Report from Dagstuhl Seminar 18322

Human-Computer Integration

Edited by

Florian Mueller[1], Pattie Maes[2], and Jonathan Grudin[3]

1 **RMIT University – Melbourne, AU,** floyd@floydmueller.com
2 **MIT – Cambridge, US,** pattie@media.mit.edu
3 **Microsoft Research – Redmond, US,** jgrudin@microsoft.com

Abstract

The rise of technology that supports a partnership between user and computer highlights an opportunity for a new era of "human-computer integration", contrasting the previously dominant paradigm of computers functioning as tools. However, most work around these technologies only focused on the instrumental perspective to achieve extrinsic performance objectives. However, phenomenology emphasizes that it is also important to support the experiential perspective, which indicates that technology should also help people pay attention to their lived experiences and personal growth in order to deepen their understanding of their own bodies.

This seminar focuses on embodied integration, where a computer tightly integrates with the person's body. Although an increasing number of systems are emerging, a thorough understanding of how to design such systems is notably absent. The reason for this is the limited knowledge about how such embodied partnerships unfold, and what underlying theory could guide such developments. This seminar brought together leading experts from industry and academia, including those who are central to the development of products and ideas such as wearables, on-body robotics, and exertion systems. The goal was to address key questions around the design of embodied integration and to jump-start collaborations to pioneer new approaches for a human-computer integrated future.

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1 Executive Summary

Florian Mueller (RMIT University, Melbourne, floyd@exertiongameslab.org)
Jonathan Grudin (Microsoft Research, Redmond, US, jgrudin@microsoft.com)
Pattie Maes (MIT, Cambridge, US, pattie@media.mit.edu)
Zhuying Li (RMIT University, Melbourne, zhuying@exertiongameslab.org)

The rise of technology that supports a partnership between user and computer highlights an opportunity for a new era of "human-computer integration", contrasting the previously dominant paradigm of computers functioning as tools. However, most work around these technologies only focused on the instrumental perspective to achieve extrinsic performance objectives. However, phenomenology emphasizes that it is also important to support the experiential perspective, which indicates that technology should also help people pay attention to their lived experiences and personal growth in order to deepen their understanding of their own bodies. This seminar focuses on embodied integration, where a computer tightly integrates with the person's body. Although an increasing number of systems are emerging, a thorough understanding of how to design such systems is notably absent. The reason for this is the limited knowledge about how such embodied partnerships unfold, and what underlying theory could guide such developments. This seminar brought together leading experts from industry and academia, including those who are central to the development of products and ideas such as wearables, on-body robotics, and exertion systems. The goal was to address key questions around the design of embodied integration and to jump-start collaborations to pioneer new approaches for a human-computer integrated future.

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3 Introduction

Florian Mueller (RMIT University, Melbourne, floyd@exertiongameslab.org)
Jonathan Grudin (Microsoft Research, Redmond, US, jgrudin@microsoft.com)
Pattie Maes (MIT, Cambridge, US, pattie@media.mit.edu)
Zhuying Li (RMIT University, Melbourne, zhuying@exertiongameslab.org)

In Aug 2018, 28 researchers and academics from Europe, North America, and Asia Pacific gathered for a week to discuss the future of Human-Computer Integration (HInt). The goal of the seminar was to discuss the future of what it means to design interactive systems that integrate the human body and technology, a trend highlighted by emerging technologies such as implantables and ingestibles that blurs the boundary of computers and users. The motivation for the seminar stemmed from the realization that until today, with the accelerating technological capabilities, an increasing number of real-world deployments, and growing realizations of ethical and societal implications, it is increasingly important to identify an agenda for future research around human-computer integration.

A common way of identifying "generations" of computing is to consider the ratio of users interacting with computers over time. We began with the one machine/many users paradigm of the Mainframe era, shifting to the one machine/one user paradigm of the PC, and the one user/many machines paradigm of mobiles, to finally the many machines/many users paradigm of today's ubiquitous computing era [1]. However, recent developments suggest a new era where the boundary between machines and users is increasingly blurred as computers are becoming more and more integrated with the users. As such, the trend of HInt emerged, which is a growing interaction paradigm where the computer is closely coupled with the user, physically and conceptually [2]. The emphasis on HInt includes (1) the computers are worn or integrated into the user's body which forms the physical proximity; (2) the computers communicate directly to human senses rather than symbolically which forms the sensory fusion; (3) the computers can influence human task performance which forms a coordinated effort. HInt has an explicit end-goal of merging the human and the computer. Moreover, HInt views ubiquitous computing and good design practices, which suggest more rapid automaticity with and "invisibility" of computers, as waypoints towards a cybernetically integrated future. As such, HInt extends the current paradigm of Human-Computer Interaction (HCI) by introducing physical fusion and partnership with computers. The field of HInt is rapidly expanding, embracing new technologies and incorporating new disciplines. At the same time, the field has matured and is beginning to converge on key questions surrounding technology, self-perception, societal and design implications. We are excited about the potential of the HInt and how it will affect the user experiences with computers.

This seminar began with talks by all the attendees, in which they presented their works in the area, their theoretical perspective that guides their work, a description of their most and least favorite Hint projects, and their expectations for this seminar. After the presentations concluded, the seminar was mainly informed by group discussions, talking about the definition, grand challenges, and the future of human-computer integration. The structure of the seminar was based around theory, design and their intersection. From the start, it was acknowledged that if concerning oneself with technology that is integrated to the human body, not one particular theory will suffice, but rather, that a mix of theories will need to be engaged in, with all their weaknesses and strengths, with the big picture being what we get from studying this.

Figure 1 BioSync.

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4 Demo Hour

Joseph La Delfa (RMIT University, Melbourne, joseph@exertiongameslab.org)

On day two of the seminar, participants demonstrated their completed and in-progress works, giving the rest of the researchers a chance to experience some of the human-computer integration concepts and challenges discussed on the opening day.

Jun Nishida from the University of Tsukuba, Japan, presented two experiences which shift the user's perspective such that they are able to embody another person. BioSync [12] is an electronic muscle stimulation (EMS) device that can transform basic movements of the hand from one human to another. "CHILDHOOD" [11] is a visual and haptic perspective-changing experience that consists of two components, an AR experience that shifts the user's vision from eye height to waist height and a mechanical glove that transforms the capabilities of the user's hand into those of a child's hand. These two experiences offer designers a powerful insight into how do design for people with neuromuscular problems and children respectively.

Dag Svanaes from the Norwegian University of Science and Technology demonstrated artificial moveable ears that could be manipulated with a sensor-embedded glove [15]. Through

Figure 2 Artificial ears.

interacting with other people using a pair of artificial ears, one gets an idea of how computers can be used to integrate and augment with body language.

Joseph La Delfa from RMIT University Australia, demonstrated a Tai Chi drone experience [3], where participants were asked to wave their hands from left to right in time with a drone which moved around their body. The experience is designed to question how to design physical objects that can facilitate awareness of body sensations to achieve a relaxed and focussed state.

Joe Marshall from University of Nottingham United Kingdom, presented a perspective-shifting experience which aimed to mimic the kind of disorientation experienced by an infant whilst learning how to coordinate their vision with their movement. The experience highlighted the effort required to seamlessly integrate our natural sensors with our movement and questions what is required to bring an artificial sensor to the same level of integration.

Kai Kunze from Keio University, Japan, demonstrated a pair of glasses [10] capable of tracking facial expression in everyday scenarios. The device raised questions about how this technology could change the relationship between human and computer now that the computer is capable to constantly track and understand facial expressions. Kai also demonstrated a virtual reality juggling game, designed to teach the coordinated movements required to keep multiple objects in the air. The experience was able to “reduce gravity” to give the participant more time to coordinate their movements, raising questions about how computers can dynamically adjust the sensory input to reduce the learning curve of a new skill or augmented ability.

Suranga Nanayakkara from the University of Auckland presented the FingerReader 2.0 [1], a device which embeds a camera into a wearable ring, giving people with a visual disability assistance in identifying objects, text and color by pointing at them. The technology raised questions around the social and phenomenological implications of pointing to see.

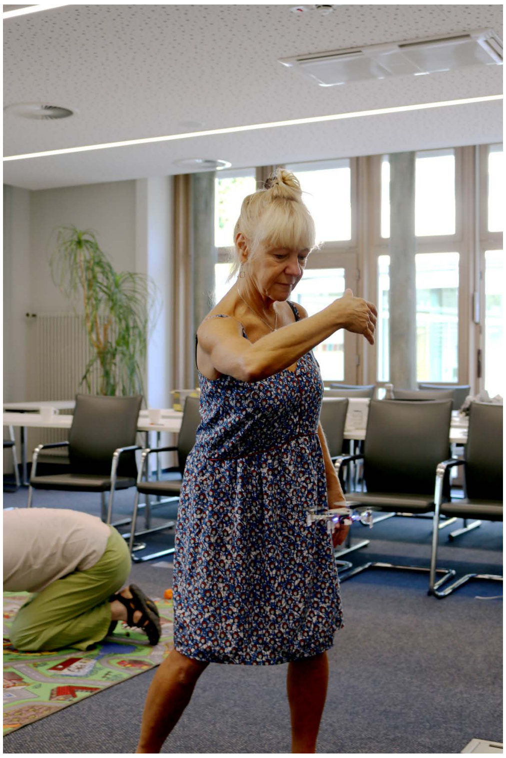

Figure 3 Tai Chi drone.

Caitlyn Seim from Georgia Institute of Technology presented a haptic glove capable of vibrating each finger individually [13]. When worn for long periods of time, the glove can passively teach the user skills such as how to play the piano, read braille, and use a new keyboard. The technology spawned conversations around the possibility of passively learning more complex skills.

The session was important to the seminar as it gave participants a somatic appreciation of the concepts and challenges that were being explored in the other sessions. Furthermore, it was fun and engaging, serving as a welcoming break from the more demanding theoretical discussion.

5 Definition of Human-Computer Integration

Since Human-Computer Integration is an emerging field, a synthesis definition is in demand. During the seminar, all the participants were divided into five groups to discuss the definition of HInt and then shared the results.

Farooq and Grudin's definition of human-computer integration [2] provides a structured description of potential ways in which digital technology and humans could be integrated. This definition suggests that computers and humans can form a partnership to facilitate integration. After the group discussions, we expanded this definition and identified two types of human-computer integration that go beyond the previous definition: (1) the significant reduction in size of sensors and effectors that enables the fusion of technology with the human sensory and motor systems; and (2) massive knowledge bases, networked infrastructure, and intelligent systems that enable a human-computer partnership or symbiosis.

Figure 4 Having the experience of an infant.

We believe that fusion is a type of HInt, which refers to systems that extend the experienced human body. To facilitate the experience of fusion, technologies are merged with the body (e.g., implanted sensors [7], ingested pills [8], and epidermal electronics), extending or manipulating the body [15], or stimulating the senses (as by actuators or augmented reality [9, 13]). Moreover, these technologies might access nearly-limitless information databases and extend our minds. For fusion to occur, interactions with systems and agents must afford direct mediation, perception, and communication. With fusion, we do not command our computers to act, we just act. We do not need to interpret the computer's feedback while we have an embodied understanding of it.

The other type of integration is symbiosis. We believe that as the power of the computer increases, the collaboration between human and computers will occur ultimately and there will be a power balance between what the human can achieve and what the computer can do. We call this type of integration symbiosis. The form of the system may vary, from systems that collaborate in creative tasks [2, 5] to brain implants that selectively trigger memory [4]. The novelty is not that there are software agents, or that the agents are smart. The novelty is that the process is truly shared between system and user as the two act in concert. An agent that has access to and an understanding of the context within which the human operates can adapt its behavior accordingly. In doing so, symbiosis can occur.

6 Grand Challenges of Human-Computer Integration

Shneiderman et al. [14] suggest that HCI as a field needs "grand challenges" to steer the direction of future research, design and commercial development. We believe identifying the grand challenges of HInt could help researchers and practitioners in this filed (1) identify

Figure 5 VR juggling.

current knowledge, capabilities and areas of opportunity where they can contribute; (2) situate their work within the larger HInt research agenda; (3) allow policy makers to better understand the HInt community, state-of-the-art technology and research, and potential applications. After the group discussions, we presented four sets of grand challenges of HInt.

First, the challenge of technology needs to be considered. For example, a close integration between computers and the human body may require the computers to feel and behave like parts of the human body. As such, the materials for the HInt systems need to be considered: it might be beneficial to be biocompatible, miniaturized and deformable. Moreover, the integrated computers need to support the wide range of shapes and sizes of the human body. Also, energy management and harvest is an interesting challenge for HInt devices.

Second, there are some challenges highlighting the identity and behaviors around HInt systems. For example, the HInt systems might change our perceptions of ourselves since such technologies have the potential to change our body schema by enhancing our sensory system and extending our capabilities.

Third, HInt systems may affect people's lives and society. For example, the influence of "digital divide" might be amplified by HInt systems. If areas of public space become designed for people with HInt systems that extend their capabilities, does the sensory-divide created by this design exclude people who cannot afford the augmentation?

Fourth, there are challenges for HInt in the field of interaction design. One of the challenges might be applying novel technologies to develop common understandings and tools for designing, developing, refining, testing and evaluating HInt systems. It is important for research to tackle the issues of robustness and practicality that enable HInt systems to be integrated into our daily lives. In conclusion, we believe the challenges we identified need to be addressed in the future to reap the full benefits of HInt.

Figure 6 FingerReader 2.0.

7 Superheros and Science Fiction

Martin Weigel (Honda Research Europe – Offenbach, DE)
Zhuying Li (RMIT University – Melbourne, AU)
Tom Erickson (Minneapolis, US)

In this session, we spent half an hour exploring the realm of superheros and science fiction to better understand the design space of Human-Computer Integration. The idea was to collect information about the special abilities of these characters as a group exercise and think about how well the abilities are integrated from the perspective of the mind, body and total integration. Groups of four got two characters handed out as a paper card. After discussing and rating these characters, they created a slide comparing them. The slides were presented by the groups to the seminar. The cards were put onto the body-mind integration scale to identify clusters and find empty spaces. As such, this session helped to identify new themes, which were later extracted from the participants' comments in a break-out session.

Based on the results of the discussion, we further created a matrix consisting of values and attributes of HInt. Attributes are aligned to values and can align to more than one value. We went through all the keywords which were used by the participants to describe the integration of the superheros. Then we classified these keywords as value or attribute. If it is an attribute, we identified what value is it associated with. We concluded values including safety, agency, extensions (something that extends the capability of an ecosystem), ethics/moral, aesthetics, and so on. Values determine how the attributes operate. We believe the values and attributes we concluded could also help make up the design space of HInt systems.

Figure 7 Haptic glove.

8 Methods of Tools of HInt

Wendy Ju (Cornell Tech, New York)
Zhuying Li (RMIT University, Melbourne)
Tom Erickson (Minneapolis, US)

We realize that the emerging field of HInt needs methods and tools. The seminar participants discussed the potential methods and tools of HInt. The assumption here assumes that the Human-Computer Integration curriculum follows an HCI 101 course. The ways that the HInt curriculum goes beyond HCI fundamentals is that: (1) HInt has a greater degree of integration with the user's body; (2) HInt systems are more "analogy" while traditional HCI projects are mainly on/off systems; (3) HInt systems are smaller and have more complex signals; (4) HInt systems has a different time scale compared to HCI systems; and (5) HInt brings about simulation and reality alignment issues.

We realized that interaction quality is important in HInt systems. To address this, In-situ/ simulation design and development including participatory design might be needed. After the prototype has been developed, an always-on test that continuous for 1-2 days is also necessary. Methods of instrumenting environments might also be applied to testing HInt systems.

When it comes to tools for HInt, hardware like Arduino and coding language such as Python might be utilized. On the mechanical side, it would be good to have stuff on adhesives, connectors, straps/sleeves/harnesses, etc. Other knowledge about signal processing, machine learning, control systems, eye tracking and VR/AR is also beneficial for HInt. Moreover, there might be an interest in getting into biochemical or pharmacological manipulations.

Figure 8 Discussing the definition of HInt in groups.

Certain design curricula is also needed for developing HInt systems. For example, designers should consider the perspective (1st, 2nd, and 3rd person perspectives) they take. Infrastrucuring might help designers take a socio-technical perspective on things. Other design knowledge from ethnography, critical design, empathic/experiential design could help the HInt system design. Designers of HInt might also need to think about the 2nd-order and 3rd-order effects and the longer term effects of design on life, people and societies. Simulation, gaming and forecasting might be used to design to anticipate these later scale effects.

9 Speculative Futures of HInt: Investigating User Scenarios

Ti Hoang (RMIT University, Melbourne, ti@exertiongameslab.org)
Pattie Maes (MIT, Cambridge, pattie@media.mit.edu)

To frame the emerging field of human-computer integration (HInt) we workshopped the concept of speculative futures for HInt to identify user cases and issues for designers of future HInt scenarios. Health and education were two specific applications explored in-depth. In each scenario, we identified the potential end-users of the Hint technology, the possible scenarios where HInt could occur, and finally developed thumbnail sketches of possible scenarios. Through this, we were able to identify fifteen key themes that represented either barriers to entry or under-explored directions for designers of HInt. Those key themes included: privacy, loss of control, security and safety, technical malfunction, graceful degradation, dependency, unequal access, disparity, techno tribalism, simulations to increase empathy, discontinuation of services, expectations of the technology, addiction to technology, psychological and social impact, and environmental impact and sustainability.

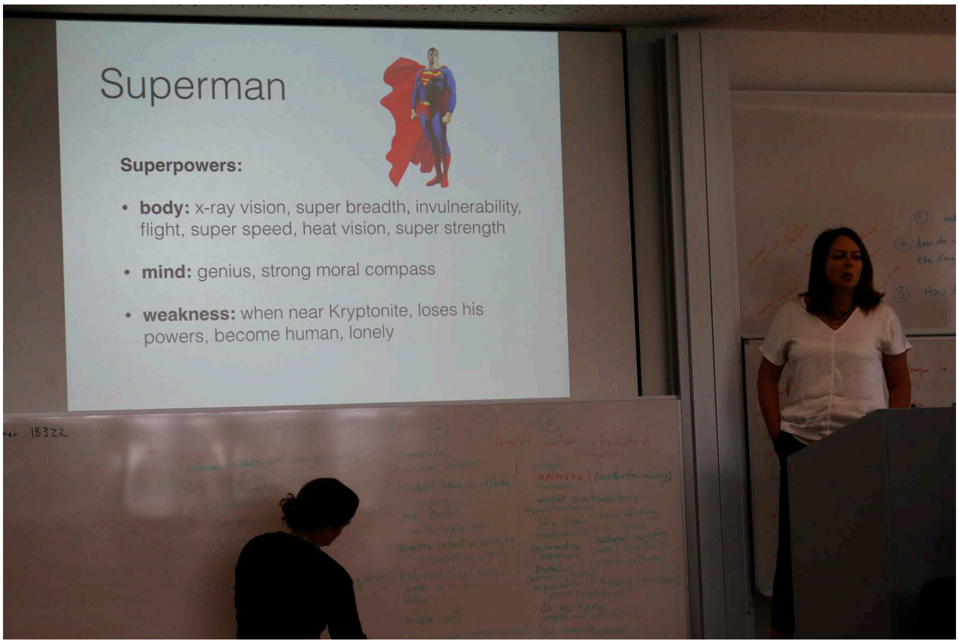

Figure 9 Discussing the level of human-computer integration of superheroes.

In attempting to frame the future of human-computer integration we offer the name HInt as a way to describe and differentiate human-computer integration from the previous focus of human-computer interaction. We classified HInt technology as either off-body, on-body, or in-body. We defined "off-body" as technology which is situated in the environment around the body and does not physically attached to the body, "on-body" was defined as technology that exists on the surface of the body such as wearables or hand-held devices and which can be separated from the body, and "in-body" as technology which exists internally within the body such as ingestible devices. We also draw inspiration from comic book characters with superpowers as a fictional representation of HInt for the purpose of suspending disbelief and encouraging creative thinking to consider alternative futures of HInt.

To identify future possible scenarios for HInt we undertook an informal brainstorming and discussion session which focused on what we believed would be the future of HInt. The discussion involved four phases not too dissimilar to the ideation and concept generation process used within design disciplines: brainstorming ideas to generate a set of possible directions for Hint, identifying and selecting specific applications from the set of possibilities for further investigation, and generating user scenarios for those applications. Designing and developing mock-ups of user scenarios was outside of the scope of the activity, and instead, the intent was to identify themes to assist designers in developing future HInt systems.

The initial brainstorming phase resulted in the mapping out of the broad philosophical HInt questions: What is the HCI discipline in a decade? What will be new approaches to designing HInt? Will these systems be distributed? What are the software agents? How can HInt facilitate social interactions or assist in unifying the self? What are exemplars of HInt? And is the integration of technology with the body even a path we should be undertaking? To explore possible HInt health scenarios we first identified the users of the system, and they included patients, extended family, or health practitioners. One possible future HInt scenario re-imagined how practitioners might practice healthcare. It

Figure 10 Lay on the floor and feel the 1st person perspective of live experience.

was suggested that practitioners could use technology such as virtual reality to walk through the virtual body of a patient. Another suggestion proposed assistive technology could be developed to guide users in learning to eat well, prepare for surgery, or experience what others experience. The HInt user scenarios were classified into three areas: transformative powers, restorative powers, and superpowers. The use of the term "powers" was a playful prompt for re-imagining the outcomes of HInt and draws from the notion that comic book characters with superpowers are fictional representations of HInt. Our second scenario investigated educational Hints. The users of HInt learning were students and human tutors, and future HInt scenarios might include downloadable skills, technology to enhance the human senses, and deep brain stimulation. For on-body HInt scenarios, the group generated three possible scenarios: deep brain stimulation, sensory enhancement, and mobile learning using AR. This scenario generated concepts such as wearable clothing, or a hand-held stick, that can assist in translating languages.

While exploring user scenarios for each application, we also identified how this technology might break down. Concerns included: privacy, loss of control, security and safety, technical malfunctions, discontinued software, dependency and addiction, environmental sustainability, psychological and social impact, disparity brought about from the cost of technology and policy making. More intriguing breakdowns and perhaps specific to HInt technology came after the initial list of issues was identified. Concerns of techno tribalism where users could potentially become technologically isolated due to the brand or manufacturer of HInt technology that they choose; body-mining of technology where the value of HInt technology could result in crime; and heirloom HInt technology where people might associate the sentimental value to technology in unexpected ways.

In summary, the discussion highlighted the need to investigate where future HInt scenarios might be needed, and that designers of HInt should also be aware of the repercussions of this technology. Design approaches which allow people to re-imagine future HInt scenarios could help with developing more detailed narratives which assist to move the discussion towards richer visual and physical representations of speculative future HInt scenarios.

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10 Overview of Talks

10.1 Tom Erickson

Tom Erickson (Minneapolis, US)

After a short introduction characterizing myself and my approach, I set out three prejudices I bring to the workshop:

1. AI is stupid and brittle and is not likely to get much better.
2. Affect recognition is crude, and is not likely to get much better.
3. and therefore "human computer partnership" – a phrase often used to characterize the future of human computer interaction – is not likely to get much better, because partnership requires high cognitive and emotional intelligence.

That said, the concept of partnership need not be restricted to reciprocal relationships among co-equal partners. To enquire more deeply into partnership, I discuss a paper on "Human-Sheepdog Distributed Cognitive Systems," which is interesting because it illustrates partnership between three entities that are deeply unequal. The paper analyzes how the 'partnership' works

- the shepherd providing the plan and large-scale sensing of where the sheep are with respect to the goal, and signaling the dog on where to move the sheep
- the dog providing more acute but more local sensing of the sheep (with no awareness of the goal), and acting to move and control the sheep
- and the sheep sensing the dog, who is a predator that they fear, and trying to keep a comfortable distance away (thus, being herded)

It is interesting to note that the three entities have entirely different 'views' of what is going on:

- the shepherd is participating in a sheep-herd trial
- the dog is enacting predator routines[1], and responding to signals from its trainer
- and the sheep are responding to a potential predator.

This is an interesting example of an ecosystem of coordinated but not really cooperating entities acting in a coherent fashion. Perhaps applying this sort of distributed cognition analysis to human-computer partnership might be a way to grapple with the deeply unequal capabilities of humans and computers.

[1] The dog's predator routines have been subverted through nurture – sheepdog puppies are raised with sheep, so that while the sheep trigger their predator routines they also identify them as their 'pack' and do not attack them – and training.

10.2 Elizabeth Gerber

Elizabeth Gerber (Northwestern University – Evanston, US)

It takes a village to raise a child. Parents provide housing and moral guidance. Teachers provide instruction, etc. I presented the idea of understanding how technology raises ideas. Technologies may support social exchange – social media, online communities, live video chats, instructional videos, information exchange – crowdsourcing, or financial exchange – crowdfunding. My research mission is to use computation to advance social prosperity. My work is driven by Hutchins and LaTour's perspective of distributed cognition where cognitive processes are distributed across the members of a social group and technology facilitates exchange. I conduct this research in the Delta Lab at Northwestern University designed to bring together computer scientists, learning scientists, and organizational behavioralists to study this topic. I was formally trained as a designer and organizational behavior scholar at Stanford University.

10.3 Steve Greenspan

Steven Greenspan (CA Labs, US)

Thank you for inviting me to the Human-Computer Integration workshop (Dagstuhl Aug 6-10, 2018). My name is Steve Greenspan – a quick background: My PhD is in Cognitive Psychology and this was followed by postdocs in user experience under Don Norman and speech perception under David Pisoni. As a researcher at AT&T Labs, I led a research program in 2002 called Air Graffiti, in which a head-ups display presented audiovisual information based on the location of the user – when users entered an office with an occupant they might receive a Zork message "you've entered a room and there is a wizard at the desk", or when they passed an office co-worker's door they might hear something about the worker's latest activity – whatever the worker wished to post to passers-by.

More recently at CA Technologies, I have been involved in research projects on differential privacy, ML-facilitated visual analytics, and AI ethics. Of relevance to this workshop, I am currently working on Cobotics and IoT data trustworthiness. In the Cobotics work we are researching how teams of humans and teams of robots cooperate and coordinate work. The work on data trustworthiness is focused on how to make good decisions when the data from IoT sensors is not completely trustworthy.

There are many challenges to human-computer integration.

1. What stimuli can be mapped to what senses? Can we use synthesia to map new senses (e.g., mapping magnetic field strength to auras around objects in a person's visual field)?
2. What are the limits on the number of inputs that can be cognitively integrated?
3. Preventing Attack Vectors (security by design)
   - What are the new attack vectors? Perceptual sensitivities, illusions, maladaptions, fake affordances.
4. Ethical & Legal implications: Privacy & Responsibility

- Who is responsible for unintended and intended harm: The manufacturers? The service providers? Or the user? Under what scenarios?

We must be concerned not only with how the user integrates with new sensor and motor devices, but also with how these human-machine systems coordinate with other human-machine systems and with society.

10.4 Playful Interaction

Stefan Greuter (Deakin University – Melbourne, AU)

My presentation on "Playful Interaction" introduced previous work including the design of an interactive tablet based learning game to teach Occupational Health and Safety on Australian construction sites; Virtual Reality projects for architectural and cultural heritage visualisation, games for a full-dome system and playful interactions or industrial machines and laboratory environments. Play is important as it allows us to learn, use our creativity and imagination, improve our dexterity and physical, cognitive and emotional strength. Therefore, as our interaction with intelligent and highly integrated and automated systems progresses we need to focus on human factors and values such as our playful human nature.

10.5 Human-Computer Integration

Jonathan Grudin (Microsoft Research – Redmond, US)

In the half a century since the first graphical user interface supplemented program statements and command lines, we have shifted from software that waits for the next command to software that is continually acting on behalf of people, with or without their awareness. These human-computer partnerships, or symbioses, or integration, alongside new hardware and pervasive networking, have opened a range of development possibilities and research opportunities or even imperatives. My recent work on interactive conversational agents has revealed to me how difficult this will be. Yet it is also a great opportunity—in order to build software that simulates aspects of being human, we must understand better how human beings think and act, and when we understand that, we can support it better whether we are building conversational agents or other software and hardware.

10.6 Re-imagining the digital climbing experience

Ti Hoang (RMIT University – Melbourne, AU)

To design novel exertion games there needs to be a shift in our understanding of the ways in which interactions can occur between humans and technology. At the centre of this paradigm shift is the human body, specifically how we view the human body and the role it plays within Human-Computer Interactions (HCI).

Advances in interactive technology and their capacity to be tightly coupled with the body are opening new opportunities to explore how designers within HCI might design future exertion games that can strengthen the relationship between the body, the mind, and the environment. Rock climbing is an ideal sport for converting into a computationally-augmented exertion game because the whole body and the mind are intrinsically engaged when performing in this sport. The development of climbing gyms has also assisted in making the sport more accessible to the general public by providing a relatively safe environment for people to experience rock climbing. This increase in popularity has led to research into augmented climbing experiences. Past augmented climbing experiences have focused on: gamifying the sport by projecting digital games onto climbing walls; simulating real-world climbing experiences by creating virtual reality environments; or providing training assistance. They are also predominantly technology-driven approaches to developing digital climbing experiences, and have focused on engagement with the climbing wall. This suggests there is potential to explore the other components, such as the climber, in this experience.

This research begins by exploring rock climbing but is not limited to this sport, and has further applications for understanding how we design for exertion games. There are two emerging and distinct ways in which exertion games are being augmented, and that is either: augmenting the environment, or augmenting the body. My own research will explore how our bodies can be both physically and mentally engaged within exertion games. It will investigate ways of coupling emerging technology with the human body to extend the body's capacity to perform and experience play.

10.7 Misahiko Inami

Masahiko Inami (University of Tokyo, JP)

Masahiko Inami is a professor from University of Tokyo, Japan. His research interest is in human I/O enhancement technologies including bioengineering, HCI and robotics. He received BE and MS degrees in bioengineering from the Tokyo Institute of Technology and PhD in 1999 from the University of Tokyo. His research exploits all five senses for interaction. He proposed the concept of haptic augmented reality via projects such as SmartTools and SmartFinger. His team has archived several improvements that use multi/cross modal interfaces for enhancing human I/O. They include Transparent Cockpit, Stop-Motion Goggle, Galvanic Vestibular Stimulation, JINS MEME (electrooculography (EOG)-based smart glasses) and Superhuman Sports.

Professor Inami believes that today's Human-Computer Interaction (HCI) systems include virtual/augmented reality are limited, and exploit only visual and auditory sensations. However, in daily life, we exploit a variety of input and output modalities, and modalities that involve contact with our bodies can dramatically affect our ability to experience and express ourselves in physical and virtual worlds. Using modern physiological understandings of sensation and perception, emerging electronic devices, and agile computational methods, we now have an opportunity to design a new generation of "Human-Computer Integrated" systems.

10.8 Integration through Interaction

Wendy Ju (Cornell Tech – New York, US)

I make the case that Integration occurs through Interaction. In my research looking at how to design interactions with automation, I have discovered that often what feels natural and obvious as an interaction is different from what makes sense, cognitively or logically, as a model. This is because people engage with the world phenomenologically in the moment of interaction. Hence, in my experiment, we often perform design intervention experiments in which we elicit interaction patterns from people in-situ; often we use wizard of oz techniques wherein the wizard's instinct for interaction is as much a part of the experiment as the users' reactions. I argue that designing an interaction is like designing a conversation-you can't do it by yourself. It goes in a lot of directions; it depends a lot on context. Though I design interactions with robots and autonomous cars, I most frequently look to the writings of linguists such as Susan Brennan and Herb park for inspiration and explanation of how people communicate non-symbolically. My early work on The Design of Implicit Interaction, which looks at interactions where people are not consciously inputting information or seeking information out, illustrated how implicit commands and implicit displays change interaction patterns so that they are fundamentally different than traditional HCI interactions wherein explicit commands and displays are the norm. The advent of automation and integration make the question of how to design such interactions crucial to moving HCIntegration from technological possibility to reality.

10.9 Kai Kunze

Kai Kunze (Keio University – Yokohama, JP)

I work on technology to understand ourselves better. I'm an Associate Professor at the Keio Graduate School of Media Design, Keio University, Japan. I love science, hacking, making and playing with tech. In my research, I combine design and technology to make human experiences sharable to capture and exchange abilities, ultimately to amplify human senses. My overall goal: I want to give people a toolset to improve their physical and cognitive skills applying technology and design to enhance attention, comprehension, memory and ultimately decision making.

10.10 Joseph La Delfa

Joseph La Delfa (RMIT University – Melbourne, AU)

I introduced the octopus as a potential model of human computer integration, coving some basic concepts around cognition, proprioception and 'dependency'. Specifically the idea that the successful integration of the octopus's smaller ganglia and its larger brian are partially due to the co-dependency. I then followed with an example of the implications of wearing a garment that makes social decision on your behalf.

10.11 Play with Human-computer Integration

Zhuying Li (RMIT University – Melbourne, AU)

I am a PhD student with a background of Engineering and Game Design. I am interested in the future of play in the era of human-computer integration. I believe with the emergence of augmented-human technologies, more symbiotic human-computer interfaces will be developed to help create novel play experiences. I further explained this in my presentation by introducing two of my projects Guts Game and HeatCraft, which use ingestible sensors to facilitate playful experiences.

10.12 Devices that Overlap with the User's Body

Pedro Lopes (Hasso-Plattner-Institut – Potsdam, DE)

How can interactive devices connect with users in the most immediate and intimate way? This question has driven interactive computing for decades. If we think back to the early days of computing, user and device were quite distant, often located in separate rooms. Then, in the '70s, personal computers "moved in" with users. In the '90s, mobile devices moved computing into users' pockets. More recently, wearables brought computing into constant physical contact with the user's skin. These transitions proved to be useful: moving closer to users and spending more time with them allowed devices to perceive more of the user, allowing devices to act more personal. The main question that drives my research is: what is the next logical step? How can computing devices become even more personal?

Some researchers argue that the next generation of interactive devices will move past the user's skin, and be directly implanted inside the user's body. This has already happened in that we have pacemakers, insulin pumps, etc. However, I argue that what we see is not devices moving towards the inside of the user's body but towards the "interface" of the user's body they need to address in order to perform their function.

This idea holds the key to more immediate and personal communication between device and user. The question is how to increase this immediacy? My approach is to create devices that intentionally borrow parts of the user's body for input and output, rather than adding more technology to the body. I call this concept "devices that overlap with the user's body". I'll demonstrate my work in which I explored one specific flavor of such devices, i.e., devices that borrow the user's muscles.

In my research I create computing devices that interact with the user by reading and controlling muscle activity. My devices are based on medical-grade signal generators and electrodes attached to the user's skin that send electrical impulses to the user's muscles; these impulses then cause the user's muscles to contract. While electrical muscle stimulation (EMS) devices have been used to regenerate lost motor functions in rehabilitation medicine since the ’60s, during my PhD I explored EMS as a means for creating interactive systems. My devices form two main categories: (1) Devices that allow users eyes-free access to information by means of their proprioceptive sense, such as a variable, a tool, or a plot. (2) Devices that increase immersion in virtual reality by simulating large forces, such as wind, physical impact, or walls and heavy objects.

10.13 Cognitive Enhancement

Pattie Maes (MIT – Cambridge, US)

Most digital tools and applications today are designed for interaction with the conscious, logical, rational-thinking part of a user, with communication between the person and the technology being of a purely symbolic nature, i.e. words and pictures, and requiring the user’s complete attention. But people are more than rational, slow thinkers. A lot of our thinking and behavior is automatic, instinctive and emotional and is heavily influenced by the senses. I advocate for designing technology for the “whole” person, i.e. for both the rational and instinctive parts. I would like to encourage the HCI community to read more psychology and neuroscience, learn about the intricacies and oddities of the human brain and behavior, exploit those in new types of integrated-in-the-body interfaces that make use of non-symbolic means of interaction with the user. I believe such interfaces will be more effective in influencing and impacting users at a deep level so as to support memory, attention, learning and behavior change.

10.14 Joe Marshall

Joseph Marshall (University of Nottingham, GB)

I presented a model of embodied systems in which users experience both digital and real-world physical sensory stimulation. Taking a holistic multi-sensory perspective all current systems expose users to a mixture of real and digital sensory experiences. Our model of these digital and physical sensory stimulation mixtures considers 2 things – firstly how each sense is digitally or physically stimulated, and the congruence of digital stimulation, which relates to whether the digital stimulation is consistent with physical stimulation or whether it is imperceptibly or perceptibly inconsistent. I showed 3 examples of deliberate and perceptible incongruence – VR Playground, a playground swing with VR, where the user’s virtual motion is driven by the swing, but mapped to be very different, and Balance Ninja and AR fighter, two games which present inconsistent balance cues by affecting the user’s vestibular system (Balance Ninja), and rotating their vision (AR Fighter).

10.15 Longterm Self Tracking

Jochen Meyer (OFFIS – Oldenburg, DE)

Technology enables us to monitor our behavior and vital parameters. Since some years consumer products are available that can be used in daily life, by laypersons, and over years, decades, and ultimately lifelong.

This opens tremendous opportunities for supporting healthy living such as identification of slow changes and making decisions about future health behavior.

In such scenarios the user has a central role, acting not just as a consumer of services that are provided by a technical system, but also as a producer of data that is input to the system. These two roles may have competing requirements: As a consumer the user usually wants highest-quality services, which usually require high-quality data. As a producer, however, the user's interest more often is to reduce effort of data collection as much as possible, resulting in low-quality data with gaps and holes, which in turn limits the possibilities of using the data in applications.

This results in a mutual dependency between the application and the data: the applications defines requirements to the quality of data to fulfill the requested services as given by the user as a consumer; on the other hand the available data, as given by the user's role as a producer, defines the possibilities of the application for providing services. Balancing these two views is a key challenge for long-term applications.

10.16 Body-Computer Integration

Florian Mueller (RMIT University – Melbourne, AU)

URL http://exertiongameslab.org

I propose that one part of a human-computer integration future is body-computer integration. This is grounded in philosophy that argues for the importance of human values that ultimately ends in the good life. I illustrate this thinking by presenting recent work from the Exertion Games Lab, including a traffic-light aware eBike, a singing ice-cream and on-body robotic arms for social dining experiences.

10.17 Suranga Nanayakkara

Suranga Nanayakkara (University of Auckland, NZ)

URL www.ahlab.org

My 7-8 year experience working with deaf children made me realize that sensory impairment has nothing to do with intellectual ability. For instance, these deaf children were able to communicate over much longer distances with sign language and make beautiful computer graphics. In fact, they have such a developed special skill that I felt like the odd man.

Therefore, I believe in Human-Human Integration where technology act as an enabler to connect different communities with different abilities, helping people do things that they think they could not. At Augmented Human Lab (www.ahlab.org), we are taking some initial steps towards this.

10.18 Jun Nishida

Jun Nishida (University of Tsukuba, JP)

My presentation was about "HYPERSPECTIVE: Egocentric Perspectives by Wearable I/O Devices to Understand, Communicate and Cooperate with People." I introduced wearable devices to change the sense of body into an another person including 1) a wearable AR device that transforms the height of perspective into that of a child, 2) hand exoskeletons to change hand dimensions into that of a child, and 3) a pair of wearable muscle I/O device to share kinesthetic experience among people. These devices allow people to experience one's perspective in an embodied and egocentric manner. I believe that these hyperspective experiences would not only enhance our embodied knowledge but also change people's behaviour as well. When integrating humans and computers, it would be very important to preserve user's egocentricity and agency, because HInt devices are capable of deeply interfering user's actions, and having a full control of a user. To empower users with wearable systems, new technologies to understand a user's intentions, and to blend a device intervention and a user's voluntary are required. I hope my work encourages studies in this topic, and provide design implications to future researches in HInt.

10.19 Multisensory Experiences

Marianna Obrist (University of Sussex – Brighton, GB)

We experience the world around us through all our senses, but the way technology is designed is often limited to the stimulation of our sense of vision and hearing. In my presentation I argue for the integration of touch, taste, and smell into interactive technology. Especially the chemical senses, taste and smell, are under-exploited and yet today our understanding on those senses is more advanced than ever due to breakthroughs in psychology, neuroscience, and sensory science. Therefore we can now more actively design multisensory experiences in the future integration of human and technology. The benefit of doing that integration lies in the use of smell and taste for various application scenarios including training, education, therapy, entertainment, etc. – exploiting the strong link of those sensory stimuli to emotions and memory. My personal vision is to establish a systematic understanding of what and how to design for tactile, gustatory, and olfactory experiences in human-computer interaction (HCI), for life and experiences on Earth and beyond!

10.20 Harald Reiterer

Harald Reiterer (Universität Konstanz, DE)

Prof. Dr. Mag. Harald Reiterer holds a Magister (Mag.) degree (M.Sc. equivalent) from the University of Vienna in Computer Science and Economics. He defended his Ph.D. thesis in Computer Science at the University Vienna, Austria in 1991. In 1995 the University of Vienna conferred him the venia legendi (Habilitation) in Human-Computer Interaction. Prior to his appointment as full professor at the Computer and Information Science Department of the University of Konstanz in 2009, he was associate professor at the Department of Computer and Information Science of the University of Konstanz (1997-2009), assistant professor at the Department of Computer Science at the University of Vienna (1995-1997), and senior researcher at the Fraunhofer Institute for Applied Information Technology (1990-1995) in Bonn, Germany. His main research interests include different fields of Human-Computer Interaction, like Interaction Design, Usability Engineering, and Information Visualization.

10.21 Thecla Schiphorst

Thecla Schiphorst (Simon Fraser University – Surrey, CA)

Thecla Schiphorst is Associate Director and Associate Professor in the School of Interactive Arts and Technology at Simon Fraser University in Vancouver, Canada. Her background in dance and computing form the basis for her research in embodied interaction, focusing on movement knowledge representation, tangible and wearable technologies, media and digital art, and the aesthetics of interaction. Her research goal is to expand the practical application of embodied theory within Human Computer Interaction. She is a member of the original design team that developed Life Forms, the computer compositional tool for choreography, and collaborated with Merce Cunningham from 1990 to 2005 supporting his creation of new dance with the computer. Thecla has an Interdisciplinary MA under special arrangements in Computing Science and Dance from Simon Fraser University (1993), and a Ph.D. (2008) from the School of Computing at the University of Plymouth.

10.22 Caitlyn Seim

Caitlyn E. Seim (Georgia Institute of Technology – Atlanta, US)

My background in engineering and doctoral education in human-centered computing at the Georgia Institute of Technology inform my theories of the upcoming socio-technical shift to more integrated technologies.

Examples of this budding integration include HUDs that inform rapid decision making in order picking, sonic and tactile signals that help regulate respiration and stress, and algorithms that co-create art (images and songs) with human users.

My work on haptics and passive motor learning/rehab is one supporting example of how biosignals will help devices influence users as we become more integrated with technology.

10.23 Jürgen Steimle

Jürgen Steimle (Universität des Saarlandes, DE)

Jürgen Steimle is a full professor at the Department of Computer Science and at the DFG-Cluster of Excellence "Multimodal Computing and Interaction" at Saarland University. He is the head of the Human-Computer Interaction and Interactive Technologies Lab. He is a Senior Researcher at the Max Planck Institute for Informatics. Previously, he was an independent research group leader (W2) at Saarland University and Max Planck Institute for Informatics. From 2012 to 2014, he was a Visiting Assistant Professor and Research Affiliate at Massachusetts Institute of Technology (MIT) Media Lab. He holds a PhD in Computer Science from Darmstadt University of Technology. His research investigates user interfaces which seamlessly integrate digital media with the physical world, in order to enable more effective, expressive, and engaging interactions with computers. His current focus areas include flexible displays and sensor surfaces, on-body interaction, embedded user interfaces, and personal fabrication.

10.24 Designing for and leveraging Active Perception

Paul Strohmeier (University of Copenhagen, DK)

Material properties of the world around us are revealed to us by our interactions with them. It is tempting to think of our environment as having fixed properties which we perceive through passive sensors, but various studies suggest that the pre-conscious mircointeractions between our body and its environment create our subjective experience of the world. This becomes particularly apparent when studying haptic perception. Let us analyze lifting up an object. When holding the object, the fingertips are distorted due to shear stress. This distortion of the fingertips while the object is being lifted leads to a perception of weight [1]. When holding it, there is an interaction between the compression of the fingertip and the corresponding displacement of the fingers through the object. This interaction leads to a perception of compliance [2]. When moving our fingertip over the texture of the object, the interaction between our fingerprints and the materials surface structure causes vibrations. These vibrations are perceived as texture [3]. We experience the world around us through our interactions with the world. This is relevant for HCI as it allows us to provide users with material impressions without recreating the entire material. Rather through studying the sensory modality one wishes to target, one can create the target material by creating tightly coupled feedback loops, simulating the interaction rather than the material properties [4, 5]. This allows us to create perceptions of virtual worlds without needing to recreate the entire world, it also provides us with guidance regarding the design completely new senses and experiences.

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10.25 Dag Svanæs

Dag Svanaes (NTNU – Trondheim, NO)

Svanæs received his Ph.D. in Human-Computer Interaction (HCI) from NTNU. His research over the last 15 years has been in the fields of HCI and Interaction Design. His main focus has been on user-centered design methods and basic theory of interaction. A common theme is the importance of non-cognitive aspects of human-computer interaction – often called embodied interaction. At a practical level this involves a focus on the physical, bodily and social aspects of interaction. In his research he makes use of role play and low-fidelity prototyping in realistic settings to involve end-users in the design process.

10.26 A New Paradigm Of Human-Computer Interaction: Human-AI Collaboration

Dakuo Wang (IBM T.J. Watson Research Center – Yorktown Heights, US)

We are witnessing an emerging new paradigm of how people interact with computer systems. A few examples include computers we ate into our stomachs, artificial limbs controlled by electrical muscle stimulation (EMS), e-tattoos on our skins, various Augmented Reality/Virtual Reality (AR/VR) systems, auto-piloted cars, and various assistants enabled by Artificial Intelligent (AI) in our phones, at work, and at home. Contrary to the known paradigms, where we know how people use Personal Computers (PCs) with Graphical User Interfaces (GUI), web-based systems, mobile applications (Ubiquitous Computing), social network systems (Social Computing), we have little knowledge about how people interact with these new technologies. We know so little that we do not even have a consensus of the name for this new paradigm, thus the design of such systems is quite opportunistic. In this talk, I will firstly provide an account and a definition for this new paradigm. Then, I propose the "Human-AI Collaboration" model, which can be used as a guideline for understanding people's interactions with AI systems, and as design principles for designing such systems.

10.27 Cooperative Intelligence

Martin Weigel (Honda Research Europe – Offenbach, DE)

In my short presentation, I briefly introduced myself and my recent Ph.D. work. I also introduced the Honda Research Institute Europe, where I currently work, and our idea of Cooperative Intelligence. This idea is closely related to Human-Computer Integration. Afterwards I presented my personal thoughts on intelligent systems, technical challenges and Human-Computer Integration in general.

10.28 Katrin Wolf

Katrin Wolf (HAW – Hamburg, DE)

Katrin Wolf is a professor for Media Informatics at the Hamburg University of Applied Science in the faculty of Design, Media & Information and before she was a professor for Media Informatics at the BTK, the University of Art and Design in Berlin. She had worked as a postdoctoral researcher in the Human Computer Interaction Group at the University of Stuttgart, where she worked in the meSch project on projected guidance systems and in the RECALL project on lifelogging video navigation.

Her research focus is on human-computer interaction. Particularly, she is interested in touch and gesture-based interaction with augmented environments to foster integrated human-computer interaction. Katrin worked with physiotherapists focusing on ergonomics in gestural interaction design. She is known in the embodied interaction community for her work on microgestures using wearable sensors for gesture detection and exploring implicit interactions as well as explicit gesture interaction for wearable and ubiquitous computing.

PickRing is a wearable sensor that allows seamless interaction with devices through predicting the intention to interact with them through the device's pick-up detection. Tickle is a wearable interface that can be worn on the user's fingers (as a ring) or fixed to it (with nail polish). Therefore, the device controlled by finger gestures can be any generic object, provided they have an interface for receiving the sensor's signal. The proposed interface is an example towards the idea of ubiquitous computing and the vision of seamless interactions with grasped objects. Finally, she developed an interactive desktop lamp. The perception and gestural output space were explored in two studies those results will be summarized as the "grammar" of the lamp.

Participants

- Tom Erickson
Minneapolis, US
- Elizabeth Gerber
Northwestern University – Evanston, US
- Steven Greenspan
CA Labs, US
- Stefan Greuter
Deakin University – Melbourne, AU
- Jonathan Grudin
Microsoft Research – Redmond, US
- Ti Hoang
RMIT University – Melbourne, AU
- Masahiko Inami
University of Tokyo, JP
- Wendy Ju
Cornell Tech – New York, US
- Kai Kunze
Keio University – Yokohama, JP
- Joseph La Delfa
RMIT University – Melbourne, AU
- Zhuying Li
RMIT University – Melbourne, AU
- Pedro Lopes
Hasso-Plattner-Institut – Potsdam, DE
- Pattie Maes
MIT – Cambridge, US
- Joseph Marshall
University of Nottingham, GB
- Jochen Meyer
OFFIS – Oldenburg, DE
- Florian Mueller
RMIT University – Melbourne, AU
- Suranga Nanayakkara
University of Auckland, NZ
- Jun Nishida
University of Tsukuba, JP
- Marianna Obrist
University of Sussex – Brighton, GB
- Harald Reiterer
Universität Konstanz, DE
- Thecla Schiphorst
Simon Fraser University – Surrey, CA
- Caitlyn E. Seim
Georgia Institute of Technology – Atlanta, US
- Jürgen Steimle
Universität des Saarlandes, DE
- Paul Strohmeier
University of Copenhagen, DK
- Dag Svanaes
NTNU – Trondheim, NO
- Dakuo Wang
IBM T.J. Watson Research Center – Yorktown Heights, US
- Martin Weigel
Honda Research Europe – Offenbach, DE
- Katrin Wolf
HAW – Hamburg, DE