MoCa'Collection: Normalizing Dynamic Textile Geometry with Capacitive Sensing in Design Centric Wearables

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ABSTRACT

In this work, we promote capacitive sensing as a versatile smart textile modality through a collection of functional wearable designs. Considering the large variety of possible garment design concepts, we outline an approach to implement smart sensing technology into garments while maintaining these diverse design possibilities. After introducing the basic functionalities of capacitive sensing and the process of designing and building a smart garment, we present an assortment of garments enabled by this technology within the MoCa'Collection. Each of the projects serves a different purpose, built by people representing different backgrounds from electrical engineers, computer scientists, digital artists to smart fashion designers, starting from technical design over digital art to our latest design of a strongly design-oriented full-body capturing suit implementing the proposed technology.

CCS CONCEPTS

• **Computer systems organization** → **Embedded systems**.

KEYWORDS

Human Centered Design; Participatory Design; Wearable Technology; Capacitive Sensing

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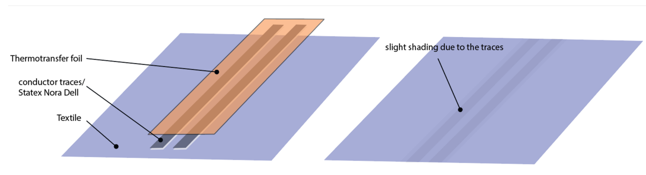

Figure 1: Heat transferring the stack of conductive traces and thermotransfer foil onto the textile

1 INTRODUCTION

MoCa'Collection implies unique advantages with minimum constraints, allowing limitless designs to be fused with the smart capacitive sensing technology. The utilized sensing element is conductive fabric, which can be tailored to the design or concealed under other textile layers. Unlike most sensors tied to rigid nodes (e.g., inertial measurement unit (IMU)), designers can incorporate the MoCa'Collection technology into their design vision. Further, the sensing principle is the deformation of the fabric patches, resulting in sensing patches working without strain (unlike resistor-based stretch sensors). [4]

Thus, with minimum discomfort brought by the material, designers can freely practice designing for comfort [3]. To demonstrate the full potential of MoCa'Collection, we present a collection of smart garments from technology-focused sensing wearables over digitally designed and laser-cut smart garments up to expressive design-centric wearable confluence-specific aesthetic concepts with capacitive sensing.

2 FUNCTIONAL CONSTRUCTS

The basis for including the proposed capacitive sensing functionality in a garment rests on the conductive fabrics and their characteristics. Such material can be used as the antenna to measure

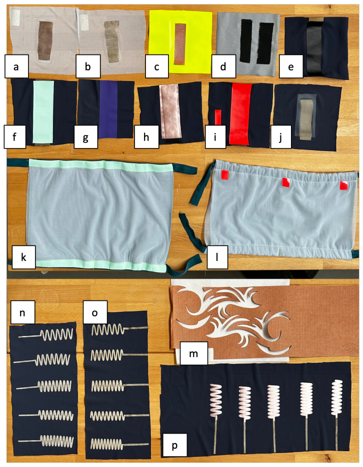

Figure 2: Testing different combinations of substrate, sensing, and cover materials using the heat transfer technology

the capacitance, which can further be applied in downstream tasks such as motion capturing or gesture recognition. To connect the conductive patches with the microcontroller (MCU) for sensing the capacitance, conductive traces from the same material can be used to route through the garment [6]. A well-established method to apply the chosen material to textiles is heat transferring it directly onto the garment. Stacking up the textile substrate, the conductive material, and a thermotransfer foil as isolating cover to add robustness, the heat pressing fully bonds the materials into one cohesive textile. With this technology, we tested multiple combinations of substrates, sensing, and cover materials, as shown in Figure 2. Each conductive part of a sample has a size of 2x10cm in order to obtain comparable results. Most of the samples **(a-j)** passed our tests of being flexible and sensitive enough to be used for measuring the capacitance change while moving the fabric. However, for sample **d**, the low interlocking between the conductor's mesh resulted in a high resistance and therefore in a low conductivity. As a result, samples with resistance values below 10 Ω are ideal for capacitive sensing whereas higher resistance may influence the measurements. From there on, we also tested different shapes of conductive patches **(m-p)** which extend the designer's possibilities for creating a unique garment. Together with the MYOW toolkit, the knowledge from the tested samples can be transferred into smart garments that benefit from the dynamic textile geometry [2, 5]. Therefore, the following points form a general guideline for designers on how to build a smart capacitive sensing garment:

1. The sensor's output is correlated to the geometry change of the conductive patches caused by human motion. There are no special requirements on the shapes of the patches, but the designer has to ensure the correct position on the garment to cover the moving area.
2. The patches can be placed further away from the small rigid sensing module through conductive traces. This separates the capacitive measurement location from the sensor's position. Further, the whole trace can be used for sensing to cover larger areas.

Figure 3: Downstream application for tracking hand and finger movement using smart capacitive sensing gloves

3. There are minimum technical constraints: a single sensing module can only connect to a fixed maximum number of patches and a single MCU can only connect to a fixed maximum number of modules. So it is best if the patches are routed in bundles to the sensing unit. For the MYOW toolkit each bundle is limited to 4 patches and each MCU can only handle 2 bundles. [5]

Next, to demonstrate the design-centric technology, we invited makers from three different backgrounds to design their own smart wearables.

3 FOR NON-ARTISTS

Coming from the technology perspective, we asked engineers from electronics and computer science backgrounds to create different designs of a smart glove. To implement the capacitive sensing technology, a downstream application is necessary, which conveys a purpose to the smart garment and the collected data. The sensor output of the capacitive patches are collected by an MCU and further processed as time-series data packages, for instance, to be used within various machine-learning applications. [6] In Figure 3, two projects for using capacitive sensing within a glove are shown to outline possible applications of the proposed technology. Both gloves sense the capacitance values for all conductive channel patches. The top, white glove uses big patches on the fingers to increase the sensitivity to finger movements, which can be forwarded

Figure 4: Laser cut vector art from digital artist

through a regression model to reconstruct the hand skeleton pose from the glove, without the necessity of additional, external sensing systems. The black glove on the bottom of Figure 3 uses the conductive traces on its own as a capacitive antenna. The focus is not on the fingers but more on the hand movement to implement a gesture recognition algorithm for drone controls [1]. As we will see in the upcoming sections, the functionality of these technical proof-of-concept prototypes can easily be transferred into more sophisticated design-oriented projects without affecting the intended purpose.

4 FOR NON-FASHION ARTISTS

We asked a digital artist to create some abstract geometry to transition from technical prototypes to design-centric smart wearables. The designer's vector art can be converted to the MoCa'Collection using a laser cutter for the conductive fabric and a programmable plotter for the isolation foil. The produced design components are heat pressed onto a plain shirt afterwards, following the introduced methodology. To express the sensor patches as prominent design elements, they can be installed on the outside of the garment, and the conductive traces, used for the wiring towards the MCU, can be routed on the inside of the garment. Figure 4 shows the final implementation of the design concept into a fully integrated smart wearable, being able to sense the wearer's shoulder movement with capacitive sensing technology.

The semi-automated workflow through programmable cutting and plotting machines promotes the diffusion of the technology as any designing enthusiast can transform their vision into motion-sensing garments. Using vector bitmaps, the designs can also be easily plugged into 3D design software such as Clo3D or Blender to visualize the design in dynamic 3D environments to iteratively fine-tune design aspects (e.g. shapes and placements) before implementation. This approach can also be replicated with processes similar to current online shirt printing services.

5 FOR SMART FASHION DESIGNERS

A major barrier for professional fashion designers when they want to integrate technologies into their smart wearables is the uncertainty of whether the design has a negative effect on the technology without close guidance of technical experts. This uncertainty greatly restricts the creative process. With MoCa, designers have simple rules to follow as explained in Section 2 which encourages them to focus on the creative process and the dynamic geometry changes of the fabric. We invited a professional smart fashion designer to express her design ideas with MoCa. While it is difficult to describe the aesthetics and inspiration aspects in words, we describe the implementation process below and show the overall design in Figure 5. The conductors are integrated into the fabric on the left-hand side, i.e. the inside. This approach has the advantage that the conductors are almost invisible in the garment. They are insulated with thermal transfer film, shielding them from skin contact. The tracks run parallel for most of the distance, which has the advantage that the ends of the tracks act as data input first, as most of the tracks run parallel and generate similar data. Some tracks have an antenna element at the ends that runs in curves. Especially in areas where diffraction causes wrinkles, the area of data collection can be spread over a larger area. We have also developed insulation for these elements and studied which types of curves remain the most elastic. The insulated tracks can be printed with decorative elements on the other side of the textile. We opted for a design that follows the course of the conductors and also laminates the conductors on the right-hand side of the fabric. The patterns follow the positions of the tracks and sensors. However, it is possible to change the pattern to suit your own requirements.

6 CONCLUSION

In conclusion, this work highlights the versatility and potential of capacitive sensing as a smart textile modality. The MoCa'Collection enables the fusion of sensing capabilities with aesthetic considerations, allowing designers to create comfortable and visually appealing garments. This research opens up new ways for technology and design to go hand in hand and paves the way for the widespread adoption of using dynamic textile geometry for capacitive sensing in the field of smart wearable technology.

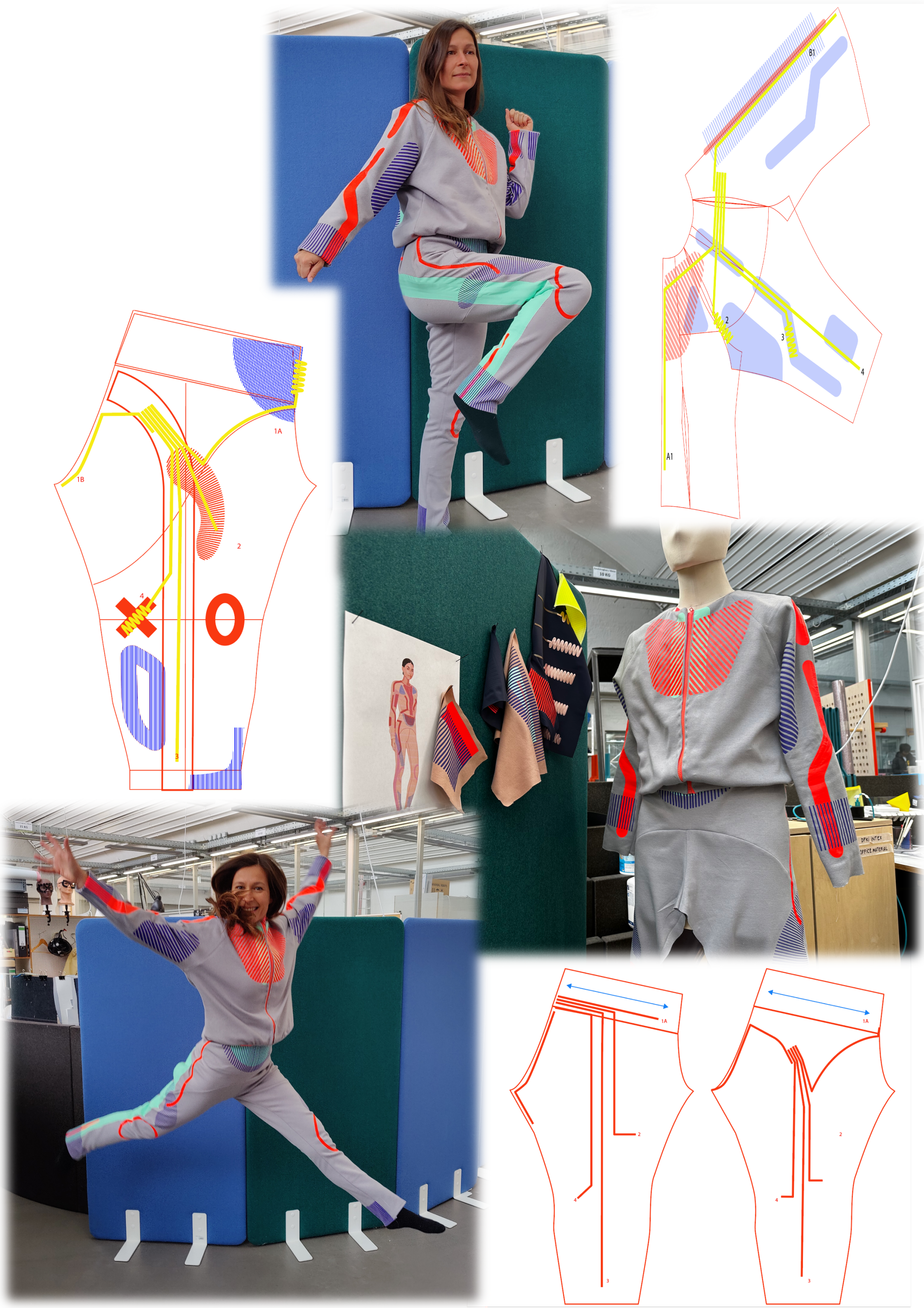

Figure 5: Design process of embedding the Moca'Collection technology into a custom build suit by a professional experienced fashion designer

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