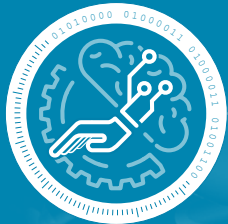




# HAPTIC RESEARCH

AT PCCL



**3**

Haptic research at PCCL

**4**

Automated surface analysis –  
Effortlessly capture haptic surface  
properties

**7**

Haptic interaction measurands  
and skin properties

**8**

Characterize subjective touch perception  
through objective material and surface  
parameters

**9**

Outlook: Smart glove

**10**

Research papers and partner references

**11**

Contact

CONTENTS

## Haptic research at PCCL

*In product development, as well as in quality testing, tactile properties of a surface have so far been evaluated purely subjectively.*

At the PCCL methods are developed that bring tactile sensing of surfaces from a purely subjective level to an objective measurement parameter level. Our goals are:

- **Automated, AI-based quality inspection** technology to characterize product surfaces in terms of haptic properties.
- **Complete characterization of haptic feel** of surfaces based on material parameters.
- **Sensorised gloves to measure surface haptics**, to open up new possibilities for glove development or to convey haptic sensations to the glove wearer.



# Automated surface analysis – Effortlessly capture haptic surface properties

A robotic arm slides an **artificial finger** along the respective surfaces and collects data related to **friction, roughness** and **hardness**. A PID controller in the main robot loop is implemented to achieve constant normal force between the artificial finger and the surface under inspection. A **machine learning based analysis** is applied to **classify the surfaces** regarding tactile properties and is used to control the amount of measurements per surface that are required for high precision and minimum measurement runs at the same time.

Our system **surpasses the human sense of touch** by precisely analyzing tactile friction and surface roughness. It delivers reproducible results and enables informed conclusions about haptic properties where human perception reaches its limits.

## USE CASES:

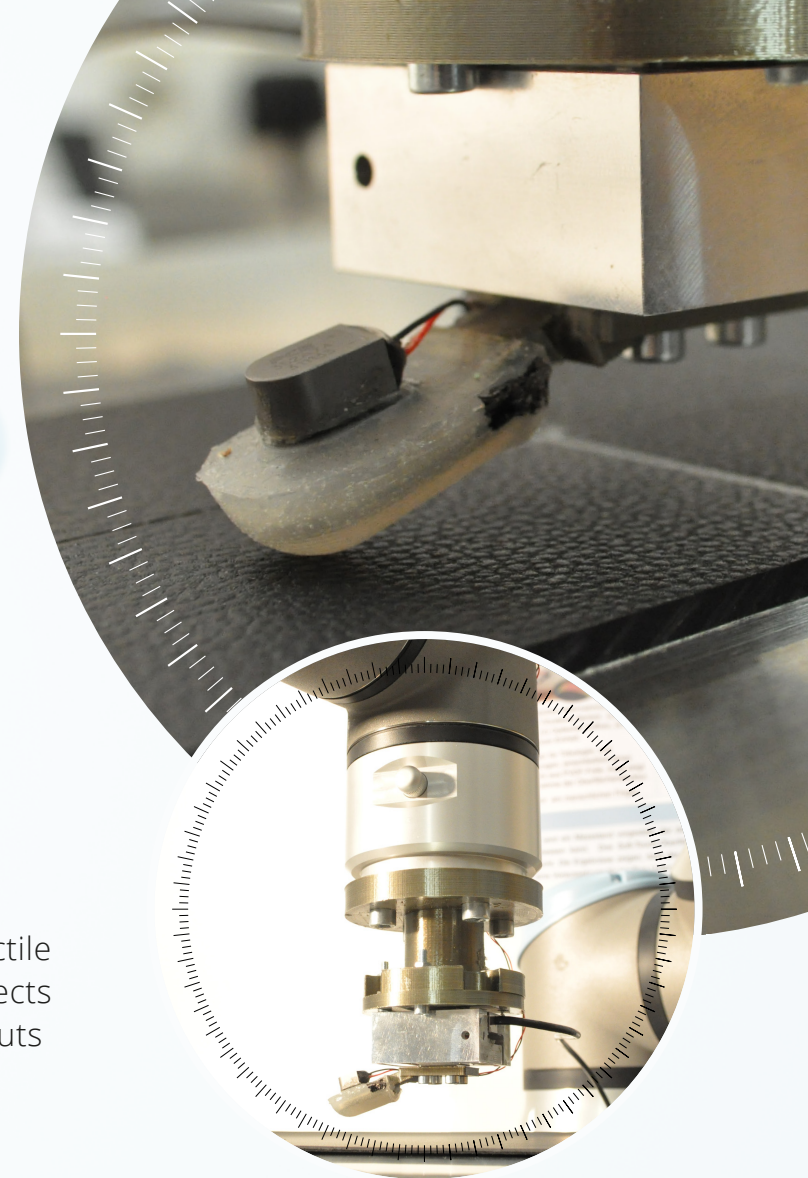


- Objective haptic classification for in-line haptic quality control

- Predict haptic effects of surfaces

- Compare haptic properties of surfaces to pre-defined and consented haptic effect

- Discover tactile surface defects like burrs, cuts or kinks



### EXAMPLE 1:

The system examines **five different car interior parts** that vary slightly in terms of friction. A **machine learning algorithm** analyzes the data and determines whether additional measurements are required for more precise classification regarding tactile friction. If necessary, the system re-measures the problematic surfaces and fine-tunes the neural network. This process repeats until the **predefined accuracy** is achieved or the maximum number of measurements is reached. The complete process takes approximately 5 minutes.

After successful classification, the system has learned the haptic characteristics of each surface, enabling it to distinguish between them, **predict their tactile perception by humans** or to compare it to other surfaces.

The robotic measurement system is **superior to a human test panel**, reaching 100% accuracy on the 5 samples. While humans can distinguish between the extremes, subtle differences are poorly recognized.

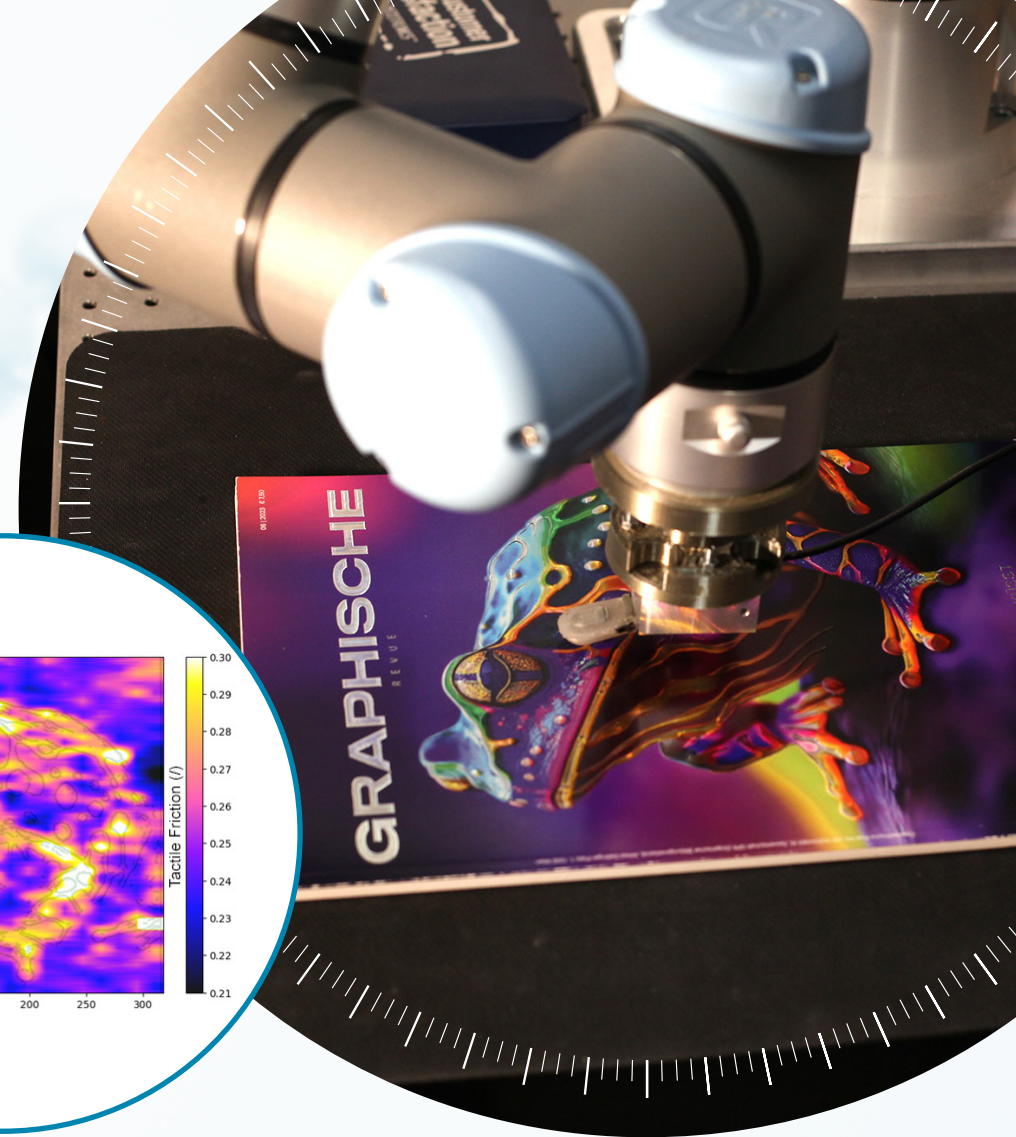
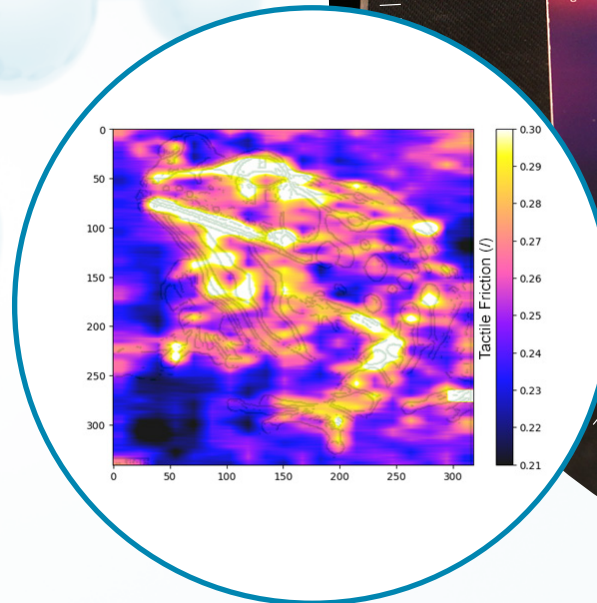


## EXAMPLE 2:

In the large image on the right, you can see the robot measuring the cover of the **Graphische Revue 06/2023**. The frog stands out in relief, and the glossy areas, particularly the yellow ones, exhibit higher friction compared to the rest of the surface. In the small image you can observe the results of our friction measurements with the contours superimposed as lines.

The system enables e.g the creation of **tactile friction maps** that closely replicate human tactile perception. If required, the local resolution can be enhanced **beyond human capabilities** by adjusting the artificial finger.

This allows for a highly detailed characterization of tactile effects – not just as an overall average, but with precise local resolution – resulting in detailed tactile maps tailored to your specific needs.



# Haptic interaction measurands and skin properties

Interaction parameters related to **friction** and **mechanical vibrations** in human skin are measured during dynamic contact with desired surfaces. While friction is related to perceived friction, the vibrations are responsible for **roughness** and **texture** perception. Both interactions strongly depend on human skin hydration levels, which determine whether skin will be soft or hard.



**Various measurement setups are available,** each focusing on different aspects, such as contact area or the influence of skin hydration. The setup shown in the image to the right illustrates the latter.

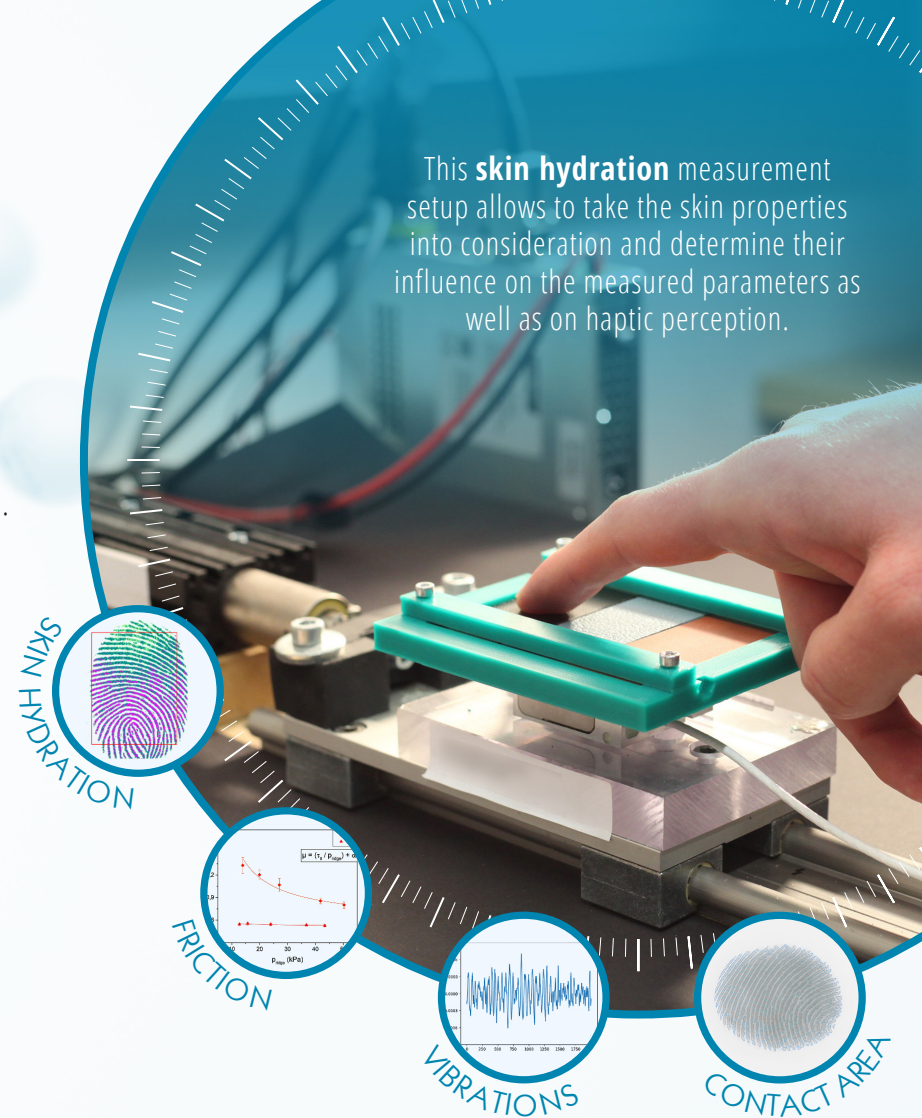
## USE CASES:

- Support development of new materials with tailor-made haptics

- Study effect of skin properties on haptics and skin friction

- Investigate if materials are harmful to skin when in prolonged contact

This **skin hydration** measurement setup allows to take the skin properties into consideration and determine their influence on the measured parameters as well as on haptic perception.



# Characterize subjective touch perception through objective material and surface parameters

To enable the production of surfaces with the desired touch feel in a targeted manner requires a detailed knowledge of the surface and material properties, which in their complex interplay evoke the desired tactile perception. PCCL is equipped to measure the complete material parameter set required to quantify the otherwise purely subjective haptic perception via material properties.

The most prominent parameters are the **elastic modulus, surface roughness, kurtosis** and **skewness, thermal conductance** and **heat capacity**. In addition, perception studies regarding the haptic feel of the surfaces can be conducted and correlated with material properties.

## USE CASES:

- Develop new materials with tailor-made haptics
- Transition to greener materials without compromising haptic properties
- Define haptic norms and standards
- Investigate the influence of skin and countersurface properties on contact mechanics and friction behavior using finite element simulations



## PROPERTIES

Surface properties  
Material properties  
Thermal properties



## DATA ANALYSIS

Machine learning  
and classical  
techniques



## PREDICTION

of tactile effects  
and consideration of  
skin hydration levels

# Outlook: Smart glove

## Integrate sensors into gloves to measure haptic interaction.

- Normal force and shear force sensors on the fingertips
- Temperature sensors
- Stretch sensors on the phalanges (measurement of finger posture and position)
- Normal force sensors distributed on the inside of the glove

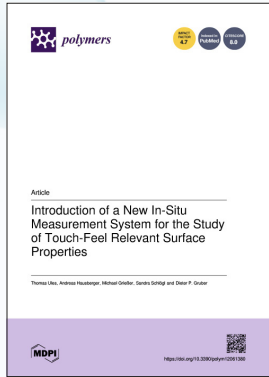
The continuously collected data is to be analysed live and displayed graphically. Suitable data analyses will then be used to objectively evaluate the haptics.

### USE CASES:

- Measure surface haptics
- Open up new possibilities for glove development
- Convey haptic sensations to the glove wearer



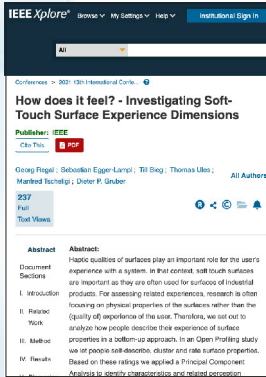
# Research papers and partner references



## > DOWNLOAD

*Introduction of a New In-Situ Measurement System for the Study of Touch-Feel Relevant Surface Properties*

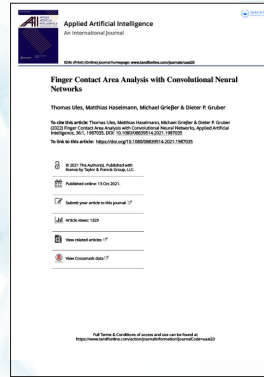
(polymers, 2020)



## > READ ABSTRACT

*How does it feel? - Investigating Soft-Touch Surface Experience Dimensions*

(IEEE XPlore, 2021)



## > DOWNLOAD

*Finger Contact Area Analysis with Convolutional Neural Networks*

(Applied Artificial Intelligence, 2022)



## > READ ABSTRACT

*Tactile friction and perception of UV-curable coatings and their relation to physical surface parameters and contact mechanic simulation*

(Journal of Coatings Technology and Research, 2023)

Our technologies have been developed through collaborative projects with industry partners such as:



KONICA MINOLTA



Volkswagen



## Contact / Cooperation

Regarding cooperation within the framework of

- contract research
- cooperative R&D projects

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