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Project acronym: SmartHand

Project title: The Smart Bio-adaptive Hand Prosthesis
Instrument: STREP
Thematic Priority: NMP

Publishable final activity report

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Duration: 36 months + 3 month extention

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Project coordinator organisation name: Lunds Universitet

1. Project execution

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<ins>Summary - project objectives</ins>

Smart Hand is a highly innovative, interdisciplinary project, combining forefront research from material sciences, bio- and information technologies with cognitive neuroscience to solve a major societal problem, namely; the development of an artificial hand displaying all the basic features of a real human hand. The successful realization of this highly visionary project requires crossing the boundaries of distinct scientific fields, merging forefront expertise of the consortium and use of state-of-the-art research results from relevant fields, to improve quality of life for disabilities by improving mobility and diminishing phantom pains associated with amputees. Smart Hand prosthesis will have major impacts on rehabilitation of amputates.

The overall, scientifically challenging, and visionary SmartHand goal is to <ins>develop an intelligent artificial hand that looks and feels like a real hand</ins>. The project integrates recent advances in nanobioscience, cognitive neuroscience and information technologies in order to develop such an intelligent artificial prosthetic hand with all basic features displayed by a real one. To realise the SmartHand vision of this intelligent hand prosthesis<ins>, the following major objectives are targeted:</ins>

1. development of a *neural interface* with recording and stimulation capability, enabling both motor control and sensation by humans
2. appropriate *neural information processing* of the signals (going to and from the neural interface) to establish a human-machine communication link
3. development of a *robotic hand* that satisfies a number of mechanical criterion such as; weight, speed, force, whilst still having a degree of freedom
4. development of an *artificial sensibility*, essential for feedback, fine manipulation and acceptance of body part
5. development of a *cognitive training system,* to train human subjects and to be tuned to the neural interface.

During the project the partners carried out the **following work:**

Neural interface development focused on the fabrication and processes to implement a soft and flexible cuff based neural interface, see Figure 1. A process to get the electrodes to stick to polymer has been developed.

Figure 1. The neural interface with self-curling silicone cuff that is plased around the nerve bundle.

Field effect transistor was developed to increase sensitivity of the neural interface, see Figure 2.

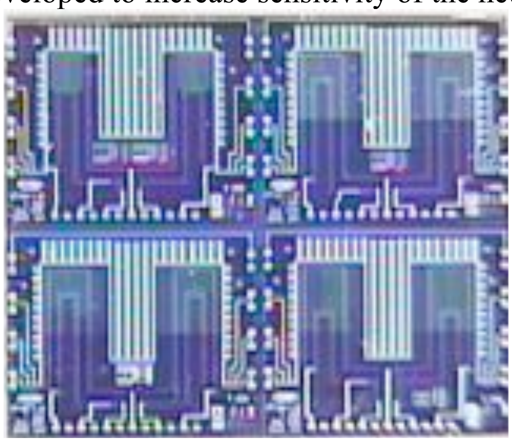

Figure 2. Array of 4 chips each contains two Ion Sensitive Field Effect Transistors (ISFETs) and one Metal Oxide Semiconductor Field Effect Transistor (MOSFET).

The neural interface has been tested in various biocopabilety studies and one of the was cell culture studies where neurons was grown on the surface of the interface, see Figure 3.

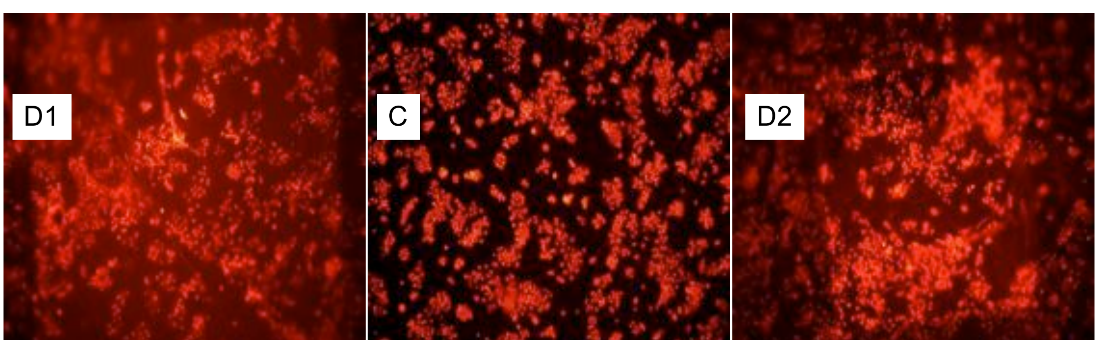

Figure 3. Nerve cells culture on the electordes. Photomicrograph of area 3 of the test device. D1 = test device 1, D2 = test device 2 and C = glass coverslip. The cell growth on the test devices and the glass coverslips appeared the same. The cell growth on the test device appeared the same on the polyamide base and on the gold electrode.

Involved partners: TAU, TYN

Main achievements:

- Neural microelectrode arrays were successfully fabricated.
- A new mechanically biocompatible neural cuff-electrode concept has been introduced
- One-dimensional electrode and two-dimensional electrode for recording and stimulation.
- Neural amplifier ready for integration, self-spiralling silicone cuffs.
- Different versions of the neural interface have been delivered.
- Platform to do in vitro study of neural interface has been delivered.
- Investigation of biocompatibility of the neural interface components
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Neural information processing. Neural recordings and stimulations were performed with cuff electrodes on animals. Initial analyse validated proof of concept, see Figure 4.

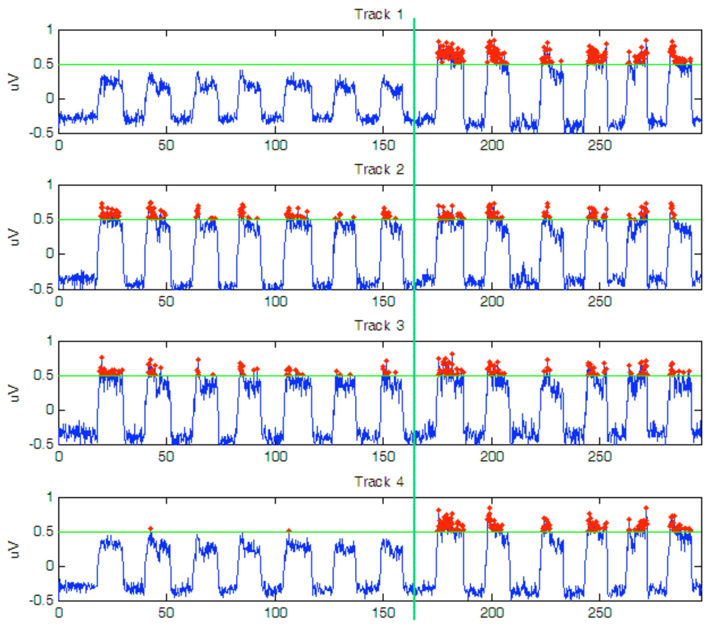


Figure 4. Nerve signals from the peripheral nerve that has been recorded and pre-processed. The diagram clearly shows distinct physical properties of the nerve signals that are identifiable both with regards to sensory and motor control.

The organization of control of grasping of various objects has been studied with healthy individuals in conditions where the visual input was modified. A system utilizing this was developed and thus the type of grasp was deseeded with the help of the video camera and laser pointer, while timing of the grasps opening and closing was done by using muscle signals (EMG).

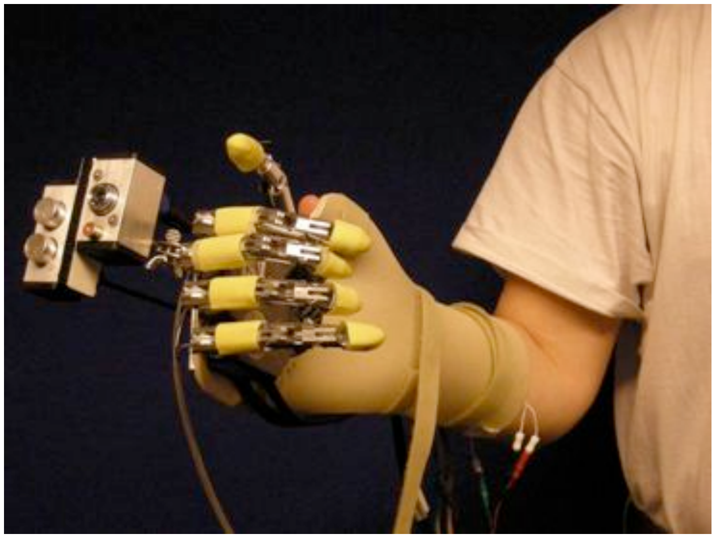


Figure 5. The cognitive vision system (webcam, ultrasound distance sensor, laser pointer) mounted on the top of the hand which is attached to the brace. At the end of the brace, leads from the EMG electrodes can be seen. This is the setup used for the experiment.

Involved partners: AAU, TAU, TYN, SSSA
Main achievements:

- The use of vision control (video camera input) has been verified to obtain a natural pre-shaping of the hand in the grasping process. It has been shown that additional input from MEMS accelerometers further, enables wrist and arm position control.
- Strategies for providing feedback
- Stimulation strategies for neural feedback.
- Neural recording and stimulation using the SmartHand neural interface

Cognitive Studies. Extensive studies were done on 6 non-amputees and 5 amputees investigating sensibility substitution in functional prosthesis, body ownership of the artificial hand and motor control of the SmartHand early prototype. The study was a joint effort and external partner supported some of the studies. The external partners were the Red Cross Hospital in Stockholm and the orthopaedic department at Lund Univerity hospital. Further subjects were studied in task “Cortical integration of the artificial hand”. Activation of somatosensory cortex has been investigated in 6 amputees and 15 non amputees have been investigated, subjected to fMRI-investigation, see Figure 6. The result has high impact and is currently prepared for publication.

a)

b)

Figure 6 a) Mapping of the fingers of the phantom hand distally in the amputation stump. b) Activation of somatosensory cortex resulting from stimulation of various parts in the skin hand map distally in the forearm (see a)). Tactile stimulation of trigger points for thumb, index finger and little finger in the hand map activates specific and well separated areas in somato-sensory cortex.

Involved partners: LU, SSSA, AAU, OSS
Main achievements:

- Results and data from human studies both on non-amputees and amputees.
- Structural prototype for artificial sensibility.
- Definition of principles for artificial sensibility in hand prosthesis
- Definition of cortical sensory adaptation of an artificial hand

SmartHand robotics development. In the further ongoing work on developing the SmartHand robotic hand the mechanics have been finalised, see Figure 7, All sensors have been integrated in the mechanical assembly, a control board, able to operate 4 motors and acquire all sensory information has been developed and integrated in the structure.

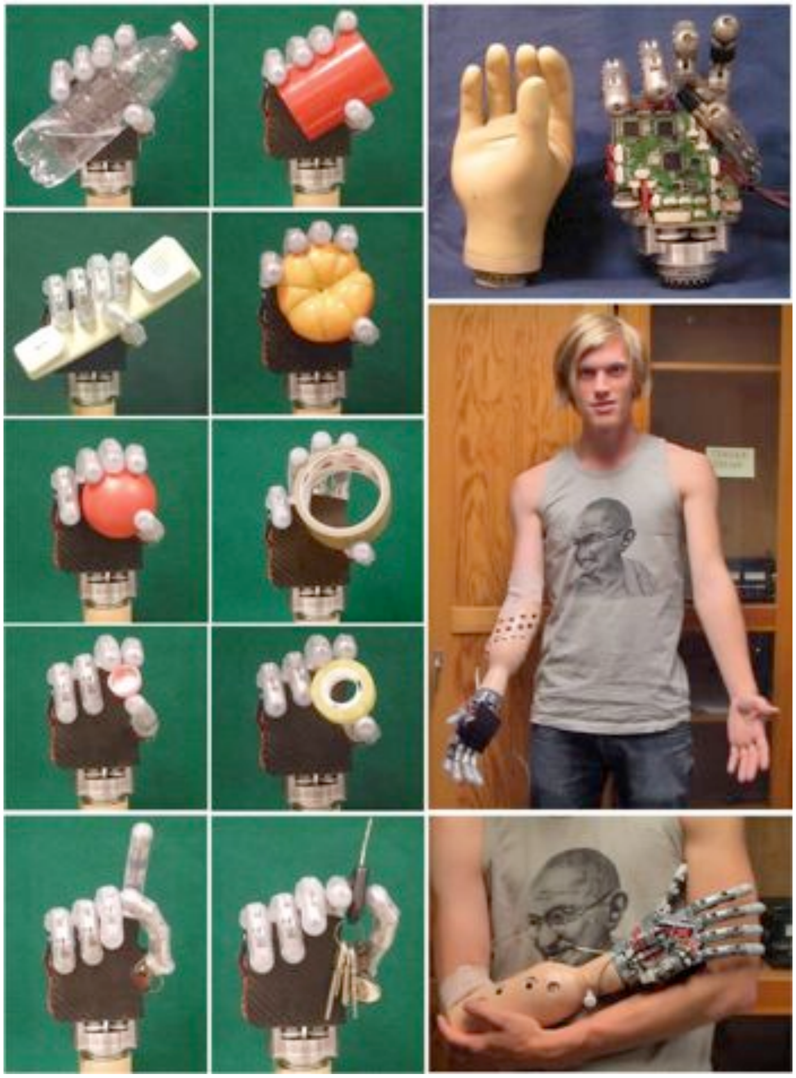
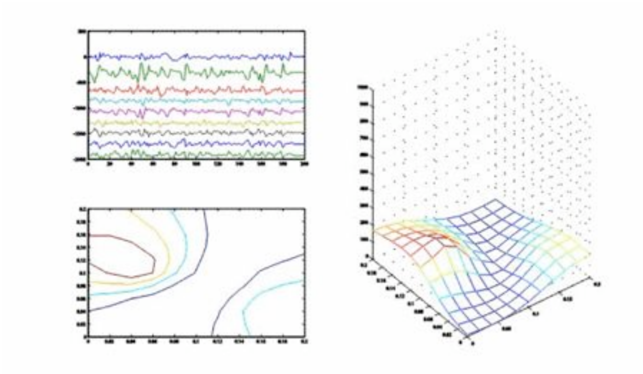


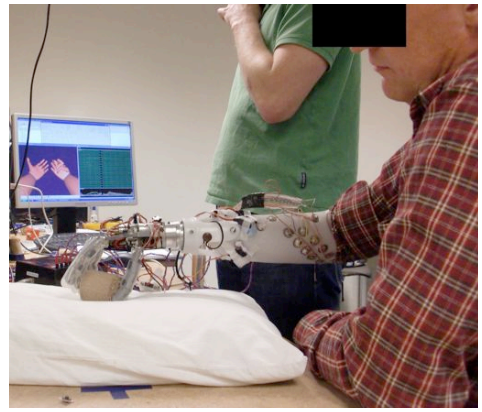
Figure 7. The SmartHand prosthesis.

Involved partners: SSA, LU, OSS
Main achievements:

- New hand prosthesis, SmartHand robotic hand, has been developed including sensor matrix configuration and new improved mechanical design complying with the clinical requirements of lower arm amputees.
- The prototype enabling individual finger movements
- The robotic hand provides sensory information through a sensor matrix configuration and serving as the basis for sensory feed-back to the patient

The Intelligent Bio-Interface Socket Development the electronics to the SmartHand prosthesis have been progressing as scheduled and deliverable. Thus Embedded system with bio-interface capability, the tactile display, the Bio-signal tracking system has been developed. The cognitive trainings system and has been tested on amputees controlling the SmartHand prosthesis, see Figure 8.





a) **b)**

c) **d)**

Figure 8. a) EMG mapping of movement 1 b) The cogentive training system with virtual hands c) The intelligent bio-interface socket

Involved partners: LU, SSSA, AAU, TAU, OSS
Main achievements:

- Delivery of the intelligent bio-interface hardware and software systems
- Human studies using the cognitive trainings system, tactile display and an early version of the SmartHand prosthesis using amputees

SmartHand Evalutation. Finally the SmartHand prosthesis systems where investigated and evaluated in different tests involving both amputees and non amputees. The different parts developed in SmartHand was integrated and tested together. The final SmartHand prosthesis was evaluated using eight amputees and the outcome was very positive.

Involved partners: LU, SSSA, AAU, TAU, TYN, OSS
Main achievements:

- Initial specification of the integration protocol, interfaces and physical connectors has been defined.
- Integration of the SmartHand robotics with the intelligent bio-interface socket
- Integration of the sensory-motor algorithms
- Report on the neural interface and the bio-interface socket
- Evaluation of the SmartHand prosthesis on amputees

2. Dissemination and use

The Plan for Use and Dissemination of Knowledge (PUDK) was finalised. SmartHand has been presented at public lectures, Research Schools, workshops and conferences, and also for the non-scientific community as an informative and interactive lecture. The flyer has further been distributed via personnel connections, but was also sent to other institutions, universities with similar research focus. The design of the final SmartHand newsletter have been done for the final edition. The SmartHand website has consciously been updated both in the public and password-restricted areas. Smarthand evalution on amputee was filmed, presented at Euronanoforum Prague, June 2009 ,and the film material was made available for TV channels in October 2009. Several new channels around the world such as BBC, CNN, SKY NEWS, NBC, EURONEWS and CBS, to mention a few, have then broadcasted theSmartHand hand prosthesis system.

Involved partners: LU, SSSA, AAU, TAU, TYN
Main achievements:

- SmartHand public website: http:///www.smarthand.org
- Document preparation for Exploitation seminar

SmartHand team Cork, Nov 5, 2008