ROMANDIC Winter School

Kranjska Gora, Slovenia, February 9th-13th

Standardization of cloth objects and its influence on robotic manipulation

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Mini project session

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Content

1. Introduction

In this document you will find guides for the mini project session “Standardization of cloth objects and its relevance for robotic manipulation”, based on the paper with the same title.

A. A guide on how to apply the measurement framework for characterizing different cloth objects through their properties.

    - Guidelines to measure the physical and mechanical properties (Section 2).
    - Step by step instructions for applying the code for measuring the stiffness (Section 2.2).

B. Step by step instructions for using the code for creating the radar chart (Section 3).

C. Guides for playing predefined action primitives on the ABB manipulator, as well as instructions for creating and executing new actions (Section 4).

    - Instructions for using the code for measuring the primitives outcomes based on IoU comparison between the initial and final area’s of the cloth.

By the end of the session, you should be able to:

1. Perform **standardized measurements of multiple cloth properties.**

2. **Relate these properties** to outcomes of common cloth manipulation primitives. Link material properties to manipulation primitives.

3. **Create a radar chart** to visually compare cloth sets based on the amount of variability that they provide.

4. **Understand why standardization matters** for reproducible robotic manipulation research.

2. Textile Characterization

To measure the physical properties you will need:

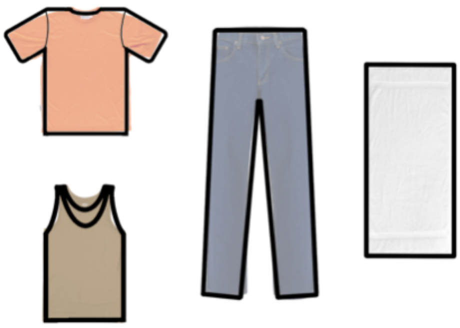
- A ruler.
- A scale.

2.1. Physical properties

Report the results in a table in the folder https://saco.csic.es/s/pM6Pwn8Ts9FLSiE

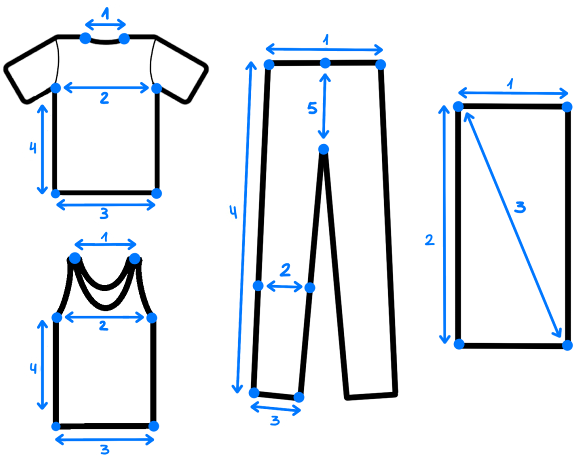
Shape

Count the number of different shapes that your object set has (e.g.. rectangular, circular, T-shirt shape, skirt, etc).



Size

Based on the shape of the cloth, measure the size at different lines. Report in a table the measured length of each line. You should end with a table where each row corresponds to an object and each column to the elasticity of each line.



Weight

Using a scale, measure the weight of each object in your set.

Color

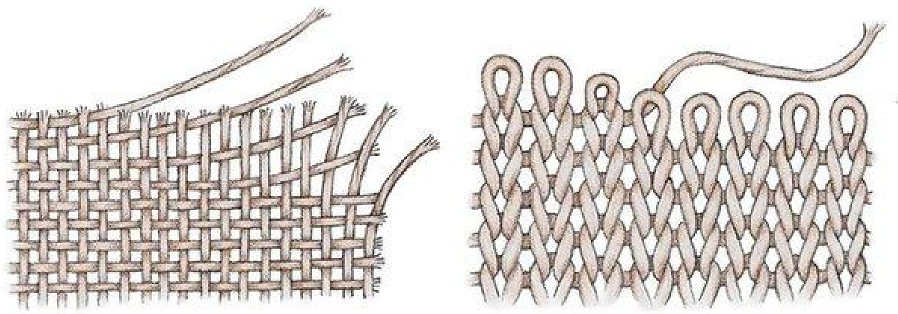
Count the number of primary and secondary colors (red, yellow, blue, orange, green, purple) without distinguishing variations in hue and also count the number of different patterns that the objects of your set have.

Fabric material

Identify the materials of the objects, such as cotton, linen, silk, etc. This information is usually provided in the coth labels. Count the number of different materials that your cloth set includes.

Construction technique

Identify the weaven process used to create the object, such as woven or knitted. You can do this by stretching it and identifying how the fibers are interlaced (woven fabric is produced through weaving two sets of yarn and knit fabric is produced by interloping one set of yarn.



woven material knit material

2.2. Mechanical properties

Report the results in a table in the folder https://saco.csic.es/s/pM6Pwn8Ts9FLSiE

Elasticity

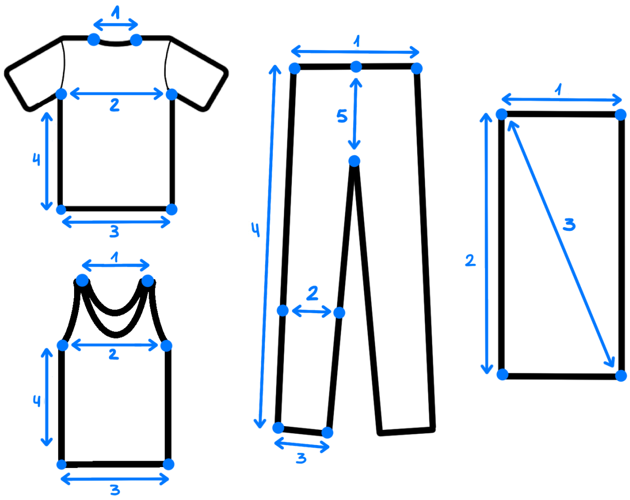
You will need:
- A pinch clamp.
- A luggage weight.
- A ruler.

The elasticity or stretchability is measured by pulling two sides of the cloth in opposite directions and assessing its elongation with:

$$elasticity = \frac{l_f - l_i}{l_i}$$

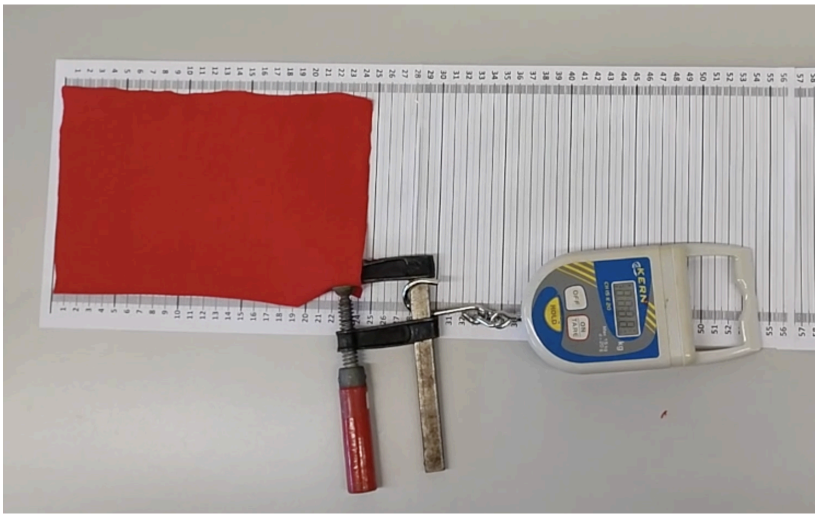
where $\mathbf{l_i}$ is the length of the cloth between the subjected points at rest and $\mathbf{l_f}$ is the length to which the cloth arrives while pulling.

This elasticity is measured for several lines based on the cloth shape:



Having selected one of the mentioned lines, the process is as follows:

1. Measure the initial length $\mathbf{l_i}$ while the cloth is flat at rest.
2. Hold and fix one of the points at the beginning of the ruler (0 cm) and grasp the second point with a clamp so you have two pinch-pinch grasps.
3. Attach the luggage scale to the clamp that is grasping the second point as seen in the image.



4. Pull the luggage weight until 0.5Kg, and while pulling report the final length $\mathbf{l_f}$.
5. Repeat steps 1 to 4 for all the lines and objects.

Report in a table the measured elasticity of each line (use the same labelling as with the size). You should end with a table where each row corresponds to an object and each column to the elasticity of each line.

Friction

To measure the friction you will need:

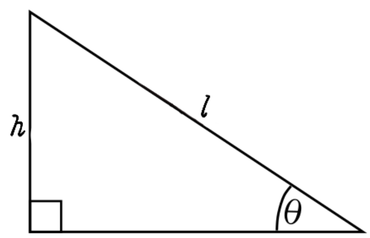
- A ruler.
- A mobile flat surface.
- A DinA3 paper or larger (the cloth to measure should fit inside it).

We will measure the friction of the object as the resistance to slide in contact with a surface. To do so, we place the cloth object on a plane and gradually increase its angle of inclination by lifting one side of the plane until the sample starts to slide.

The process is as follows:

1. Attach a ruler on a vertical plane, such as a wall.
2. Place the mobile surface near this vertical plane.
3. Attach a paper on the surface. This paper should larger enough so the object fits completely inside. This serves to standardize the surface to have comparable values.
4. If the cloth is not rectangular or circular or has an edge larger than 50cm, fold it in a rectangular shape.
5. Place it on top of the surface so its completely inside the paper.
6. Start lifting the surface from one side (slowly and continuously avoiding sudden movements).
7. When the cloth starts to slide, stop the movement and report the height with the help of the ruler on the wall.
8. Measure the friction using this height and the length of the surface as:

$$friction = \mu = tan\left(sin^{-1}\left(\frac{h}{l}\right)\right)$$



9. Repeat steps 4 to 8 for every object in your set.

Stiffness

To measure the stiffness you will need:

- A ruler.
- Circular plates (either of cardboard or 3D printed).
- A vertical stand where to place the circular plates (e.g. a water bottle) or use the 3D printed stand.

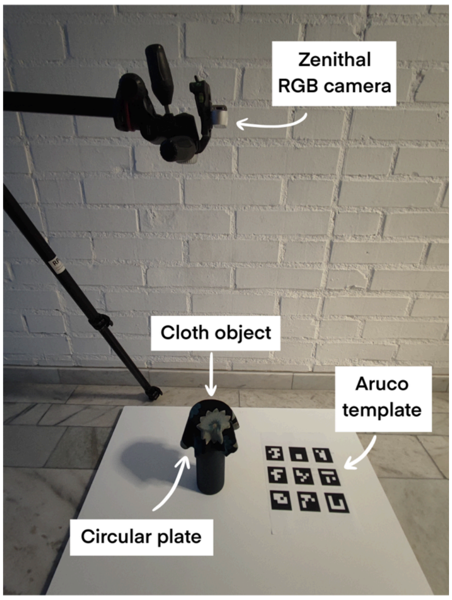
- A tripode to place the camera zenitally.
- A camera (It can be your mobile phone).
- Aruco pattern.
- Github repository to extract the drape contour and measure stiffness.

The measurement of the stiffness is based on the Cusick Drape test, which extracts the stiffness comparing the drape of a cloth while hanging on a circular plate with its flat area.

$$stiffness = \frac{A_3 - A_2}{A_1 - A_2}$$

SETUP:

1. Place the camera in the tripode to take zenital images.
2. Place the Aruco pattern on the vertical stand so it is flat.
3. Take a zenithal picture of the Aruco pattern (you will need it later for computing the pixel to centimeter ratio).



STEPS:

Once you have the setup, you can start measuring the stiffness of the cloth object:

1. If the cloth is not rectangular or circular or has an edge larger than 50cm, fold it in a rectangular shape.
2. Measure the length of the shortest edge of the cloth.
3. Create a plate or adapt the 3D circular design with the corresponding diameter (60% of the measured shortest length).
4. Place the cloth on the circular plate.

5. With the same setup (tripode+camera+stand) used to take the zenital picture of the Aruco pattern, take a zenital picture of the cloth, detecting all the drape shape of the cloth.
6. Repeat steps 1 to 5 for all the objects in the cloth set.
7. Upload the pictures to the folder in https://saco.csic.es/s/pM6Pwn8Ts9FLSiE
8. Download the github repository and follow the repository instructions to extract the cloth drape contour and stiffness value of each cloth picture.

In the terminal you should see the stiffness % of the cloth as:

```
irene@irene-virtual-machine:~/TextileCharacterization$ python3 src/stiffness.py -a Materials/aruco.jpg -f Materials/bata_flat.jpg -i Materials/bata.jpg -p 6
Getting px to cm ratio from  ./data/Materials/aruco.jpg
Measuring flat area of cloth in  ./data/Materials/bata_flat.jpg
Measuring drape area of cloth in  ./data/Materials/bata.jpg
A1 - Cloth measured area (cm2):  225.85507246376812
A2 - Plate area (cm2):  28.274333882308138
A3 - Cloth measured area (cm):  98.95833333333333
 ---DRAPE RATIO:  35.8  % ---
```

A .CSV file is saved where all the data related to the stiffness measures is stored. At the end of the mini project session, please upload this file (and the images taken) in the folder https://saco.csic.es/s/pM6Pwn8Ts9FLSiE

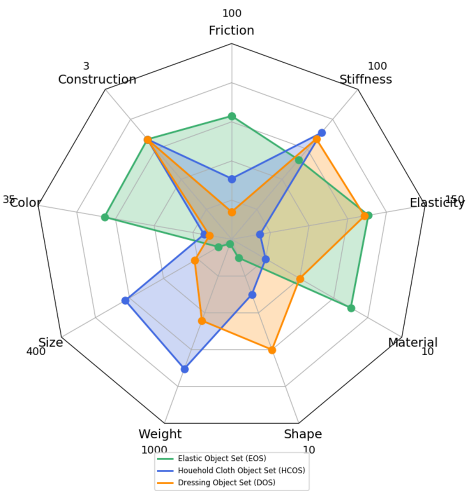
3. Creation of the radar chart

Once you have a database with the measurements of all the objects in your cloth set, you can create a radar chart as the following one to visually compare it to other cloth sets based on the amount of variability that it provides on each of the properties.

To do so, obtain the maximum and minimum values of each property and compute the variance (maximum value - minimum value), this is the number that you will use in the radar chart. For the size and elasticity, which have several columns for a same object based on the lines where we measured them, obtain the variance selecting the maximum of all the lines and the minimum of all the lines.
Create a table with the variance of all properties with the following structure:

	Object set 1	Object set 2
Friction	`friction_variance_os1`	`friction_variance_os2`
Construction	`contruction_variance_os1`	`contruction_variance_os2`
Color	`color_variance_os1`	`color_variance_os2`
Size	`size_variance_os1`	`size_variance_os2`
Weight	`weight_variance_os1`	`weight_variance_os2`
Shape	`shape_variance_os1`	`shape_variance_os2`
Material	`material_variance_os1`	`material_variance_os2`
Elasticity	`elasticity_variance_os1`	`elasticity_variance_os2`
Stiffness	`stiffness_variance_os1`	`stiffness_variance_os2`

You can directly create a radar chart of your cloth set using the *radar_chart.py* script from the GitHub repository. having a .CSV file with the previous table.



4. Executing action on the ABB manipulator

Leveraging the labels extracted on Section 2, we can now conduct an analysis of how textile properties influence on robotic manipulations. For this, you will select a set of 5 objects that have extreme value of each mechanical property (stiffness, elasticity and friction) and study how the outcomes of 5 predefined primitives change.

- Lift
- Fold
- Drag
- Pull
- Push

Creating and Editing a Program on the Teach Pendant

To create a new program, open **“Code”** from the main menu on the teach pendant. In the top-right corner, open the **three-dot menu** and select **“New program”**. When prompted, press **“Don’t save”** to start with a fresh program.

Once the program is created, open the **main module**. Select the line where you want to insert a new instruction. On the right-hand side of the screen, choose **“Add instruction”** and select the desired instruction type, such as:

- **MoveL** (linear motion),
- **MoveJ** (joint motion),
- **WaitTime**, and others.

You can modify existing instructions at any time. When adding a movement instruction, the default target position is always the robot’s **current position**. This allows you to easily teach points by moving the robot manually first.

To change numerical values such as wait times or speeds, tap the **three dots next to the value** and select **keyboard input**.
For movement targets, you can also click the **three dots** next to the position and update the target to the **current robot position**.

Editing and Managing Instructions

If you select **“Edit”**, you can remove instructions or comment them out temporarily. This is useful for testing different parts of the program without deleting code.

Using Debug Mode

Under **“Debug”**, you can select **“Move PP to main”**, which moves the program execution cursor to the beginning of the program. This should be done **before each program run**.

In Debug mode, you can also execute individual instructions. Select a motion instruction, choose **“Go to position”**, and hold the **“Go to”** button to move the robot to that target safely.

Controlling the Gripper via I/O

To open or close the gripper, go to the **main menu** and open **“I/O”**. Then navigate to:
EtherNetIP → ABB_Scalable_IO

Locate the digital outputs with names ending in **DO1** and **DO2**. One output must be set to **0** and the other to **1** (they must always have opposite values). Switching these values will open or close the gripper.

Jogging the Robot Manually

To move the robot manually, go to **“Jog”** in the main menu. There, you can choose whether to:

- move individual joints,
- move the robot linearly in Cartesian space,
- or change the end-effector orientation.

Use the joystick to move the robot in different directions. You can also rotate the joystick clockwise or counter-clockwise for additional directions.

Force Control Mode

In some tasks, it is useful to control the robot based on **force** rather than only position. This allows the robot to push gently against objects, maintain contact, or apply a specified force in a given direction.

To use force control, you must add **advanced motion instructions** to your program.

Adding Force Control Instructions

1. Open your program in **Code**.
2. Select the line where you want to insert the force control logic.
3. On the right-hand side, choose:

```
Add Instruction → Groups → Motion Adv.
```

Here you will find the force control–related instructions.

Typical Force Control Sequence

A basic force-controlled motion usually follows this sequence:

1. **FCRefForce**
    - Defines the **desired force and direction**.
    - Open **Optional arguments** to set which axis and the force.
    - You must specify:
        - the direction in which the force is applied,
        - the magnitude of the force.
    - This does not activate force control yet; it only sets the reference.
2. **FCAct**
    - Activates force control.
    - Select **tool0** as the tool unless a different tool is explicitly required.
3. **FCRefStart**
    - Starts applying the previously defined force reference.
    - From this point on, the robot will regulate motion to maintain the desired force.
4. **WaitTime**
    - Keeps the robot in force control mode for a specified duration.
    - Adjust the wait time depending on how long contact or force application is needed.
5. **FCRefStop**
    - Stops the force reference.
    - The robot will no longer actively regulate force.
6. **FCDeact**
    - Deactivates force control completely.
    - The robot returns to standard position control.

Practical Workflow Tip

If you want the robot to move to an initial position and grasp the cloth as part of a program, first select the **first move instruction**. Then go to **Debug** and move the robot to the target position. After the robot reaches the position, open the **I/O menu** and close the gripper manually. Once the cloth is grasped, continue with normal program execution.

Measuring the result

To measure the outcome we will measure shape-retention comparing the initial and final areas of the cloth as:

$$\mathrm{FR} = \frac{\mathrm{A}_f}{\mathrm{A}_i}$$

To do so, use the zenital camera attached to the manipulator

1. Take a zenital image of the Aruco placed on the workspace.
2. Place the cloth flat on the initial position.
3. Execute the manipulation primitive.
4. Take a zenithal picture of the final result.

Note the for the Lift action, you will have to change the camera point of view to have frontal images.

Upload the initial and final images in the folder:
https://saco.csic.es/s/pM6Pwn8Ts9FLSiE