Perceiving and Handling Textiles: a Robotics Perspective

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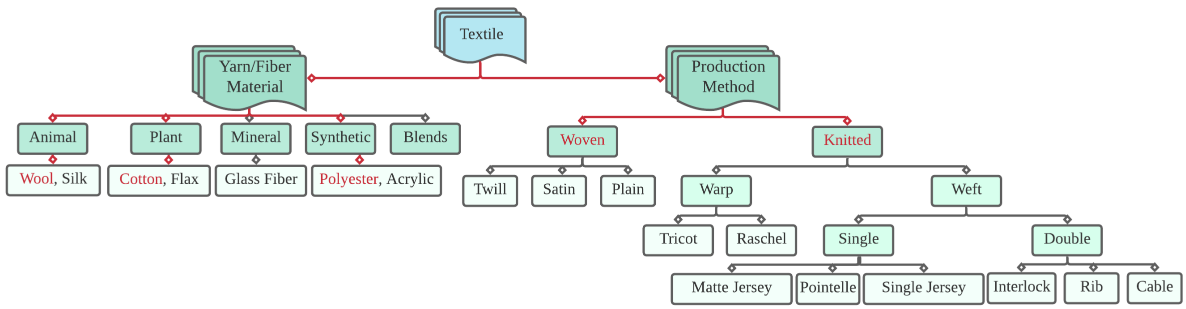

Fig. 1: Textile taxonomy based on yarn material and construction technique. The paths highlighted in red correspond to the classes explored to validate the proposed taxonomy.

***Abstract*— The ability to perceive and handle textiles is important for many applications in service and industrial robotics. We present and discuss some of the open scientific challenges in this area and how perception, planning and control can contribute to address them.**

I. Introduction

The need for perceiving and handling textile and non-rigid flat materials has already been identified several decades ago [1]. Textile in particular has gained significant attention in the scientific community, as its modelling and handling is important in applications such as assisted dressing [2], folding, automated sewing and textile recycling, to name a few. Open challenges arise from the theoretical perspective regarding perception, planning and control, as well as the ability to demonstrate advances in practice, given still rather limited sensing and actuation capabilities of commercial robot systems.

The industrial relevance originates not only from assistive and service robotics, but also from the fashion industry. The latter is undergoing a huge transformation to address sustainability concerns. Textile production and subsequently its recycling and reusing, is largely not automated as there are still huge limitations in how robots can handle deformable objects. Also, robotics and fashion communities need to be brought closer together. In our recent work [3], we outlined a textile taxonomy considering the production process and fiber material commonly used in the textile production industry, see Fig. 1. We also showed how production method and fiber material can be used for classification and discussed how this classification affects control and planning of textile handling. One of the most important insights was the effect of the production method on the textile's properties and behavior when it is pulled or twisted: the textile will stretch differently along or vertical to the weaving or knitting direction. Furthermore, there are differences in behavior between weaved or knitted textiles, based on how threads are interlocked.

There are many different textile properties we would like to study and using an integration of data-driven methods, sensors and actuation available in robotics community makes this possible. For example, we may want to understand textile strength, elasticity, softness for the purpose of assistive dressing. We may also want to understand heat insulation, water absorbency/repellence and resistance to chemicals for recycling and washing. To this end, we need to define a structured approach of how these can be studied and their relevance for different applications. In this work we outline a non-exhaustive table of conditions and properties we would like to identify with relevant sensing and manipulation approaches in Fig. 2 and present below some of the additional insights on these from our ongoing work.

II. Motivation and Onging Work

Existing works on textile manipulation in robotics focus on domestic chores such as laundry handling [4] or folding [5]–[7]. Other non-contact techniques were employed for perceiving textile by leveraging spectral measurements and close-range high-resolution texture defining imaging [8]. In addition to vision, haptics are also employed for material identification [9]. We use the term material here to include the works that go beyond textile since many of the works do not focus on textile specifically but additionally consider other materials such as wood, glass, plastic, etc. Although vision may not be enough to perceive textile physical properties, examples show that wrinkles captured in video can be correlated to the stiffness and density of textiles [10]–[12].

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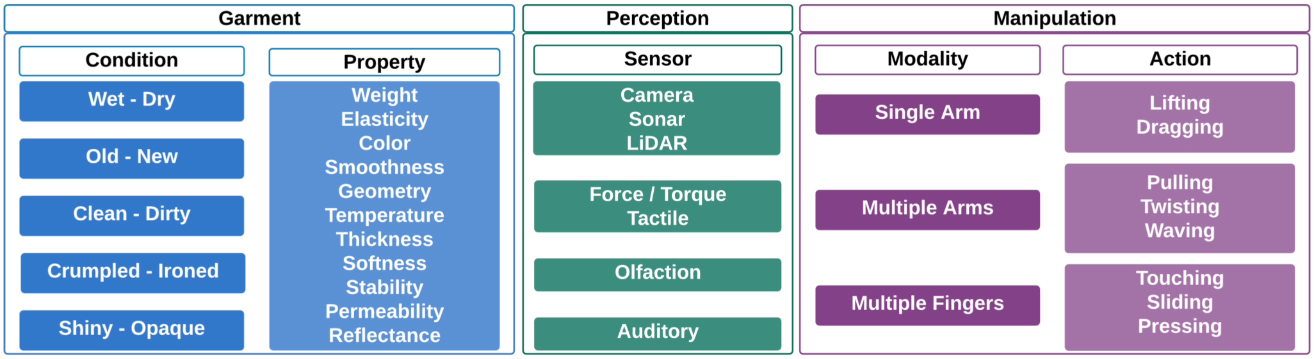

Fig. 2: Examples of garment conditions and properties we would like to address given robotic sensing and actuation.

In the robotics community there is currently no structured approach for studying and comparing works addressing textile perception and handling. One of the difficulties is the large number of conditions and properties we may be interested in modelling. An additional challenge is the multitude of different sensors used that are chosen specifically for each application. Lastly, manipulation is regarded simply as means of executing the task rather than utilized as a tool for simplifying perception. Fig. 2 summarizes some of the conditions and properties we may be interested in identifying and available sensing and manipulation capabilities it is possible to employ. In addition, the taxonomy outlined in Fig. 1 is another example of structuring work with respect to production method and fiber material. We now summarize how this taxonomy was used in our recent work [3].

A. Exploiting Textile Taxonomy

Textile is a flexible material composed of interleaving or interlacing yarns depending on the production method used. Fiber material has an important effect on the textile property, but the construction method is equally important. As an example, t-shirts and jeans may be made of cotton, but in terms of elasticity they behave differently due to differences in the production method: t-shirts are commonly knitted and jeans are woven. Indeed, woven textile are often hard and non elastic by production while knitted textile are usually soft and stretchable in all directions. However, even for the woven textile we can control elasticity by weaving partially elastic threads. The production method also has implications on textile durability. Knitted textiles are more prone to get loose, and yarns are easily destroyed in interaction with sharp surfaces, [13]. Woven fabric is commonly more durable but may require larger forces to shape and handle, such as for example, when sewn or dressed.

There is an additional insight regarding the production method and to what extent it can be identified using cameras we commonly equip robots with. Given an image taken by a regular camera, we may not be able to distinguish between the fiber structure, which is only visible on a microscopic level, see Fig. 3. The images on the right reveal the difference between satin and plain weaving patterns and can also provide the direction of yarns which is then directly related to the elastic properties of the textile. Thus, if no high-resolution, microscope images are available, we may need other ways of identifying the production method and the direction of knitting/weaving. Similarly to humans, robots can use haptic sensing in combination with actions such as pulling and twisting to identify these patterns. In other words, the integration of multimodal sensing with actuation is needed for identifying different properties of textiles.

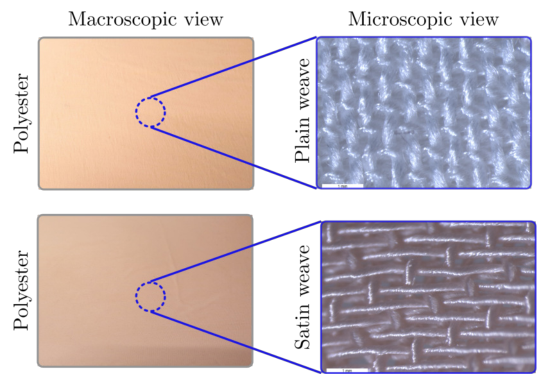

Fig. 3: Textile can look the same given regular camera (left), but are very different on the microscopic level (right).

To exploit the taxonomy, we devised a dataset of wrench measurements used for studying fiber material and production method [3]. The dataset consists of samples from 40 textiles that were pulled and twisted by a dual-arm robotic system equipped with wrists-mounted F/T sensors. The work relates closely to parts of Fig. 2 as we looked into identifying elasticity properties using a combination of sensing and manipulation. The dataset covers three different yarn materials (cotton, polyester and wool) and the two main production methods (knitted and woven). Initial results showed that introducing action facilitates classification of fiber material and production methods, see Fig. 4. For example, there is a clear difference between Cotton-Woven and Cotton-Knitted samples, same fibers material but different production method. Also, as expected, interacting with woven samples results in larger forces compared to knitted ones, see Fig. 5, relating to the elasticity of samples. We may also observe some trend that pulling was more informative than

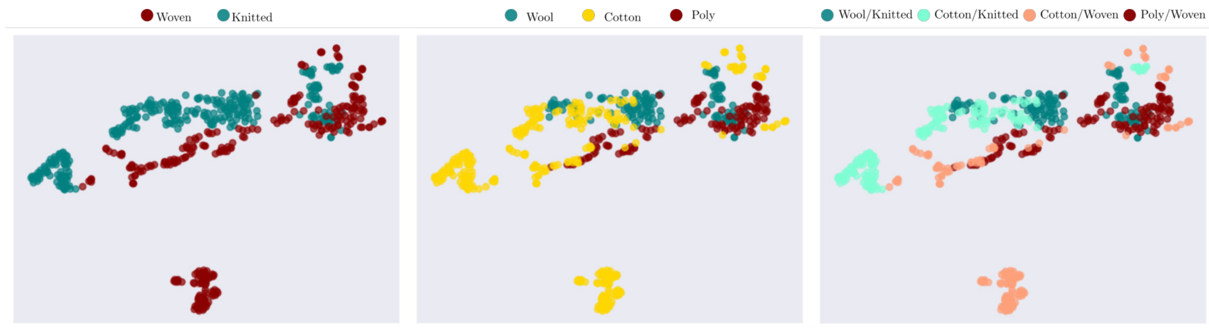

Fig. 4: Examples of classification results for textile samples based on the production method and fiber material.

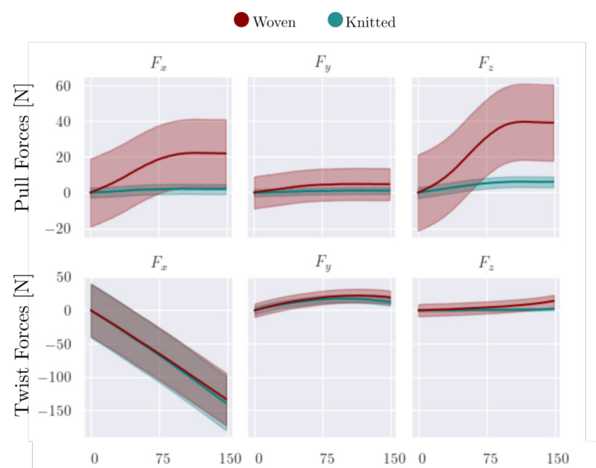

Fig. 5: Force measurements during pulling and twisting woven and knitted samples.

twisting for classification but more thorough experiments need to be conducted to obtain an even better understanding.

III. Open Problems

Perception and handling of textile, garments and non-rigid flat materials remains an open challenge not only in robotics but also in the computer vision and graphics communities. We have only seen the beginning of how the results from the research community can be used in, for example, fashion and service robotics industry to address various types of applications. Robotics research can have a huge impact on the applications areas, especially from the sustainability point of view. An important aspect in deformable object manipulation is the interplay between perception, planning and control. Recent advances in the development of simulation environments and machine learning methods are an important tool for integrating data-driven and analytic approaches in terms of planning and control.

The goal of this paper is to shed some light on the complexity of textile handling and what aspects may need to be addressed in order to make robotics research even more relevant from the textile industry perspective. It is on us to demonstrate how the textile industry can be made more sustainable. Handling of textiles is only one dimension - there are interesting applications also from the perspective of the raw material sourcing, logistics and customer experience.

We have summarized our ongoing work on using pulling and twisting for textile classification, outlined a suitable taxonomy and identified conditions and properties that are of relevance and should be addressed by our community. Apart from visual and haptic feedback, auditory perception and olfaction may be important to identify conditions such as clean/dirty or whether parts of a garment are made of plastic or metal, to name some. Many of the future applications are also related to the ability to perform dexterous manipulation, including coordination of several robotic arms and advanced robotic hands. Handling of deformable materials will also push for using more soft structures when building robots and go beyond simple actions of grasping, pulling and pushing - we may be in need of new theoretical foundations for in-hand manipulation.

Perception remains an open problem. Representation learning from the multi-modal perspective is another interesting challenge. How to integrate range, haptics, auditory and olfaction to provide real-time feedback to the control and planning modules? Or is it so that perception and action should be represented in an integrated manner and that we can exploit reinforcement learning frameworks to explore the set of possible actions while maximizing the perceptual feedback? And how can we do this if it is not possible to generate large-scale data on real robotic systems and the state-of-the-art simulators are still not at the level where advanced interaction between rigid and deformable objects can be easily generated?

Apart from the complex interaction dynamics, there are further conditions and properties of textiles we want to understand. Some of these are stated in Fig. 2. Wet or dry are not defined as two distinct states but there is a whole range of states that may be relevant for drying, ironing or folding. Thus, planning of when to fold while ironing or deciding when drying is finished will require suitable state representation. Naturally, some of these will be learned by observing humans rather than using simulation - thus offering interesting new challenges for the areas of human action recognition and learning by demonstration.

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