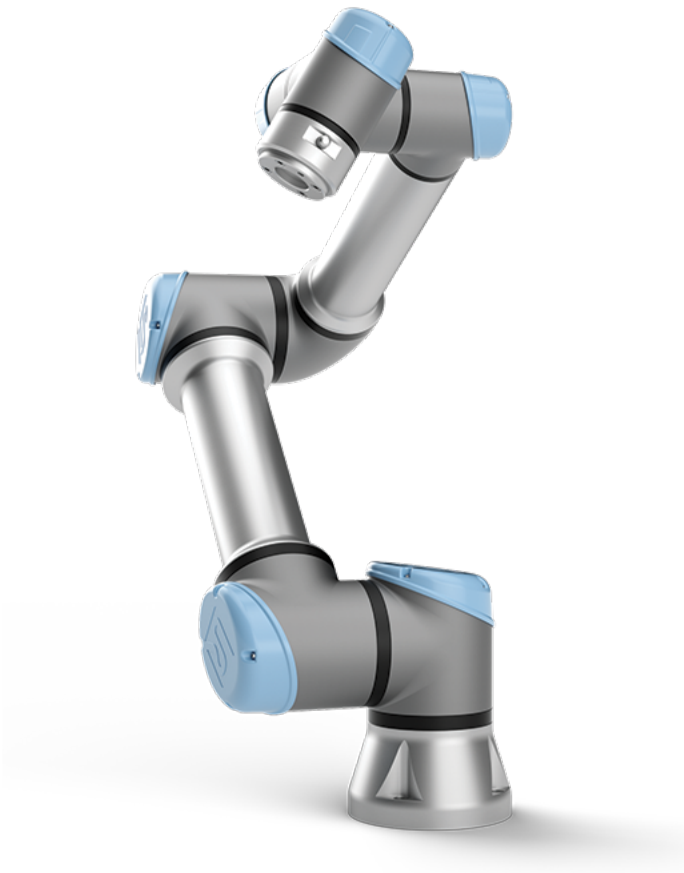
École Polytechnique Fédérale de Lausanne

Product development and engineering design

Concept Selection - Group 8



[1]

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Erwin HAMMERLI, SCIPER : 341144

1 Concept generation

1.1 Fin-ray

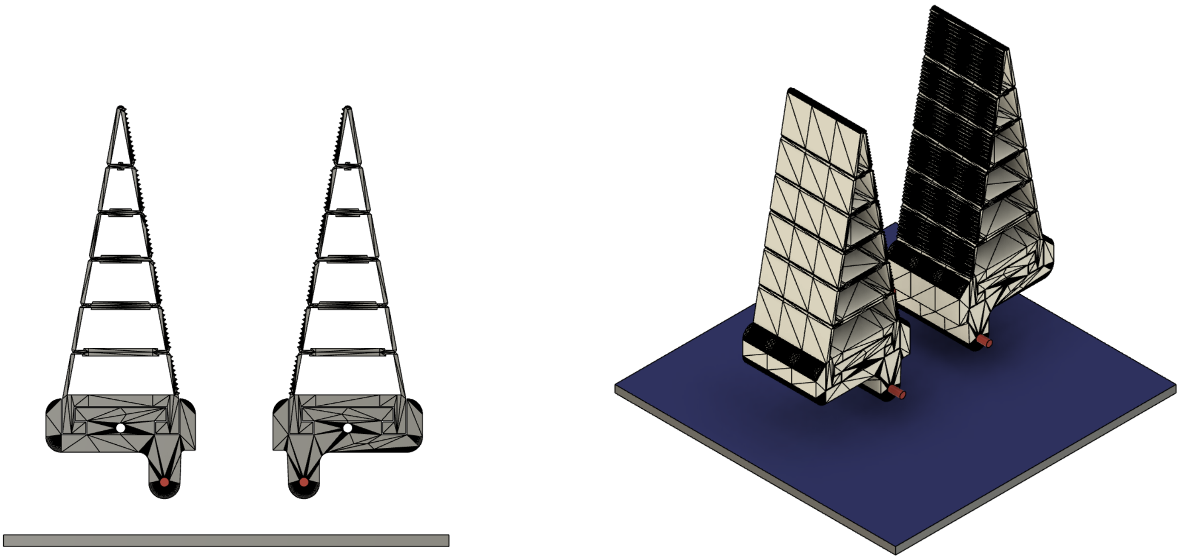


Figure 1.1: Fin-ray 3D

The following concept allows us to take advantage of the Fin-Ray effect, which is inspired by fish fins. The structure shown in the figure above is able to deform and adapt its shape when a normal force is acting on it. In other words, the base and tip will bend in the direction of the applied load and conform around various objects. [2]

The fingers are 3D-printed since they have delicate cross-beams and the measurements need to be precise. The inconvenient part of using this model is that a complex finite element analysis is required to predict the deformation of the fingers and the loads that can be supported. However, we can find the maximum value of the latter quantity by doing multiple experiments. If the fingers do not have the capacity to lift the desired load, we have little control over the scaling of the dimensions since the adaptive fingers were found online. [3]

On one hand, it is advantageous to use this method for any object that has a bulky or round shape (apple, egg, tennis ball...). On the other, picking up items like a bunch of grapes or sunflower seeds is a little more challenging. The basic idea is to align multiple fingers along a rigid bar (in red) that will rotate when picking up the desired target. A motor is strapped to the plate along with a metal detector that can be built around an Arduino to check whether we're dealing with cutlery or food, as indicated by the blue plane. The size of the plate gives us a lot of space to deal with and add necessary components such as other sensors or connections that will help the rotation of the fingers. Since the fingers are just a 3D print away, the challenging part would be the electronics analysis along with the control strategy to adapt.

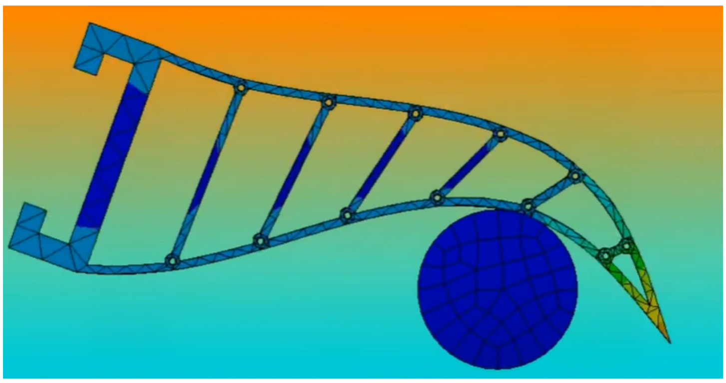
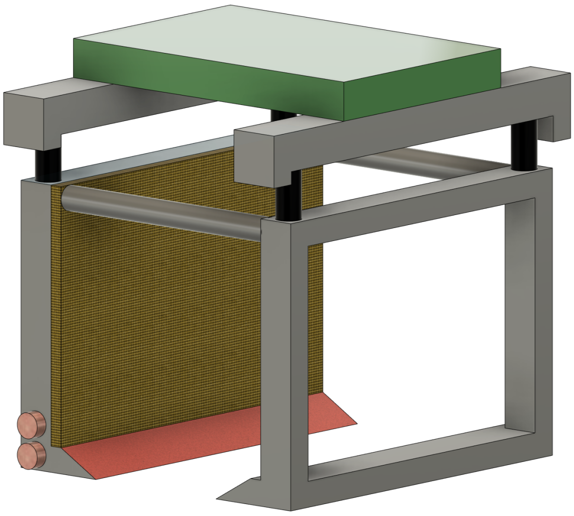
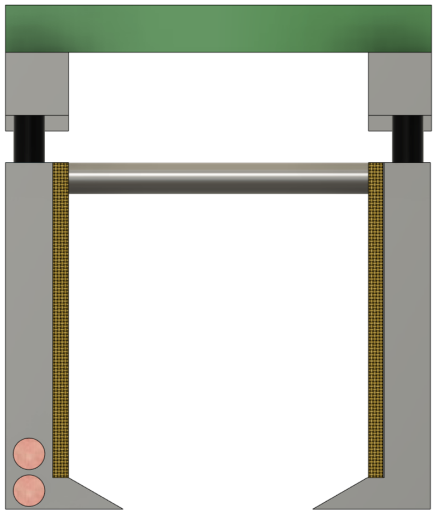


Figure 1.2: Fin-ray deformation

1.2 Elastic gripper



(a) Isometric view



(b) Front view

Figure 1.3: Elastic gripper

Note : in the Fig. 1.3a, the elastic of the right frame has not been shown.

Components :

- Green : Actuator
- Black : springs
- Yellow : elastic band
- Copper : metal detector (coil)
- Red : inclined planes

* * *

The purpose of the gripper is to pick up various objects such as grapes, seeds, cutlery, apples... To cope with so many different shapes and materials, this concept uses elastic bands that follow the shape of the objects to be caught.

The idea is that the two frames shown in grey come together. A rubber band (the yellow part in the 3D above) is stretched across each frame. So when the rubber bands start to touch an object, the frames keep moving forward so that the rubber bands surround the object as best they can. This ensures minimal movement of the object being gripped. The diagram shows two inclined planes in red, which are designed to bring the object to be gripped into the area of the rubber bands.

The springs shown in black enable the robot to press the gripper against the table to ensure that the inclined surfaces are in contact with the table to retrieve the objects.

Ideally, all objects are gripped by the same elastic system, and cutlery is identified by a metal sensor (copper in the image). We've also thought of a default open-circuit system, which closes on contact with a cutlery item.

There are few problems with this design. First, the rubber bands are not conventional elements and must be properly sized. Second, the forces applied to the frames must also be calculated to avoid premature deformation of the gripper. Finally, the phenomenon of excessive bending must be avoided.

On the other hand, this system presents some advantages. The first one is the adaptability of the gripper : it can take and hold different objects with different shapes or materials. The second one is the documentation. After some research, we found an article documenting a similar system: *A Scooping-Binding Robotic Gripper for Handling Various Food Products* [4]. Finally, this systems seems to be easy to program since it only uses a linear movement.

1.3 The Clamp

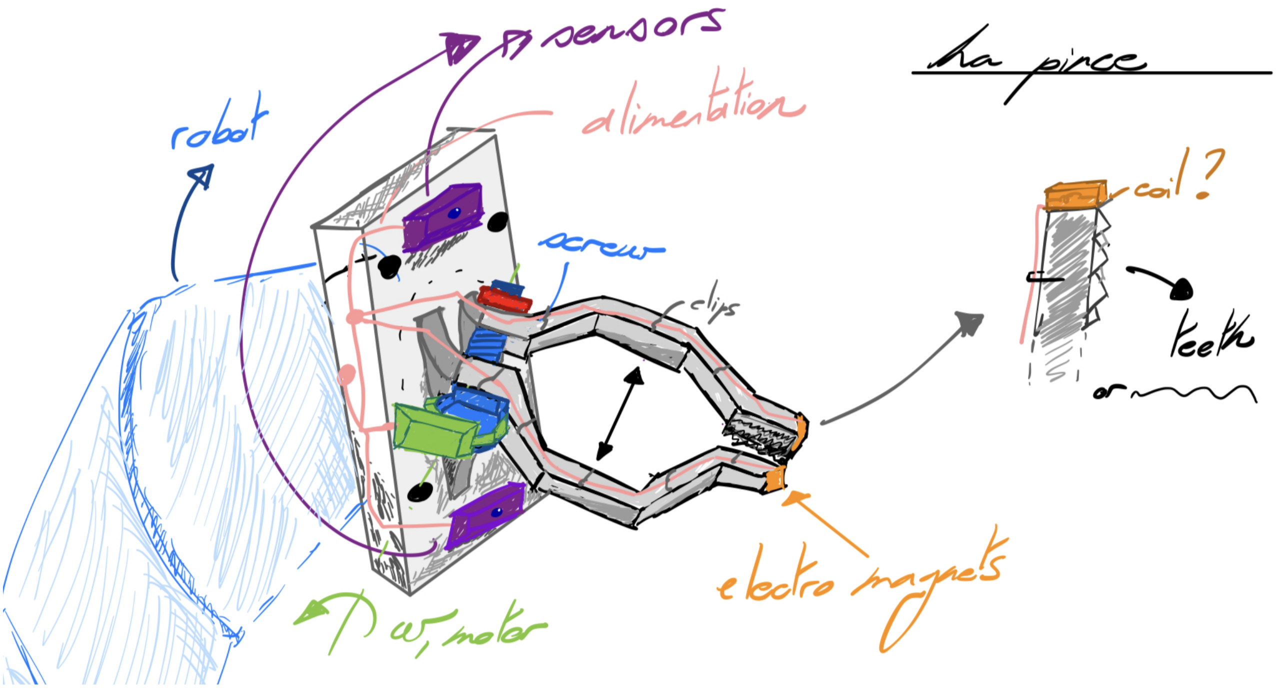


Figure 1.4: Drawing of the clamp

The following concept uses as main component a screw to enable precise object manipulation with the clamp. This motion transitions from rotation to translation thanks to a concealed screw mechanism, facilitating the secure closure of the gripper around the desired object. The primary source of power for this system is an electric battery that empowers a DC motor, affording precise control of the clamp.

Detection functionality is entrusted to a color sensor. In particular, it identifies the presence of the color grey, which serves as an indicator of cutlery. For any other color, it categorizes the object as a fruit, neatly organizing it onto the designated plate.

Furthermore, the gripper is equipped with pressure control mechanisms for handling the more fragile objects, such as grapes.

In evaluating this design, we uncover several advantages:

- Simplicity of construction.
- Minimal part count.
- Compact form factor.
- Comprehensive documentation for easy replication.[5]
- Precise calculation of mechanical and electrical forces, ensuring performance predictability.

Nevertheless, it's essential to acknowledge the design's limitations, which include:

- Challenges in adapting to various utensils.
- The intricacies of handling minute objects and seeds.

In conclusion, after a meticulous assessment, we've decided not to proceed with this particular concept. Its limitations in managing small objects and cutlery, crucial aspects of our project, require us to explore alternative designs. However, we remain open to the possibility of incorporating some of the elements from this concept into our final chosen design.

1.4 Brush excavator

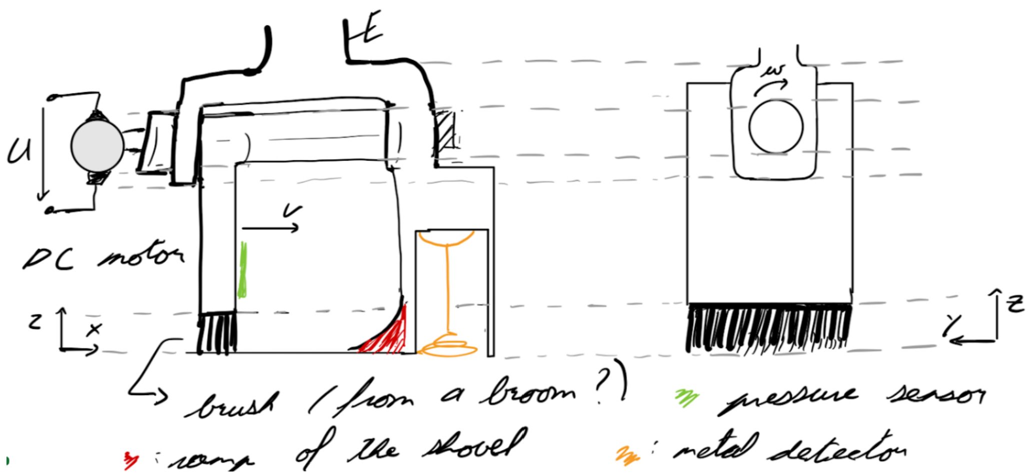


Figure 1.5: Drawing of the "brush excavator"

This concept is composed of a hard brush (left side of the drawing) and an excavator (red ramp on the right side) inspired by the commonly known dustpan. This system is meant to adapt to almost[1] every situation. Grains and similar objects can be swept with the brush onto the excavator part. Bulky objects like an apple can be squeezed between the excavator and the upper part of the brush arm. In this case, the pressure sensor is utilized in order to maintain the right amount of pressure to hold the object. In the case of cutlery, the mechanism of grabbing is the still the same as for the grains but the system is equipped with a metal detector (the orange part) to detect them.

In order to hold the various products, the excavator section is motionless and the brush moves in translation with a lead screw mechanism (upper side of the drawing) engaged by a DC motor. The lead screw mechanism ensures accurate control of the brush part and, therefore an accurate control of the force applied to the objects especially for the most fragile ones.

Advantages:

- great versatility
- simple mechanism
- simplicity of the mechanical analysis
- accurate with the lead screw
- can be modulated fairly easily with our other concepts

Disadvantages:

- placement of the pressure sensor
- placement of the metal detector
- need a brush hard enough in order to sweep the sunflower seeds and especially heavy slender objects like a smartphone
- can be a bit bulky
- a lead screw mechanism is slow

To conclude, despite concerning disadvantages of the concept, we decide to keep it at least for the first phase of selection. The simplicity and versatility of the concept, its ability to grab bulky objects and small ones without fundamentally changing the gripping mechanism, has played a essential part in our decision procedure .

[1] see the disadvantages later in the text

2 Concept selection

Finally, based on the concept scoring and the TAs review, we have selected the brush excavator model. It combines both simplicity and functionality allowing us to accomplish the given tasks.

Detailed scores are shown in the table in the following figure:

		1		2		3		4	
		Pince (*Erwin*)		Elastic gripper (*Teo*)		Fin-Ray (*Roy*)		Brush excavator (*Edwin*)	
Selection criteria	**Weight (/10)**	Rating	Weighted score	Rating	Weighted score	Rating	Weighted score	Rating	Weighted score
Adaptability	8	3	24	4	32	2	16	5	40
Control feasibility	6	2	12	4	24	3	18	4	24
Dimensions	4	4	16	3	12	2	8	2	8
Ease of manufacture	4	5	20	4	16	2	8	4	16
Ease of use	7	1	7	4	28	4	28	4	28
Electrical analysis	5	5	25	4	20	3	15	4	20
Mechanical analysis	5	4	20	3	15	2	10	4	20
Sensor placement	7	4	28	3	21	2	14	4	28
Simplicity	6	4	24	4	24	3	18	4	24
Success rate	8	3	24	4	32	3	24	4	32
	Total score	200		224		159		240	
	Rank	**3**		**2**		**4**		**1**	

Figure 2.6: Grades table

The following figure shows the functional diagram of the selected concept.

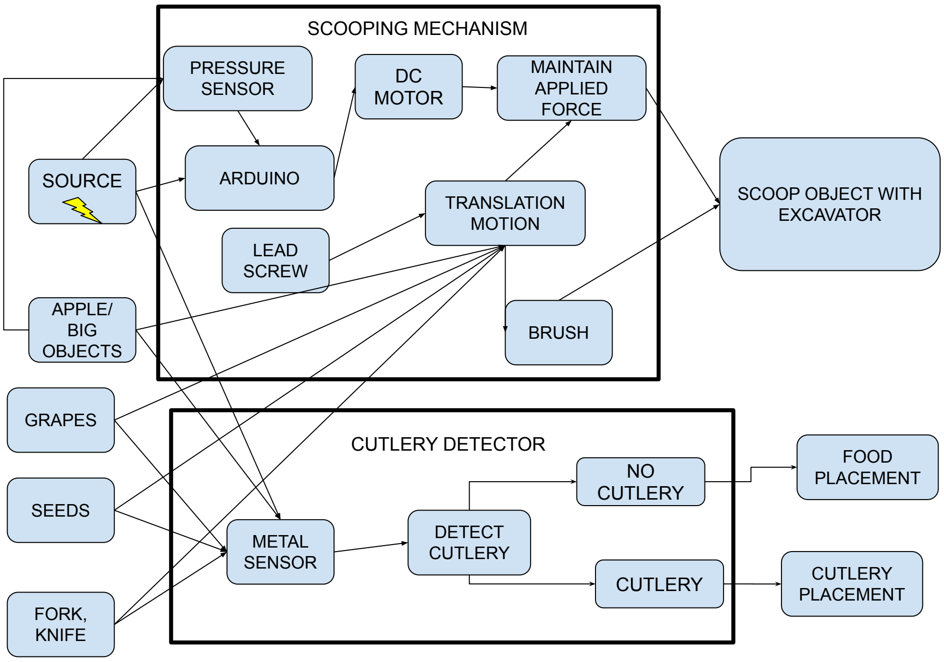


Figure 2.7: Functional Diagram

Weekly Gantt Chart Gripper

PROJECT: Gripper - Product development and engineering design - ME - 320
Project Manager: Josie Hughes
Project Members : Erwin Hämmerli, Edwin Hämmerli, Roy Turk ,Teo Halevi

Milestones
Dependences
Task category

Task name	Stard date	End date	Assigned	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14	WEEK 15	WEEK 16
Concept Generation	**21/09/2023**	**11/10/2023**													
Documentation	11/10/23	-	Erwin, Roy												
Concept Selection	11/10/23	25/10/23	All												
Concept Selection	**18/10/23**	**25/10/23**													
Design Review 1	18/10/23	18/10/23	All												
TAs feedback	18/10/23	25/10/23	All												
Design Selection	25/10/23	25/10/23	All												
Prototyping	**25/10/23**	**22/11/23**													
Sensor choices	-	22/11/23	Erwin												
Actuator choices	-	22/11/23	Edwin												
Transmission choices	-	22/11/23	Erwin, Edwin												
CAD of the parts	-	22/11/23	Teo, Roy												
CAD casing	-	22/11/23	Edwin												
3D Printing & assembly	-	22/11/23	Teo, Roy												
Design Review 2	22/11/23	22/11/23	All												
Testing	**22/11/23**	**20/12/23**													
Practise sesssion	6/12/23	-	All												
Testing	13/12/23	19/12/23	All												
Final testing	-	20/12/23	All												
Report															
Drawings	-	22/12/23	Roy												
Final report due	-	07/01/24	All												

References

[1] U. Robots, Ur5e. [Online]. Available: https://www.universal-robots.com/products/ur5-robot/ (cit. on p. 1).

[2] W. Crooks, G. Vukasin, M. O'Sullivan, W. Messner, and C. Rogers, "Fin ray® effect inspired soft robotic gripper: From the robosoft grand challenge toward optimization," Frontiers in Robotics and AI, vol. 3, 2016, ISSN: 2296-9144. DOI: 10.3389/frobt.2016.00070. [Online]. Available: https://www.frontiersin.org/articles/10.3389/frobt.2016.00070 (cit. on p. 1).

[3] L. Robotics, Fin-ray adaptive gripper. [Online]. Available: https://www.youtube.com/watch?v=_D4-hCSQ51Y (cit. on p. 1).

[4] Z. Wang, H. Furuta, S. Hirai, and S. Kawamura, "A scooping-binding robotic gripper for handling various food products," Frontiers in Robotics and AI, vol. 8, 2021, ISSN: 2296-9144. DOI: 10.3389/frobt.2021.640805. [Online]. Available: https://www.frontiersin.org/articles/10.3389/frobt.2021.640805 (cit. on p. 2).

[5] J. Hernandez, M. S. Sunny, J. Sanjuan, et al., "Current designs of robotic arm grippers: A comprehensive systematic review," Robotics, vol. 12, p. 5, Jan. 2023. DOI: 10.3390/robotics12010005 (cit. on p. 3).