Fundamental material and process developments for the integration of cognitive properties into textile surfaces using bionic solution approaches

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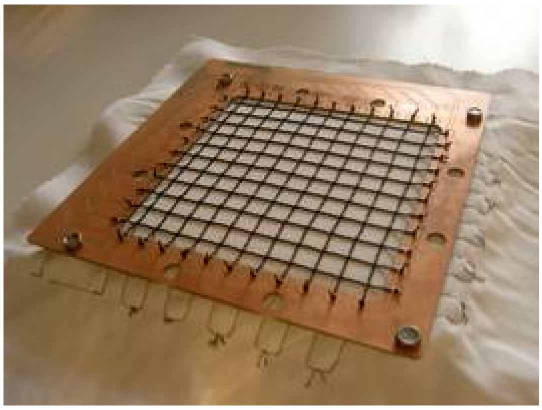
Project Description:

This projects aims to develop a flexible array of sensor integrated into a textile carrier structure of predetermined stiffness for its application in the field of medicine or robotics. The human skin is used as the biological model for the design process as is represents the greatest sensory organ in humans.

Within the scope of this project, all anatomic components involved in signal transmission and processing (stimulus conduction) are analysed and, based on the findings, transposed into a technical model. Those anatomic components include skin layers and their tissue characteristics, boundary surface structures (papillae) as well as types of mechanoreceptors and their distribution within the skin layers.

In human skin, the majority of the sensors are located at the interface between skin layers called papillary dermis and intertwines with the rete ridges (connective tissue papillae) of the epidermis. The height and number of individual papillae is dependent on the local mechanical strain they are exposed to. When pressure is exerted on the exterior surface of the skin, the flank surfaces of the papillae experience a measurable offset and thus allow for the modulation of mechanical stimuli.



The skin houses a variety of heterogeneous mechanoreceptors with task-specific functions. Using natural dermal functions as the bionic model an analogue technical model can be established, which consists of textile layers displaying a range of consistencies and surface structures. Hence, a diverse collection of sensors can be integrated into the surface or within layer interfaces.

Textile carrier materials are chosen due to the variety of advantages they provide over other materials such as:

-Possible development of multilayer systems
-Variations of interface structures
-Range of fibre orientations

In regards to sensor materials, graphite-doped silicone is considered due to its flexibility and ability to change its electrical resistance under physical strain. When manufactured into threads or miniscule plates, those sensors allow for a simple integration into the textile carrier structures without negatively influencing important functions of the material such as flexibility and resilience. However, other types of sensors may also demonstrate potential for their integration into the system.

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The spatial arrangement of the sensor array within the textile matrix is designed such that contact pressure is registered as normal force while associated forces (shear forces, torsion and bending moments) can be detected and identified separately. The next step is to integrate actuators in form of soft silicone elastomer hoses of 3 – 6 mm diameter into one of the textile layers. This way, the matrix can be directionally deformed using pneumatic pressure of max. 2 bar. Hence, this adjustable actuator stiffness during the measurement process improves the adaptability to external forces of the entire system.

The integration of mechanical adaptability into the sensor array within the carrier matrix as described above is supposed to advance its integration in robotics, the automobile industry and medicine (prosthetics, orthotics, rehab-tools). Potential application include measurements of pressure distribution in shoe inlays (pedography), bandages with massage effects, mattresses and padding layers between prostheses and body parts for decubitus-prophylaxis. Furthermore, the off-set created by internal pressure can extend the measurement frame of the pre-stressed sensor system and hence, balance individual variances (e.g. in body mass). The active adjustment of its form presents the opportunity to improve the placement and application of sensor-integrated bandages based on individual body shapes.

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