ADVANCES IN THE FIELD OF DIGITALIZATION BY MULTIMODAL INSPECTION OF TEXTILES - DIGITAL HAPTICS

Krzywinski S[1], **Pietsch K**[1], **Boll J**[1], **Alma A**[2], **Martin Ch**[3], **Rataj C**[4]

[1] *Technische Universität Dresden, Institute of Textile Machinery and High Performance Material Technology,*
[2] *Technische Universität Dresden, Institute of Acoustics and Speech Communication,*
[3] *Technische Universität Dresden, Institute of Automation,*
[4] *GFaI Gesellschaft zur Förderung angewandter Informatik e. V., Berlin*

E-mail of the Presenting Author: Sybille.Krzywinski@tu-dresden.de

ABSTRACT

A current interdisciplinary research project focuses on the development of application-oriented principles for tools for the multimodal, in particular tactile, inspection of textile surfaces for communication systems. For this purpose, product actuators have been created to scan the virtual surface and to capture the "frequency image" of the surface structure, so that a haptic perception can be simulated and tactile properties can be derived from it by stimulation of the sensory organs. To improve perception, these data are extended by auditory and visual modalities to achieve a multimodal description of product surfaces. The parameters are combined to a compressed representation of the information and converted by tactile actuators. Another focus are the development and selection of suitable techniques for the reproduction of tactile properties of surfaces. In addition, it is important to ensure the synchronization of the displayed modalities during transmission. For this purpose, requirements are determined which result from the selected HMI devices on the user side and the achieved project results for the product interface.

Key Words: digital haptic, multimodal inspection, tactile properties, handfeel, roughness

1. INTRODUCTION

The inspection of spatially separated product surfaces is an important topic for industry, e.g. in terms of quality assurance along value and supply chains of globally operating machine plants, the consumer goods sector, for example e-commerce, and people with impaired eyesight or mobility. Surfaces of consumer goods as well as industrial products are multimodal, i.e. they are characterized by a combination of visual, auditory, and haptic properties. There are already promising approaches towards the digital transmission of visual and auditory modalities operating individually, i.e. independently of one another. As an example, textile companies no longer need to send colour and fabric samples around the globe to potential customers, but instead can make use of multispectral technology for digital colour matching. Even auditory characteristics, for example the sound of leather creaking, can be digitally reproduced. In contrast, producers and potential customers are presently unable to assess haptic properties in a similar manner since virtual reality (VR) applications cannot yet display this type of impression. However, many industrial sectors could profit from technological advancements in this field, e.g. the textile industry, the paper and timber industry (furniture), the automotive industry (interiors), in addition to the service and IT sectors, who could employ this technology for communication within value chains as well as with end users.

Figure 1. Left: From physical to digital feel; Right: Screenshot of the Android App

Hence, despite all existing options for virtual product presentation (virtual mirror) in the static or dynamic states (virtual catwalk), clothing consumers are currently not enabled to capture and evaluate haptic properties. The "feel" is one of the most important quality parameters for soft materials, considerably affecting the quality evaluation of a surface as a direct result of tactile perception.

Numerous research projects performed in the past four decades addressed the development of device technology and mathematical models, generating so-called feel marks based on comprehensive instrumental measurements on the mechanical properties of textiles. However, these feel marks were only used in the context of research, but could not establish themselves in practice due to the fact that they cannot properly represent textile surfaces including stiffness, smoothness, and softness for customers.

The state of the art in the fields of communication and information technologies allows for novel solution approaches aiming at the multimodal presentation/reproduction/inspection of haptic product surface properties. Nevertheless, there is still a lack of communication interfaces and models suited to the realistic description of product surfaces that are able to digitally reproduce visual and auditory as well as haptic characteristics. The user would thus be provided with information on the geometry (shape, size, …) and material properties (surface structure, stiffness/elasticity, …) of product surfaces.

Hence, globally operating industries and digital/virtual markets – currently characterized mainly by auditory and visual impressions – could be significantly advanced by adding tactile sensations. Digital solutions for haptic inspections generate new business opportunities along the value chain and in e-commerce. In order to seize these opportunities, interdisciplinary, cross-industry research focuses on the development of multimodal inspection methods for textile surfaces suited to digital applications (Figure 1).

2. INTERDISCIPLINARY COLLABORATION

This innovative approach requires interdisciplinary efforts, supported by two research associations (Textil e. V., GFaI e. V.). This involves employing industrial test scenarios to record and digitally transmit characteristic values for the haptic definition of product surfaces, in particular in terms of textile surfaces.

For many years, the Chair of Ready-made Technologies at the ITM has been involved in material testing and simulation for textiles, coupled to virtual product development, visualization, and manufacturing.

The Chair of Acoustics and Haptics, TU Dresden is actively investigating auditory and multimodal perception processes, whereby topics such as "virtual reality" and "audio-tactile interaction" are of particular interest. Researchers focus on the development of haptic reproduction technologies and multimodal human-machine interfaces in addition to innovative reproduction methods for sound and vibration.

The expertise of the Chair of Automation, TU Dresden lies in the development of methods and strategies for the systematic design of user interfaces, taking into account specific requirements for different devices and modalities.

The Society for the Advancement of Applied Computer Science (Gesellschaft zur Förderung angewandter Informatik, GFaI e.V.) is mainly concerned with creating fundamentals and applications for the textural description of surfaces. Generated results contribute to applications in industrial environments.

3. OBJECTIVE - RESULTS

This interdisciplinary project aims at the development of methods and application-oriented basics for tools that are suited to the multimodal inspection of product surfaces for communication systems based on vibro-tactile signalling.
At the beginning of this project, research efforts address the possibilities for describing haptic properties (tactile, kinaesthetic) and their transmission into suitable signal structures (physics engine). For multimodal inspection, visual and auditory information is additionally recorded and combined to support the characterization of product surfaces (Figure 2).

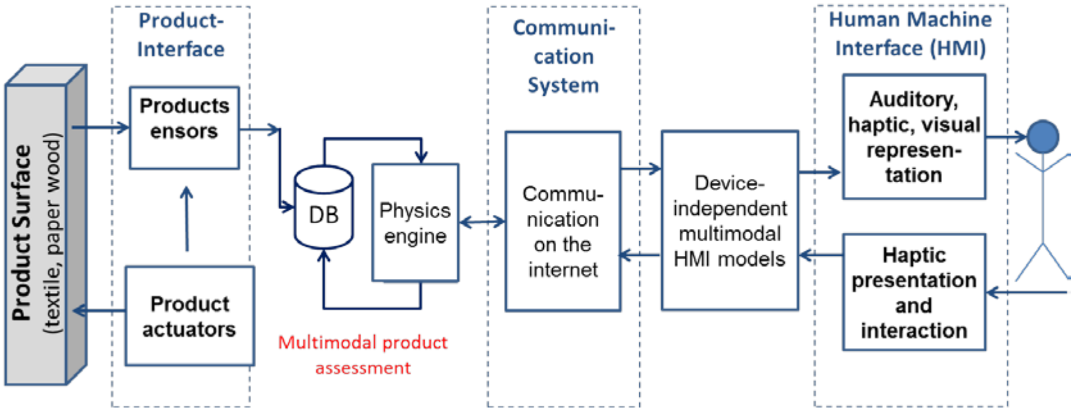

Figure 2. Project structure [1]

In contrast to the haptic properties of wooden and paper product surfaces that can be comprehensively described by means of friction and roughness parameters, textiles are characterized by their feel based on material stiffness. To efficiently determine the required characteristic values using industrial testing technology, specific experimental setups and devices were designed and implemented (Figure 3). It is not aimed at precisely representing individual physical properties, such as bending and elongation behaviour or friction, but instead, cumulative parameters are measured and compared to perceptual values; this method allows one to precisely determine haptic properties, while simultaneously enabling differentiation between materials. Based on the test setup, characteristic values describing the surface as well as stiffness (friction behaviour – pull strength, bending stiffness – draping behaviour) can be determined during testing. This add-on module can be easily mounted onto a standard tensile testing machine.

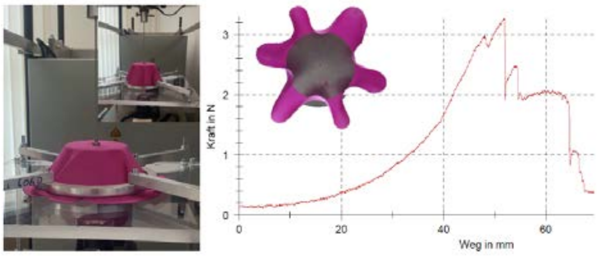

Figure 3. Modified ring penetration test with optical detection of the drape image

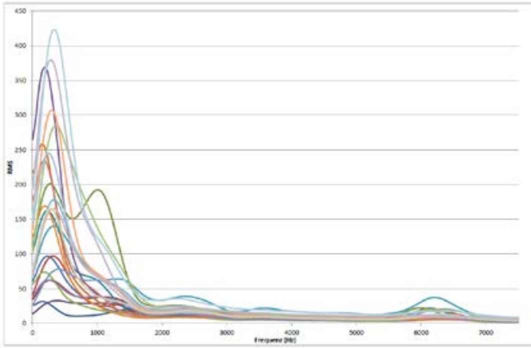

Figure 4. Determination of the roughness of textiles by means of TSA [2]

Additionally, tests for the evaluation of textile surfaces were performed using a TSA measuring device provided by emtec Electronic GmbH [2]. In the case of this device, an impeller pressed onto the tensioned fabric sample rotates, thus generating a noise. This level of noise is recorded by a microphone and translated into a sound frequency spectrum. Hence, the peak of the measuring curve recorded at a frequency of up to 750 Hz represents the roughness of the textile material (Figure 4). Based on this characteristic value, the broad spectrum of textile materials (clothing textiles – woven fabrics, weft- and warp knitted fabrics, made from natural and synthetic fibres; automotive textiles; home and household textiles) was divided into 5 classes (Figure 5). Selected materials were investigated as part of a haptic perception experiment (blind test) involving 20 probands (10 laypersons, 10 experts). Figure 6 illustrates the achieved agreement between subjective and objective assessments of the criteria roughness and smoothness.

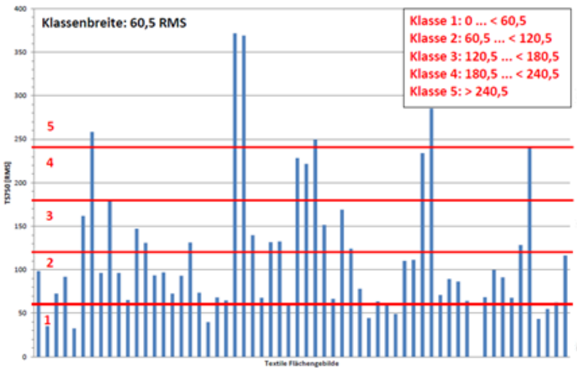

Figure 5. Classification according to TS 750

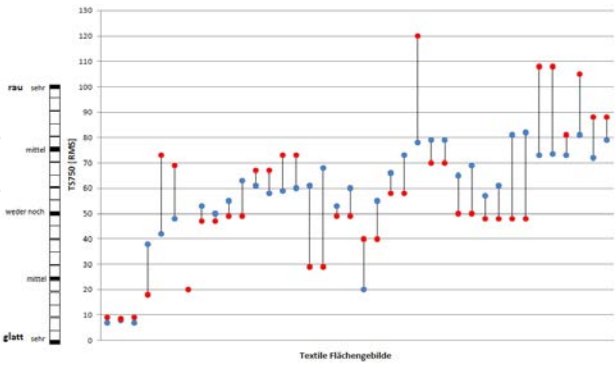

Figure 6. Agreement of subjective (rough / smooth - blue) and objective evaluation of roughness TS750 red

To achieve multimodal interaction, the digital representation of textile structures must be as realistic as possible (sample size/resolution), and the detection of the surface profile must provide information that enables the assignment of an acoustic signal to the position of the finger in z-direction when "touching" the fabric sample on a tablet or smartphone. Images were taken with a camera under defined environmental conditions (angle, lighting) with shading correction and equalization as displayed below. To evaluate the suitability of the visual representation of colour images, various geometric resolution levels were provided for different terminal devices (smartphone, tablet) (Figure 7). A robotic, high-resolution scanning head (laser triangulation) was used for 3D measurements.

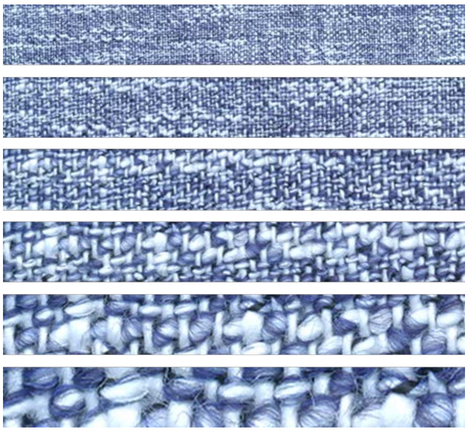

Figure 7. Geometric resolution levels for different devices

Figure 8. Digital perception experiment

To generate characteristic acoustic values for textile materials, a motion simulator was developed, where the textile material is placed on a rotary drum and scanned by a needle array. The recorded frequency ranges of the acceleration levels are the basis for vibratory structure surveys. The additionally captured real acoustic signal patterns do not allow for proper differentiation between textile materials, and thus, synthesizing algorithms were developed. The current status of development enables the vibro-tactile representation of roughness on a textile surface. The tablet is positioned on an electrodynamic shaker to enhance the vibratory perception of surface roughness (Figure 8).

All experimentally determined characteristic values (textile-physical, geometrical, visual, acoustically, haptic) of evaluated textiles are stored in a database (relational section), e.g. thickness, weight per area, size of textile samples, roughness, and bending stiffness. The data-based part contains images, 3D scans, and audio files. Retrieving relevant data is enabled by a compliant database module.

The final objective of this project is the development of an android app for tablets from the customer market, which is able to generate an audio output based on the speed of a finger swiping the screen and a vibration signal due to the finger position and the height value (3D scans) (Figure 9).

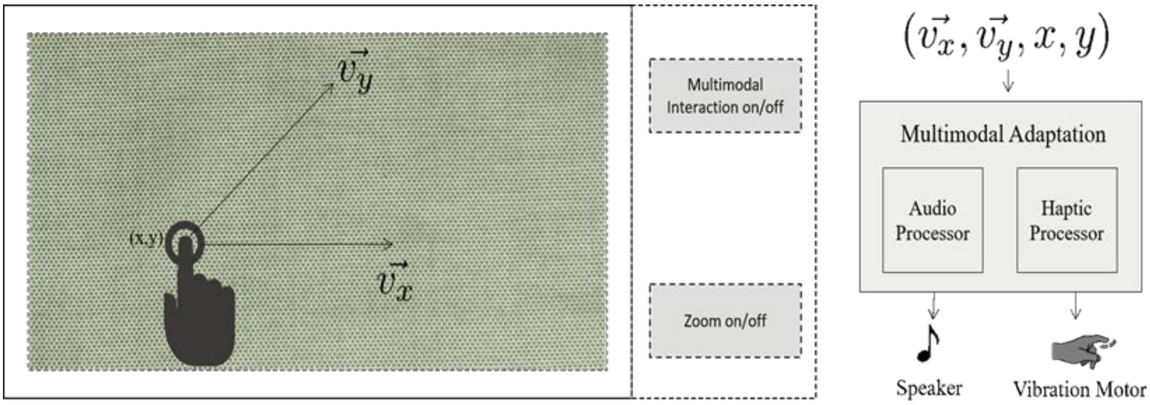

Figure 9. Adaption of audio and vibration output based on finger position and speed

The visualization of the geometric resolution of a textile structure corresponding to the actual structure supports consumers´ perception, which is complemented by auditory and haptic signals. To prevent individual perception channel from becoming dominant, the tuning of signal levels must be further investigated. Nevertheless, the realistic representation of roughness was proven successfully.

In order to synchronize and transmit multimodal data, suitable protocols and communications technology must be selected. Thus, the potential of data generation on a server or on a client via Web-Service interface for the supply of product data via HTTP as well as continuous data transfer (streaming) will be evaluated. Presently, intolerable delays impair the process of data streaming, whereas the use of 5G was identified as potential solution to this issue.

ACKNOWLEDGEMENT

The IGF research project 19479 BR of the Forschungsvereinigung Forschungskuratorium Textil e. V. is funded through the AiF within the program for supporting the „Industriellen Gemeinschaftsforschung (IGF)“ from funds of the Federal Ministry for Economic Affairs and Energy (BMWi) by a resolution of the German Bundestag.

Supported by:

Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag

4. REFERENCES

1. Krzywinski S, Altinsoy E, Braune A, Püschel F: Methodenentwicklung für die multimodale Inspektion (haptisch, visuell, auditiv) von Produktoberflächen als Beitrag zur fortschreitenden Digitalisierung. (Method development for the multimodal inspection (haptic, visual, auditory) of product surfaces as contribution for the progressive digitalization), IGF-research project 19479 BR, 2017-2019.
2. Emtec Electronic GmbH, https://www.emtec-electronic.de/de/, 1.3.2019.