Andrea Gaggioli, Alois Ferscha, Giuseppe Riva, Stephen Dunne, Isabelle Viaud-Delmon

Human Computer Confluence

Transforming Human Experience Through Symbiotic Technologies

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Foreword

The editors of this volume bring together a collection of papers that, taken together, provide an interesting snapshot of current research on Human Computer Confluence (HCC). HCC stands for a particular vision of how computing devices and human beings (users) can be fruitfully combined. The term was coined some 10 years ago in an attempt to make sense of the increasingly complex technological landscape that was emerging from different interrelated research strands in Information and Communication Technology (ICT). It was clear that computers could no longer be seen just as machines that execute algorithms for turning input into output data. This simply seemed to miss a lot of the ways in which computers were starting to be used, in which 'users' could interact with them and the multitudes of shapes they could take. After the era of 'desktop computing', the power of an application was no longer just residing in the sophistication of its algorithmic core, but also, or maybe even mainly, in the way it blends into the user's sensation of being engaged into some value-adding experience (for work, for health, for entertainment,...). Moreover, everything that had been learned about how to design good screen-based interfaces seemed useless for dealing with settings of, for instance, wearable or embedded computing. In order to capture all this there was a pressing need for new concepts, a new language, new ways of measuring and comparing things.

Human Computer Confluence became the name of a 'proactive initiative' (EC, 2014), funded by the European Commission's Future and Emerging Technologies (FET) programme under the Seventh Framework Programme for Research (FP7). In a nutshell, the mission of FET is to explore radically new technological paradigms that can become the future assets for a globally competitive Europe that is worth to live in. A FET proactive initiative aims to assemble a critical mass of research around such a technological paradigm in order to shape its distinct research agenda and to help building up the multi-disciplinary knowledge base from which the paradigm can be explored and further developed into a genuinely new line of technology.

Not all the work that is documented in this volume has been funded through FET. Many of its authors would not even say that they are doing their work under the umbrella of HCC. HCC is not a strictly defined school of thought. It is rather an undercurrent that permeates across many lines of contemporary research activities in information and communication technologies. In that sense, the concept of Human Computer Confluence is more like a road sign marking a direction in the socio/technological landscape, rather than a precise destination.

1 The views expressed are those of the author and not necessarily those of the European Commission

What's in a name? Why was there a need for a new term or concept such as Human Computer Confluence? After all, there was already 'ubiquitous computing' to capture the visionary idea of anywhere, anytime and contextualised computing. After all, there were already emerging areas like Presence research and Interaction Design, both with their essential focus on techniques to develop characterise and even measure the 'user experience', be it in virtual reality, augmented reality or embedded and ambient computing/settings. These areas of research are all very relevant for the emerging HCC research agenda, and it is at their intersection that the idea of HCC takes shape.

As should be obvious from the name, perhaps the most essential feature of HCC is that it is not just a technological research agenda. Somewhat retrospectively, one can argue that its whole *raison d'être* was to counterbalance the technology-dominated vision of ubiquitous computing that (with a detour through ambient intelligence) is now developing into Internet of Things. The whole human side of it that was initially very strong (especially in Disappearing Computing and Ambient Intelligence) got overpowered by the more pressing and concrete technological research agenda of components, systems, protocols and infrastructures. With the more fundamental questions of the human side of the equation temporarily side lined, there was an obvious need for longer term research such as funded by FET to do some groundwork on this. It is in this context that HCC both as a term and as an initiative was born. Ultimately, it will be in its contribution to turning Ubiquity and Internet of Things into something worth to have for Europe's citizens that its long-term impact should be measured.

It is worth mentioning the other big school of thought for a human/technology combination, namely the convergence research agenda of NBIC – Nano-Bio-Info-Cogno. This is a strongly reductionist vision of human engineerability, based on its reduction to elementary material and ultimately engineerable building blocks over which perfect control can be exercised. In its most radical versions it leads to Transhumanism where human nature itself gets inevitably replaced by a superior bio-techno hybrid nature. Human Computer Confluence points to an alternative approach of trying to understand and enhance the human sense and experience of technological augmentation by building technology that takes into account the full human nature of the 'user'. In that sense it is also a good illustration of what the European version of the NBIC convergence agenda could look like (HLEG, 2004).

HCC addresses what seems to be a paradox: how can we become more human through technology, instead of less?[2]

– Humans as equal part of the system to be studied: HCC cannot be reduced to a purely technological challenge. Whereas before the human was a factor to be

2 This list is based on the outcome of a panel discussion at the second HC2 Summer School, IRCAM, 2013 (HC2, 2013)

taken into account (for example for usability) it is now an equally important part of the study. This redefines the boundaries of the 'system', and hybridises the nature of it in a fundamental way. The old idea of interface as the fine line that cuts between system and user is no longer tenable. One rather has to think about how complex process on both side interact and intertwine, at different levels (for instance, physical, behavioural, cognitive) and based on a deep understanding of both.

- Empowerment rather than augmentation: HCC is not about augmentation of specific human capabilities (for example force, memory, concentration, perception, reasoning), but about empowering humans to use their abilities in new ways, themselves deciding when and what for.
- Social enhancement rather than individual superiority: it appears useful to anchor HCC in a networked view of computing, such as ubiquity or internet of things, in order to keep it focused on group, community and social dimensions, in addition to the individual user's view (Internet of Everything).
- Privacy and trust are essential for user's to engage into the experiences that HCC enables for them. HCC requires much more transparency on who or what is in control or has certain rights. It remains to be seen whether current trends in big data are going to provide a sufficient framework for this.
- Another emerging feature of the HCC idea is that users are creative actors. In HCC there is a sense that we put things together, more than that they are pre-packaged technology bundles. The active involvement of the human as the composer or bricoleur of its own technology-mediated experience is stronger, maybe even more essential then the automated adaptation of the technology to the user. In this sense HCC resonates well with current trends of 'makers', fablabs and social innovation. Will HCC bring everyday creativity and popular cultural expression to the heart of the research agenda, not just as a creative methodology to design new technologies but as an integral feature of any human/socio-technological system?

Looking at this list, it is clear that HCC has not been achieved yet in a significant way. The combination through technology of such features as personal empowerment, social enhancement, trust and user creativity has not yet been demonstrated in a strong way. It is not even clear what form such a demonstration would take. Beyond research, one can only speculate about the killer application that would demonstrate its power. Maybe it could be in sports, in gaming or in fashion, where playfulness and serious results can be combined and where wiling early adopters can be easily found. What would be its first big market: commerce, entertainment, the grey economy, education, the public sector or ecology? Or will it be and remain generic from the outset, leaving it entirely to the users as creative actors to invent what it can do?

As the chapters of this book illustrate, Human Computer Confluence is a fascinating vision in which a lot remains to be understood. Some of the choices mentioned above will need to be made more consciously in order to grow beyond the incidental

flashes of insight to a genuinely new paradigm of information technology. It has the potential to create the opportunities for a distinct European approach to how humans and technology can be combined.

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Section I: **Conceptual Frameworks and Models**

Alois Ferscha

1 A Research Agenda for Human Computer Confluence

Abstract: HCI research over three decades has shaped a wide spanning research area at the boundaries of computer science and behavioral science, with an impressive outreach to how humankind is experiencing information and communication technologies in literally every breath of an individual's life. The explosive growth of networks and communications, and at the same time radical miniaturization of ICT electronics have reversed the principles of human computer interaction. Up until now considered as the interaction concerns when humans approach ICT systems, more recent observations see systems approaching humans at the same time. Humans and ICT Systems apparently approach each other confluently.

This article identifies trends in research and technology that are indicative for the emerging symbiosis of society and technology. Fertilized by two diametrically opposed technology trends: (i) the miniaturization of information and communication electronics, and (ii) the exponential growth of global communication networks, HCC over it's more than two decades of evolution, the field has been undergoing three generations of research challenges: The first generation aiming towards autonomic systems and their adaptation was driven by the availability of technology to connect literally everything to everything (Connectedness, early to late nineties). The second generation inherited from the upcoming context recognition and knowledge processing technologies (Awareness, early twentyhundreds), e.g. context-awareness, self-awareness or resource-awareness. Finally, a third generation, building upon connectedness and awareness, attempts to exploit the (ontological) semantics of Pervasive / Ubiquitous Computing systems, services and interactions (i.e. giving meaning to situations and actions, and "intelligence" to systems) (Smartness, from the mid twentyhundreds). As of today we observe that modern ICT with explicit user input and output are becoming to be replaced by a computing landscape sensing the physical world via a huge variety of sensors, and controlling it via a plethora of actuators. The nature and appearance of computing devices is changing to be hidden in the fabric of everyday life, invisibly networked, and omnipresent, with applications greatly being based on the notions of context and knowledge. Interaction with such globe spanning, modern ICT systems will presumably be more implicit, at the periphery of human attention, rather than explicit, i.e. at the focus of human attention.

Keywords: Humans and Computers, Pervasive and Ubiquitous Computing, Human Computer Interaction, Ambient Intelligence, Socio-technical Systems

1.1 Introduction

Human Computer Confluence (HCC) has emerged out of European research initiatives over the past few years, aiming at fundamental and strategic research studying how the emerging symbiotic relation between humans and ICT (Information and Communication Technologies) can be based on radically new forms of sensing, perception, interaction and understanding. HCC has been identified as an instrument to engage an interdisciplinary field of research ranging from cognitive neuroscience, computational social sciences to computer science, particularly human computer interaction, pervasive and ubiquitous computing, artificial intelligence and computational perception.

The first definition of HCC resulted out of a research challenges identification process in the Beyond-The-Horizon (FET FP6) effort:

"Human computer confluence refers to an invisible, implicit, embodied or even implanted interaction between humans and system components. ... should provide the means to the user to interact and communicate with the surrounding environment in a transparent "human and natural" way involving all sense..."

A working group of more than 50 distinguished European researchers structured and consolidated the individual position statements into a strategic report. The key issue identified in this report addressed fundamental research: *"Human computer confluence refers to an invisible, implicit, embodied or even implanted interaction between humans and system components. New classes of user interfaces may evolve that make use of several sensors and are able to adapt their physical properties to the current situational context of users. In the near future visible displays will be available in all sizes and will compete for the limited attention of users. Examples include body worn displays, smart apparel, interactive rooms, large display walls, roads and architecture annotated with digital information – or displays delivering information to the periphery of the observers' perception. Recent advances have also brought input and output technology closer to the human, even connecting it directly with the human sensory and neural system in terms of in-body interaction and intelligent prosthetics, such as ocular video implants. Research in that area has to cover both technological and qualitative aspects, such as user experience and usability"* as well as societal and technological implications *"Researchers strive to broker a unified and seamless interactive framework that dynamically melds interaction across a range of modalities and devices, from interactive rooms and large display walls to near body interaction, wearable devices, in-body implants and direct neural input and stimulation"*.

Based on the suggestions delivered with the Beyond-The-Horizon report, a consultation meeting was called for "Human Computer Confluence" in November 2007, out which resulted the FET strategy to *"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..."*, and consequently the implementation of the respective research funding instruments like (i) new forms of interactive

media (Ubiquitous Display Surfaces, Interconnected Smart Objects, Wearable Computing, Brain-Computer Interfaces), (ii) new forms of sensing and sensory perception (New Sensory Channels, Cognitive and Perceptual Prosthetics), (iii) perception and assimilation of massive scale data (Massive-Scale Implicit Data Collection, Navigating in Massively Complex Information Spaces, Collaborative Sensing, Social Perception), and (iv) Distributed Intelligence (Collective Human Decision Making, The Noosphere).

1.2 Generations of Pervasive / Ubiquitous (P/U) ICT

The novel research fields beyond Personal Computing could be seen as the early 'seeds' of HCC. Preliminarily suffering from a plethora of unspecific, competitive terms like "Ubiquitous Computing" (Weiser et al., 1996), "Calm Computing" (Weiser et al., 1996), "Universal Computing" (Weiser, 1991), "Invisible Computing" (Esler et al., 1999), "Context Based Computing" (UCB, 1999), "Everyday Computing" (Abowd & Mynatt, 2000), "Autonomic Computing", (Horn, 2001), "Amorphous Computing" (Servat & Drogoul, 2002), "Ambient Intelligence" (Remagnino & Foresti, 2005), "Sentient Computing", "Post-Personal Computing", etc., the research communities consolidated and codified their scientific concerns in technical journals, conferences, workshops and textbooks (e.g. the journals IEEE Pervasive, IEEE Internet Computing, Personal and Ubiquitous Computing, Pervasive and Mobile Computing, Int. Journal of Pervasive Computing and Communications, or the annual conferences PERVASIVE (International Conference on Pervasive Computing), UBICOMP (International Conference on Ubiquitous Computing), MobiHoc (ACM International Symposium on Mobile Ad Hoc Networking and Computing), PerComp (IEEE Conference on Pervasive Computing and Communications), ICPCA (International Conference on Pervasive Computing and Applications), ISWC (International Symposium on Wearable Computing), ISWPC (International Symposium on Wireless Pervasive Computing), IWSAC (International Workshop on Smart Appliances and Wearable Computing), MOBIQUITOUS (Conference on Mobile and Ubiquitous Systems), UBICOMM (International Conference on Ubiquitous Computing, Systems, Services, and Technologies), WMCSA (IEEE Workshop on Mobile Computing Systems and Applications), AmI (European Conference on Ambient Intelligence), etc. This process of consolidation is by far not settled today, and more specialized research conferences are emerging, addressing focussed research issues e.g. in Agent Technologies and Middleware (PerWare, ARM, PICom), Privacy and Trust (STPSA, PSPT, TrustCom), Security (UCSS), Sensors (ISWPC, Sensors, PerSeNS, Seacube), Activity Recognition and Machine Learning (e.g. IEEE SMC), Health Care (PervasiveHealth, PSH, WiPH, IEEE IREHSS), Social Computing (SocialCom), Entertainment and Gaming or Learning (PerEL).

Weiser's seminal vision on the "Computer for the 21st Century" (Weiser, 1991) was groundbreaking, and still represents the corner stone for what might be referred to as a first generation of Pervasive/Ubiquitous Computing research, aiming towards

embedded, hidden, invisible and autonomic, but networked information and communication technology (ICT) systems (Pervasive / Ubiquitous ICT, P/U ICT for short). This first generation definitely gained from the technological progress momentum (miniaturization of electronics, gate packaging), and was driven by the upcoming availability of technology to connect literally everything to everything (Connectedness, mid to late Nineties), like wireless communication standards and the exponentially growing Internet. Networks of P/U ICT systems emerged, forming communication clouds of miniaturized, cheap, fast, powerful, wirelessly connected, "always on" systems, enabled by the massive availability of miniaturized computing, storage, communication, and embedded systems technologies. Special purpose computing and information appliances, ready to spontaneously communicate with one another, sensor-actuator systems to invert the roles of interaction from human to machine (implicit interaction), and organism like capabilities (self-configuration, self-healing, self-optimizing, self-protecting) characterize this P/U ICT generation.

The second generation of P/U ICT inherited from the then upcoming sensor based recognition systems, as well as knowledge representation and processing technologies (Awareness, early Two Thousands), where research issues like e.g. context and situation awareness, self-awareness, future-awareness or resource-awareness reshaped the understanding of pervasive computing. Autonomy and adaptation in this generation was reframed to be based on knowledge, extracted from low level sensor data captured in a particular situation or over long periods of time. The respective "epoch" of research on "context aware" systems was stimulated by Schillit, Adams and Want (Schilit et al., 1994), and fertilized by the PhD work of Dey (Dey, 2001), redefining the term "context" as:

"...any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves.".

One result out of this course of research are autonomic systems (Kephart & Chess, 2003). Later, 'autonomic elements' able to capture context, to build up, represent and carry knowledge, to self-describe, -manage, and -organize with respect to the environment, and to exhibit behavior grounded on knowledge based monitoring, analyzing, planning and executing were proposed, shaping ecologies of P/U ICT systems, built from collective autonomic elements interacting in spontaneous spatial/temporal contexts, based on proximity, priority, privileges, capabilities, interests, offerings, environmental conditions, etc.

Finally, a third generation of P/U ICT was observed (mid of the past decade), building upon connectedness and awareness, and attempting to exploit the (ontological) semantics of systems, services and interactions (i.e. giving meaning to situations and actions). Such systems are often referred to as highly complex, orchestrated, cooperative and coordinated "Ensembles of Digital Artifacts". An essential aspect of such an ensemble is its spontaneous configuration towards a complex system, i.e. a

"... dynamic network of many agents (which may represent cells, species, individuals, nations) acting in parallel, constantly acting and reacting to what the other agents are doing where the control tends to be highly dispersed and decentralized, and if there is to be any coherent behavior in the system, it has to arise from competition and cooperation among the agents, so that the overall behavior of the system is the result of a huge number of decisions made every moment by many individual agents" (Castellani & Hafferty, 2009).

1.3 Beyond P/U ICT: Socio-Technical Fabric

Ensembles of digital artifacts as compounds of huge numbers of possibly heterogeneous entities constitute a future generation of socially interactive ICT to which we refer to as Socio-Technical Fabric (late last decade until now), weaving social and technological phenomena into the 'fabric of technology-rich societies'. Indications of evidence for such large scale, complex, technology rich societal settings are facts like 10^{12} -10^{13} "things" or "goods" being traded in (electronic) markets today, 10^{9} personal computer nodes and 10^{9} mobile phones on the internet, 10^{8} cars or 10^{8} digital cameras with sophisticated embedded electronics – even for internet access on the go, etc. Todays megacities approach sizes of 10^{7} citizens. Already today some 10^{8} users are registered on Facebook, 10^{8} videos have been uploaded to YouTube, like 10^{7} music titles haven been labeled on last.fm, etc. Next generation research directions are thus going away from single user, or small user group P/U ICT as addressed in previous generations, and are heading more towards complex socio-technical systems, i.e. large scale to very large scale deployments of ICT to large scale collectives of user up to whole societies (Ferscha et al., 2012).

A yet underexplored impact of modern P/U ICT relates to services exploiting the "social context" of individuals towards the provision of quality-of-life technologies that aim for the wellbeing of individuals and the welfare of societies. The research community is concerned with the intersection of social behavior and modern ICT, creating or recreating social conventions and social contexts through the use of pervasive, omnipresent and participative technologies. An explosive growth of social computing applications such as blogs, email, instant messaging, social networking (Facebook, MySpace, Twitter, LinkedIn, etc.), wikis, and social bookmarking is observed, profoundly impacting social behavior and life style of human beings while at the same time pushing the boundaries of ICT simultaneously.

Research emerges aiming at understanding the principles of ICT enabled social interaction, and interface technologies appear implementing "social awareness", like social network platforms and social smartphone apps. Human environment interfaces are emerging, potentially allowing individuals and groups to sense, explore and understand their social context. Like the human biological senses (visual, auditory, tactile, olfactory, gustatory) and their role in perception and recognition, the human

"social sense" which helps people to perceive the "social" aspects of the environment, and allowing to sense, explore and understand the social context is more and more becoming the subject of research.

Inspired by the capacity of human beings acting socially, in that shaping intelligent societies, the idea of making the principles of social interaction also the design, operational and behavioral principle of modern ICT recently has led to the term "socio-inspired" ICT (Ferscha et al., 2012). From both theoretical and technological perspectives, socio-inspired ICT moves beyond social information processing, towards emphasizing social intelligence. Among the challenges are issues of modeling and analyzing social behavior facilitated with modern ICT, the provision access opportunities and participative technologies, the reality mining of societal change induced by omnipresent ICT, the establishment of social norm and individual respect, as well as e.g. the means of collective choice and society controlled welfare.

1.4 Human Computer Confluence (HCC)

Human Computer Confluence (HCC) has emerged out of European research initiatives over the past few years, aiming at fundamental and strategic research studying how the emerging symbiotic relation between humans and ICT can be based on radically new forms of sensing, perception, interaction and understanding (Ferscha, 2011). HCC has been identified as an instrument to engage an interdisciplinary field of research ranging from cognitive neuroscience, computational social sciences to computer science, particularly human computer interaction, pervasive and ubiquitous computing, artificial intelligence and computational perception.

In order to further establish and promote the EU research priority on Human Computer Confluence, research road-mapping initiatives were started (see e.g. HCC Visions White Book, 2014), aiming to (i) identify and address the basic research problems and strategic research fields in HCC as seen by the scientific community, then (ii) bring together the most important scientific leaders and industrial/commercial stakeholders across disciplines and domains of applications to collect challenges and priorities for a research agenda and roadmap, i.e. the compilation of white-books identifying strengths, weaknesses, opportunities, synergies and complementarities of thematic research in HCC, and ultimately to (iii) negotiate and agree upon strategic joint basic research agendas together with their road-mapping, time sequencing and priorities, and maintain the research agenda in a timely and progressive style.

One of these initiatives created the HCC research agenda book entitled "Human Computer Confluence – The Next Generation Humans and Computers Research Agenda" (HCC Visions White Book, 2014). It has been published under the acronym "Th. Sc. Community" ("The Scientific Community"), standing for a representative blend of the top leading scientists worldwide in this field. More than two dozens of research challenge position statements solicited via a web-based solicitation portal

are compiled into the book, which is publicly available to the whole scientific community for commenting, assessment and consensus finding. Some 200 researchers (European and international) have been actively involved in this process. In addition, the HCC Research Agenda and Roadmap is presented also in the format of a smartphone app, available in online ("The HCC Visions Book"-app). In the past 3 years (2010–2013), the HCC community has become a 650 strong group of researchers and companies working together to understand, not only the technological aspects of the emerging symbiosis between society and ICT, but also the social, industrial, commercial, and cultural impact of this confluence.

1.5 The HCC Research Agenda

The HCC research agenda as collected in "Human Computer Confluence – The Next Generation Humans and Computers Research Agenda" (HCC Visions White Book, 2014) can be structured along the following trails of future research:

1.5.1 Large Scale Socio-Technical Systems

A significant trail of research appears to be needed along the boundaries where ICT "meets" society, where technology and social systems interact. From the observation how successful ICT (smartphones, mobile internet, autonomous driver assistance systems, social networks, etc.) have radically transformed individual communication and social interaction, the scientific community claims for new foundations for large-scale Human-ICT organisms ("superorganisms") and their adaptive behaviors, also including lessons form applied psychology, sociology, and social anthropology, other than from systemic biology, ecology and complexity science. Self-organization and adaptation as ways of harnessing the dynamics and complexity of modern, networked, environment-aware ICT have become central research topics leading to a number of concepts such as autonomic, organic or elastic computing. Existing work on collective adaptive systems is another example considering features such as self-similarity, complexity, emergence, self-organization, and recent advances in the study of collective intelligence. Collective awareness is related to the notion of resilience, which means the systemic capability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event. Resilience has been subject to a number of studies in complex networks and social-ecological systems. By creating algorithms and computer systems that are modeled based on social principles, socio-inspired will find better ways of tackling complexity, while experimenting with these algorithms may generate new insights into social systems. In computer science and related subjects, people have started to explore socially inspired systems, e.g. in P2P networks, in robotics, in neuroscience, and in the area of agent systems. Despite this

initial work, the overall field of socio-inspired system is still in an early stage of development, and it will be one of future research goals to demonstrate the great potential of social principles for operating large-scale complex ICT systems.

1.5.2 Ethics and Value Sensitive Design

ICT has become more sensitive to its environment: to users, to organizational and social context, and to society at large. While ICT has largely been the outcome of a technology-push focused on core computational functionality in the previous century in the first place, it later extended to the users needs, usability, and even social and psychological and organizational context of computer use. Nowadays we are approaching ICT developments, where the needs of human users, ethics, systems of value and moral norm, the values of citizens, and the big societal questions are in part driving research and development. The idea of making social and moral values central to the matrices, identity management tools) first originated in Computer Science at Stanford in the seventies. This approach is now referred to as 'Value Sensitive Design' or 'Values in Design'. Among the most prevalent, ubiquitously recognized, and meanwhile also socially pressing research agenda items relate to the concerns humans might have in using and trusting ICT. Well beyond the privacy and trust related research we see already today, the claim goes towards ethics and human value (privacy, respect, dignity, trust) sensitivity already at the design stage of modern ICT (value sensitive design), on how to integrate human value building processes into ICT, and how to cope with ignorance, disrespectful, offending and violating human values.

1.5.3 Augmenting Human Perception and Cognition

To escape the space and time boundaries of human perception (and cognition) via ICT (sensors, actuators) has been, and continues to be among the major HCC research challenges. Argued with the "Total Recall" prospect, the focused quests concern the richness of human experience, which results not only from the pure sensory impressions perceived via human receptors, but mostly from the process of identifying, interpreting, correlating and attaching "meaning" to those sensory impressions. This challenge is even posed to be prevalent over the next 50 years of HCC research. Dating back to the "As we may think" idea (Bush & Think, 1945), claiming ICT to support, augment or even replace intellectual work, new considerations for approaching the issue are spawned by the technological, as well as cognitive modelling advance in the context of brain computer interfaces. Understanding the operational principles (chemo-physical), but much more than that the foundational principles of the human brain at the convergence of ICT and biology poses a 21st century research challenge. The ability to build revolutionary new ICT as a "brain-like" technology, and at the

same time the confluence of ICT with the biological brain mobilizes great science not only in Europe (see e.g. FTE flagship initiative HBP), but in neuroscience, medical and computing research worldwide.

1.5.4 Empathy and Emotion

Humans are emotional, and at the same time empathic beings. Emotion and empathy are not only expressed (and delivered via a subtle channel) when humans interact with humans, but also when humans interact with machines. The ability to capture and correlate emotional expressions by machines (ICT), as well as the ability of machines (ICT) to express emotions and empathic behavior themselves is considered a grand challenge of human computer confluence, while at the same time realism is expressed on the potential success ever being possible towards it.

1.5.5 Experience and Sharing

With novel ICT, particularly advanced communication systems and ubiquitous networking, radically new styles of human-to-human communication -taking into account body movements, expressions, physiological and brain signals- appear technologically feasible. With cognitive models about individuals, and digital representations of their engagements and experiences abstracted and aggregated from a combination of stimuli (e.g. visual, olfactory, acoustic, tactile, and neuro-stimulation), a new form of exchanging of these experiences and "thoughts" seem possible. Novel communication experiences which are subtle, i.e. unobtrusive, multisensory, and open for interpretation could build on expressions and indications of thoughts as captured and related to a cognitive model on the sending side, encoded and transmitted to a recipient through advanced communication media, and finally translated into multimodal stimuli to be exposed to the receiving individual, and by that induce mental and emotional states representing the "experience" of the sender.

1.5.6 Disappearing Interfaces

Seemingly in analogy to what was addressed at the turn of the century as the ICT research challenge "The Disappearing Computer" (EU FP4, FP5), articulated as (i) the physical disappearance of ICT, observed as the miniaturization of devices and their integration in other everyday artefacts as, e.g., in appliances, tools, clothing, etc. and (ii) mental disappearance, referring to the situation that artefacts with large physical appearance may not be perceived as computers because people discern them as (ICT also mentally move into the background) – appears to have come to a revival

as far as notions of interfaces are concerned. As of today we observe that modern ICT with explicit user input and output is becoming to be replaced by a computing landscape sensing the physical world via a huge variety of sensors, and controlling it via a plethora of actuators. Since the nature and appearance of computing devices has widely changed to be hidden in the fabric of everyday life, invisibly networked, and omnipresent, "everything" has turned to become the interface: things and objects of everyday use, the human body, the human brain, the environment, or even the whole planet. Systems that happen to be perceived, understood and used explicitly and intently as the interface tend to disappear. Implicit interaction replaces explicit interaction.

1.6 Conclusion

Human computer confluence is a research area with the union of human brains and computers at its center. Its main goal is to develop the science and technologies necessary to ensure an effective, even transparent, bidirectional communication between humans and computers, which will in turn deliver a huge set of applications: from new senses, to new perceptive capabilities dealing with more abstract information spaces to the social impact of such communication enabling technologies. Inevitably, these technologies question the notion of interface between the human and the technological realm, and thus, also in a fundamental way, put into question the nature of both. The long-term implications can be profound and need to be considered from an ethical/societal point of view. Clearly, this is just a preliminary, yet evidenced classification of HCC research from the solicitation process so far. As this research roadmap aims to evolve continuously, some next steps of consolidation may possibly rephrase and reshape this agenda, as new considerations, arguments and assessments emerge.

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2 Designing Blended Spaces for Collaboration

Abstract: In this paper, we reflect on our experiences of designing, developing, implementing and using a real world, functional multi-touch enabled interactive collaborative environment (ICE). The paper provides some background theory on blended spaces derived from work on blending theory, or conceptual integration. This is applied to the ICE and results in a focus on how to deal with the conceptualization that people have of new collaborative spaces such as the ICE. Five key themes have emerged from an analysis of two years of observations of the ICE is use. These provide a framework, TACIT, that focuses on Territoriality, Awareness, Control, Interaction and Transitions in ICE type environments. The paper concludes by bringing together the TACIT framework with the principles of blended spaces to highlight key areas for design so that people can conceptualize the opportunities for creative collaboration that the next generation of interactive blended spaces provide.

Keywords: Interaction Design, Collaboration, Multi-touch, Multi-surface Environment, Interactive Environments, Blended Spaces

2.1 Introduction

Blended spaces are spaces where a physical space is deliberately integrated in a close-knit way with a digital space. Blended spaces go beyond mixed reality (Milgram & Kishino, 1994) and conceptually are much closer to tangible interactions (Ishii & Ullmer, 1997) where the physical and digital are completely coupled. The concept of blending has been in existence for many years in the field of blended learning where the aim is to design a learning experience for students that blends the benefits of classroom learning with the benefits of distance, on-line learning, but more recently the concept of blending has been applied to spaces and to interaction.

O'Hara, Kjelsko and Paay (O'hara, Kjeldskov, & Paay, 2011) refer to the distributed spaces linked by very high quality video-conferencing systems such as Halo as blended spaces because of the apparently seamless joining of remote sites. In systems such as Halo, great attention is paid to the design of the physical conference rooms and to the angle and geometry of the video technologies in order to give the impression that two distant rooms are collocated. High-end video conferencing supports the collaborative activity of business discussions, but it does not deal well with shared information resources. O'Hara, et al. (O'hara et al., 2011) use the term blended interaction spaces for 'blended spaces in which the interactive groupware is incorporated in ways spatially consistent with the physical geometries of the video-mediated set-up'. Their paper explores the design of a blended interaction space that highlights the