Wise Skin for tactile prosthetics

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Problem
Amputation of a hand or limb is a catastrophic event resulting in significant disability with major consequences for amputees in terms of daily activities and quality of life. Although functional myoelectric prostheses are available today (e.g. hand), their use remains limited due, in part, to a lack of sensory function in the prostheses. At the same time, as the world’s population both grows and ages, the number of people living with disabilities, such as persons who have lost limbs for whatever reason e.g. trauma, diabetes or cancer, also increases. A sense of tactility is needed for providing feedback for control of prosthetic limbs and to perceive the prosthesis as a real part of the body, inducing a sense of “body owner ship”.

Today, there is no solution for restoration of a natural sense of touch for persons using prosthetic limbs.

Solution
WiseSkin provides a solution for restoration of the sensation of touch. It embeds tactile sensors into the cosmetic silicone coating of prostheses, which acts like a sensory “skin” providing the sensation of touch, enabling improved gripping, manipulation of objects and mobility (walking) for amputees. Flexibility, freedom of movement and comfort demand unobtrusive, highly miniaturized, ultra-low power (ULP) sensing capabilities built into the “skin”, which is then integrated with a sensory feedback system. The focus is on non-invasive (external actuation) sensory feedback mechanisms. The main elements of the project are:

- flexible, skin-like, material embedded with tactility sensors
- miniature, flexible, soft-MEMS based sensors (e.g. pressure, shear)
- ULP, event driven wireless communication (radio and protocol) between the sensors and processing / control module
- a conformal, stretching powering system based on a metallic mesh grid
- use of the metallization layers as a waveguide
- a system for sensory feedback based on a tactile display (i.e., on the amputation stump or the back) using miniature actuators / electrodes
- Proof-of-Concept demonstrator (i.e., tested on volunteers) combined with brain imaging to investigate neural mechanisms of tactile perception.

Impact
WiseSkin pushes the forefront of technology in miniature, ULP sensor and communication devices, materials and sensory feedback systems. Importantly, it enables new prosthetic products, with improved functionality, hopefully offering improved quality of life for amputees. It also opens the door for new solutions made of intelligent materials such as smart gloves, smart clothes and artificial skin for tactile robots able to more safely work along side people (e.g. in factories and homes robots).

Technical challenges
- Reliable sensors / sensing (e.g. pressure and shear) to feel objects, grip and rapidly adjust (moving hand).
- Ease of use, freedom of movement, natural look and feel of the prosthetic demand unobtrusive, highly miniaturized sensor devices placed almost anywhere
- Minimum impact on autonomy of the myoelectric prosthesis.
- Scalability / modularity are critical (e.g. communication, processing power). There are potentially many sensors (e.g. 100-150 mechanoreceptors / cm² at the fingertip).
- Real-time response is needed and latency is of high interest in order to react to slipping or failing, use of the prosthesis without actually watching
- Sensory feedback / actuation is essential and the Human-electronics Interface is key. Issues include the number of electrodes, shape and frequency of current pulses.
- Advanced material engineering for sensing; piezoelectric AlN on elastomers, metallized PDMS for waveguide, stretchable cap sensors

Key innovations
- Wireless and sensor technology
- Scalable routing, adaptable MAC, robust, event driven, new solutions for High Density Wireless Sensor Network (HD-WSN)
- Reliable, miniature, soft-MEMS sensors (e.g. pressure)
- Conformal power distribution system
- Grid like, stretchable power distribution and signal transmission layers
- Interfaces for electro-mechanical sensor integration and miniature flexible antenna
- Tactile sensory perception and human-eletronics interface (HEI)
- Study and test of a non-invasive HEI on real patients
- Multi-sensory perception, MRI brain imaging analysis (e.g. map phantom finger somatotopy)
- WiseSkin system and technology integration
  - A flexible, stretchable artificial skin / smart material that is relatively easy to manufacture
  - Restore a natural sensation of touch, ease of sensor placement and coverage of large areas