there is air leakage which is difficult to suck up air inside the prototype. In order to solve the problem, we are planning to use suitable size of rubber cloth and instead of using the glue to seal the silicone rubber and rubber cloths, we will ty and use plastic materials to make a sealed bag. We could also pour silicone gels on top and below the bag, after it is cured and will peel off the gel and fill in the bag with small particles.

IV. Conclusion

This four finger soft, delicate robotic gripper was primarily designed to be used as an educational tool and simulate children's interest in field of robotics, biomedical and engineering applications. Secondly, it can be expanded further to be used as a rehabilitation device with optimal control and fine design parameters. There were numerous trials performed in testing the hand and provided an initial satisfactory results. The novelty to use this fabrication procedure is to investigate the air powered soft robotic gripper using Lego bricks and hence no 3D printing required. The asymmetry of the gripper is been counterbalanced using granular material for more delicate range of operations. Here we have used several granular materials as commonly available e.g Pasar Barley and Pasar Green Beans for our experiments. In the future, we will work closely with increased complexity to formulate coherent solutions for biomedical interventions especially in surgical manipulations.

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