Soft Gripper Using Pneumatic Network Actuators

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Abstract—As the robots are advancing beyond the conventional fields i.e manufacturing and automation, we need more than the conventional rigid robots as the robots are more interacting with human, we need some safety as rigid robots can easily harm humans.Soft robotics is the perfect solution when the interaction between the humans and robots increases, as soft robots cannot harm the humans or objects they are interacting with. Also, the main attraction of using soft material for making robots are Low cost, high compliance and easy control.This project report is about using Pneu-nets for making a soft gripper.In this paper, a tri-fingered gripper is made using Pneu-nets is made and tested to grasp and hold various objects with varying size, weights and geometry.

Index Terms—Soft Robotics, Pneu-nets,Compliance,Adaptivity

1 INTRODUCTION

Rigid conventional robots have limited abilities when it comes to elastically deform or to adopt their shape to the external environment and obstacles.As we know that these rigid robots have the potential to be incredibly powerful and precise, but they are highly specialized i.e. they don't display multi-functionality.As the field of robotics is advancing beyond manufacturing and industrial automation into the domain of health care,search and rescue, and most importantly service robots, the robots have to be less rigid so that we can achieve a safe functionality between the robots and human.

So as to achieve this safe harmony we have to tend towards robots made from soft materials. In contrast to rigid robots, soft robots have bodies made out of intrinsically soft and extensible materials that can easily deform and absorb much of the energy arising from a collision.Soft robots are highly adaptive to their surrounding environment and objects, so they can easily perform complex tasks with any extensive planning or controls.Furthermore, to achieve inherent compliance and adaptability, the soft robots could be combined with the conventional robotic designs.

Service robots are needed as the global aging presents a new challenge, the robots are needed assist humans beings in Activities of Daily Living, with humans being the main interaction target, the primary concerns are safety,adaptability,task-worthiness, and low cost.The following requirement makes soft robotic grippers as the potential candidates, exploiting the intrinsic properties of the soft material.Also, to achieve inherent compliance and adaptability, the soft material can be combined with conventional robotic designs. But, the inherent compliance of the soft grippers often limit the maximum output force, hence decreasing the grasping reliability and payload capacity.

Over the time,researchers have always taken inspiration from nature to design and built complex machines. Robotics has been always inspired from Humans. Grippers have been based on human hand and fingers. Human hand has a pretty good prehensile system, which always researchers to use them in order to mimic its skills. The human hand has a total of twenty-two DOF, moved by forty muscles,

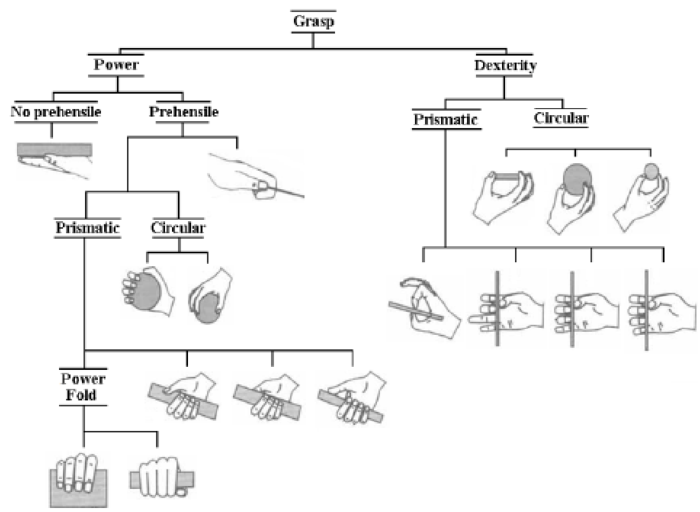


Fig. 1. Classification of Grasps

which makes it a complex structure.The muscles allow different grasping configurations which are classified into two main groups, the prehensile and non prehensile, further classification on the Grasping is shown in Fig 1. [1]

The objective of this project was to make a soft gripper using Pneu-net actuators and to grasp and hold different objects with varying sizes, weights and geometry. The paper is structured in the following way, Section 1 gives introduction of the project and soft robotics, Section 2 gives some information about the related work done in the field of soft robotics in grippers, section 3 explains about the pneu-nets and their fabrication , section 4 explains about the gripper, Section 5 is about the results from the project and section 6 is conclusion.

2 RELATED WORK

For the following paper, i have done an extensive research work different soft gripper available right now. Recently there has been much development for using soft robot with

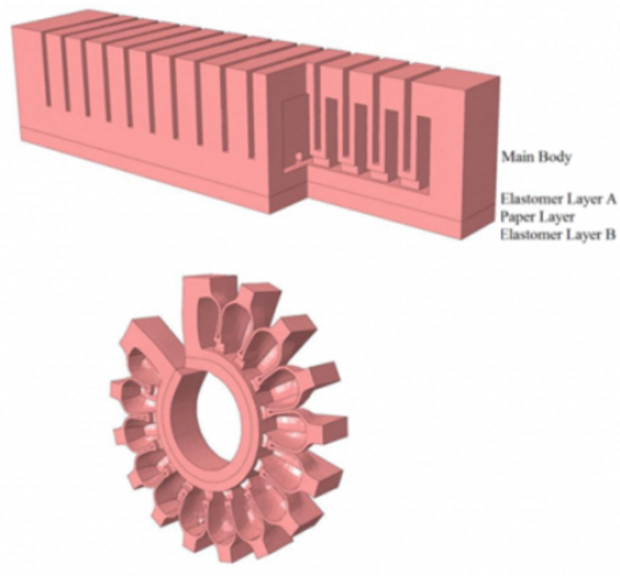


Fig. 2. Internal Structure of the Pneu-net

the readily available conventional rigid robots. Dameitry et al. [2]have proposed a finger actuator to perform grasping to hold various objects, which is attached to a aerial manipulator.In their paper, Zhou et al. [3]have proposed a novel tri-fingered gripper comprising of three dual-chambered ellipse-profile soft pneumatic fingers and a novel palm design with a compliant chamber. Homber et al. [4]have made a new soft robotic gripper attached to a Baxter robot, the gripper has proprioception by embedding a flex sensor inside the finger to get the curvature of a finger around a certain axis.

Apart from just using the soft actuator, Wei et al. [5] have presented a gripper with a variable stiffness for adaptive grasping and robust holding by combining the soft actuator with particle pack which is capable of holding objects with different shapes, weights and rigidities.Galloway et al. [6] have presented an interesting work, they have presented the development of an underwater gripper using two different types of soft actuators to delicately manipulate and sample fragile species in the deep reef.

3 Pneumatic Network

The Pneu-net actuator [7] consists of chambers arranged parallel in a row.The wall sections between two chambers are thin and their is a strain-limiting layer embedded in the base.When the actuator is inflated, this chambers expand and the thin walls bulge which causes the actuator to expand in the axial direction, but due to the strain-limiting layer it doesnt expand but bends instead.The actuator consists of two parts as shown in the Fig.2, the Main body which expands and the base layer which has the inextensible paper layer embedded inside.The stiffness of the actuator can be changed without changing the material, by making a wall thicker, the stiffness of the actuator can be increased easily.

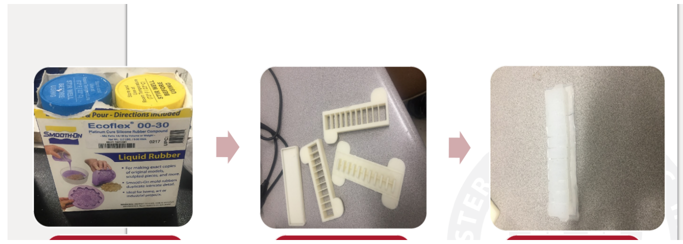


Fig. 3. Fabrication process

3.1 Fabrication

The actuator made here has 11 chambers, each chamber is 8 mm long, 15 mm wide, 15 mm high. The sidewall thickness is 1mm, the other walls have a 2 mm thickness. The central channel which allows the air to pass to all the chambers has a cross-section of 2mmX2mm.

As discussed above, the actuator is made up of two parts, so the two parts are casted separately and then glued together, so for that we need two molds. As shown in the Fig 3, the molds are 3D printed using PLA plastic, as the main body is complex so it is printed into 2-part mold and the base layer is printed separately.

Fig shows the complete fabrication process, Ecoflex-0030 is the silicon is used for making the soft actuator, so the first step is preparing the silicone, for the entire molding of 1 Pneu-net 60 gm of Silicone is required. Once the silicone is prepared, it is poured into the 3D printed molds, the main body is filled entirely and the base layer is filled upto the half way mark and a paper(inextensible layer) is embedded to the base layer such that it does get submerged into the silicone. Then both the parts are allowed to cure in the oven for around 40 min, if they are allowed to cure at room temperature it take around 8-10 hours to completely cure the finger.

After the two parts are cured, we need to glue them together with using a small layer of silicone and let it cure for another 40 min to completely make the finger.But this is the trickiest part of the process as we have to take care about not blocking the central channel of the actuator which supplies pressure to all the channels.The weight of each finger is around 65 gm and the finger actuates at a low pressure of 2 PSI.For me it took 14 fingers to make 3 perfect actuators which can be used for the gripper.

4 Gripper

For the gripper design, i took inspiration from human hand. The hand is divided into two sides, the skill side and stabilizing side as shown in Fig 4, the index, middle finger and thumb are the part of the Skill side and the last two fingers are for stabilizing the hand. As we know that most of the grasping, holding and writing part is done by the skill side of hand, so for my design i choose to have three fingers which try to mimic this kind of skill side of the hand.

The gripper(Fig 5) has three soft actuators, two on one side and the third one on the other side. The two on the same side represents the index and middle finger of the human hand and the third one represents the thumb. The actuators were attached on a cardboard with zip ties as i could change

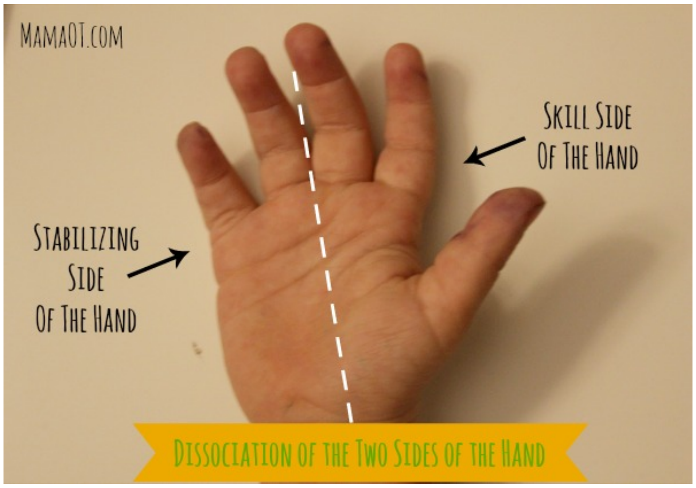


Fig. 4. Dissociation of the two sides of the hand

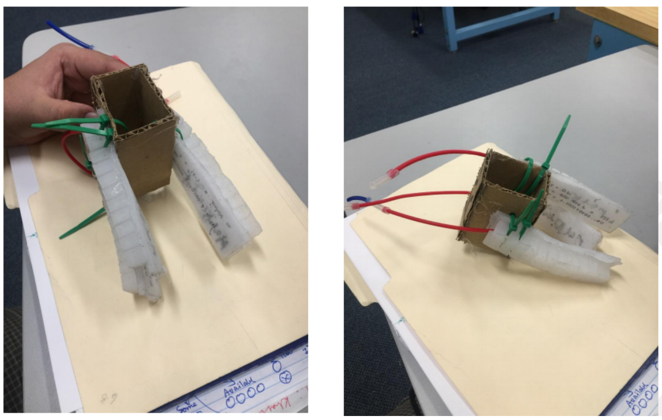


Fig. 5. Gripper Prototype

the position of the actuator according to my needs. Due to time constraint, i was not able to make a soft palm so i had used a cardboard block to make a palm where the fingers are attached.

The actuators are inflated by using a small pipe which is connected to a power source, all the three actuators are connected to single pressure source, so the assumption here is that pressure is uniformly distributed on all the three actuators and the actuators inflate at the same time and the bending in all the three fingers is uniform.The gripper is 240 gm in weight and all the fingers actuate at a small pressure of 2 PSI.

5 Results

For testing the gripper prototype, I did several grasping experiments for the testing the capabilities of the designed prototype. The experiments are done on two separate things, first the grasping capabilities of a single finger and the second was for testing the capabilities of the entire gripper.

For checking the grasping for a single finger, i tasted the finger to grasp a few different things within a range of different weight size, geometry. The first thing i used the finger to grasp was a plastic cup weighing around 9 gm, to

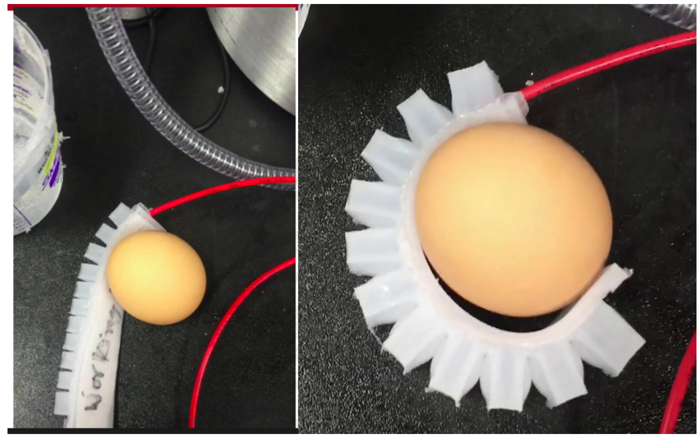
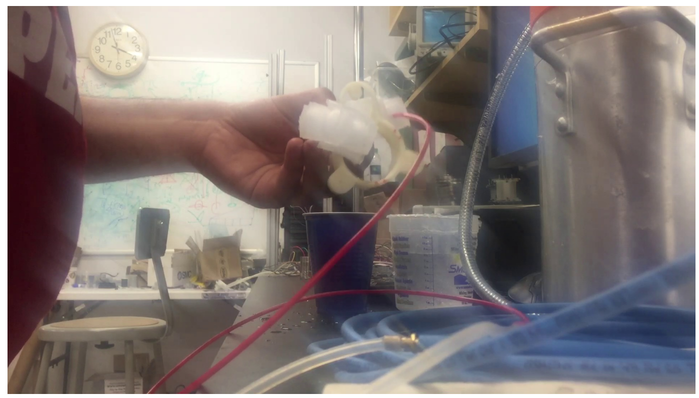


Fig. 6. Grasping an Egg



test the grasping and it was successfully grasping the cup and holding at a constant pressure of 2 Psi. Second item i used to test the grasping was an egg weighing around 58 gm and it was successfully holding the egg without breaking the egg as shown in Fig 6.

For testing the range of objects, i tested the finger to grasp various objects varying from a pen to a complex 3D printing part which was available in the lab. The finger was able to grasp and hold objects from a weight of around 4 gm to 70 gm at a constant pressure, so it was good enough to test the fingers on the gripper.

Their are various disadvantages of using the fast Pneu-net, as the thickness of the wall is very small so it easily gets bubble out on applying more pressure than 2 Psi. Also, the central channel gets blocked while the curing of the fingers and so all the chambers don't get actuate so perfect bending is not achieved,so its hard to make the Pneu-nets.

After making the gripper,to test the grasping capabilities various objects with varying sizes, weights and geometry were tested. First, for testing the holding capability the gripper was made to hold and grasp a cup weighing 6 gm at a constant pressure. For getting a range of weights, i kept on adding weights to the cup to check the limit of the gripper.So, starting with 6 gm till the weights reached 458 gm . It was successfully able to grasp and hold the cup weighing 458 gm.

To test the range of objects, i tested objects which were available in the lab, first thing was a jaco Arm head weighing 130 gm as shown in the Fig. The jaco arm head has a

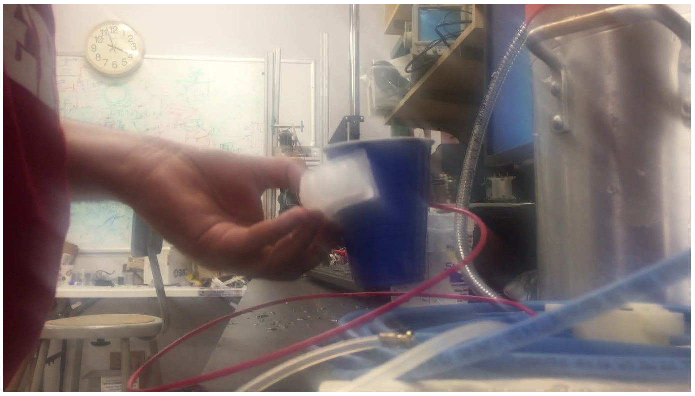


Fig. 7. Finger holding a cup

Fig. 8. Gripper holding the cup

complex shape and also it was smooth so it hard to grasp but the gripper was successfully able to hold and grasp the object. The other object was a syringe which was weighed around 70 gm, the gripper was able to hold the object both horizontally and vertically.

To check the holding capability of the gripper, the gripper was made to hold the cup and the gripper was shaken vigorously. It was successfully able to hold the cup to some extent, the hold was quite strong, so it took some vigorous shaking to finally lose the gripper's hold.So it was a good result to check the holding capacity.

The Gripper failed to grasp and hold a plastic bottle weighing around 500 gm but it was successful to hold when the bottle weigh around 350 gm. The Gripper was successful to grasp the bottle when the weight was high but was not holding the bottle. So the gripper successfully grasps

Fig. 9. Gripper holding the Jaco-arm Head

various objects but it can only hold up till some extent.

With all the advantages, their is also a problem for the gripper, it is the same problem of bubbling out of the chambers, so when we apply more pressure the bubbling out happens and also, when the grasping is done for a longer time the bubbling effect also takes place.So we have to decrease the pressure so that the actuators do not popped out.

6 Conclusion

Soft reinforced actuators can be used in a range of various applications. People have used them in industrial for making an automated bakery, where the soft gripper is used to grasp and hold fragile bakery items.There are many problems with Pneu-net actuators as they are very hard to manufacture, they can be easily bubbled out as the thickness of the wall is very small.

Also, variable stiffness is needed to grasp very complex which can be implemented on the actuator. This actuator can be used for stroke rehab, as we can attach the actuators to each finger of the human can use the bending of the actuator to bend the finger and help the patient to gain some movement in the fingers. Currently, there is no sensing on the fingers, we can add force and flex sensors to the actuators which can help more in the grasping and holding characteristics.

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