Tactile Prosthetics in WiseSkin

J. Farserotu, J-D. Decotignie, J. Baborowski, P-N Volpe, C.R. Quirós and V. Kopta[1]
Integrated and Wireless Systems
CSEM, Neuchatel, Switzerland

C. Enz[1], S. Lacour[2], H. Michaud[2] and R. Martuzzi[3]
[1] ICLAB, [2] EPFL STI IMT LSBI, [3] LNCO
École polytechnique fédérale de Lausanne
Switzerand

V. Koch, H. Huang and T. Li
Department of Engineering and Information Technology
Bern University of Applied Sciences, Biel, Switzerland

C. Antfolk
Dept. of Biomedical Engineering
Lund University, Lund, Sweden

***Abstract*— Abstract: The use of prosthetic hands is limited in part by the lack of sensory feedback to the wearer. In order to provide sensory feedback, an adequate number of sensors must be integrated with the prosthesis. The WiseSkin project targets the use of artificial skin embedding ultra-low power wireless sensor nodes. This presentation provides an overview of the WiseSkin project and the current status of the developments.**

Keywords—prosthetics, tactility sensors, artificial skin, ultra low power, wireless, MEMS, sensory feedback

I. 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. Today, there is no solution for restoration of a natural sense of touch for persons using prosthetic limbs. This is the goal of WiseSkin. 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 is growing and aging, the number of people living with disabilities, including lost limbs e.g. trauma, diabetes or cancer is increasing A sense of tactility is needed to provide feedback for control of prosthetic limbs and to perceive the prosthesis as a real part of the body; a sense of "body owner ship".

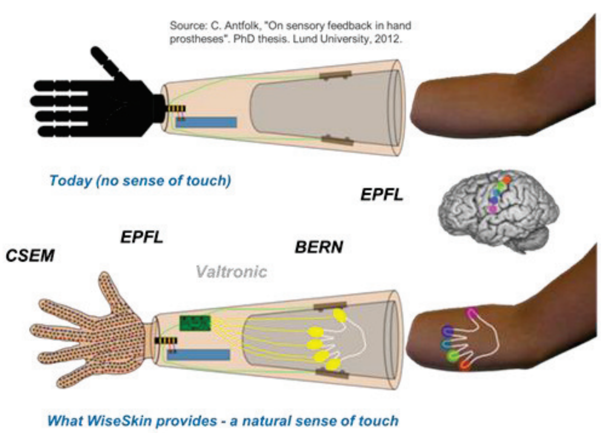

Fig. 1: The concept for transducing artificial skin outputs into electrical pulses applied on amputee nerve stumps.

II. Solution

WiseSkin [1,2] provides a solution for restoration of the sensation of touch. It embeds tactility 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. In WiseSkin, the focus is on non-invasive (external stimulation) sensory feedback mechanisms. However, the solution may be adapted to support invasive (e.g. implantable electrodes) as well as non-invasive means of stimulation.

The main elements of the WiseSkin project are:

- a flexible, skin-like material embedded with tactility sensors

- miniature, flexible, adaptable, soft-MEMS based sensors (e.g. pressure, shear)

- an ULP, event driven wireless (radio and protocol) between the sensors and processing / control module

- a conformal, stretchable powering system based on metallization layers

- the use of the metallization layers (e.g. gold, liquid metal) embedded in the artificial skin as a waveguide

- sensory feedback based on a tactile display (i.e., on the amputation stump or the back) using miniature electrodes

- Proof-of-Concept system tested on volunteers with brain imaging to investigate neural mechanisms of tactile perception.

III. Technical Challenges

Realization of the WiseSkin solution poses a number of technical challenges. Reliable sensors / sensing (e.g. pressure and shear) are needed in order to feel objects, grip them and rapidly adjust (moving hand). Ease of use, freedom of movement, natural look and feel of the prosthetic demand highly miniaturized sensors. The solution must have minimal impact on the autonomy of the myoelectric prosthesis (i.e., maintain ability to operate at least 16-24 hours before

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recharging). There are potentially many sensors (100-150 mechanoreceptors/cm^2 at fingertip) and there may also be additional sensors in the future (e.g. temperature, shear). Thus, scalability / modularity are critical (e.g. communication and processing). Real-time response and low latency are needed to react to slipping or falling, use of the prosthesis without actually watching. Sensory feedback and actuation are essential and the Human–electronics interface is key (e.g. electrodes, vibration). Additionally, advanced material engineering is needed for sensing e.g. sensor integrated in elastomers, metallized PDMS waveguide and stretchable sensors.

IV. INNOVATION

To meet the challenges, WiseSkin targets innovations in multiple domains. WiseSkin provides for scalable routing, an adaptable MAC layer protocol, robust, event driven communication and new solutions for High Density Wireless Sensor Network (HD-WSN). The vision is that of a scalable, event driven, very short range, robust, HD-WSN with sensors almost anywhere. An illustration of the sensor relay concept is provided by Fig. 2. On the sensor side, it addresses reliable, miniature, soft-MEMS sensors (e.g. pressure). A conceptual illustration is provided by Fig. 3.

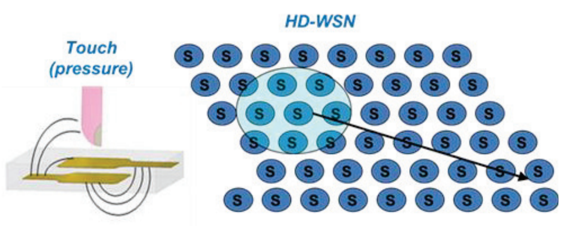

Fig. 2: Wireless sensor concept

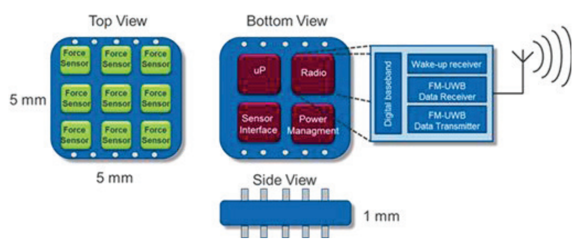

Fig. 3: Conceptual illustration of the miniature tactility sensor - communication device

Further, WiseSkin develops an artificial skin that provides for stretchable, conformal power distribution as well as signal transmission layers. An illustration is provided by Fig. 4. It also addresses electro-mechanical sensor integration. On the application side, it studies and tests a non-invasive human-electronics interface (HEI) on real patients, studies multi-sensory perception and performs brain-imaging analysis (e.g. map phantom finger somanotopy) bringing new insight into tactile sensory perception and the HEI. The integrated result is an innovative solution that provides a flexible, stretchable artificial skin that is relatively easy to manufacture; enabling restoration a natural sensation of touch, ease of sensor placement and coverage of large areas.

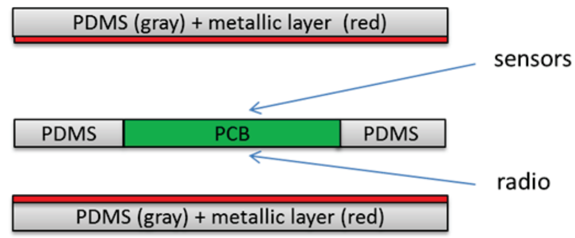

Fig. 4: Conceptual illustration of the WiseSkin layers

V. STATUS AND NEXT STEPS

The project is currently 18 months into a 48 month project. Initial prototypes are expected to be available for testing in Q2 of 2015. A conceptual illustration of a hand prosthesis equipped with 16 WiseSkin sensors is provided by Fig. 5. This is the target for the initial prototype. A set of high level system specifications is provided in Table 1, to be validated and refined for prototype 2 (target solution).

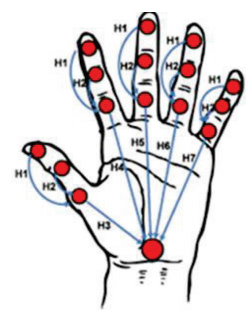

Fig.5: Prototype 1 concept

Table I High level WiseSkin specifications for prototype 1

Item	Description
Sensors	Type: Pressure sensors Number: 16 wireless tactility sensors on a prosthetic hand Thickness sensor – wireless module ≤ 2 mm (encapsulated) Area ≤100 mm^2 (incl. microprocessor and antenna)
Wireless	2.4GHz BTLE compatible radio (icyTRX), 1 Mbps rate Data: average of a few bytes of data per sensor, per event (e.g. 3 bytes or 24 bits to perhaps 8 bytes or 64 bits) 10ms (e.g. gripping), 1ms (fast update rate e.g. detecting shear) 16 sensors x 24 bits/sensor x 100 updates/s = 38.4kbps
Module	Thickness: ≤ 2 mm (encapsulated wireless sensor module) Area ≤100 mm^2 incl. sensor(s) on one side wireless, antenna, microprocessor and power management on the other
Skin	Silicon / PDMS based glove Dual metallization layers (powering, waveguide, shielding) Thickness: 2-3 mm (less at the joints)
Sensory feedbac	Haptic display: 1) vibrotactile display using either eccentric rotating mass (ERMs) or linear resonant actuators (LRAs) or 2) mechanotactile with servo motors providing feedback.
Other	Scalability (e.g. devices and data rates) Low power (minimal impact on prosthesis autonomy) Low cost and ease of manufacturability Ability to cover large areas and place the sensors anywhere

VI. CONCLUDING REMARKS AND IMPACT

WiseSkin targets the provision of a natural sensation of touch for users of prosthetic limbs. To do so, it pushes the forefront of technology in miniature, ULP sensor and communication devices, materials and sensory feedback systems. It enables new prosthetic products, with enhanced functionality, hopefully offering improved quality of life for amputees. It also opens the door for new solutions made of intelligent materials (e.g. smart gloves) artificial skin for tactile robots able to more safely work along-side people (e.g. in factories and homes robots) and haptic interfaces (e.g. gaming).

ACKNOWLEDGEMENTS

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