Human Computer Confluence

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Report

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Some definitions

Human n. A bipedal primate belonging to the mammalian species Homo sapiens

Computer n. An electronic machine which is used for storing, organizing and finding words, numbers and pictures, for doing calculations and for controlling other machines

Confluence n. A flowing together of two or more streams. The point of juncture of such streams. The combined stream formed by this juncture.

Human-computer confluence: A research program to investigate how the emerging symbiotic relation between humans and computing devices can enable new forms of sensing, perception, interaction, and understanding.

Executive Summary

In this report we propose a program of research that seeks to employ progress in human computer interaction to create new abilities for sensing, perception, communication, interaction and understanding. This proposal is the product of a panel of 14 experts assembled on the 16th of November by the European Commission's unit on Future and Emerging Technologies to examine the future of human-computer confluence. After a series of position statements, the panel engaged in a lively 3 hour brainstorming session on research issues raised by confluence. The result was a set of 12 inter-related research issues that were raised and explored in the discussions. In preparing this report, these 12 issues have been clustered into four research themes that could be addressed by a proactive research program.

For each of these issues we have worked to identify the trends in the evolution of enabling concepts, methods and technologies. From this we have identified both the opportunities and the risks to society brought about by these trends. We have illustrated each of the 12 issues with examples of research challenges that could be used to develop a better understanding of the opportunities and challenges.

In the first section we place human-computer confluence in the context of past commission research programs. In particular, we argue that recent programs by the commission and by industry have focused on technical problems related to massive scale interconnection of ubiquitous computing elements, but have not paid sufficient attention to how this phenomenon can be harnessed. We argue that recent progress in virtual and augmented realities and human-computer interaction may offer a means to harness this new form of computing to create new forms of sensing, new forms of sensory perception, new forms of human-computer and human-to-human interaction, and new forms of experience and understanding.

Our vision for creating new forms of sensing, perception, interaction and understanding is developed in the second section. We present each of the 12 research issues proposed by the panel in the context of four research themes. In addition to the research themes, we propose careful use of benchmarking and performance evaluation within projects, and recommend that research on human-computer confluence be accompanied by investigation on normative and applied ethics to provide a deeper understanding of how this new technology can be properly used to benefit mankind. Each research issue is illustrated by a identifying one or more open research challenges. In the final section we summarize our recommendations.

1. New Forms of Sensing, Perception, Interaction, and Understanding

Current research on human computer interaction concentrates on technical issues. We propose to complement such research with a program devoted to the opportunities and associated risks raised by confluence. Specifically, we propose a program to investigate how technologies for human-computer interaction, including virtual and augmented realities, can be harnessed to create new forms of sensing, perception, interaction and understanding.

A number of previous and current Commission research programs have addressed various aspects of this challenge. For example, the FET proactive initiatives on the Disappearing Computing were very effective in exploring the opportunities and the social impacts for new devices and services made possible by the increasing mobility and density of such devices. A recent program on Complex Systems has sought to develop analytical models and tools that could be used to predict and control emergent behaviour of massively complex networks of autonomous devices. However, none of these initiatives have sought to explore the interaction with human cognitive abilities and human society.

The Presence I and Presence II initiatives have explored the foundations of virtual and mixed realities. By exploring the neurophysiological and psychophysiological foundations of sensation and perception, Presence research has sought to increase the bandwidth of human-computer interaction. Projects have explored means to convey telepresence, imagery enhanced learning, localization in virtual and real worlds, perceptually oriented ego-motion, tactile sensing, and enhancement of sensory perceptions. Projects have demonstrated interaction and presence in urban environments, augmented social interaction, and immersive multi-modal interaction. In parallel the FET Open program has funded projects on haptic perception, walking, computer-mediated services, and brain-computer interfaces. The substantial investment of the EC, and in particular FET, into understanding new forms of perception and interaction provide the first steps for an enabling technology to respond to the challenge of confluence.

In the most recent Call 1 of Framework VII, the FET office has funded a proactive initiative on Pervasive Adaptation. The PERADA initiative concerns technologies and design paradigms for massive-scale pervasive information and communication systems, capable of autonomously adapting to highly dynamic and open technological and user contexts. Projects are to focus on evolvable and adaptive pervasive systems, as well as networked societies of artifacts for context-sensitive service delivery in rapidly changing and technology-rich environments. This directly addresses the technology development that enables the exponential growth in interconnected computing devices to continue. As such, the PERADA initiative will likely contribute to, and accelerate, the emergence of the computing milieu. In Human Computer Confluence (HCC) we propose a complementary program that examines how such technology can be adapted and mastered by individuals and societies. In particular, in HCC should examine new modalities for perception, interaction, cognition and experience by individuals and groups made possible by confluence.

In this report, we propose a program to explore (1) New forms of interactive media, (2) New forms of sensing and sensory perception, (3) Perception and assimilation of massive scale data, and (4) Distributed Intelligence. These themes would be completed by transversal efforts on benchmarking and performance evaluation, as well as the study of ethical and societal issues. In particular, we recommend that efforts on benchmarking, performance evaluation, ethics and societal issues should not be consigned to separate projects, but rather, should be integrated into each (or most) of the research projects that compose this program.

2. Research Themes in Human Computer Confluence

In this chapter, we present four research themes that encompass the 12 research issues identified in the position statements and group discussions of the HCC panel. We then discuss benchmarking and performance evaluation and examine the need for research on normative and applied ethics raised by the human computer confluence. In a final section, we illustrate the issues with possible research challenges.

2.1 New Forms of Interactive Media

Currently, the most effective technologies for new media for sensing, perception and experience are provided by virtual and augmented realities. At the same time, the most effective means to augment cognitive human abilities is provided by access to information spaces such as those provided by the world-wide-web using a graphical user interface. A current challenge is to bring these two media together. This challenge is not as easy as it sounds.

To enter into a virtual reality or to experience augmented reality it is necessary for participants to suit up in various ways. At a minimum it is necessary to put on a pair of special glasses, but normally much more than that. The challenge is to invent displays and interactive systems that are entirely unobtrusive, so that the transition from physical to virtual reality is essentially unnoticeable.

Obtrusiveness means that the fake nature of the virtual experience shines through. Avoiding obtrusiveness requires overcoming a number of barriers. The first such barrier is the process of suiting-up. We must find means to erase the transition from normal to augmented or virtual spaces. Further barriers arise from virtual representations, dynamics, and feedback. It is obtrusive to interact in a place where the lighting does not behave as it would in the real world, or to interact with virtual characters who move awkwardly or incorrectly, or who cannot change their facial expression, or who cannot move their lips properly as they talk or who have no apparent inertia when pushed.

In robotics, researchers have discovered an "uncanny valley" concerning the acceptability of robots as intelligent. The more a robot is made to resemble a human, the more sensitive humans become to the subtle differences, shattering the illusion of intelligence. An "Uncanny Valley" also seems to apply to virtual and augmented realities. As the virtual world approaches reality, humans become increasingly sensitive to minor differences. With so many aspects of human-computer confluence so far away from this point, the strive to improve fidelity, to avoid the obtrusive limitations of the technology, is still very much at the forefront of major scientific and technological challenges.

Four forms of media appear to offer promise of progress toward improved interaction.

1. Ubiquitous display surfaces,
2. Interconnected Smart Objects
3. Wearable computing, and
4. Brain-Computer Interfaces.

Each of these media raises fundamental new possibilities for individual and group interaction, as well as new forms of sensing, perception, experience and understanding.

2.1.1 Ubiquitous Interactive Displays

Organic LED's technologies make it possible to print large numbers of inexpensive and interconnected LEDs onto a paper or plastic substrate, creating such marvels as smart wall paper and 3D displays. OLED devices are already being rushed to market as a highly energy efficient and reliable form of lighting. Similar technologies make it possible to print computing displays onto paper or plastic at extremely low cost. Over the next 10 years, we should see increasing use of such "smart wall paper" technologies used on walls, floors, ceilings, and furniture. A current challenge is to complete low-cost visual display with similar technologies for acoustic, tactile and other sensory channels. Such a technology could be used to create a simple and inexpensive form of immersive CAVE-like environment. When combined with sensors for proximity and identity, such technologies make it possible for personalized information display to migrate through an environment to maintain proximity with an individual.

Combining sensing with multimodal display converts an information display into an interactive medium. Sensing technologies such as charge-coupled capacitive sensing can be used convert OLEDs into interactive displays, enabling interaction with menus, widgets and hypertext on any surface. In addition to interior and exterior walls, such a technology can be used to construct desks and other furniture augmented with computing, communications and display technologies.

This massive deployment may initially be driven by novelty and convenience of ubiquitous communications and access to information. At some point, advertising may emerge as a driving influence, drawn by the massive scales of presentation. Thus is appears likely that over the next 5 to 10 years, the growing exponential density of computing devices may be accompanied by a similar growth in interactive media, creating an imminent danger of unsolicited, distracting publicity (ubiquitous spam). However, as Google and others have shown with internet search, information about task and social context, coupled with presentation that avoids distraction, makes it possible to convert a publicity from a distracting nuisance to a valuable information resource.

The key to avoiding distraction in ambient information presentation is context awareness [Dey 01]. Just as search engines currently harvest keystrokes and mouse clicks to model human search activity, context aware systems must harvest signals from environmental sensors to recognize and model human activities, human to human interactions, human social organizations, and human task structures. Such a technology would enable massive deployment of ubiquitous interactive displays to augment human activities with non-disruptive access to information and communications.

2.1.2 Smart Objects and Tangible Interfaces

Micro-Electronic technologies increasingly makes it possible to augment ordinary objects with abilities for sensing, display, actuation, communications, and computing. Such devices, are sometimes referred to as smart objects or Tangible User Interfaces. It has recently become possible to extend such technology to all sorts of everyday objects including desks and chairs, eating utensils, and walls. Ad-hoc assemblies of such smart objects can transform an ordinary physical environment into a new form of interactive media in which the environment is the interface. This new interactive media can be used to enable new forms of human-computer interaction, as well as new forms of computer-mediated human-to-human communication.

Fundamental technical challenges are raised by the ad hoc assembly of smart objects. To some extent, technical challenges related to communications and service composition have been addressed in several recently initiated research programs, including the FET proactive initiative on "Pervasive Adaptive Systems". None-the-less, many challenges remain, particularly related to the interactive use of assembles of such devices. For example, the problems of unobtrusive interaction, described above, become even more urgent when devices can not only flash, but also sing and dance. In his work on "physical icons" [Isshi-Ullmer 97], Hiroshi Ishii has demonstrated how smart objects can use motion and color to provide unobtrusive display for both physical events and social presence. The Nabastag "rabbit" provides audio and illumination displays for social presence as well as for information such as current weather conditions. However, current demonstrations tend to be simplistic one-way displays. Little use has been made of such devices as an interactive medium.

2.1.3 Smart Clothing

An important form of smart object is smart clothing. Micro-electronics are increasingly making it possible to embed sensing, display, actuation and communications in clothing. Researchers have experimented with display and sensing technologies embedded in the fabric of clothing. Wearable sensors have been shown that can obtain information about physiological state (heartbeat, EEG, temperature, movement, arousal), as well as location and activity. Progress has been documented by a series of international conferences, as well as a journal under the heading of wearable computing. However, a number of emerging challenges remain to be addressed.

Wearable computers are commonly defined as computers worn on the body. Wearable computers have been demonstrated for applications such as behavioral modeling, health monitoring systems, and mobile access to information technologies. Wearable computers appear suitable for applications that require computational support while the user's hands, voice, eyes or attention are actively engaged with the physical environment. Many researchers are experimenting with wearable devices for monitoring of the elderly and infirm. Current research on wearable computing places the focus on the computing, often resulting in bulky and uncomfortable devices. Unobtrusive interaction requires placing the focus on the clothing, creating comfortable and maintainable garments, augmented with sensing, display, actuation and communications.

Biomonitoring of body-kinematics and physiological and behavioural signals offers many potential new services. Integrated wearable systems are able to transduce heart rate and electrocardiographic signals (ECG), as well as electro-miographic signals (EMG), electrodermal response (EDR), respiratory values and arterial oxygen saturation. Acquired information is correlated to obtain blood pressure, body temperature, heart rate variability (HRV), end tidal CO2 and thoracic impedance pneumographic values, although much remains to be done with regards to organic chemistry (e.g., cortisol or other hormones). A most recent breakthrough in the development of wearable systems has involved the recently developed textile substrates for the distributed on-body biochemical measurements and monitoring of body fluids. Intelligent reading strategies of unobtrusive piezo-resistive networks and physiological modelling allow human upper limb kinematic variables to be inferred. This property has recently been exploited in the realization of sensor enabled garments, such as gloves, leotards, seat covers capable of reconstructing and monitoring body shape, posture and gesture to record and classify non-verbal communication and body language. Embedding sensors for physiological and emotional state can convert clothing into a form of interactive social media.

Weaving sensors and communication interfaces into fabric raises the possibility of converting clothing into a "second skin". In this way clothing could become an extension of human sense for natural phenomena such as wind, temperature or radioactivity, as well as non-natural phenomena such as wifi coverage or presence of other forms of radio signals. An open challenge is how existing sensory channels, such as skin pressure or temperature can be exploited to provide sensory channels for such augmented clothing to provide new forms of sensing and perception. This challenge is developed in section 2.2 below.

2.1.4 Brain Computer Interfaces

A brain-computer interface (BCI) is a direct communication pathway between a human or animal brain and an external device. In one-way BCIs, computers either accept commands from the brain (e.g. by recognizing neuronal signals) or send signals to it such as in deep brain stimulation, for example, to restore vision. Two-way BCIs would allow brains and external devices to exchange information in both directions but have yet to be successfully implanted in animals or humans. Progress has continued on directly sensing and influencing the brain using both invasive and non-invasive technologies.

Invasive BCI research has targeted repairing damaged sight and providing new functionality to paralysed people. Invasive BCIs are implanted directly into the grey matter of the brain during neurosurgery. As they rest in the grey matter, invasive devices produce the highest quality signals of BCI devices but are prone to scar-tissue build-up, causing the signal to become weaker or even lost as the body reacts to a foreign object in the brain. Partially invasive BCI devices are implanted inside the skull but rest outside the brain rather than amidst the grey matter. They produce better resolution signals than non-invasive BCIs where the bone tissue of the cranium deflects and deforms signals and have a lower risk of forming scar-tissue in the brain than fully-invasive BCIs.

Non-invasive technologies include for BCI (stimulation and monitoring) include functional magnetic resonance, transcranial magnetic or inductive and electric stimulation and Electroencephalography (EEG). Neuro-imaging signals have been used to power muscle implants and restore partial movement in an experimental volunteer. Although they are easy to wear, non-invasive implants produce poor signal resolution because the skull dampens signals, dispersing and blurring the electromagnetic waves created by the neurons. Although the waves can still be detected it is more difficult to determine the area of the brain that created them or the actions of individual neurons. Electroencephalography (EEG) is the most studied potential non-invasive interface, mainly due to its fine temporal resolution, ease of use, portability and low set-up cost. But as well as the technology's susceptibility to noise, other substantial barriers to using EEG as a brain-computer interface is the extensive training required before users can work the technology, and the complexity of suiting-up that is required. Moreover, the available computational technologies for rapid and reliable interfacing is still limited. Currently some efforts are underway to use artificial neural networks and other computational intelligence techniques to shift the learning phase from the user to the computer, as well as the extraction of new features from multi-channel EEG data.

2.2 New Forms of Sensory Perception

Sensory perception is the awareness of phenomena through physical senses. It may be possible to enable new forms of sensory perception for both natural phenomena and information using smart clothing, ubiquitous displays, brain computer interfaces or other technologies.

2.2.1 New Sensory Channels

There is no firm agreement among neuro-scientists as to exactly how many senses there are, because of differing definitions of a sense. A more informed definition of a sense might be "a system that consists of a sensory cell type (or group of cell types) that responds to a specific kind of physical phenomenon, and that corresponds to a defined region (or group of regions) within the brain where the signals are received and interpreted." Where disputes as to the number of senses arise is with regard to the exact classification of the various cell types and their mapping to regions of the brain.

One intriguing aspect of the neuronal mechanisms underlying different modalities is that their anatomical and physiological organizations are rather uniform (Wyss et al 06). This suggests that only a few computational principles can give rise to a plurality of modalities including modalities that have not been produced by biological evolution but can be realized through human invention. This would truly represent the creation of new senses.

The challenge is to determine if it is possible to create new forms of sensory channels by provoking a neural mapping from an artificial medium directly to an appropriate brain region. If such media could then be augmented with access to computing, this would create an entirely new form of sensor perception in which human awareness would be extended from physical presence into the computing milieu. The result would be a sort of "extended mind" in which computing would become a very powerful cognitive and perceptual prosthesis.

Artificial synesthesia has been evoked as one possible approach to providing a new sensory channel by exploiting existing chanels. Synesthesia is a neurological phenomenon in which stimulation of one sensory or cognitive pathway leads to automatic, involuntary experiences in a second sensory or cognitive pathway. In one common form of synesthesia, known as grapheme color synesthesia, letters or numbers are perceived as inherently colored. In another form, ordinal linguistic personification, numbers, days of the week and months of the year evoke personalities. Artificially stimulated synesthesia could be used to create new forms of sensory perception.

An alternative is to co-opt little used neural pathways, as currently investigated in creating visual prosthesis for the blind. According to the European Blind Union, over 7.4 more European citizens are legally blind or have severely impaired eyesight. Over a million people in the United States are listed as legally blind. As a result, a substantial investment has been made in experiments for creating visual prostheses. Various attempts have been made to exploit retinal and neurological implants, audio, tactile stimulation on the tongue, the back and other regions of the body. Such research could be adapted to create artificial sensory organs to directly channel information and interaction from the computing milieu.

2.2.2 Cognitive and Perceptual Prosthetics

Cognition refers to the processes of comprehension, judgment, memory, and reasoning. Perception is part of the cognitive process, and is characterized by the recognition and interpretation of sensory stimuli for knowledge or motivation of action. Cognitive and perceptual prostheses are computational systems that leverage and extend human intellectual capacities, just as the steam-shovel was a sort of muscular prosthesis. We propose to develop prostheses that can extend the cognitive, emotive or perceptual abilities of normal humans, in order to both augment existing perceptual and cognitive abilities and to enable new and richer forms of perception and understanding.

As an example of a cognitive prostheses, consider a wearable device that can inform its user about the current situation by providing access to information about the current context. The information for such a device could be provided by wearable computers equipped with audio-visual sensors and massive storage, or be obtained from environmental sensors. The challenge for such devices is to present information that is relevant to the current social and task context in a manner that does not distract or annoy the user.

A variety of other forms of cognitive and emotional prostheses can be made possible by ubiquitous sensing and interaction. For example, wearable clothing can be used to capture information about emotional and physiological state. Such information could be communicated during human to human interaction allowing a much richer and accurate awareness of shared emotional experience. The amalgamated emotional state of a an audience could be communicated to a speaker or entertainer making it possible to adapt a presentation to most effectively communicate to the audience. Emotional prostheses can be used to maintain a sense of social presence with loved ones separated by distance.

Coupling an unobtrusive (or non-disruptive) sensor channel for digital communications over the Internet offers the possibility to augment human cognition and perception with any of the myriad information sources available. The challenges are

1) To determine a suitable unobtrusive (or non-disruptive) sensory channel, and
2) To provide a means to determine the current task and social context awareness.

Examples of possible sensory channels include eye-glasses that have been augmented with a computer display, and hearing-aid like devices that can provide acoustic communications. Automatic awareness of task and social context is a hard scientific challenge because of the individual nature of context, as well as the extreme diversity in human environments.

2.3 Perceptual Assimilation of Massive Scale Data

2.3.1 Massive-Scale Implicit Data Collection

Over the last 10 years, human computer interaction has increasingly migrated from isolated personal computers to web-based services distributed over the Internet. One of the consequences of this migration has been the emergence of systems that "harvest" web-based activity. Many commercial web services are shadowed by systems that silently collect information about how people interact with web pages, and what hyperlinks they use. For example, both the search ranking services and the advertising revenue of Google are based on recording and interpreting mouse clicks. The continued doubling in the size of the Internet drives a continued doubling in both the value, and in the difficult of collecting and interpreting such information.

As information and communication technologies increasingly pervade human activity, it will become progressively easier to passively "harvest" other information about day-to-day activity. Any interaction with an interconnected computing object can potentially be recorded and communicated to data collection centers, whenever human activities for communications, for entertainment, for work, for travel, and other day-to-day activities may be logged and archived. In addition, as informatics and communications technologies are increasingly used to manage energy, logistics, illumination and security of habitats, even indirect information may be logged.

While many people initially react to such possibilities with cries of "big brother" and "1984", ill-defined concerns are rapidly put aside in favor of a multitude of information services made possible by such logging, as made evident by the success of Google and its competitors, not only for search, but for email, agenda management, navigation and many other services. A similar phenomenon may be expected to drive acceptance of massive scale implicit data logging in domestic, commercial and industrial activities. Ethical guidelines should be elaborated before such practices become established.

A multitude of very challenging scientific, technical, social, and ethical questions are raised by massive scale implicit data collection. Assimilation of such massive volumes of data is currently limited to off-line data-mining. Remarkable progress has been made in the applications of statistical learning theory, not only to recognize pre-defined phenomena, but also to inductively infer new categories and phenomena from such data. None-the-less, such off-line interpretation is expensive, and of limited value. A dramatic increase in the individual and collective value of such data may be made possible by direct, on-line perception. Such use requires discovery of new methods to use human sensory perception and cognition to interpret such massive volumes of data in real time to enable assimilation, understanding and interaction with such informational spaces.

In addition to the technical challenge, social and ethical challenges are also raised by this possibility. For example, activity logs enable individuals to better understand their life style and daily habits. Can such abilities be used to increase awareness of unhealthy behaviors and to encourage individual creativity and development? Could such perception be used to manipulate behaviour to impose social controls? Who owns or is responsible for the activity of autonomous agents and avatars?

A number of fundamental ethical challenges are raised by this possibility. Who owns the data? Who receives the financial gain? Should public environments be totally transparent (anybody can see anywhere at any time now or in the past) or should every individual have the right to protect a "personal bubble" of privacy? Does society have a right to impose collection against the will of individuals (as has recently become the practice with international phone traffic)?

2.3.2 Navigating in Massively Complex Information Spaces

The massive amounts of data that may be collected about individual human activity by wearable or environmental sensors is only one of the variety of massive data sets that are increasingly available from the massive scale interconnection of computing devices. Other examples include planetary scale interconnected weather sensors, medical sensors, interconnected traffic sensors for city-road and highway networks, sensors used to control electrical and gas distribution systems, air-traffic control systems, telephone switching networks, and any of the myriad data collection systems on the internet. In addition, interconnected space-based sensors are increasingly collecting massive amounts of data about the earth, other planets, the sun, the galaxy, and the universe.

All of these systems generate massive amounts of data. The challenge is to discover new means to present such data to individuals and groups to allow them to individually or collectively assimilate, explore and more fully understand the causes and consequences of known phenomena, as well as to discover and understand new phenomena..

A fundamental open question in this area concerns the nature of the most effective sensory modalities for exploring massive data sets. A variety of forms of virtual and mixed reality technologies can be brought to bear on this problem. Immersive displays, CAVEs, wearable computing, even Brain-computer interfaces could potentially be used as exploration media.

Another possible challenge for HCC is to bring human abilities for perception and understanding to develop new insights into the interrelations of weather patterns. In particular, new forms of presentation and interaction are required to make it possible to integrate information across spatial and temporal scales, and to extend the range of scales in both the temporal and spatial dimensions. By interactively exploring the structure of tropical hurricane, we could conceivably better understand and predict the effects of driving forces. By observing global weather cycles over long temporal scales it may be possible to discover new patterns or phenomena.

Another possible challenge is to complete passive data collection with active data seeking by autonomous systems.

2.3.3 Collaborative Sensing

Human-computer confluence enables new forms of computer mediated human-to-human collaboration. One such form is collaborative sensing, in which large numbers of humans may join together to acquire or interpret massive data sets.

An example of collective acquisition is made possible by the fact that most modern cell phones contain digital cameras, as well as microphones. A simple form of such a collective sensing would be a service that allows groups to combine cell phone images taken from different view-points to build a shared record of a public event, as recently demonstrated by the IPCity project in the Presence II initiative. The combination of digital and acoustic recording, with communications, make it theoretically possible for a group of people to create an ad hoc sensor network to record or even monitor an event from a diverse collection of viewpoints. Services for pooling recorded information about events could create new forms of recordings and awareness allowing interactive exploration.

A fundamental open question is how to use information and communication technologies to control the collection, integration and interpretation of sound, images and other sensor signals taken from distributed sensors.

2.3.4 Social Perception

Ubiquitous sensing and communication increasingly make it possible for geographically distributed groups to share a sense of social presence. In computer and telecommunications networks, presence information is a status indicator that conveys ability and willingness to communicate. The most common use of augmented group communication today is to display an indicator icon on instant messaging clients, typically from a choice of graphic symbol with an easy-to-convey meaning, and a list of corresponding text descriptions of each of the states. Common states on the user's availability are "free for chat", "busy", "away", "do not disturb", "out to lunch". Communication of such information has become increasingly popular among dispersed members of families, as well as between tribes of (typically teenage or adolescent) friends. This is a simple example of a more general phenomenon that could be called "Social Perception".

In its most general form, social presence allows maintenance of a variety of information about activity, health and well-being. For example, social presence information can be used to reassure the family and friends of isolated senior citizens, making it possible to extend the period during which they can maintain an autonomous life style. Social presence can be used by parents to monitor the well being of children while physically separated by work or other activities.

Currently, the communication of social presence is limited by sensors and displays. The challenge is to develop novel new forms of sensing and machine perception that captures relevant information, while respecting privacy, as well as novel new forms of display and actuation that can communicate social presence in a manner that does not distract or disrupt human activity. For example, consider a context aware "baby phone" that would sense and communicate heartbeat, breathing, and emotional state to parents, in the form of a wearable or pocket based device that uses temperature, vibration or perhaps sound to display physiological and emotional states, for example, to indicate that the baby is hungry, needs a diaper change or has colic.

2.4 Distributed Intelligence

Computer-Supported Co-operative Work (CSCW) has emerged as a well-defined scientific discipline focused on understanding the nature and characteristics of co-operative work. In particular, CSCW draws on knowledge from the social and technical sciences to examine competition, socialization and play among spatially or temporally distributed groups. The challenge for confluence is to go beyond CSCW, to create new forms of collaborative sensing and distributed intelligence.

2.4.1 Collective Human Decision Making

The new media created by human-computer confluence can enable new forms of collective decision making as well as collective sensing. Research in machine learning has demonstrated that recognition based on voting by a large number of weak classifiers systematically out-performs a single strong classifier. It can be argued that a similar result can be expected for the selection of a course of action by a committee of experts. However, the analogy with pattern recognition may not hold.

When the problem of decision making is posed as recognition of the best solution from a fixed set of alternatives, then a committee of weak experts may offer the best course. However, when a committee is involved in generating alternatives, compromises between incompatible view-points can often lead to inefficient courses of action. Decision making does not always occur in an ideal setting, where people have the time integrate all information and all perspectives. A good decision making tool would help set priorities and integrate missing information with enough flexibility to support decision making under the pressure of continuously unfolding events. Research is needed to better understand the strengths and weaknesses of collective decision-making and collective intelligence. How can very large groups of experts best collaborate? What is the most effective way to organize communication and sharing of understanding? How can we facilitate cooperation of experts with different expertise? Is it possible to facilitate emergence of common lexicons, perhaps through alignment of specialized ontologies.

2.4.2 The Noosphere

The Noosphere [Verdansky 1926] can be seen as the "sphere of human thought" being derived from the Greek "noos" meaning "mind" in the style of "atmosphere" and "biosphere". In the original theory of Vernadsky, the noosphere is the third in a succession of phases of development of the Earth, after the geosphere (inanimate matter) and the biosphere (biological life). Just as the emergence of life fundamentally transformed the geosphere, the emergence of human cognition fundamentally transforms the biosphere. Confluence of human intelligence with a highly connected computing milieu, augmented with abilities for passive data collection and collective perception on a massive scale could bring about a form of Noosphere, in which human thought, cognitive efforts, and social behavior are supported by emerging technologies.

A Noosphere would involve the assembly of a large numbers of human experts and artificial cognitive entities to create a form of collective intelligence. This would go beyond collective sensing or collective decision making to include collective emotions, collective perceptual experiences, and collective social interaction.

2.5 Benchmarking and Performance Evaluation

Scientific inquiry proceeds by the elaboration of concepts, theories and models that predict and explain. Proper science requires verifiable prediction. Inquiry into any new phenomena inevitably raises problems of what can be predicted and how it can be measured. The same should be expected for human computer confluence. Investigations into new forms of sensory perception, new forms of human computer interaction and new forms of understanding will require research on how to predict and evaluate performance.

A program on human-computer confluence should be grounded on a solid basic science effort for validation and the specification of fundamental underlying principles. It is important to assure that resources are devoted to defining benchmark tests and performance evaluation metrics. New forms of human-computer interaction must be accompanied by predictive theories (such as Fitts Law) that guide design. New forms of sensing, perception, cognition, emotion and experience should be accompanied by objective psychophysical measurements of performance. Phenomena gleaned from passive data collection, and collective sensing must be verified. Claims for benefits of collective decision-making and collective intelligence must be validated. In addition to benchmarks, it will become increasingly important to develop common experimental and data protocols for the leverage of community expertise.

2.6 Exploring Ethical and Societal Issues.

Many aspects of human-computer confluence raise fundamental ethical and societal issues. Emerging abilities such as passive data collection and collective sensing raise problems about ownership, privacy and individual rights. There is an urgent need to elucidate the ethical challenges created by human computer confluence, and to carefully explore the issues related to these challenges before unhealthy practices become custom.

Ethics [Feiser 07] issues related to human-computer confluence go beyond privacy. Ethics problems include ownership, believability, controllability, scrutability as well as privacy. Societal issues concern understanding possible effects that technologies created by human computer confluence will have on society. Much as research in global warming and genetic engineering, human computer confluence carries the potential to profoundly alter human society. The risks and opportunities need to be understood.

Some examples of ethical issues include:
1. Who should have access to passively collected information, and how should it be used?
2. How reliable and useful is information gained from passive collection?
3. How can passively collected information be evaluated and regulated for accuracy, reliability, and utility?
4. Does an individual have the right to withhold information about activity?
5. Who owns and controls information activities carried out in private? Who owns and controls information activities carried out in public?
6. How does personal information affect an individual and society's perceptions of that individual?
7. What psychological impact might result from greater awareness or transparency of personal lifestyle or social situation?
8. How do we as a society balance privacy limitations and social risk with long-term benefits?
9. How will human computer confluence alter individual development, individual behavior, and social behaviour?
10. How are property rights and accessibility of data and materials determined for passive sensing and collective perception?

Unlike current practice, the ethical and societal problems raised by human-computer confluence go beyond the mandatory ethical practices evaluation during proposal evaluation. These issues must be studied "in vivo". This is not about an evaluation panel giving validity to a set of guidelines, but about including serious investigation of ethics issues as part of the research program. Research projects should be encouraged to include study of ethical and societal issues as part of their project.

In addition, research proposals must follow the current ethical guidelines for conducting ICT research in FP7, and in particular, must comply with explicit guidance in the area of ICT implants and wearable computing:

- ICT implants should only be developed if the objective cannot be achieved by less-invasive methods such as wearable computing devices and RFID tags.
- To the extent that an individual, via an ICT implant or wearable computing device, becomes part of an ICT network, the operation of this whole network will need to respect privacy and data protection requirements.
- ICT implants in healthcare are, in general, acceptable when the objective is saving lives, restoring health, or improving the quality of life. They should be treated in the same way as drugs and medical devices.
- ICT implants to enhance human capabilities should only be developed: to bring individuals into the “normal” range for the population, if they so wish and give their informed consent; or to improve health prospects such as enhancing the immune system. Their use should be based on need, rather than economic resources or social position.

- ICT implants or wearable computing devices must not allow individuals to be located on a permanent and/or occasional basis, without the individual's prior knowledge and consent; allow information to be changed remotely without the individual's prior knowledge and consent; be used to support any kind of discrimination; be used to manipulate mental functions or change personal identity, memory, self-perception, perception of others; be used to enhance capabilities in order to dominate others, or enable remote control over the will of other people.
- ICT implants should not be developed to influence future generations, either biologically or culturally.
- ICT implants should be developed to be removed easily.

3. Research Challenges in Human Computer Confluence

A variety of research challenges were identified by the panel to illustrate the research themes. These include:

Non-disruptive context aware ambient advertising
The challenge is develop methods to provide people with ambient offers for products and services in a manner that is non-disruptive, and that is relevant to their current task. Non-disruptive, task relevant advertising can be of benefit to both the advertisers and potential customers, thus become an important generator of wealth.

Augmented mobile immersion
A second challenge is to create augmented and mobile realities that migrate across ubiquitous displays to follow users as they move through an environment. For example, imagine a navigation service that uses ambient ubiquitous displays to present navigation information and location awareness as a person moves through a complex environment.

Ordinary objects as interfaces to the world wide web
The challenge is to show how ordinary objects such as appliances, furniture and clothing, augmented with communication, sensing and display can be combined with the world wide web to create a new interactive media, and to provide new forms of services.

The Holodeck
Immersive VR without suiting up. Can we combine ubiquitous display with interactive objects to create an immersive cave that unobtrusively creates the illusion of teleportation? Can such a technology be used to create real-feeling virtual meetings?

Real-time whole body haptics
The ability to receive haptic information on any part of the body (e.g., through contingent collision with a virtual object) without wearing a whole body suit.

Bidirectional BCI
Create a device that can communicate information directly to the brain as well as sense and reactive to commands.

Cognitive prosthesis
Construct a system that combines wearable sensors with ad-hoc access to ambient (environmental) sensors, to maintain a complete multi-modal record of daily experience, and automatically structure this information so as to create an unobtrusive cognitive prostheses for memory and information.

Construct and demonstrate a new sensor modality.
An example of a challenge in this area is to exploit the plasticity of the brain to create a new sensory channel for interaction with the computing milieu. Such modalities could be used to monitor large complex systems such as electric power distribution grids, or the weather. They could also be used to observe functions with the human body, or to monitor behaviour of populations.

Tools for collective decision making

Identify the conditions under which a collective decision making will systematically outperform decisions made by a single individual. Developing tools to avoid drawbacks in collective decision-making especially in difficult contexts, e.g. under high time pressure, in presence of a large number of constrains, and/or with actors distributed in time and space. The scaffolding tool must incorporate knowledge to prevent common mistakes, yet be sensitive to the situated nature of decision making that would make formal, pre-defined strategies unsuitable.

A Noosphere for planetary awareness

Providing society with technological tools to build, access, and ethically manage a Noosphere, exploiting its contents and potentials, supporting new forms of distributed cognition and collective intelligence that can sense and perceive social, physical, geological, meteorological and biological phenomena and events on a planetary scale.

4. Conclusions and Recommendations

Human computer confluence offers an opportunity to harness the growing power of computing and, in particular, the large scale interconnections of massive numbers of computing devices to create new forms of media, new forms of sensing and sensory perception, new forms of cognition and experience, new methods for on-line assimilation of massive scale data, and perhaps even distributed intelligence. Progress on such technologies will raise many new ethical and societal problems. A coordinated program of research is needed to properly respond to this challenge.

We recommend that the FET unit of the EC create a proactive research initiative to address these issues. Such a program should offer funding for projects that build on recent progress in computing and communications technologies to create and study the fundamental science and enabling technologies for

1) new forms of interactive media
2) new forms of sensory perception.
3) new forms of cognition and experience,
4) new methods to employ human senses to assimilate and understand massive scale data, and
5) new forms of collective sensing and collective intelligence.

Projects in these areas should combine research on creation or use of technology with research on theoretical models and/or empirical validation that can be used to predict and explain phenomena resulting from this technology. Projects should validate their results through the use of experimental performance evaluation, as well as participate in the creation of publicly available benchmarks for performance.

We further recommend that ethical issues raised by these projects be studied within the context of the project, in addition to the required ethical reviews. Specifically we recommend that projects be encouraged to include work on normative and applied ethics by qualified experts within their workplans.

Annex I: List of Participants

David	Benyon	Napier University
Wolfgang	Broll	Fraunhofer FIT
Heinrich	Buelthoff	Max Planck Institute for Biological Cybernetics
Danilo	De Rossi	University of Pisa
Andreas	Engel	Universitätsklinikum Hamburg
Alois	Ferscha	J. K. Universität Linz
Luciano	Gamberini	University of Padua
Antonio	Krueger	University of Muenster
Jose	Millan	IDIAP
Giulio	Ruffini	Starlab Barcelona
Albrecht	Schmidt	Lancaster University
Mel	Slater	Technical University of Catalonia
Chris	Van Hoof	IMEC
Paul	Verschure	Universitat Pompeu Fabra
Johannes	Zanker	Royal Holloway University
James	Crowley	INRIA – rapporteur

ANNEX II: Bibliography

Articles in Technical publications

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[Ishii-Ullmer 97] H. Ishii and B. Ullmer, "Tangible bits: towards seamless interfaces between people, bits and atoms", Proceedings of the SIGCHI conference on Human factors in computing systems, (ACM), Atlanta, Georgia, pp 234-241, 1997.

[Verdansky 1926] Geochemistry and the Biosphere: Essays by Vladimir I. Vernadsky, English Version published in 2007 by Synergetic Press, Santa Fe, New Mexico.

[Wyss et al 06] Wyss, R., König, P., & Verschure, P. F. M. J. (2006). A model of the ventral visual system based on temporal stability and local memory. Public Library of Science Biology, 4(5), 836-843.

Web based resources

[Fieser 07] James Fieser, The internet encyclopedia of philosophy, http://www.iep.utm.edu/e/ethics.htm

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Annex III: Workshop Terms of Reference

FET Proactive - FP7 Call 4 Workshop: Human-computer confluence Brussels, 16th November 2007

FET (Future Emerging Technologies) Proactive structures research in a number of strategic initiatives, which consist of a set of funded projects around a common theme. The themes are shaped through interaction with the research communities, and focus on novel approaches, foundational research and initial developments on long-term research and technological innovation.

In preparation of the next work programme (2009-2010), we are currently in a consultation process aiming at identifying new research challenges and opportunities through interactive workshops/meetings with high level scientists.

The current work programme identifies three candidate areas for Call 4 in 2009. One of them is titled "Human-computer confluence" with an objective "*to investigate an invisible, implicit, embodied ore even implanted interaction between humans and system components, for natural interaction (including communication) in surrounding environments, themselves augmented with pervasive and ubiquitous infrastructures and services*". The theme, its title and objectives are indicative only. Since it was formulated some time ago, the crucial research challenges associated may have changed or have already been partially covered by other initiatives and programmes. The aim of the workshop is to discuss the research challenges opportunities and update and refine the research themes that could be called within this FET proactive initiative.

You will be asked to contribute to advance the "Human-computer confluence" theme, by providing more details and/or by taking a wider view and/or shifting the focus. You will also be asked to indicate what type of funding schemes are most suitable – Specific Targeted Research Projects (STREP), Integrated Projects (IP), Networks of Excellence (NoE) or Coordination Actions. The purpose is not to define research projects, but rather to provide a proposal for a possible scope of the initiative.

You will be helped by a rapporteur who will consolidate the inputs to a report after the meeting, and you should interact with him to conclude the work. The report will list a set of proposals, each of which identifying and detailing the associated research challenge(s).

Provisional Agenda

Friday 16 November: Human Computer Convergence
33 Avenue de Beaulieu, room 0/54, 1160 Brussels

09:30 Welcome and introduction, Wolfgang Boch,
Head of Unit FET Proactive
10:00 Presentation of participant's views
Giulio Ruffini (Starlab, Barcelona)
Mel Slater (UPC)
Paul Verschure (Universitat Pompeu Fabra)
Wolfgang Broll (Fraunhofer)
David Benyon (Napier University)
Jose Millan (IDIAP)
Danilo De Rossi (University of Pisa)
Chris Van Hoof (IMEC)
Andreas Engel (Universitätsklinikum Hamburg)

	Johannes Zanker (Royal Holloway University)
	Luciano Gamberini (University of Padova)
	James Crowley (INRIA – rapporteur)
	Antonio Krueger (University of Muenster)
	Albrecht Schmidt (Lancaster University)
	Heinrich Bülthoff (Max Planck Institute)
12:30	Lunch Break
13:30	Discussions and Conclusion
15:15	Coffee Break
15:30	Discussions and Conclusion (continued)
17:00	Close of day

Annex IV: Individual contributions

1. Peach Grand Challenge for Presence - Giulio Ruffini, Mel Slater, Paul Verschure
2. PEACH contribution - Giulio Ruffini (Starlab, Barcelona)
3. Physical/Virtual Confluence - Mel Slater (UPC)
4. Obtrusiveness of virtual/mixed reality environments - Mel Slater (UPC)
5. Text from Wolfgang Broll (Fraunhofer)
6. New forms of interaction - David Benyon (Napier University)
7. Text from Danilo De Rossi (University of Pisa)
8. IT-based Assistance in Human Decision Making - Johannes Zanker (Royal Holloway Univ.)
9. Mastering the Exponential Growth in Density of Computing Devices James Crowley (INRIA)
10. Unlimited Mobility - Heinrich Bülthoff (Max Planck Institute)

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Links

You are invited to look at the FET-proactive website http://cordis.europa.eu/fp7/ict/fet-proactive/, in particular to see the scope of the two proactive initiatives on Presence research, of which this proactive initiative is an evolution.

You are also invited to look at the **FET FP6 website** (http://cordis.europa.eu/ist/fet/id-fp6.htm#speccons) which contains reports about a previous consultation process that was used in 2005 and 2006.

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FET in the 7th Framework Programme:
http://cordis.europa.eu/fp7/ict/fet-proactive/home_en.html

FET in the 6th Framework Programme:
http://cordis.europa.eu/ist/fet/home.html