BioRobotic Laboratory

EPFL

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Hardware Integration of a Universal Gripper to the Roombot Module

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Abstract

The goal of this project is to integrate a universal gripper to a modular robot developed at the Laboratory of Bio-Robotic, the Roombot. The gripper consists of an inflating membrane filled with granular material that allows various types of objects to be picked up using an air pumping system. Integrating the gripper to the Roombot enables it to interact with various daily life objects that haven't been specifically designed for it. It opens, as well, the possibility to interact with human beings harmlessly, thanks to the compliant property of such gripper.

Firstly, object pickup will be demonstrated in this project. Secondly, two modules will be equipped with a gripper and sensorless, mid air, object passing will be performed, which is a novelty in the field of modular robotic.

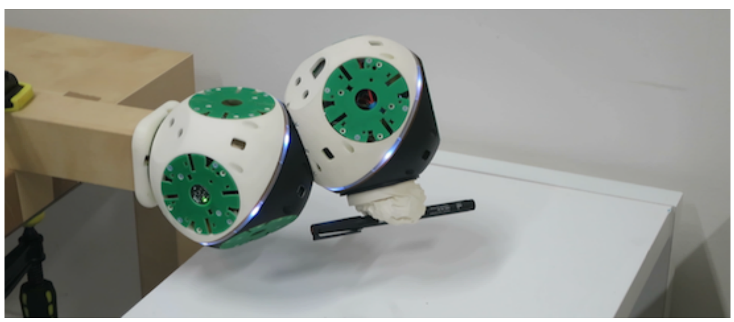

Figure 1: Object pickup with the Roombot

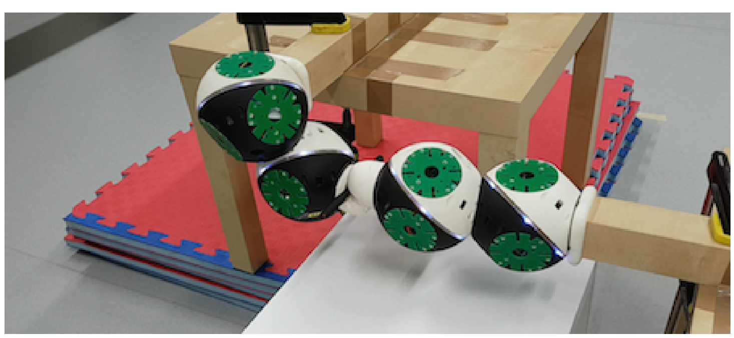

Figure 2: Object passing with the Roombots

1 Introduction

Figure 3: The Roombots as adaptive furniture

The Roombot project takes place in the field of modular robotic. Each module is capable of 3 rotations and has the ability to grip to one another and to certain surfaces specifically designed for the gripper. With those properties, the Roombots are capable of versatile tasks as they can move, combine, reassemble with one another or with passive elements. One application for the Roombots would be in assistive technologies, the modules would assemble into adaptive furniture that move and rearrange according to the users' needs. Elderly or people with motor handicap would be the first to benefit from such modular robots, as they would regain mobility thanks to a new environment that will adapt to solve their daily life difficulties. The Roombots

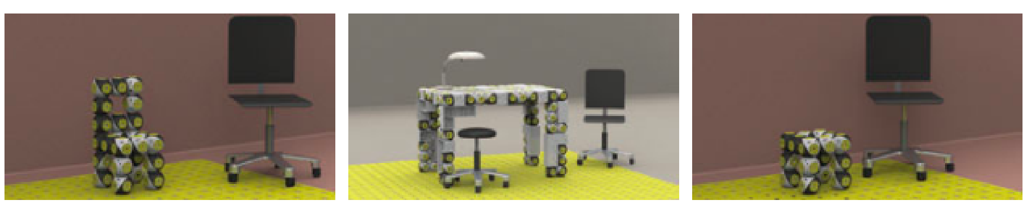

Figure 4: A vision of the Roombots

are already able to, assemble to one another, assemble with passive element and move on and off grid. The grid being a specially designed surface on which the modules can grip onto. Those capabilities allow a wide range of applications to be envisioned but remain limited in term of interaction with the environment. The Roombots can so far only interact with elements that have been specifically designed for them. The integration of a universal gripper to a Roombot module will allow much wider interaction as various object can be picked up. Direct interactions with human beings can be possible due to the compliance of such gripper. Finally, equipping two modules with a gripper will allow mid air sensorless object passing between two Roombots, which is interesting as such task are usually complex in robotic and had not been achieved in the field of modular robotic yet.

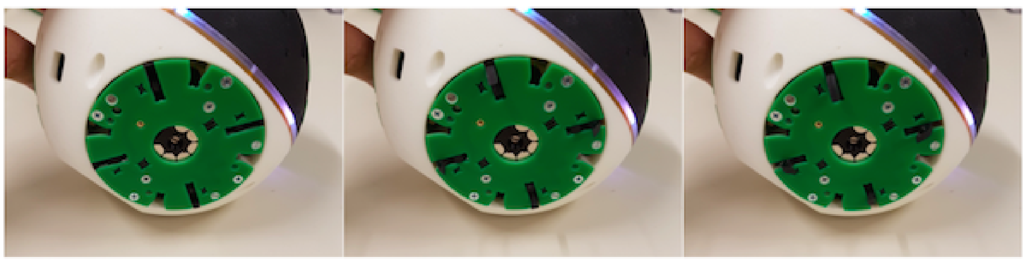

Figure 5: The existing gripper

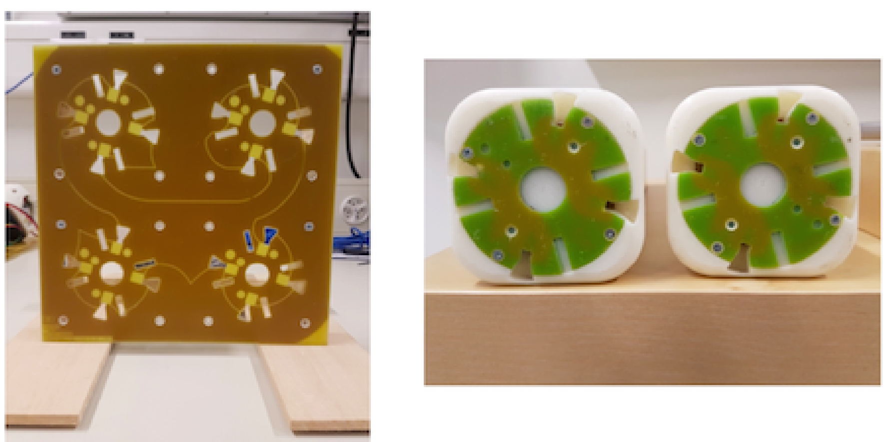

Figure 6: Passive gripping elements

2 Design

2.1 Existing Hardware

A gripper had already been designed in a previous project [1] as a test setup lying out of the Roombot. The first focus of this project was to integrate those elements into a Roombot shell.

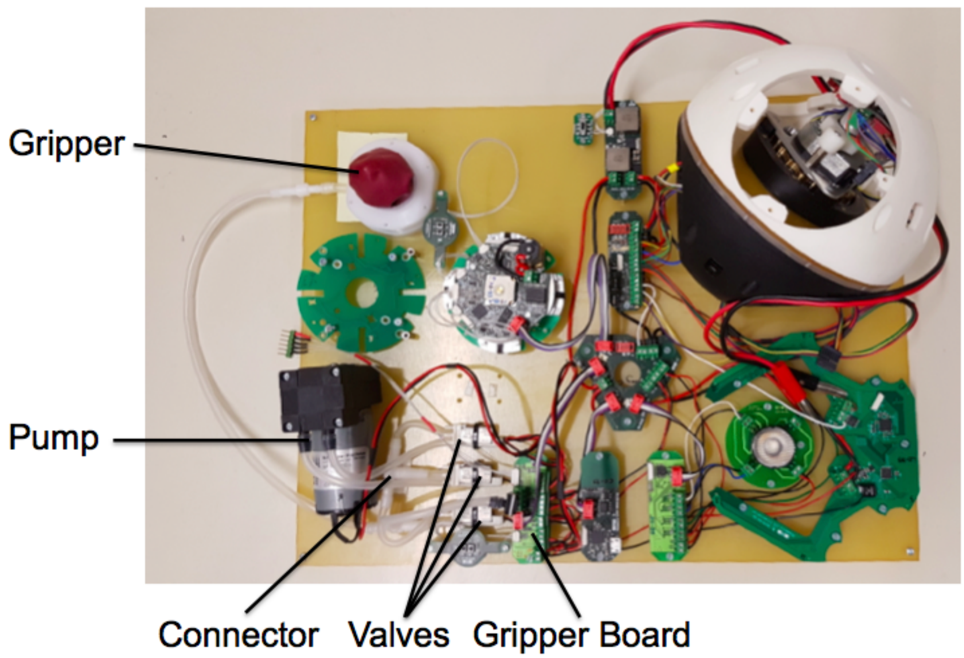

Figure 7: Existing gripper setup

The following elements are specifically part of the gripper:

- Gripper board
- 3 Valves
- A large pump
- Large connectors
- Tubing
- Gripper

2.2 Designed Elements

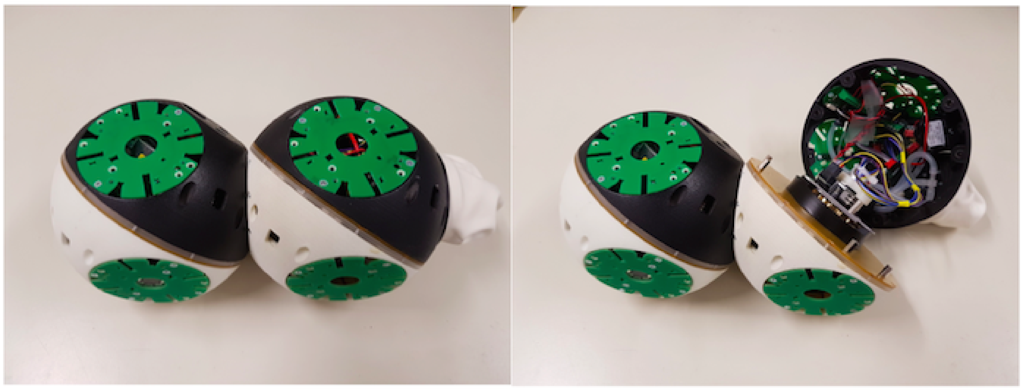

Figure 8: The Gripper, closed and open

The space constrains being very challenging; a few iterations were necessary to fit all the components into the module. The difficulty resides in the fact that cables, connectors and tubes are not represented in the CAD and end up taking a relatively large space. The tubes could not be bent more than a minimum radius in order to avoid the tubes to collapse.

The following elements have been designed/changed to meet the constrains.

- Pump support
- Valves support
- Machined 3 ways tube connector
- Redesign of the upper and lower plate of the gripper
- Selection of a smaller pump

The two plates (upper and lower) holding the membrane have been redesigned and machined to fit ergonomically onto the Roombot's shell. A smaller pump than the originally chosen one was selected to fulfill the space constrains. The aspiration provided by the smaller pump was tested and was sufficient to performed the required tasks. Finally, the Roombot was closed and experimentation could be started.

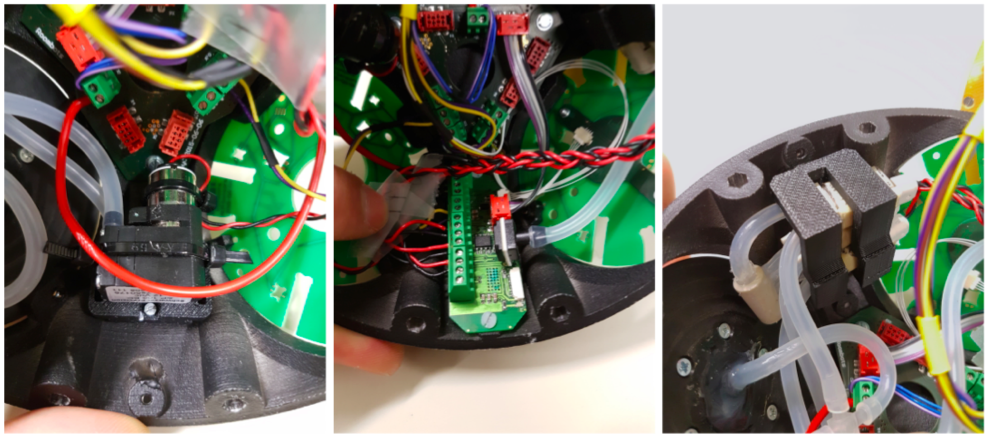

Figure 9: Left: Pump and its support Middle: Gripper PCB Right: Valves and support, designed tube connector

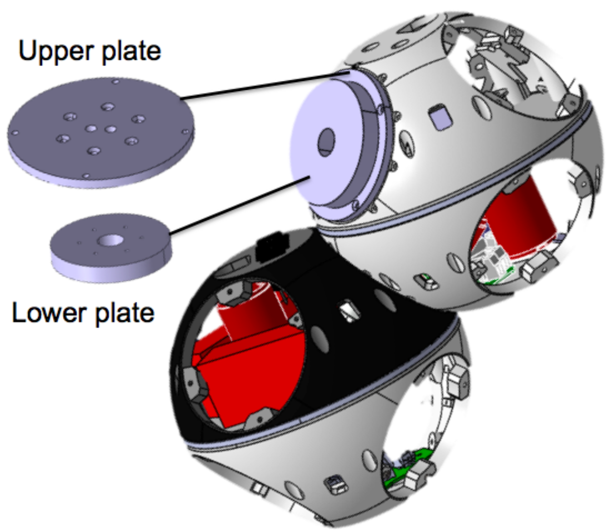

Figure 10: Redesign of upper and lower plates to fit the Roombot

3 Picking Up Objects

The first goal was then to prove that the newly integrated gripper was able to pick up objects. To do so, a downward motion onto an object was programmed followed by the suction of the air out of the membrane. A few setups were tested, each of them lead to incremental improvement to finally be able to pick up with a pen with a 100% success rate as well as various other small objects using the same trajectory.

3.1 Setup 0, First Object Pickup

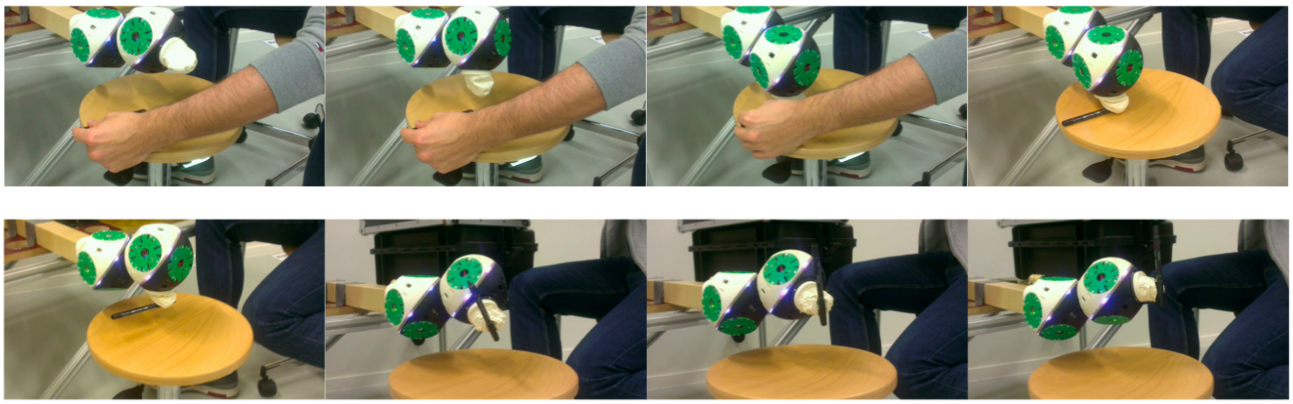

Figure 11: Setup 0, First object pickup

A first trial was done as soon as the Roombot's gripper was ready. After a few experiments, the Roombot was able to pick up a pen. The gripping was slightly assisted as the pen was held by the user while it was picked up. This first trial showed that such object pickup was possible and lead to the second setup of experiment which goals was to quantify how reliable was the object pickup.

3.2 Setup 1, Object Pickup Reliability

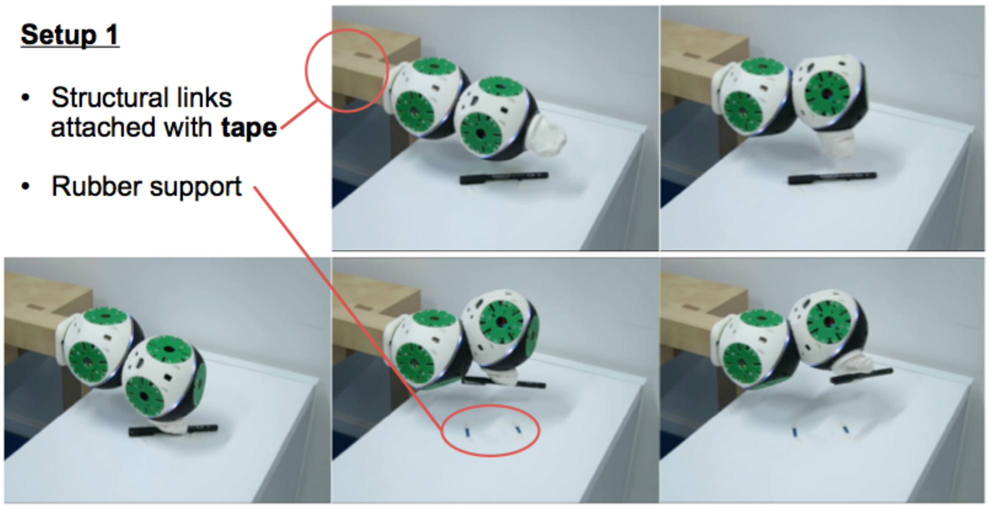

Figure 12: Setup 1, Low success rate

The first configuration showed underwhelming results. Only 15% of the time was the Roombot able to pick up an object. A rubber support was used in order to avoid slippage from the pen. After analysis two main elements were improved that lead to Setup 2 : The structural links were improved, the Roombot was firstly attached to a support that was weakly linked to the table with tape. This structural linked was rigidified using clamps. And the motion of the Roombot was reworked to obtain a better vertical downward motion onto the pen to limit slippage.

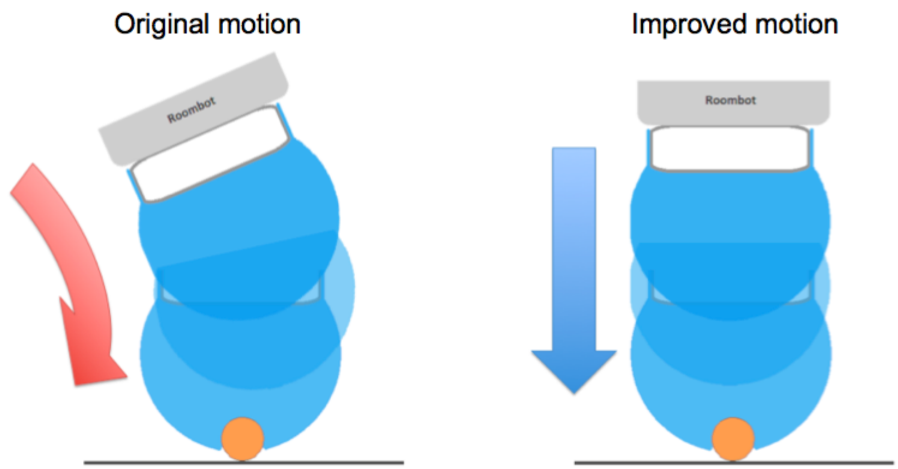

Figure 13: Original and improved motion

3.3 Setup 2, Stronger Structural Links and Improved Motion

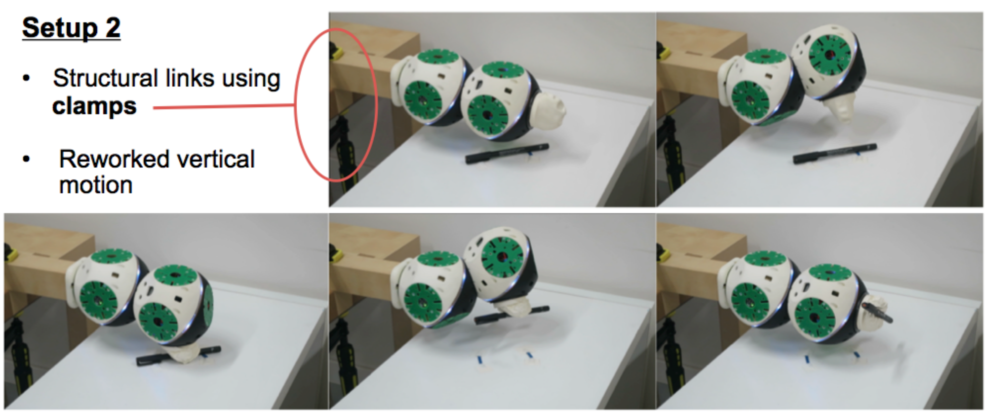

Figure 14: Setup 2, 100% success rate with support

The revised motion and stronger structural links greatly improved our results as the pen was picked up with a 100% success rate after those modifications.

3.4 Setup 3, No Support and Slight Inflation Before Pickup

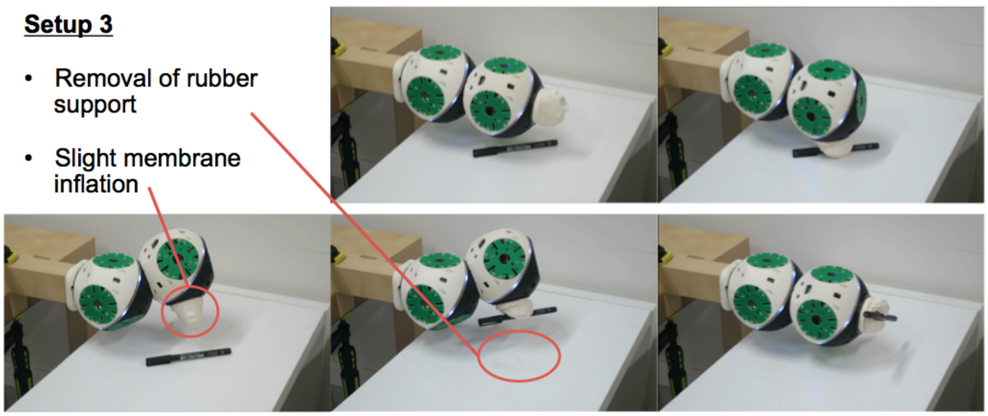

Figure 15: Setup 3, 100% success rate without support

Finally, having such good results with configuration 2, configuration 3 was tested without the rubber support. A slight inflation was added before picking up the object, to offer an even gripping surface as the membrane is tensed. Once again, a 100% success rate was achieved and the rubber support showed to be no longer necessary. The motion is described in the code sent to the Roombot in a following section.

3.5 Various Object Pickup

Various object pickups were performed using the same trajectory to demonstrate the versatility of such gripper: USB key, screwdriver, paintbrush, glasses, bottle cap...

Figure 16: Various object pick up: bottle cap, glasses, screwdriver and USB key

Setup 1	
Dropped	Picked Up
1	
	1
1	
1	
	1
1	
1	
1	
1	
1	
1	
1	
1	
1	
1	
1	
1	1
1	
Success	**15.79%**

Setup 2	
Dropped	Picked Up
	1
	1
	1
	1
	1
	1
	1
	1
	1
	1
	1
	1
	1
	1
	1
Success	**100%**

Setup 3	
Dropped	Picked Up
	1
	1
	1
	1
	1
	1
	1
	1
	1
	1
Success	**100%**

Figure 17: Reliability of pen pickup: Setups 1 to 3

3.6 Conclusion of Picking up Object

Those experiments validate that object pick up with a universal gripper integrated to the Roombot is possible and works. In the vision of Roombot used as assistive furniture, this new capability increases greatly the interaction the modules can have. It is now able to pick up various object that are not specifically designed for it.

The goal of this section was to achieve object pick up, the trial and error approach allowed us to reach that goal as fast as possible. In further research, different aspect of the object pick up would be interesting to quantify. *Does the filling of the membrane matter? What influence has the positioning and orientation of the pen? Is the membrane asymmetry problematic? What other motion are possible? ...* Those questions are partly answered in other researches [2] [3] [4] [5] [6] but could be of interest for future work.

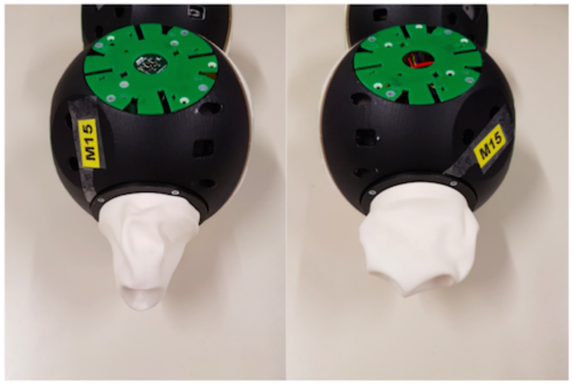

Figure 18: Membrane Asymmetry

3.7 Code Submission to the Roombot

In order to send code to the Roombot, the software CoolTerm for Mac has been used in combination with a USB Bluetooth terminal.

Listing 1: Code sent via Bluetooth Setup 3

```
//Zero position
sM2-15pa0
sM1-15pa0
sM0-15pa0

//Pre pick up position
sM0-15pa500
sM2-15pa-1300

//Slight membrane inflation
sG0-15dp2000

//Movement onto the object
sM0-15pa-150
sM2-15pa-1000

//Air suction
sG0-15dp1200

//Object pick up
sM0-15pa500
```

```
sM2−15pa−1350

//Zero position motor 2
sM2−15pa0

//Zero position motor 1 and 0
sM1−15pa0
sM0−15pa0

//Object release
sG0−15atm
```

4 Sensorless Mid-Air Object Passing

4.1 Strategy

A universal gripper has the property to pick up object without the need of a high accuracy positioning. This property has been used to pick up objects in the previous section and will be used for our object passing strategy. A sequence of commands will be sent to each of the module that will perform them without feedback loop.
First the object will be picked up as demonstrated earlier. The strategy then is to use a combination of motion and membrane inflation to transfer the object from the first gripper to the second. This combination will provide a certain pressure onto the object to help it be picked up by the second gripper. This pressure is necessary to have the granule surround the object we want to pick up to form a kind of hook. The details of the motion are commented 4.3.

4.2 Passing a Double Pen

The first attempts of object passing were done using a particular object: "a double pen." This object has two clear gripping surfaces that should ease object transfer from one module to another. This experiment was successful but only represented only an intermediary step before trying object passing of a "real" object.

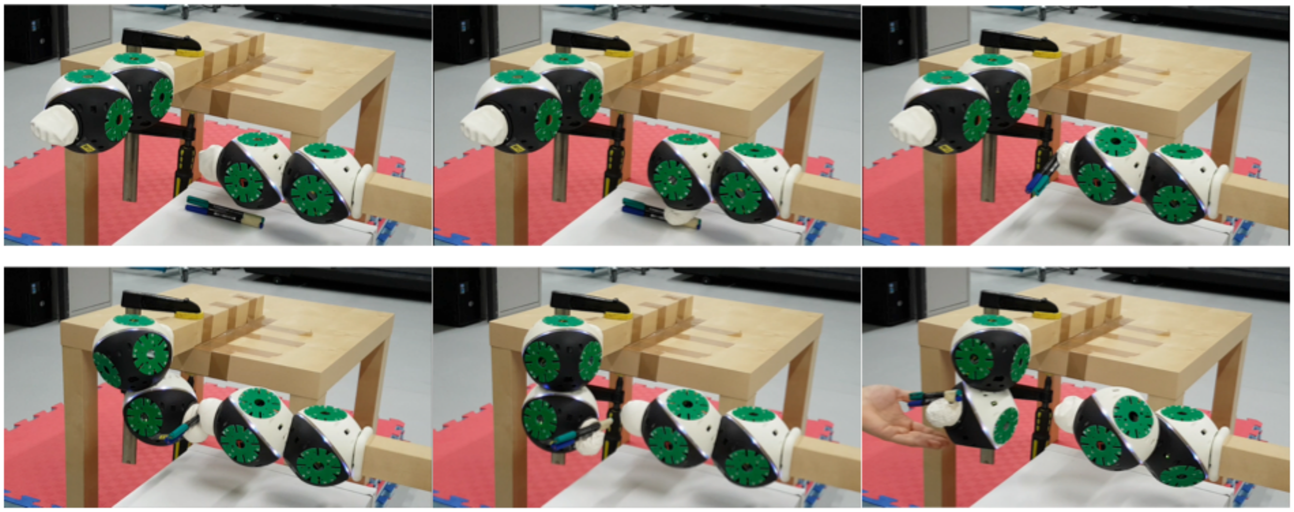

Figure 19: Passing a "Double Pen"

4.3 Passing a Pen

Finally, a complete object passing from one module to another was achieved using our usual pen. The complete motion is described here under and the video: Object Transfer.mp4 should be watched.

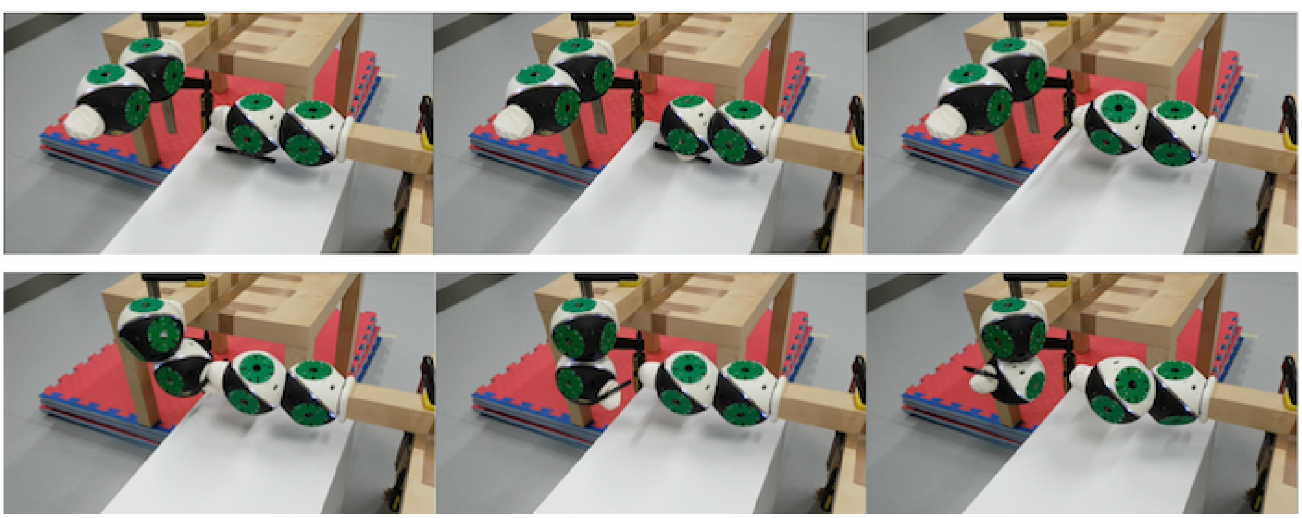

Figure 20: Passing a Pen

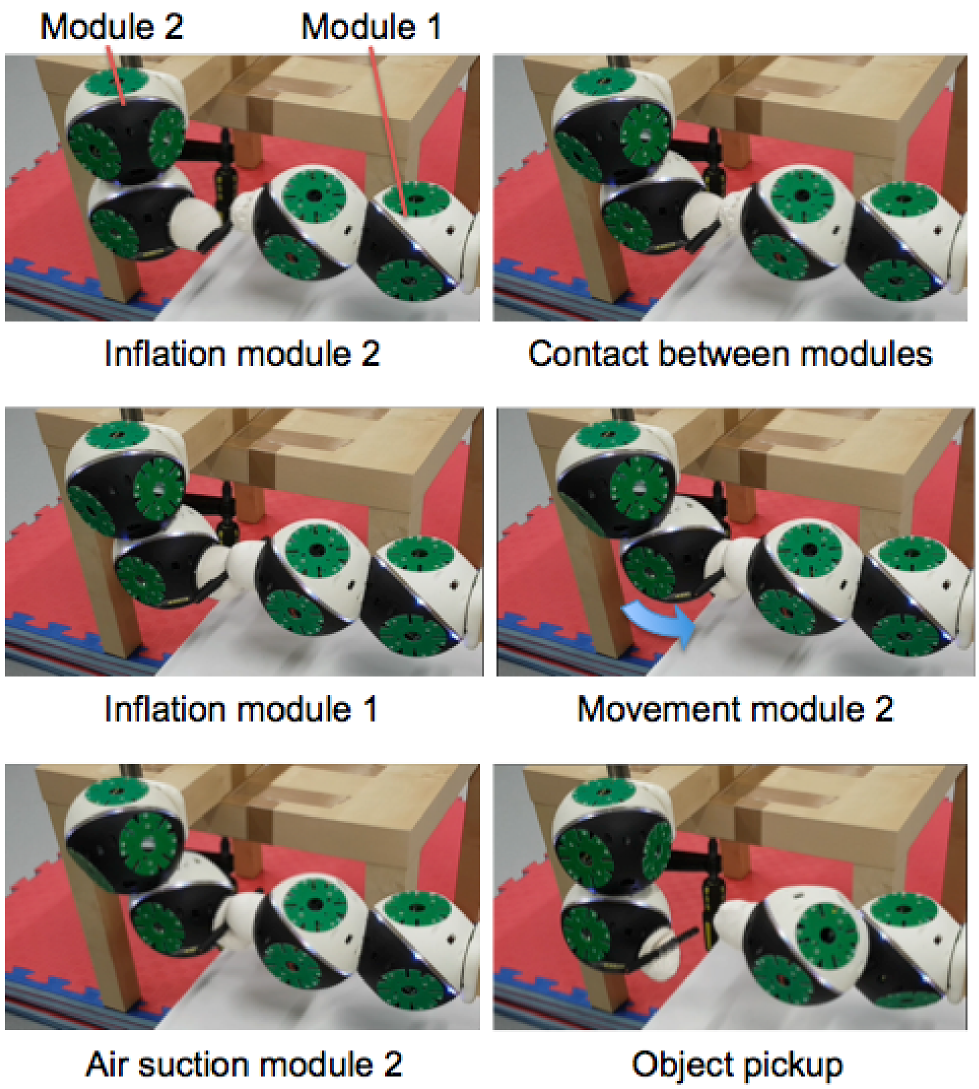

Figure 21: Passing a Pen Strategy

The experiment was a success and demonstrates that with a certain strategy, sensorless object passing is possible between two modules. This observation opens the path to further research on the topic. For example, other strategies can now be envisioned and compared, the conditions under which object passing is possible can be investigated, and so on..

4.4 Code Submission to the Roombot

The following coe was sent to the Roombots for this last experiment.

Listing 2: Code Sent via Bluetooth Object Passing

```
//Zero position module 2
sM0-12pa0
sM1-12pa0
sM2-12pa0
sG0-12atm

->M1
//Zero position module 1
sM2-15pa0
sM1-15pa0
sM0-15pa0
sG0-15atm

//Positioning before pickup and slight membrane inflation
sM0-15pa500
sM2-15pa-1300
sG0-15dp2000

//Movement down to pick up object and suction of the air
sM0-15pa-150
sM2-15pa-1000
sG0-15dp1200

//Object pick up
sM0-15pa500
sM2-15pa-200

//In position for transfer
sM1-15pa100
sM0-15pa200

->M2
//Positioning before transfer and slight membrane inflation
sM0-12pa-1200
sM2-12pa-1200
sG0-12dp2000
```

```
//Contact between the two membranes
sM0−12pa−1400
sM2−12pa−1000

–>M1
//Inflation of module 1 membrane
sG0−15dp2000

–>M2
//Motion towards module 1
sM0−12pa−1600
sM2−12pa−800

//Air suction
sG0−12dp1000

//Movement away
sM0−12pa−1100
sM1−12pa−200
sM2−12pa−1000

–>M1
//Leaving space for module 2
sM2−15pa−500
sM0−15pa500
sG0−15atm

–>M2
//Motion with object
sM1−12pa−1000
sM2−12pa−1500

//Object release
sG0−12atm
```

5 Conclusion and Future Work

The goals of this project were achieved, a universal gripper has been integrated to two Roombots modules, which enabled them to pick up various object as well as passing object from one module to the other. Those new skills allow the Roombot to perform new tasks that are completely relevant in the framework of the Roombots as assistive furniture: Fetching object, recovery from a fall, objects manipulation... will now be possible.
A few trajectories iterations allowed the pickup of small objects to be achieved with a 100% success rate and different objects were picked up using the same trajectory. The object transfer was performed using a certain strategy that uses the possibility of inflating the membrane to help transfer an object from one module to another in combination with a certain motion. This project will serve as a proof of concept on which further research can be undertaken to investigate under which conditions this object transfer is possible: *Are there other strategies to pass objects? Are they better? Bigger membranes could be used, what are the size limitations for a given pump? How a more powerful pump impacts the quality of the object gripping? Does the orientation of the object matter? What type of objects (size, shape, surface) can be picked up?...*

6 List of Tables and Figures

7 References

[1] Ahmet Safa Ozturk. Universal gripper controller design with visual feedback. *EPFL, Semestre Project, BioRob*, January 2016.

[2] John R. Amend, Jr., Eric Brown, Nicholas Rodenberg, Heinrich M. Jaeger, and Hod Lipson. A positive pressure universal gripper based on the jamming of granular material. *IEE Transactions on Robotics*, 28(2), April 2012.

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[5] Nadia G. Cheng and al. Design and analysis of a robust, low-cost, highly articulated manipulator enabled by jamming of granular media. *IEEE International Conference on Robotics and Automation (ICRA)*, pages 4328–4333, 2012.

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