Human Computer Confluence

The Next Generation Humans and Computers Research Agenda

A book by *Th. Sc. Community*

Research Challenges in Human Computer Confluence

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Lead editor / coordinator

Univ. Prof. Dr. Alois Ferscha
Institute for Pervasive Computing
Johannes Kepler University Linz
Altenberger Straße 69
A-4040 Linz
Email: ferscha@pervasive.jku.at

Assistant editor

Michael Matscheko

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The Human Computer Confluence Research Agenda

Generations of Pervasive / Ubiquitous (P/U) ICT

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 (1994), and fertilized by the PhD work of Dey (2000), 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 and Chess 1003). 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 and Hafferty, 2009).

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.

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.

Human Computer Confluence (HCC)

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 individuals 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.

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. 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, consultation meetings were called for "Human Computer Confluence" in November 2007 (Brussels) and in November 2011 (Brussels) respectively, out which resulted the FET (Future and Emerging Technologies) 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…". Already during the implementation of this strategy in FP7 (2007-2013), Human Computer Confluence has been mentioned to become a research priority in the "Horizon 2020" (2013-2020) funding programme of the European Commission.

In order to establish and promote the EU research priority on Human Computer Confluence, a research roadmapping initiative was started under the HC2 project (www.hcsquared.eu), 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 a white paper 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.

Towards the manifestation of Human Computer Confluence as a field of research, (i) a structured process for the solicitation of research visions, challenges and matters, involving the key researchers, scientists and industrial stakeholders shaping the field of HCC, (ii) a web based, participatory HC2 Research Agenda Solicitation Portal (www.hcsquared.eu/visions) to serve the scientific community, national and international funding institutions and industrial and commercial interest stakeholders has been created, including (iii) a novel concept of melting the web based appearance of the research agenda with a print layout, book style appearance of it.

The HCC research agenda book –entitled: “Human Computer Confluence – The Next Generation Humans and Computers Research Agenda”– you hold in your hands now, has been generated at the press of a single button in the Solicitation Portal, and reflects the state of the research agenda as of October 2013. It is published under the acronym “Th. Sc. Community” (“The Scientific Community”), standing for a representative blend of the top leading scientists worldwide in this field. It presents a collection of 26 research challenge position statements solicited via the Solicitation Portal, and 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. Two international “HC2 Visions” workshops have been organized, with the most renowned researchers in this emerging field as invited keynote speakers. The first was held during May 14-15, 2012 in Vienna, Austria, the second during May 16-17, 2013 in Barcelona, Spain. All presentations and discussions were captured in video, voice and text, and are provided to the scientific community again via the HC2 Research Agenda Solicitation Portal (www.hcsquared.eu/visions). The HCC Research Agenda and Roadmap is presented also in the format of a smartphone app, available in Google Playstore for Android Operating Systems ("The HC2 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.

Human Computer Confluence Research Agenda

The HCC research agenda as collected in this roadmap can be structured along the following trails of future research:

(i) 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.

(ii) 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 development of ICT and to embed values in ICT artifacts (architecture, code, interface, integrity constraints, ontologies, authorization 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. (Jeroen van den Hoven)

(iii) 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 (Vannevar Bush, 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.

(iv) Emapthy 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.

(v) 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.

(vi) 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.

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. All this will be continued at the Research Agenda Solicitation Portal (www.hcsquared.eu/visions).

Linz, October 2013 Alois Ferscha

Alois Ferscha
(HCC Research Agenda Coordinator)

Institute for Pervasive Computing
Johannes Kepler University Linz
Altenberger Strasse 69
A-4040 Linz

Phone: +43-732-2468-4762
Mobile: +43-699-1111-1010
ferscha@pervasive.jku.at
http://www.pervasive.jku.at

Chapter I: Large Scale Socio-Technical Systems

Chapter II: Ethics and Value Sensitive Design

Chapter III: Augmenting Human Perception and Cognition

Chapter IV: Emapthy and Emotion

Chapter V: Experience and Sharing

Chapter VI: Disappearing Interfaces

I — Large Scale Socio-Technical Systems

Hybrid and Diversity-Aware Collective Adaptive Systems

Fausto Giunchiglia

Academic Contribution
indifferent (0) Agreement
mid term Duration
ground breaking (10) Importance

VISION

The physical and virtual dimensions of life are becoming more and more deeply interwoven. Society is merging with technology, giving rise to a global socio-technical ecosystem. In a society comprising people and machines as actors we often see people-to-people interactions mediated by machine and machine-to-machine interaction mediated by people. The speed and scale of this change and the differences in culture, language and interests make the problem of establishing effective means of communication and coordination increasingly challenging. Our vision is that a new generation of systems, hybrid (i.e., including humans and artificial peers, as well as social groups), distributed, open and large-scale, is needed to tackle these issues. In such systems, multitudes of heterogeneous peers will produce and handle massive amounts of data; peers will join/leave the system following unpredictable patterns with no central coordination and will interoperate at different spatial and temporal scales. Aware of the ethical issues, and by identifying the right incentive schemes and privacy levels, these systems will assist individuals and collectives in their everyday activities, coping with the diversity of the world and working in the presence of incomplete and incorrect information.

APPROACH

A lot of research in so far [1] has mostly focused on providing or imposing some form of harmonization or lightweight coordination of meaning and actions, where machines do most of the computation and humans mostly act as service/data consumers. Even systems that involve so-called human-based computation, and in which human intelligence [2] is used to execute computational tasks, are usually handcrafted in order to satisfy a specific application objective and lack a solid engineering design methodology. In these settings, collectives are generally homogeneous and are orchestrated to achieve a common global goal with limited or no knowledge adaptation.

Our proposal is to move towards a hybrid system, where people and machines work together tightly to build a smarter society. In these systems humans and machines compose to synergistically complement each other, thus bridging the semantic gap between the low-level machine interpretation of data and the high-level human one. In particular human capacity to make sense of the open-ended nature of context and its role human understanding plays a key bridging role here. In such systems, humans and technologies interoperate collectively to achieve their possibly conflicting goals at individual, organizational and societal levels. This approach is based on the assumption that there are tasks humans are better than machines at [6]. For instance, while machines are very effective in computational tasks, they cannot compete with humans in creativity, making judgments, expressing subjective opinions, abstract thinking and scientific reasoning. Operationally, peers in the system will implement a continuous unbounded cycle in which data is sensed, interpreted, shared, elaborated and acted upon. Actions are taken on the basis of system suggestions and the way humans react to them. Actions generate new data, thus driving the adaptation and evolution of the system. While massive-scale current Web systems (e.g., Google, Facebook) are already managing global user communities of hundreds of millions of users, they are only able to support only rather 'crude' machine-human interactions, such as data entry, search, and offline data analysis. They are instead unable to combine heterogeneous complex interactions in an adaptive, diversity-aware fashion. The hybrid systems we envision will be based on the core ideas of compositionality and diversity:

— Compositionality: humans and machines cooperate seamlessly by leveraging their respective strengths. People produce and manipulate their data by providing individual/local implicit or explicit semantics. Machines compose and adapt to people because they learn from people and in turn help them to achieve their local and global goals. This does not necessarily mean that these systems are able to reach global consensus (in terms of semantics and action), but they rather aim to offer the ability to interoperate by means of emerging good enough social semantics and collective (not necessarily collaborative) action by means of good enough coordination. These systems adapt their behaviour continually - evolving to meet the needs of the diverse society they are embedded in.

— Diversity: the ability to cope with the heterogeneity of agents, roles, possibly conflicting goals, data sources, language and semantics [3]. This requires effective design to support diversity-aware data and operation profiling, data and knowledge representation schemes, and interaction strategies.

Reaching this ambitious goal requires interdisciplinarity. Ethics is fundamental to the governance of smart societies and the definition of their design principles, including novel techniques for ensuring privacy by design in their application. Data and knowledge representation and human computer interaction are fundamental in determining the underlying diversity-aware data model and the mechanisms supporting the incremental construction of the shared semantics as well as achieving interoperability between peers. Agent systems will have to focus on reasoning and decision making about interaction situations [4] and be able to make good enough decisions fast, and support methods to combine human and machine computation [5]. ICT in general is fundamental for the development of the infrastructure supporting the overall system.

AN APPLICATION SCENARIO – BEYOND SMART CITIES

In order to alleviate traffic jams and pollution in cities we could envision a system in which pervasive sensors continuously monitor, elaborate and record data about traffic conditions and air quality levels. Each driver has (local, personal) objectives that could include journey time, journey cost, environmental impact, pleasure in the trip etc. While policy makers - given precise national directives - have the (global) goal to guarantee a certain level of air quality as well as the non-functional requirement to make citizens, including drivers, happy. Using the drivers' history of responses to situations, hybrid algorithms involving humans and machines have understood the driving population's response to situations and how their driving behaviour responds to incentives (e.g. free refreshment at the next service station, a change in road pricing, new cost estimate of the trip, a faster route given the blockage etc.).

From the analysis of sensor data, machines can "understand" (from low-level analysis) that a critical traffic situation has arisen. This initiates a hybrid computation that calculates the best incentives to offer different strata in the driving population in order to align driver behaviour with global policy objectives. This computation might involve polling of a "pilot population" or expert decisions, or econometric simulations in some combination. Once users receive the notification, they may communicate further to the system providing high-level interpretation that allows refinement of the incentive offers. As the incident proceeds the CAS can adjust incentive offers depending on the driver response. Citizens will be notified through their mobile phones so they can: avoid areas presenting high pollution levels, avoid presenting at accident and emergency units with minor problems, give blood for specific rare groups and so on. Incentives will be given to appropriate target groups depending on their needs and expectations. People can ignore such suggestions and decide autonomously on what they believe is best for them. The system will be flexible enough to react in real time by recording decisions taken by users (data produced by actions) in order to recalibrate incentives offered to citizens.

IMPACT

The European knowledge society is entering a new phase of development where ICT can provide the key basic infrastructures for all vital social and economic processes and become the most influential key technology in delivering innovations across all industries. ICT is becoming indispensable to address key social challenges and continues to play a defining role in our economy, providing a critical infrastructure for the global economy. The main impacts will be in:

— Science: The new science takes as its focus: (a) the development of theories and mechanisms that allow predictable human-machine compositionality; (b) the development of mechanisms that support diverse social organizations within which this human-machine synthesis is embedded; and (c) the study of the effects of scale on human-machine compositionality and diversity awareness. The main scientific impact will be in: (i) The development of systems that support collective social action through an analysis of and support for diversity; (ii) devising operating principles that allow us to consider the multiple scales of such social groups, their interrelationships and how to structure the information environment, incentives, and the broader physical context to enable diverse collective action (iii) devising predictive models of our hybrid, diversity-aware, systems that support appropriate abstractions that would enable policy makers to consider different approaches to incentive structures, information resources and action capacities made available to social groups. This in turn requires (a) closing the semantic gap between humans and machines, (b) developing principles for the composition of human and machine action, and (c) developing new theories, notations and tools for the design of multi-scale, multi-objective incentive systems that enable the emergence, in a plurality of local information eco-systems, of diverse collective social action.

— Technology: The design of a new generation of ICT to enable social innovation, whereby ICT enables social entrepreneurship and complex collaborative problem solving while ensuring resilience to unanticipated events in the system. This is achieved through the structured and principled development of a new type of hybrid and diversity-aware systems, representing the backbone of our future smarter society.

— Society: The ultimate objective is to transform our understanding of the relationship between large-scale organizations, social structures and the ICT systems that pervade them. This will unlock the capacity to achieve concerted collective action directed to tackle multiple societal challenges through ICT-enabled social innovation.

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Towards Socio-Technical Urban Superorganisms

Franco Zambonelli

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

VISION

Progresses in the area of mobile and pervasive computing, along with the penetration of smart portable sensing and computing devices (e.g., smart phones and alike), are already paving the way for innovative services and mobile applications to perceive detailed information about the surrounding physical and social world, and interact/act in it [1]. In parallel, collaborative and social Web technologies are promoting innovative models and tools to engage a large number of persons in collaboration activities, whether oriented to solve problems (e.g., via crowdsourcing) or simply to socialize (e.g., as in smart mobs) [2].

In urban scenarios, the future integration of the above two aspects let us envision fascinating possibilities. In particular, let's consider coupling the sensing, actuating, and computing capabilities of pervasive technologies with those of humans, and integrating them all together via distributed collaboration technologies. The result could be in an immense number of inter-connected actors, whether humans or ICT devices, capable of working together in orchestrated and adaptive way towards specific goals, as if they were a single organism, i.e., a "superorganism" [4].

Socio-technical superorganisms, beside representing the ground above which a variety of innovative services can be provided, can notably enrich the activities and the rhythms of urban environments with capabilities of autonomous adaptation. That is, the same as biological organisms do, urban superorganisms can be made capable of self-actuating a variety of actions to react to contingencies and to adaptively achieve specific urban level objectives, such as minimizing energy consumption, reducing traffic and pollution, maintaining its overall wealth.

APPROACH

There are an uncountable number of diverse scientific and technological challenges to face in order to enable such future vision and make sure it won't turn out into an urban nightmare.

From my own perspective of expert in the area of coordination models and middleware, I tend to consider of key relevance the following ones: (i) defining innovative coordination models to facilitate spontaneous and effective interactions in the large, also accounting for the very different interaction means that should be put in place at the human level, at the ICT level, and at the frontier between the two levels; (ii) reaching a better understanding of the complex inter-play between the dynamics taking places at the human/social level and at the ICT level, and the overall resulting behavior of the superorganisms; (iii) on this basis, identify proper means by which the dynamics of the superorganisms and its adaptive behavior can be made somehow controllable, and can be effectively oriented towards specific objectives.

An additional, somewhat more inter-disciplinary, issue, concerns identifying means to ensure that components in the superorganism are prone to put their capabilities at the service of the collectivity. That is, identifying and designing novel mechanisms of incentive to push interactions among the many and diverse components to occur. While several proposals have already appeared to promote cooperative and/or opportunistic sharing of sensing devices, it is very likely that brand new incentive and pricing mechanisms will have to be identified towards the definition of a peculiar economy ruling the metabolism of urban superorganisms.

IMPACT

Researches on the emergence of socio-technical organisms can have notable scientific and technological impact. From the scientific viewpoint, acquiring new insights on the complex dynamics emerging in such heterogeneous and large-scale systems can be of fundamental importance not only to better understand our society, but also to better steer its evolution.

However, enabling the vision of future socio-technical superorganisms promises to have also notable economic and societal impact. In fact, can indeed transform the very essence of our urban environments and of our living in it.

On the one hand, a self-adaptive urban organisms could self-optimize depending on need the exploitation of its resources, there included energy resources, with an overall impact on pollution. Just to mention an example, among many specific actions that future urban organisms will be capable of in order to adapt, a specific one will concern the capability of affecting the mobility patterns of its components (vehicles or pedestrian). For vehicles, actuators such as traffic lights and digital traffic signs (not to mentions future actuators of self-driving vehicles) can be put at work to this purpose. For pedestrian, public wall displays as well as personal displays (such as that of smart phones) can be used to suggest people directions. As a consequence, rather than (as we mostly to today) passively sense mobility patterns and try to adapt the provisioning of urban services to such patterns [4], future socio-technical urban organisms will make possible to steer mobility patterns so as to maximize the quality of services and of urban life overall.

On the other hand, for the people, living in an adaptive environment that is capable of tuning its rhythms to our own need, can lead to very high quality of life. Not to mention that being part of a superorganisms (and feeling part of it) can bring in society a renewed and stronger sense of citizenship.

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From Individual to Collective Attention – Models and Dynamics

Alois Ferscha

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

VISION

In media-rich living spaces (like cities of the future, urban and rural living residencies, virtual societies, etc.), where thousands of people are overflooded with signals and messages at all levels of perception and modalities (visual, auditory, tactile, olfactory) while engaging -actively or passively- in the mechanisms of social life and society, the (i) dynamics of individual attention and the (ii) emergence of collective attention appear to be among the most demanding challenges of the information society. It is of high interest to understand how spontaneous, local, individual attention to novel information items occurs, propagates and eventually fades among large populations.

Some two decades of pervasive and ubiquitous computing research have clearly revealed [1], that out of the many indicative design factors for modern ICT, human attention is the first source of perception, consequently as awareness towards information and other individuals. As such, human attention represents the primary concern in the design and operation of pervasive, socio-technical systems [2].

Over the last decades, attention research has succeeded in identifying several attention types as well as physiological mechanisms and neural processes and revealing its relation to memory, learning, decision making and perception [3] [4]. In the history of attentional research many different attentional mechanisms have been discovered and according descriptive models have been developed. Usually, these models adequately describe single or several aspects of attention, e.g. the ambiguity of single- and multi-tasking capability, whereas a general, overall theory of attention is still missing.

APPROACH

We favour a synthesis driven research approach, combining (i) existing theory and its assessment, with (ii) insights from analysing large data sets collected from operational socio-technical systems (mobile communications networks, TV and broadcast networks, road traffic and transportation networks, social networks on the WWW, Internet of Things networks, etc.)

Synthesis of Attention Models The first step towards human attention models as the underpinning design, deployment, operational and evolutionary principles of Socio-Technical Systems is to understand, and in further to have reliable models on how individuals perceive (i) reality, (ii) other individuals, and the (iii) collective behaviour of human societies. Crucial towards collective attention is to understand from observations of the attention of individuals the potential impact to collective behaviour. A possible approach is to start with established attention models developed in cognitive and social sciences (Theory Driven Models, TDMs), and to try to validate them with datasets drawn from real world settings (e.g. using the research methods of the Computational Social Sciences like Reality Mining and the analysis of Big Data). The empirical support for TDMs will then related to findings gathered from empirical observations (Data Driven Models, DDMs). The synthesis of the two respective model categories (TDMs and DDMs) will thus represents the foundational grounds for formal models of individual and collective attention, combining the rich body of cognitive models from neuroscience and artificial intelligence, with evidence from the symbiosis of real world societies and real world ICTs.

Synthesis of Information Diffusion Models The process of the emergence of collective attention is steered by the way how information is shared in societies. Understanding the ways of information diffusion has attracted research in many, even complementary fields (social network analysis, epidemiology, anthropology, social psychology, organizational theory, network science). Most of the analysis techniques, and thus most of the existing theories for information diffusion have been developed in sociology, mathematics, statistics and recently in computational social sciences and network science. Again, to relate this pure theory driven models (TDMs), with findings from exposing huge socio-technical system data sets (mobile communications data, traffic mobility patterns, smart meter readings, public display frequency and attention counts, etc.) to advanced mining techniques (DDMs) will unveil the underpinning support of information diffusion to the raise and fade of collective attention in societies.

IMPACT

More than two decades of pervasive and ubiquitous computing research have brought the vision where the “computer” is not a single device or a network of devices, but rather the entirety of all services originating in a digital world (i.e. a globe-spanning, dynamic, complex infrastructure), which are perceived through the physical world (i.e. technology rich spaces and objects of everyday use).

In this emerging symbiosis of the digital and the physical world, human attention is the most crucial, yet least understood, but fundamental underpinning of a flourishing human computer confluence.

The development thus of a (i) body of formal methods and computational models for attention, together with the respective (ii) design principles, (iii) operational principles, and (iv) evolutionary dynamics represents the foundational underpinning of a novel, "human-friendly" ICTs - as future generation ICTs apparently will have to be grounded on (i) individual socio-cognitive capacities (attention, perception, expectation, belief, meaning, trust, experience, forgiving and empathy) and (ii) collective social capacities (social adaptiveness, social self-organization, collective consensus) [5].

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VISION

The economy of tomorrow will be ever more service-oriented. Instead of owning equipment, developing entire projects in-house, or employing large numbers of full-time workers, companies will be able to pay for external services when needed in pay-as-you-go fashion, cutting down on upfront and maintenance costs and enabling unprecedented scalability. Today's cloud-based software services are already a successful example and an indicator of the direction others will follow. Other companies, such as Amazon MTurk or Car2Go are also well-known already, but it is not hard to imagine even more exotic examples, such as service providers "selling" guaranteed amounts of kilometers instead of tires to transport companies.

This general trend is expected to completely change the way humans work. Full-time employment relationship with a single employer will become less common. Instead, people will be providing their professional services to many different customers in a competitive and global market, often forming ad-hoc teams with other human workers and software services [1][2]. The short-lived nature of these transactions and the unrestricted mobility and availability of workers means that traditional ways of attracting, controlling and rewarding workers through bonuses, salaries, promotions and direct supervision are not appropriate anymore. In fact, among many other challenges that the emerging socio-technical systems will have to face, the human workforce management is one of the most complex ones.

Due to human weaknesses and self-awareness, the existing QoS metrics, monitoring and control methods used for software cloud services cannot be applied in this case. People can be expected to fail, make errors and willingly try to deceive the system. This requires developing specific methods for addressing these issues in this context – incentives for socio-technical systems.

Relying on the fundamental reward/punishment psychological effects incentives are an efficient way of influencing humans in order to set up a fair and competitive working environment within a socio-technical system. If standardized and coherently applied over different systems within a longer period of time, the historical records of incentives applied upon a worker and his responses provide a reliable professional reputation proof. This is one of the key requirements to support human workforce management in socio-technical systems, and, ultimately – careers in the cloud.

APPROACH

While collaborations and working environments in novel socio-technical systems will have drastically changed for the people involved, it is safe to assume that the well-known, fundamental incentive mechanisms will still exert the same psychological

Incentives – Enabling Complex Collaborations in Socio-technical Systems

Schahram Dustdar, Ognjen Šćekić and Hong-Linh Truong

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

effects on humans. However, due to altered working environments, the proven principles cannot be applied in the old way (e.g., a crowdsourcing worker cannot be given a promotion).

Therefore, our first step in designing an incentive management component for socio-technical systems was to identify, model, and standardize a set of general, context-independent incentive mechanisms, relying on the extensive corpus of incentive research in economics, game theory, psychology and applied research. We validated the basic incentive mechanism model we derived from literature by surveying an extensive range of today's social computing companies, non-profit organizations and crowdsourcing initiatives and verifying that the proposed model's expressivity and coverage were satisfying [3].

Next, we focused on developing a programming model and the underpinning software architecture [4] needed to encode the formal model and deploy it on a future, real-world socio-technical systems. The programming model is evaluated functionally – through a selected number of representative case studies that demonstrate its features.

The focus of our research until now was not to devise novel or better incentive mechanisms, but rather to provide useful models and tools to the incentive experts to easily encode, deploy, monitor and alter different combinations of incentive mechanisms on different underlying systems. To this end, we will be developing an accompanying domain-specific language enabling these desirable properties. Ultimately, our work should produce an end-to-end solution for providing the service of incentive management for different socio-technical systems, such as [5].
Our future work will also focus on designing and developing artifact-centric incentive mechanism models, encapsulating customized incentives along with business artifacts. This will allow our models to be used also within artifact-centric workflows – what we believe is a highly adequate approach for socio-technical systems.

IMPACT

Developing formal and programming models of incentive mechanisms will set the basis for the development of reusable, portable and scalable incentive strategies, applicable on various socio-technical systems or offered as a service. This will further open up possibilities for the development of an entirely new class of business management software products.

For the system owners, incentives can also be seen as an indirect instrument for workforce management and runtime team adaptability, allowing for formation of more adequate virtual teams in socio-technical systems. However, incentives do not exhibit their effects only during the life-span of a virtual team; they can be used for post-runtime log analysis as well, in a fashion similar to process mining. Record logs of incentive mechanism applications make it possible to detect unfair individuals and situations creating cost/performance bottlenecks.

For the human workers participating in such systems, incentive management means working in fairer workplace environment, where experience, expertise, team play and past behavior will be valued, and foul play punished. Ultimately, people should be able to successfully build a career just by providing professional services to various third parties through virtual team hosted on socio-technical systems acting as mediators.

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Computer Mediated Social Sense-Making - An Interesting Special Case of Social Computation

Stuart Anderson and Mark Hartswood

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

VISION

We live in a data rich environment where we have the capacity to access overwhelming quantities of data. It is much less clear how we should go about interpreting that data. There are a multitude of issues that complicate the interpretive task. For example, there are issues around the provenance of data. In the absence of strict controls over its collection, we are dealing with data that potentially has highly variable provenance. Typically data is created or gathered in a particular context, for a particular purpose and using particular methods. Our experience is that data is often very firmly rooted in the context in which it was generated. Difficulties arise when we attempt to repurpose data and when we attempt to move data from one context to another.

Tackling these problems using computer systems alone is an impossible task because the issues arise from the contexts of generation and use of the data. So the task of making sense of such data must employ both people to understand subtle aspects of context and machines to bring data together and to allow its rapid processing. Finally, the data is often of mixed provenance and comes from diverse contexts so the task is inherently social requiring some level of cooperation from people in the generating and consuming contexts in order to ensure the interpretation is adequate and sufficiently stable for the intended purpose.

Our vision is the development of design techniques for social computation systems [2] whose purpose is to support communities in maintaining a shared interpretation of a data collection. This will involve the design both of new algorithms and systems that deeply interweave human and machine-based computation and requires the construction of systems of incentives to help shape individual and group responses to the tasks required to participate in the social computation. Such systems enable computer-mediated social sense making. We believe such systems are an interesting and useful class of social computations that merit study.

APPROACH

We will begin by taking an empirical approach. De Roure [1] advocates first understanding the variety of social machines that are already in existence. Ours is the more modest goal of understanding the diversity of approaches to constructing social computations whose primary goal Is to stabilize the interpretation of a data collection for a particular group. For example we have identified the following concrete situations:

— Telemonitoring: Remote monitoring of chronic conditions promises to help manage the extensive healthcare demands of an ageing population. However Physiological data gathered in the home but interpreted by remote clinicians often leads to high False Positive rates [3]. How can patients, relatives and carers be enabled to supplement physiological data with missing contextual detail to improve the quality of remote interpretation [4]?

— Data curation: Data is an increasingly seen as a valuable commodity to be mined over and again to solve problems beyond those for which it was originally collected. However, without access to the context of its production our ability to re-purpose data is degraded, moreover data users generate insights about data quality and utility but which are often neither accumulated nor shared [5]. How can tools enable access to originating contexts and capitalise on the expertise that is created when data is used in order to increase the value of data archives for the wider community of users?

— Validation of scientific models: Computational models make strong contributions to policy formation and scientific advance, often in economically important or politically contentious arenas such as climate change. However, effective interpretation of model results for scientific advance and policy formation often requires access to non-local domain expertise. (This is similar to other 'data analysis' tasks where data interpretations are crowd-sourced [6].) How can collaborative interpretations be facilitated by shareable, annotatable data representations?

Once we have a collection of good empirical examples of this class of sense making systems then we believe they will form the basis for more systematic study. We will explore new approaches to the design and development of such systems. This will involve the design of new algorithms that draw deeply on collective expertise and on the construction of incentive systems to encourage and shape collective action on the part of human participants. The broader study of such system that takes in their resilience and ability to withstand organized attempts to disrupt their operation will draw on a broader base involving game theory, economics, sociology and social psychology.

IMPACT

As we begin to study the operation, design and evolution of collaborative adaptive systems and systems that attempt to display collective social intelligence, a fundamental issue is how, potentially conflicting and competing groups can stabilize their interpretation of large and diverse data collections sufficiently to allow them to carry out tasks based on such interpretations. Systems that operate in this way arise across science, health and care delivery systems and other global systems such as markets and other financial service environments. Understanding this process of computer mediated social sense making is essential to the development of a deeper understanding a very wide class of social computation system.

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VISION

Maintaining cohesion among culturally diverse populations remains a challenge in modern day society. Certain people are more likely to integrate into a new environment and certain people are more likely to embrace others of a differing background. It is well known that people have a tendency to associate and bond with others of a similar kind. Homophily is the principle that similarity breeds connection; birds of a feather flock together [1]. Each human is uniquely defined by a wide range of traits, including gender, race, ethnicity, age, class background, education. Research in the social sciences has shown that contact between similar people occurs at a higher rate than among dissimilar people. While there are many factors that may influence homophily and its dynamics, in the early 2000's it was shown that homophily in race and ethnicity created the strongest divides in personal environment, with age, religion, education, occupation, and gender following in roughly that order [1]. In this new age of abundant data, social interactions can be measured on much larger scales than before. Humans can now interact through different means (e.g. online, offline) and these dynamic interactions can be continuously captured on large-scales and used for research on social behaviour, particularly homophily and trait-specific homophily for which data was previously not easily accessible.

APPROACH

The large-scale modelling of human social behaviour was previously limited due to two major reasons, the sheer complexity of human behaviour and the lack of large scale data. While the discipline of machine learning and data mining have made great progress, the use of these models to address research in social science is quite recent. Traditional research in sociology for human social behaviour analysis considers surveys, interviews, and participant self-reported information to obtain very small-scale fine-grained, static data for analysis. However, ubiquitous sensing and online social network data, allows a much larger-scale, dynamic means to obtain data. The mobile phone is a particularly powerful sensor due to its widespread ubiquitous nature; people already carry mobile phones as they go about their daily activities in every community all around the world. They additionally contain various sorts of sensors, such as location, interaction, and accelerometers, allowing to infer a potentially wider spectrum of context for an individual than other data sensors may capture. Sensor-specific knowledge is necessary to preprocess data and address data-related issues to make effective use for sociology research. Social network data can be used, for example, to obtain details about an individuals' relationships, tastes, experiences, and opinions. Social interactions can be captured by several types of sensors on a mobile phone. Phone calling and messaging communication capture one type of interaction. Bluetooth can capture physical proximity interactions.

Reality Mining for Socio-Ethnic Behaviour Analysis

Katayoun Farrahi

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

IMPACT

This longitudinal interaction data from mobile phones on very large scales can be used to obtain new quantitative measures of human social behaviour relating to cohesion among individuals and correlating this with human traits.

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II — Ethics and Value Sensitive Design

Responsibility Sensitive Design and Human Computer Confluence

Jeroen van den Hoven

Academic Contribution
indifferent (0) Agreement
mid term Duration
ground breaking (10) Importance

VISION

No matter what advanced systems we design and produce in the 21st century, the only candidates for bearing responsibility for outcomes are humans. The fact that we have trouble in figuring out how to allocate moral responsibility in contexts where we find it difficult to trace back the steps to humans and human agency, does not imply that whatever human entity implicated is exonerated and machines or systems can bear responsibility or can even be construed as fully fledged moral agents. It will take a very long time before we can start to think sensibly about holding or making autonomous and intelligent systems morally responsible or about sharing responsibility with them.

APPROACH

In the last 2000 years there have been many institutional experiments involving the ascription of responsibility, the bringing to justice and the punishment of animals, inanimate objects and artefacts [4]. We have all abandoned them. I think it will take such a long time before it would start to make sense to think along these lines that it would be irresponsible to devote considerable research time and serious attention now in law, engineering and ethics to the idea in the next hundred years or so, if it will ever make sense. This line of thinking is especially worrying because it can lead to relativizing efforts to think more deeply and extensively about the urgent questions regarding human responsibility and autonomous systems today. I call this the Austere View of Responsibility.

The Austere View has a number of problems which we have to overcome in the context of HC2 research. Attributing and apportioning responsibility to human beings in the field of IT, especially regarding large systems and complex adaptive systems that are contiguous and confluent with human beings, their bodies and brains, is problematic. Complex adaptive systems and autonomous systems that have been brought into being over a number of years with many different parties involved, after hundreds of thousands of design decisions, and are contiguous and confluent with humans, make it hard - when things go wrong - to answer questions about responsibility and liability, other than in a contrived and often unsatisfactory way. Often there does not seem to be an obvious person who could have prevented or mitigated the untoward outcomes or has had any direct control over what happened.

It may become problematic to separate out components in an obvious and morally relevant way after the fact. Often there are unforeseen consequences and emergent properties. This poses a difficult attribution problem. If we would be able to attribute responsibility to human beings, then we would immediately be confronted with the apportioning problem, the problem of distributing and apportioning responsibility, and state in what sense and to what extent the identified human and non-human entities are candidates for responsibility?

Thirdly, there is a framing problem. Sometimes there is an obvious human candidate, a driver, a pilot or an operator, a manager. These human agents however are often framed in socio-technical systems qua choice architectures. The moral implication is that the range of their relevant moral options is limited by design. This makes it often unfair and sometimes ridiculous to ask questions about the responsibility or the moral obligations of the framed agent. A non-technical example: Is Sophie in Sophie's Choice morally responsible for the outcome? Does it make sense to ask what her moral obligation is? She is the victim of a perverse Nazi officer's choice architecture. Human beings design and create (or allow them to evolve) the environments in which other agents, often long after the designers and makers are gone, must act and bear responsibility. Pilots, surgeons, fire fighters, soldiers, managers, and operators (users) ought respectively to transport persons, save lives, extinguish fires, rescue innocent citizens from the hands of the enemy, create jobs and prevent explosions. They are dependent for their moral performance on the designers and engineers who have supplied them with the tools (designers and engineers). The fact that users are dependent on designers and engineers in this sense does not necessarily fully excuse users and operators in case they fail or are implicated in untoward outcomes. Like the drunken driver there may have been moments were they could have done something that could have affected the outcome, even if at the moment of the accident they did not have any control over the vehicle.

IMPACT

A possible solution to these and other responsibility problems in HC2 contexts is to start to think about responsibility sensitive design, that is think about responsibility as a matter of (a) design (b) in advance in (c) a fairly fine grained way in order to bring about the conditions under which human beings can be held responsible [1,2,5] even in cases of HC2 and intricate entanglement of humans in advanced robotic and sensor environments.

(Ad a) We should not expect that if we embark on the production and use of socio-technical systems contiguous and confluent with human beings without prior attention to the allocation and ascription (both attribution and apportioning) of responsibilities, that we can answer questions about responsibility ex post in a satisfactory way. If we want to be able to hold John responsible for performance of task X in the future, we should make him responsible for X now. If we want to hold him responsible now, we should have made them responsible yesterday.

(Ad b) Both engineers, designers and users have task responsibilities (obligations to see to it that something happens) and role based duties in situ (e.g. landing the plane, checking the temperature in the reactor, removing a tumour) but they also have what I call meta task responsibilities, i.e. obligations to see to it that favourable conditions obtain for fulfilling task responsibilities, or assess prior to the task performance whether the environment in which they will have to work, is likely to allow them to do what they ought to do in situ and to ascertain that it at least does not prevent them from doing what they ought to do. The checklist the pilot goes through before take-off is a protocol that assists him or her in honouring his meta-task responsibility. The flight system interface, the cockpit and the output devices, (in combination with procedures and protocols, instructions), should be such that they provide the pilot with reliable signals about the state of the aircraft and to gauge whether he or she will be able to do what is morally required. The possibility to switch from auto-pilot to manual during landing is a design for agency, autonomy and responsibility of the crew.
If users and operators have this type of meta task responsibility in addition to a range of other responsibilities (tasks, negative task, supervising and (self-) monitoring responsibilities), then one of the important responsibilities of all of those (including the users themselves) who shape the environment of future users (institutional and technological) is to bring about the conditions under which they can successfully discharge those responsibilities, or at least try to prevent designs which would interfere with them discharging these responsibilities.

(ad c) We need a much more fine grained vocabulary to talk in advance about designing for responsibility. This distinguishes between causality (cause), reactivity (emotion), liability (compensation), accountability (description and justification) and performativity (task and role), identity (character and personality). Within task responsibilities we even have to go to finer granularity.

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Future Mobiles as Keys to the Future Internet

Max Mühlhäuser

Academic Contribution
indifferent (0) Agreement
long term Duration
paradigm changing (15) Importance

VISION

In 2025, global citizens should use their mobile device as fully trusted devices worldwide, representing their owner in cyberspace exactly the way she wants. By then, the cyberspace will host most of our economic life (Internet of Services), social life (social networks, Internet of Crowds), and IT resources (Internet of Clouds), and act as area-of-control for the real world through cyber-physical systems (Smart Spaces, Internet of Things). As a consequence, the vision of the said 'fully trusted device' concerns several planes:

— economic plane: it enacts the commercial / financial behavior of its user (e.g., tightly controlling subscribed and pay-per-use services, screening newly encountered services according to preferences and needs, and evaluating them wrt. trustworthiness); it also represents the user as a nomadic economic and social being, offering and requesting (location based) services according to her self-conceptualization wrt. personal-mobile-business, participation-in-crowd-sourcing, or social-responsibility (ad hoc volunteer services)

— juridical plane: it executes its user's constitutional right to informational self-determination (e.g. choosing between anonymity, pseudonyms, and identity), and enforces (and complies with) SLAs and legally imposed aspects of services provision / use

— interaction plane: it controls the interaction with smart objects and products, smart environments, and available interaction devices (worn/carried or encountered) it federates with; in all cases, it ensures a consistent and personalized user experience

— computing plane: it determines the behavior of its owner's networked IT resources ('clouds') and enforces the expected behavior of surrounding devices (e.g., via remote attestation / TPM) to which it delegates interaction or computing functionality

APPROACH

The 'fully trusted device' (FTD) can be pictured as

— the replacement of SIMcards, …

— NOT embedded in Smartphone-like devices, …

— with 'bootstrapping capabilities' for processing, storage, interaction, communication, positioning/orientation …

— such that the FTD functionality can be exercised without an 'enclosure device' – except for electric power.

Initial 'enclosure devices' resemble today's Bluetooth headsets. A plug/socket standard ensures easy device-swapping; soon, fashion accessories like necklaces, wrist watches, eye-glasses etc. will follow.

Access to the 'classical' public mobile network is provided by a device class resembling today's Smartphones (featuring next generation visual-haptic interaction). This class will just be one-of-many, next to, e.g.

— Smart-LargeScreens (acting as Cyberspace access points),

— Smart-Pads (provided by restaurants, hotels etc., accessing cyberspace through corporate networks),

— Smart-Products (for which the FTD acts as remote control – partly without user interception since it acts-on-behalf)

— etc.

All Smart-Devices have to feature short-distance communication ('bootstrapping communication capability' of the FTD) and a standardized 'sandbox' where trusted code can be executed on behalf of the FTD.
Voice is the 'bootstrapping interaction capability'. The 'bootstrapping positioning/orientation capability' draws its accuracy from 'fixes' with infrastructures such as Galileo. Positioning infrastructures are legally required to follow the FTD-imposed policy wrt. the FTD-owner's position/orientation.

The bootstrapping processing/storage capability ensures security measures, privacy enforcement, trust assessment, remote attestation of sandboxes on connected Smart-Devices (see above), etc. – all based on the FTD standard.

IMPACT

In order to understand the tremendous impact of the FTD vision, one has to reckon that the biggest challenge is a political one. The FTD is fundamentally different from today's mobile phones in that the latter are 'paid but not owned by their users': three kinds of stakeholders determine their functionality, namely hardware and operating system manufacturers (Samsung, Google etc.), and Telcos (like Deutsche Telekom). Their influence prohibits full control (i.e. trust!) by the owner. The following decisive question must be answered by the EU - probably the only political entity in the world empowered to execute a positive answer: Is it the political will of the EU to physically limit the control exercised on its population by commercial stakeholders, and to ensure 'self-determined connected citizens'? If the answer is YES, the realization (of the FTD vision) will cause POSITIVE mid-term economic effects due to improved social acceptance – but short-term commercial interests will be a huge obstacle (cf. Telco lobbying for the EU research programmes). Politically, the FTD vision must materialize in legislation, technology funding, and finally a global standard. It affects the entire future mobile use of the cyberspace (including telephony). In other words: the resulting standard would exceed the significance of the GSM standard, Europe's last global success in this domain (back in the 1990s!).

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The Future of Interaction

Yvonne Rogers

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

VISION

20 years ago, a common caricature of computing was of a frustrated user sat staring at a PC hands hovering over a keyboard and mouse. Nowadays, the picture is quite different. The PC has been largely overtaken by the laptop, the smartphone and the tablet; more and more people are using them extensively and everywhere as they go about their working and everyday lives.

Mark Weiser's highly influential vision of Calm Technology, back in the early 90s, saw the relationship between people and computers as one where people would interact with and use computers without thinking about them. Technology would blend into "the fabric of everyday life" freeing up their time for a more empowered society. While there has been an impressive amount of research following in his footsteps, it does not match up to anything like Weiser's World. Instead we are becoming increasingly dependent on them, becoming more enveloped in our own digital bubbles; that require increasing amounts of our focal attention.

And what will the world of computing be like in 2020? Digital technologies will continue to proliferate enabling ever more ways of extending and augmenting how we live and interact with information and data. Rather than only being used when needed, they will be ever present, sensing, monitoring, informing and influencing human behaviour in unprecedented ways. Such future developments raise a number of challenges: how will such technological developments improve the quality of life, empower people, and make them feel happier, more productive and creative?

A driving force behind much R&D has been to promote 'smart' technologies and the 'internet of things' – rather than making people smart, the emphasis is more on how new technology can be developed and implemented to sense, connect and mine the wealth of data about ourselves, our cities and the environment. We are witnessing a data revolution that is resulting in vast amounts of data about ourselves, our activities and the environment. There is a real danger, however, that rather than improving the quality of our lives, it will make them more overloaded and fragmented.

How can we ensure that the new data streams, in their various forms, will benefit society? A key challenge of the smart movement, the digital data revolution, and the proliferation of devices, from a human-computer perspective, is to put the welfare of people first and determine how best to optimise well-being and the quality of life.

APPROACH

To address this challenge, we need to begin asking fundamental questions about what it means to be human in a world suffused with technologies embedded in our

environments, objects and our clothing that can interact with other devices and sensors, with or without our control, and our knowing. We need to rethink how our relationship with technology will evolve with a clear set of human values in mind. To achieve this requires using user-centered analytic tools, interactive visualizations and situated displays that will provide people with the kind of information that they can readily understand and act upon when needed.
Key questions that need to be addressed include how meaningful is the data that is presented; do people understand it; how ethical is it to be collecting data about people's habits, movements and uploading them indefinitely to the Cloud – anonymized or not. Also where is the data kept and what access do people have to it?

The goal of much big data research has so far been to help businesses become more agile and competitive. There is much talk about how data can be turned into 'actionable information' from a business perspective, increasing profit margins, etc. In contrast, there has been a paucity of research into how new insights about what people do when interacting with their computers, etc., can feed into enhancing their working and everyday lives. A future HCC research agenda needs to understand how to analyse patterns of user data, from and for the user perspective; where users, themselves, can interact with new information visualizations about their own behaviour and decide how to change it. In particular, how can big data analytic techniques be used and made accessible to help people understand their own 'small' data to improve their lives in ways that are acceptable to them?

IMPACT

A better understanding of how new technologies and interaction techniques can be used effectively with the new streams of data will lead to all sorts of ways in which technology can impact on society. It can provide governments, policy-makers and researchers with a powerful new set of tools to augment everyday and working lives. The impact on society could be profound; a future where humans, augmented by novel combinations of technologies, can effect change in a whole range of behaviours that they have not had the information or the ability to do so before.

New insights can be gained from HCC research investigating future technology interactions, leading us to rethink how best to design them to support and augment a diversity of applications, including healthcare, education, work, leisure and well being in novel and extensive ways. There are many benefits for a society in which people have a proactive rather than an increasingly dependent relationship with technology. Ultimately, an approach that views the confluence of humans and computers as one that empowers people so they keep control, can potentially help solve the world's increasingly complex problems.

III — Augmenting Human Perception and Cognition

Personal Memory Augmentation: Acquisition, Retention, and Attenuation

Marc Langheinrich and Nigel Davies

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

VISION

Technology has always had a direct impact on how and what humans remember. This impact is both inevitable and fundamental – technology radically changes the nature and scale of the cues that we can preserve outside our own memory in order to trigger recall. Such change is not new – we have seen the transition from story-telling to written books, from paintings to photographs to digital images and from individual diaries to collective social networks. However, in recent years three separate strands of technology have developed to the extent that collectively they open up entirely new ways of augmenting human memory:

— near-continuous collection of memory cues has become possible through the use of technologies such as Microsoft's SenseCam, social networks and interaction logs.

— advances in data storage and processing now enables widespread mining of stored cues for proactive presentation, both in terms of cues collected by an individual and in terms of complex networks of related cues contributed by others.

— the presence of ubiquitous displays (both in the environment and via personal devices such as Google Glasses) provides many new opportunities for displaying memory cues to trigger recall.

The time seems ripe to attempt creating memory augmentation technology that provides the user with the experience of an extended and enhanced memory, but which is based on improvements in the collection, mining, and presentation of appropriate information to facilitate cued memory recall. In particular, we are in a position to lay the scientific foundations for a new technology eco-system that can transform the way humans remember in order to measurably and significantly improve functional capabilities while maintaining individual control. No such memory augmentation systems exist today and their emergence would represent a radical transformation in the way we understand and manage human memory acquisition and recall.

APPROACH

Contemporary memory theories already highlight how recall can be used to both reinforce and attenuate memories. However, numerous technical and societal challenges need to be addressed before augmented memory systems are possible. The main challenges are threefold:

— Collection. We need to create novel classes of capture systems that specifically support human memory functions while offering a fine-grained level of control over their recording and fully respecting personal privacy. This entails novel approaches to the integration of captured data across devices, domains, and owners.
— Presentation. We need novel tools and methods for integrating, correlating, and visualizing captured sensor data and other information sources into a coherent "memory prosthetics" stream. Such streams need to be based on theoretical principles of human memory organization, in order to positively influence the acquisition, retention and attenuation of knowledge from personal experiences.
— Theory. On a theoretical level, we need to validate human memory theory in real world environments. Such a validation will allow us to deepen our understanding of how human memory works outside carefully controlled lab studies, and will provide insights into the mechanisms that can be used to alter and amplify human memory in every-day use. Of particular interest would also be the feasibility of targeted attenuation of unwanted memories.

Fundamental research along these three strands needs to be integrated into pervasive, long-running systems that can combine the collection and presentation of memories into a non-invasive ambient memory aid. Such system would need to have a potential "run-time" of decades, supporting the constant evolution of sensor technology, display formats, and interaction modalities. This also entails high levels of fault tolerance (network and power disruptions, faulty and missing sensor data, etc.) and open data formats to provide strong data ownership, i.e., people are able to freely inspect, manipulate, and export their data.

We envisage an environment in which augmented memory systems make everyday use of peripheral, ambient multi-media content – delivered via large wall-mounted displays, smartphone wallpapers, or wearable in-eye projectors – to intelligently integrate, display, and enable the review of life-relevant personal data. Such systems would integrate information actively entered by the user (e.g., calendar entries, photos) with additional relevant data collected automatically through a multitude of capture technologies, in accordance with the user's privacy preferences. Through the ambient review of their activities over a range of timescales users would be able to actively manage their memories: they could enhance the later accessibility of needed information, whilst attenuating the recall of unwanted information.

IMPACT

Successful memory augmentation systems have a transformational impact on all spheres of life – the workplace, family life, education, and psychological well-being – by measurably improving the acquisition of new knowledge, the retention of existing knowledge, and the loss of unwanted knowledge.

Historically, memory enhancement technologies such as the ability to keep written records or photography have been instrumental in advancing society. The selective nature of such recordings, however, required a conscious pre-mediated effort of choosing “important” events to write about or capture on film. Novel capture technologies and advanced filtering and control methods could offer a fundamentally different capture experience. Combining this with fundamental memory research would provide the foundation for a new understanding of how such technology can be used to retain or attenuate human memory.

Individuals would gain new means to externalize memory and to use selective recall to pursue personal goals. However, personal memory augmentation would also have a significant impact on society in the way it affects what can be retained in a collective societal memory. Memory, the ability to learn and remember, is strongly linked to what a society can achieve, from a cultural as well as from an economic perspective. Hence we argue it is essential that we as a society need to understand the opportunities and potential threats of technologies that offer memory augmentation and that we should develop a technology for memory augmentation that is compatible with a European understanding of individual rights and the function of the society we value.

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Cross-modal HCI

Lynn Huestegge and Iring Koch

Academic Contribution
indifferent (0) Agreement
mid term Duration
ground breaking (10) Importance

VISION

The interplay between individuals and information technology becomes more and more complex every day. One of the main research prospects of human computer confluence will be a thorough understanding of what determines the efficiency of multi-modal information flow between humans and machines. Modern input devices are no longer restricted to uni-modal action input (e.g., manual clicks and button presses), but rather involve a large array of multi-modal action modalities, including verbal action, foot responses, and gaze control. However, only little is known about the cognitive mechanisms of cross-modal action control in the context of HCI.

APPROACH

In basic research on principles of cognition, there has been a boom of research on the role of cross-modal processing across multiple input- and output modalities. However, what is still lacking is a thorough implementation (and dissemination) of this knowledge in applied fields where cross-modal cognitive control of complex actions is an essential ingredient for efficient overall system performance.

For example, one research stream in cognitive sciences is devoted to the question of which perceptual modalities (e.g., vision, audition, touch, smell etc.) are more efficiently linked to which action modalities (e.g., manual, vocal, oculomotor etc.) in the context of multitasking demands. As a result, preferred modality-specific processing pathways have been identified. For example, manual actions are typically more efficiently triggered by visual stimulation, and vocal actions are preferably initialized by auditory stimuli, while voluntary oculomotor actions appear to be triggered equally well by both (visual and auditory) stimuli [2]. However, there is a lack of research on how such preferred modality-specific processing pathways may affect performance in complex HCI settings.

Another research stream in cognitive sciences is devoted to the question of how human cognition is able to prioritize certain action modalities in the context of cross-modal cognitive action control. For example, recent findings suggest that modality-dependent prioritization patterns may exist whenever humans are involved in simultaneous action demands across different action modalities. For example, oculomotor action is typically prioritized over vocal actions, whereas vocal actions are usually prioritized over manual actions [1]. However, it is unknown how such priorities may affect multi-modal action control in HCI, and how such priorities may be strategically altered to optimize overall performance.

IMPACT

Thus, we propose that the rise of multi-modal input devices (in turn requiring complex multi-modal action control within humans) strongly calls for significant research progress in the field of cross-modal action control in the context of HCI.

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Turn on, tune in, drop out - Better interaction through cognitive prostheses

Ricardo Chavarriaga

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

VISION

With the advance of pervasive computing, we will be surrounded by a constellation of devices we can interact with. Physical interfaces will disappear and neuroprosthetic interfaces will allow these devices to send information directly into our sensory neural pathways. However, this information may not always be suited to each user or to the particular spatiotemporal context. In consequence, as these devices compete for our attention, effective interaction may be impaired by the 'data deluge' they will generate (Baraniuk, 2011). Therefore a main challenge lies on the way these devices choose "what" to communicate us, as well as "how" and "when" to do it.

Neurophysiological studies have shown that perception is affected by the brain state even before any stimulus is presented (e.g. Monto et al., 2008; Busch et al., 2009). Detection of these states (e.g. level of attention, mental workload, etc.), even when there is no overt behavior linked to them, will be crucial to tailor the information exchange across humans and smart objects. 'Cognitive neural interfaces' able to assess those states based on multimodal monitoring of the human behavior and physiological signals have thus to be developed.

These interfaces will enhance our perception capabilities by delivering the right amount of information at the moment we are better fit to process it. Exploiting user-centered design built upon knowledge of the cognitive, behavioral and physiological basis of perception, their development will be the result of ground-breaking advances in neuroscience, bioengineering and human-machine interactions.

APPROACH

Recognition of human cognitive states from behavioral, physiological and neural signals will allow pervasive smart technologies to efficiently provide information without saturating the human sensory channels. This will require research efforts on several research lines, including:

Sensing technology able to provide continuous, reliable measurements of physiological signals, including activity of the central and peripheral nervous systems, has to be developed. These devices should be non-intrusive, and potentially be able to harvest energy from in-vivo sources. They should also be able communicate other on-body and environmental sensors and devices.

In addition, most research on human cognition --at the behavioral, psychophysical and neurological level-- is based on simple tasks performed in well-controlled laboratory conditions. Therefore, scarce information is available on how these processes take place in real-life environments. Wearable, self-powered sensing of physiological signals will make it possible to study such processes outside the lab and provide insights for their potential use in human-computer interfaces.

Currently, neural interfaces have used deep-brain stimulation to treat Parkinson disease, chronic pain or affective disorders (Kringelbach et al., 2007). Similarly, both invasive and non-invasive stimulation has been used to substitute or restore impaired senses (e.g. cochlear and retinal implants, tactile displays) (Bach-y-Rita and Kercel, 2003). Further developments on the understanding of the neural basis of multimodal perception and material biocompatibility for implanted devices will be required for the integration of these type of feedback into practical, daily life cognitive prostheses.

IMPACT

Cognitive neural interfaces will augment our sensory capabilities by providing contextual information gathered by surrounding environmental sensors, smart objects or previously stored data. This information will be provided through external stimulation or directly sent into our sensory neural pathways. Moreover, these interfaces will also monitor our cognitive states so as to assess our intentions and capabilities. On this basis they will tune the information exchange to selectively drop out unnecessary, redundant information from the environment.

Besides the clear benefits of these interfaces for people with sensory impairments, they will also have impact on other scenarios. Multimodal contextual information from several sensors can be linked to the user cognitive state to create spatiotemporal footprints. The system can use this information to better customize its features according to the user preferences or habits. Alternatively, they can become stored as mementos of previous experiences that can later be retrieved to overcome memory loss. Moreover, the use of neural feedback, provided on a timely fashion can exploit our brain's associative capabilities to facilitate the learning of mental models of the systems we interact with. This can be of great benefit for people attentional deficits or learning impairments.

Despite its potential benefits, it is clear that the development of such prostheses and the possibility of monitoring the human cognitive states will raise further challenges in terms of the ethical use of such information and respect of privacy. Issues that have to be carefully considered at early stages of the research process.

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Understanding Human Nature - Grand Challenge in Confluence of Humans with Computers

Włodzisław Duch

Academic Contribution
indifferent (0) Agreement
mid term Duration
ground breaking (10) Importance

VISION

Personal computing devices and computing environments will eventually integrate so closely with people that they will become a part of their extended minds. There is a growing body of research in cognitive sciences showing how various artifacts become parts of cognitive systems in building internal models of the world and providing control functions. This may range from simple extensions of sensory capabilities, improvements of episodic, semantic and working memory, attention and orientation, to sophisticated systems that help to regulate one's own behavior manipulating brain plasticity and changes in a conscious way, and in effect change personality and character of a person. In the longer run understanding real needs of people is most important, understanding what is beneficial for their development, what will lead to happiness and lasting satisfaction, and what will turn bitter after brief excitement. This may be very risky and dangerous ground, because it requires the ability to imagine long term consequences of one's own behavior, learning to optimize to improve the chance of reaching long-term goals. ICT may create new, and strengthen already existing patterns of behavior that helped in the past to maintain social coherence, provide role models for members of the society, increase self-reflection, develop positive values, reciprocal altruism, and define human nature in different cultures.

Confluence of humans and computers may be important both for individual human development as well as social development. Full understanding of this process requires multidisciplinary perspective: brain research, cognitive psychology, philosophy, cultural studies, sociology, psychiatry, ICT, to name a few. The challenge is to understand what could be the role of ICT in such process, how can it help to learn about ourselves in a better way, look at ourselves from other people's perspective, make us aware of possible consequences of our actions, show plausible scenarios of the future, helping to define long-term goals. So far ICT has been introduced in a blind way, without any understanding how the new technology is going to influence people on personal and social level, how it will change their perception and models of reality. Important questions related to the role of ICT in human development have not yet been posed: how do we learn about ourselves in childhood, constructing structures of the self and models of our own behavior, what can we learn from internal information flow in the brain, what is the role of imagery and top-down processes and how ICT is changing it? What do we need to learn by interacting with other people and what do we learn only by observation of effects of our behavior on them? How are media, bombarding people with exceptions to normal behavior, influencing their world models, how does it influence their behavior and goals?

APPROACH

Research on Human Computer Confluence has been focused largely on brain-computer interfaces, virtual embodiment, complex data exploration, but neglecting human development. Extending sensory substitution to new ways of interacting with the environment may be done through additional sensors and augmented reality which could not only provide information, but also enhance people's imagery showing possible consequences of their behavior. Understanding how brains "resonate" with each other during social interactions is gaining popularity thanks to the ability to observe activity of several brains interacting with each other. This should help to understand what conditions facilitate stronger coupling between people. Development of EEG or NIRS brain monitoring in combination with TMS techniques for brain activation should lead to the possibility of direct synchronization of brain states between people, giving them the ability to better understand each other through the insight based not only on behavior, but also on internal perception of brain states.

ICT may help in many ways to control one's own behavior, overcoming addictions and various flaws of character. In case of more serious problems, such as obsessive-compulsive disorders, surgery implanting electrodes near some subcortical brain structures (nucleus accumbens, amygdala) gives people the ability to externally control themselves; a few psychiatric interventions of this sort have been made. Non-invasive techniques based on combination of neurofeedback with TMS may be used by wider group of people, changing the way their brains generate behavior and analyze information. Neurofeedback has been used with success to treat attention-related problems, but also to increase creativity in musicians and dancers. Brain plasticity is the key to learning not only in education but also in successful psychotherapy. It can be induced using various multimedia resources. Affective computing research may help to evaluate brain arousal, finding ways for more effective learning. Games may develop various skills but may also be used to test our reactions. Application of such systems to increase empathy and to decrease impulsive behavior, to explore possible life scenarios depending on one's actions, may be important in criminal rehabilitation.

Continuous monitoring should help to better define and understand oneself, making people aware of information extracted from sensors that could help them to change their behavior. Models of human personality based on alter ego computerized systems may learn about their owner, observing and mimicking her/his behavior and eventually becoming virtual doubles that show similar reactions, sharing many memories and becoming partners that could serve as avatars in many situations. Such systems may eventually prevent harmful behaviors, serving as "guarding angels", initially being only extensions of memory, later advising people on health issues, guiding their education, helping in making important decisions, etc. They may also be important as companions to elderly people suffering from memory loss, helping them to maintain structures of their selves by bringing memories of important events in their past, and thus facilitating strong relations with their friends and families. This requires development of "Artificial Minds" or personoids, software and robotic agents based on brain-inspired cognitive architectures that humans can talk to and relate to in a similar way as they relate to other humans. Development of cognitive science and electronic hardware leaves no doubt that in 10+ years time artificial minds are going to be one of the central topics in science and technology.

IMPACT

This vision goes well beyond the state of the art, in the direction of systems that will help to increase wisdom and happiness, helping people to regulate their own behavior in a better way. Specific outcomes may include popularity of various systems that should be built to achieve these goals, progress in science towards deeper understanding of human nature and social structures that form and reflect it, success in application of ICT in psychotherapy and decrease in the prevalence and severity of mental disease. There is no community at present that focuses their effort in the direction of using ICT for better understanding of human nature, using it for understanding other people (including cross-cultural issues), self-therapy and self-development. Psychiatry and psychotherapy is used for interventions only in serious cases of mental problems. Although some people are interested in self-development procedures the lack of science and technological support leaves this area of human activity largely to new age spiritual gurus and religious leaders.

The Time Dimension in Human-Computer Confluence

Panos Trahanias

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

VISION

Current research in human computer confluence (HCC) has mainly concentrated on how machines may enhance the sensory and perceptual capacities of humans at given environment states (i.e. two way Brain-Computer Interfaces to provide new sensory modalities, smart clothing to monitor body state, enter into augmented realities, processing of massively complex information spaces). Relevant applications refer mainly to modes of limited-time interaction between humans and computers. Still, the seamless confluence of the two ends encompasses an inherent temporal dimension that is typically overlooked by contemporary research. In contrast to the human brain, existing intelligent computational systems cannot efficiently handle time, therefore significantly limiting the realm of human computer confluence.

Evidently, time is an important dimension in the human-human interactions (we set rendezvous, we discuss about the past, we make plans for the future, we use tenses in natural language communication) and thus any machine that will be seamlessly integrated into human environments is expected to have mature Temporal Cognition (TC) abilities (i.e. experience the flow of time and consider the temporal aspects of real word phenomena).

Based on the above, artificial TC emerges as a major and timely research challenge in the broader field of HCC. Despite the crucial role that sense of time has in our daily activities, the capacity of computer devices to effectively process time remains largely unexplored. Therefore, it is now high-time to equip artifacts with TC, a capacity with the potential to significantly promote the capabilities of artificial systems and render them more human friendly.

APPROACH

To design an effective approach for implementing TC in artifacts, we need to consider that humans process time before being capable to use clocks, while animals that also perceive and process time cannot of course use clocks at all! This is a clear indication that contemporary approaches based on accurate time measurements, the time-stamping of information and the use of temporal or other logics, can hardly reach the levels of human TC. Alternatively, taking inspiration from nature and mimicking the working principles of the brain might be the proper way for implementing TC in machines.

Interestingly, time is involved in our daily cognitive processes in a multitude of ways. Research questions that should be considered include, but are not limited to, the following topics:

— The perception of synchrony and the ordering of events (e.g. should this set of tasks be processed in parallel or sequentially, and if so, in which order?)

— The formation of the experienced present (e.g. what is the meaning of “now” in different contexts?)

— The perception of granularities and the flexible processing of abstracted temporal durations (e.g. what means that I now have a “short” visit to Brussels?)
— The ability to mentally travel in time (e.g. how we, at the present time, think about past and future events?)
— The ability to share temporal views about the world (e.g. how time affects understanding of social norms).

IMPACT

The wide acceptance of TC as an essential component of intelligence will significantly affect the methodological approaches used for implementing artificial systems. This is because TC acts as an integrator that binds together the perceptual, behavioral, cognitive, emotional and communicative processes of intelligent systems.
Moreover, incorporating in computer devises TC that is a fundamental capacity of the human and animal brain will have a major impact in HCC that will be advanced in at least the following three broad strands:
— Machine Identity: Furnishing artificial systems with TC accomplishes a significant milestone towards the development of consciousness in computer-based devices, therefore providing a significant impetus in their truly autonomous operation.
— Cognitive Capacities: Artificial TC paves the way for implementing into many devises sophisticated cognitive skills which rely heavily on effective temporal associations (mind reading, prospective memory, cause attribution, risk undertaking, etc.), therefore enabling radically new types of services to be provided to humans.
— Naturalistic Socializing: Considering the temporal dimension of life, enables computer devices to communicate and interact in human terms, therefore being seamlessly and actively engaged in human daily setups.

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IV — Emapthy and Emotion

Emotionally Intelligent Interfaces

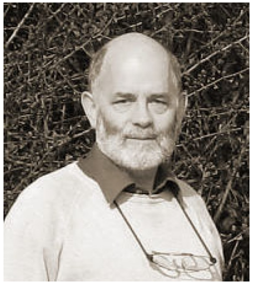
Peter Robinson

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance



VISION

When people talk to each other, they express their feelings through facial expressions, tone of voice, body posture and gestures. They even do this when they are interacting with machines. These hidden signals are an important part of human communication, but most computer systems ignore them. A major challenge for human-computer confluence is to integrate emotions into man-machine communications.

APPROACH

The importance of emotional expression as part of human communication has been understood since the seventeenth century, and has been explored scientifically since Charles Darwin and others in the nineteenth century. Recent advances in psychology have greatly improved our understanding of the role of affect in communication, perception, decision-making, attention and memory. At the same time, advances in technology mean that it is becoming possible for machines to sense, analyse and express emotions. We can now consider how these advances relate to each other and how they can be brought together to influence future research in perception, attention, learning, memory, communication, decision-making and other applications.

The first challenge is to develop applications that address the wide range of affective states that people experience, communicate and attribute to each other. This entails continuing to push affect-sensing technologies and models that can identify subtle nuances and intensities of a wide range of affective states, which consider the rich spectrum of modalities that humans employ to express themselves, and which consider the dynamics of these channels. Models should represent emotions as emergent processes, which change with internal and external contextual cues, including a person’s past experiences, appraisal of current events, and relationship with the interaction partner.

The second challenge is brought about by adopting an embodied approach to sensing people’s state, where systems are not just passive sensors but are instrumental in driving human-computer and human-human interactions. Besides the challenges brought about by sensing people “in the wild”, there are challenges in implementing real-time, dynamic mechanisms and novel applications that learn with their users rather than simply being trained in advance. With the increasing use of robots and agents that will interact with people, there is growing interest in enabling machines to learn better by learning from people in a more natural, collaborative manner, not just from people who program the computer or robot.

The third grand challenge is to move towards new methodologies that enable not only large-scale sensing of people's individual affect-related data, but also networks of data, such as face-to-face interactions of groups of people, or physiological sensing of large audiences. Within this framework, every instance of an interaction can be considered as an opportunity to learn about that person's specific knowledge and experiences.

IMPACT

Computers have moved beyond simple desktop workstations to permeate every aspect of our lives. Every day we make routine use of mobile phones, satellite navigation systems and portable music players, as well as computer systems that support manufacturing, commerce and education. Much of our time is spent communicating with embedded and conventional computer systems, and these systems need to be equipped with the same emotional intelligence that informs human communications. 60 years have passed since the first computers were built; 40 years have passed since graphical interaction became available; 20 years have passed since large displays and tangible interfaces were introduced. The next step will be to equip computers to understand their users and communicate through more subtle channels.

Identifying Emotional States for Human-Computer Confluence

Roberta L. Klatzky

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

VISION

The vision put forward here is one in which a deeper understanding of the psychology and neuroscience of emotion, combined with knowledge derived from decades of research on human cognition, informs novel areas of application in human-computer confluence. The basis for doing so is by making inferences about the emotional state of the human user during human/computer interaction.

Arguably the most common format for people to interact with computers in social, educational and work contexts is the one-person/one-machine model. The user receives and transmits text, graphics, and/or video in interaction with another person (as in social communication) or in running some dedicated application. In this scenario, the human-computer interaction is affected only by the transmitted data. The state of the user is irrelevant unless it is directly part of the information content (e.g., an emoticon or self-description in social interaction). Others present in the environment are irrelevant as well.

The interaction context just described would generally be sufficient, if people, like computers, were essentially symbol manipulation devices. This assumption has served well for many computer-based applications. For example, cognitive tutors based on models of human cognition that treat people as symbolic processors have had great success. This approach is fundamentally limited, however, because human behavior is driven not only by cognition, but by states outside of cognitive control. It could be claimed that human behaviors derive from emotional states more often than from thought. Certainly people exhibit non-rational behaviors of many sorts.

A distinction between behaviors that are emotionally driven versus cognitively based has arisen in the fields of psychology and neuroscience [1]. The field of human decision making, for example, has shown that rational economic models based on maximizing expected utility do not generally apply [2]. As an appreciation of emotional bases of behavior has increased, there have been significant advances in the understanding of emotion and the roles of different regions of the brain in regulating behaviors of different types.

APPROACH

The research approach suggested here is multi-pronged, but its thrust is to detect and identify emotional states in the context of human-computer confluence, and to use this information in ways that benefit the user.

To achieve this thrust, many challenging research issues would need to be attacked. They include:

— Expanding the analysis of data acquired from keyboard and camera to include, for example, keystroke rate and force, head gestures, emotional expressions, or implicit speech;

— developing sensors that will enhance the range of relevant data beyond keyboard and camera, e.g., by measuring skin conductivity, heart rate, or skin temperature;

— constructing a catalog of emotional states and building algorithms to reliably translate sensed data into those states;

— integrating the analysis of the user's state with the computer-directed activities of the user; e.g., determining that a social communication is governed by anger or an on-line auction bid is based on "gambler's high";

— analyzing interactions between multiple simultaneous users, e.g., in terms of collaboration, conflict, or peer pressure;

— providing timely interventions in the face of evidence for behaviors of negative consequence to the user.

IMPACT

The intended potential impact is to provide people who are interacting with computers with knowledge about their states and motivations, to their benefit.

One impact would be better decision making. A body of research points to emotion as an implicit basis for decisions that might otherwise seem to be fully rational. For example, a distinction has been made between unconscious and conscious decisions, the first arising from coarse statistical approximations cutting across many variables, and the latter optimizing across a small number of dimensions [3]. A complementary literature describes a transition from controlled to risk-taking behavior, as the result of depletion of resources otherwise used for cognitive control [4]. Yet another approach directly attributes non-rational choices to emotional arousal, which yields rational, cortical control to older brain areas.

Another potential impact is to recognize and reduce peer pressure in group interactions. Risky behaviors can be modulated by the presence of peers [5]. To the extent that peer incentives toward risk can be detected, and reminders can be put forth, risk might be reduced.

Another impact is that recognition of emotional state could be used protectively for users of various types. It could be used in at-risk populations to detect precursors to self harm, or it could warn equipment or vehicle operators of arousal levels that might interfere with their control.

In short, emotion recognition during human-computer interaction presents major research challenges but has potentially great utility. This effort could be expanded to recognizing emotions in broader contexts.

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The empathic side of human-computer confluence

Amílcar Cardoso

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

VISION

Current technological developments are making available an increasing computational power in conditions of low power consumption: there is a clear trend toward miniaturization of computing devices. The emergence of ambient intelligence, provided by pervasive computing systems, offering storage, processing and data communication capabilities available ubiquitously, is already a visible phenomenon. The ongoing investment in the Internet of Things [1] reinforces this trend by seeking to bring computational capabilities to the common objects of day-to-day life.

The confluence between man and machine turns out to be, in such scenario, one of the most significant challenges and also a source of research opportunities. In our research we explore the vision of the computer as a cognitive extension, i.e., the development of new forms of intelligence that may "amplify and extend our cognitive abilities" [2, 3]. Pervasive systems should be able to provide cognitive services to exploit the enormous amount and diversity of information and the increasing computational power made available, while interacting in a natural and empathic way. The latter aspect is particularly relevant in this context: the computer should be able to engage communication in a natural way, to understand context, to empathically adapt attitude to the human's mood.

The research challenge we propose is to make these cognitive extensions empathic, i.e., leading them to recognise (in a non-intrusive way) human emotional changes and, whenever needed, adapt their behaviour accordingly.

APPROACH

The complexity of combining a range of cognitive services and emphatic communication in a resource bounded pervasive system is the sticking background of this research.

Providing emphatic properties to pervasive systems involves research in three interrelated streams: the system needs to be able to recognize and induce human emotions, and to adapt its behaviour in a believable way.

Research in affective computing [4] has been tackling these problems in the last years, particularly regarding the proposal of models for representing emotional states in artificial agents. The specific characteristics of pervasive systems and the need to make emphatic characteristics available in time and in place poses specific challenges that should motivate the proposal of specific solutions.

Emotion recognition may involve the analysis of a diversity of physiological data, and

also the analysis of facial expression, body posture and gesture, and speech. This involves research in data analysis and machine learning, particularly to seek for solutions for recognizing and processing emotional patterns in resource bounded setups. There are also opportunities for research in other directions, like in non-intrusive data sensing and in data fusion.
Emotion expression and induction may involve research in a diversity of areas, ranging from natural language processing to speech processing. The use of narrative forms of communication, visual language, music and sound, narrative forms of communication are also examples of other specific research streams that should be involved.

IMPACT

We consider that this research is viable, in the sense that each identified research topic has an established research map. Combining them in the required situation results in the significant increase of complexity. The research is expected to produce important contributions to several research areas, like affective computing, machine learning, agent architectures, natural language processing, speech processing, semantic processing of speech, visual information, sound and music, sensing devices and data fusion.

We also envisage that research in this area may result in a mass use of empathic cognitive extension devices in the course of the following 10 to 20 years resulting in significant increases in productivity and life quality.

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Driver-vehicle confluence or how to control your car in future?

Andreas Riener

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

VISION

To address the problem of complexity reduction in driving, solutions in the past have focused primarily on technological aspects. Now time has come for improvements related to human factors (i.e., the driver) by employing new forms of driver-vehicle interaction that improves on driving experience and pleasure.

To achieve this, improvements should be considered in the following lines:

— V1. Focused attention is required from the driver: Information that is presented to the driver needs to be preselected and/or filtered to preserve attention resources at the driver and devote them to driving related tasks. A second issue is that future UIs need to be more natural to experience and intuitive to use in order to avoid reasoning about how to use a control to execute a certain function (evident for example to complex multi-stage controls such as iDrive).

— V2. Driver emotions need to be detected (and controlled?) as emotions in driving exhibit a serious distraction level (similar to those experienced by the classical distraction sources). The emergence of negative emotional stress, most likely caused by operation complexity, need to be compensated but also the effect of (too) positive emotional experience need to be discovered as (over-)happiness and high spirits results in incautious driving. Last but not least emotions and their relationship to culture, ethic heritage, etc. have to be investigated.

— V3. Future cars have to 'understand' what the driver wants, i.e., the vehicle has to detect the current mental/emotional state of the driver, infer his/her intention, and react accordingly. This calls for a appropriate emotional state model for driving and includes full-fledged knowledge of state transitions and the relationship between emotions but also ways and means to inform or stimulate the driver unobtrusively.

— V4. Collective rather than individual behavior: To achieve improvements in road throughput or traffic jam avoidance, but also in a reduction of CO2 emissions, intentions/reservations of all the individual drivers within a certain area or with common goal should be forwarded to a 'collective (artificial) brain' featuring common decision making and thus traffic optimization.

APPROACH

To come as close as possible to the visions stated before, that is to achieve optimal driving experience with at the same time road safety kept high, "driver-vehicle confluence" is the proposed solution. Merging all the information coming from the driver, the vehicle, and the environment into a collective foundation should allow for improved interaction between the involved parties. In particular, the following individual points need to be addressed.

— Input modalities: The main weak point of vehicle control (or more abstract in the chain of sensory perception) is addicted to the cognitive-motor task of the driver. To disburden this link in the cycle chain, implicit input is the preferred solution today, even with some possibilities for further improvements (e.g., driver state estimation from pressure sensors integrated into the seat, thermal imagery to assess cognitive overload or driving stress, physiological sensors). Even higher potential is expected from the application of neural techniques (one-way brain-computer interface (BCI)) to gather and process input from the driver in a fully implicit, inattentive, embodied, distraction- and workload-free manner.

— Output channels: Despite the fact that the visual channel is highly overloaded while steering a car, driving is (still) a pure visual task. Head-up displays (HUDs) solved the problem partly, but with inattentional blindness [1] another emerges. To solve this problem for good and all, new information channels such as tactile feedback and olfactory stimuli or modalities of perception like subliminal feedback (i.e., information transmission below aware perception) need to be established.

— Behavior adaptation: To achieve the visions above (in particular V3, V4), one have to look at the intrinsic fundamentals of driving. Inspiration could be borrowed from biology by identifying similarities that can be adopted to driving or driver behavior modeling. One example might be the movements of ants on a trail - which is in some concerns similar to (motorway) traffic. Using pheromones, ants, bees, etc. share not only information about the environment (food sources, traffic jam ahead), but also changes the behavior and/or physiology of pheromone receivers [2]. A similar approach could be also used in the car to change driver condition/behavior by application of hormones [3] or neurotransmitters.

By considering all the individual potentials for improvements (brain-computer interface, implicit interaction, messaging below aware perception, etc.), "driver-vehicle confluence'' would finally define a setting where the car implicitly recognizes the behavior and condition of the driver (e.g., movement, stress levels, fatigue, communication behavior, stored history), infers what the driver wants, informs the driver (tactile/olfactory/etc. feedback; subliminal stimulation) or reacts accordingly (adjust AC, control car stereo, volume +/-, turn off the phone, switch lights off, etc.). Another basic property of such a system would be that all the adaptation is done automatically, maybe even proactively, but in any case without involving the driver (meaning that it is operating fully autonomously in the background). Finally, on detection of deviations (e.g., in the driven route) the vehicle would warn the involved driver(s) or would even intervene by applying brakes or changing the lane.

IMPACT

By putting the driver rather than technology in the center of efforts with regard to complexity reduction in vehicle operation we see great potential to revolutionize traffic in Europe and to achieve the long term visions and road safety goals of the European countries ("Vision Zero"). In particular, we expect that drivers have a more relaxed driving experience and feel pleasure while steering their cars. This 'individual behavior enhancing' add-on of vehicles offers huge chances on the market for (European) automobile manufacturer (with expected much higher impact than yet another assistance or driver information system).

A further expected impact is that sort of collective understanding of the traffic situation together with a concerted behavior modification of drivers should have the potential to enable improvements such as reducing the overall fuel consumption or CO2 emission.

This could be achieved by a kind of "collective brain'' gathering neural input from all the drivers in a common area of interest and featuring common decision making and negotiation on the route or lane taken by each individual driver within the collective. Of course, this includes also the control of traffic lights, speed limitations, and traffic signs to optimize the traffic flow.

(This is rather different to how collective driving behavior is practiced/understood today: On a detected traffic jam the navigation system automatically calculates and proposes a alternative route; the problem is, however, that the rerouting algorithm works equally in all navigation systems of a certain manufacturer, which finally leads to the emergence of a "new jam'' on the diversion route while the main route gets free.

Much better would be a common decision making/negotiation who goes where, maybe based on rewards, to establish kind of load balancing on all the roads.)

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V — Experience and Sharing

VISION

Imagine a large number of users, e.g. 10% of the population, are sharing in real time what they see, hear and experience using wearable devices (e.g. camera glasses). The shared information is stored, tagged with contextual information, searchable by content and meta-data, and easily accessible from anywhere. Such an infrastructure would allow users to look at remote places and look at events in the past.

Computing and communication technologies, integrated with sensors and actuators, will enable entirely new forms of interaction with our environment [4]. We envision that the temporal and spatial limitations of human perception will be overcome with new information and communication technologies [5]. Sensing and capture becomes ubiquitous and allows to understand more about the user [3]. Communication infrastructures are globally available. This will result in humans gaining unprecedented and virtually instant access to vast amounts of information and perception will no longer be limited to the here and now.

The central challenge of the next 50 years is to create novel platforms that include capture, indexing, correlating, understanding, distribution and access of experiences. This will enable human perception that is not limited by space and time, allowing random access across space and time. Such technologies will provide means to virtually be in any other place (or multiple places at the same time) on the planet. Through storage it will also enable to go back in time to access information. The data available combined with advanced simulation technologies will even allow us to make precise predictions about the future.

We believe that through research in ICT devices and systems can be created that will inevitably revolutionize the way people perceive the world, interact with each other, and act based on what they perceive.

APPROACH

This research will focus on capture and access of human experience, on interaction with implicitly and explicitly created content. On an application level this will include personal assistance, memory aids, and ubiquitous information spaces.

Perception Beyond the Here and Now

Albrecht Schmidt

Academic Contribution

indifferent (0) Agreement

mid term Duration

paradigm changing (15) Importance

The overall approach will be fundamental research into new forms of human computer interaction that is inspired by the opportunity of the creation of new senses. The research is focusing on fundamental question and the investigations are motivated by envisioned future applications. For this type of research an experimental and empirical approach following a user centered process is most suitable.

This type of research has computer science questions at its center, but will require multi-disciplinary efforts from computer science, psychology, design, and ethics. It does not require new research in physics, material science and neurology, as the basic technologies and mechanism are well developed and understood, but their potential is not yet exploited. To create the vision it requires basic research in human-computer interaction, data mining, computer vision and visualization in order to understand how such systems can be created. This research needs to be combined with research in psychology and ethics in order to evaluate how this can be made in a way that is acceptable to humankind.

Given the vast search space in this research it is most promising to have a large number of exploratory smaller projects (e.g., 3-4 partners, 6 people at most) with a longer duration (e.g. 4-6 years) as longer-term effects of created systems and interventions need to be studied.

IMPACT

Such new forms of perception will fundamentally change the way in which we interact with our natural, artificial and social environment. As gathering information can be done implicitly, without any effort by the human user, such technologies can be designed to be invisible to the user. We expect that such a technology will massively change an individual's abilities and productivity. In [1] the impact reported of even small scale capture is very encouraging but at the same time there are major challenges to values, privacy [2] and ethics.

The major impact is that human knowledge and experience will be easily preserved and made available to others. Anything a person does and decides not to keep it secret (e.g., repaired a bicycle tire, pruned a tree, carved a piece of wood, or cooked a meal) will become accessible by others and be added to the common knowledge of a society. Humans will create content and knowledge with their actions. Doing something is enough to keep a permanent memory of it for mankind. Accessing the information space will be accessing experiences of other humans, some may be provided in real time, others abstracted or condensed.

The societal transition envisioned can be compared to the transition from oral societies to community having a written language. The richness of human experience will be captured and become accessible. By this societies which can keep a record of their explicit and implicit knowledge will have a clear competitive advantage. For the society that will have no access to such technologies we would expect that they are left behind. The difference we expect can be as drastic as the difference between societies using books and those who remained oral.

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Multisensory Internet Communication

Adrian David Cheok

Academic Contribution
indifferent (0) Agreement
mid term Duration
ground breaking (10) Importance

VISION

Currently digital communication is mainly limited to audio and visual information, which is mainly based on logical communication. However in our physical human interaction, touch, taste, and smell play an extremely important role, and are tied to not only logical communication but emotional communication. By extending the digital and Internet communication to incorporate all of our human senses, including taste and smell, we can move from the current information communication to experience communication. Both human gustatory sensory system (taste) and olfactory sensory system (smell) perform a significant role in enhancing one's everyday life experiences through memory and emotions. Some studies have suggested that taste and smell related memories have a stronger emotional content than those triggered by other sensory modalities.

Taste and smell memories are considered to have proven qualities, commonly known as "Proustian characteristics", which includes resistance to interference, uniqueness, and independence from other modalities. Furthermore, research has discovered that taste and smell senses are directly associated with one's mood, stress, retention, and recall functions.

APPROACH

We propose a new communication medium, which allows people to digitally share taste and smell sensations with a remote person through existing networking technologies, for example the Internet. Although there were few experiments conducted on non-chemical stimulation of taste and smell senses, there are no evidences of an interactive system for stimulating those senses. Thus, in this research, our focus is on gaining digital control of taste and smell senses through noninvasive stimulation methods such as electrical, thermal, and magnetic. With these methods we will also be able to enable interactive and remote communication through those senses.

IMPACT

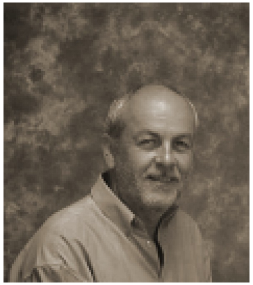
By introducing this technology, we expect people to share their smell and taste experiences with their family and friends remotely. Sharing these senses is immensely beneficial since those are strongly associated with individual memories, emotions, and everyday experiences. As the initial step, we can develop a control system, an actuator, which could digitally stimulate the sense of taste and smell remotely.

By communicating these senses remotely and digitally, we can enrich interactive communications that are currently dominated by vision and audio based interactions. Furthermore, the multimodal interaction and communication researches as well as virtual reality researches are in need of digitizing taste and smell senses.

Living in Blended Spaces

David Benyon

Academic Contribution
indifferent (0) Agreement
mid term Duration
ground breaking (10) Importance



VISION

Mixed reality describes various combinations of physical and digital space such as augmenting a physical space with video observed through a smart phone or interacting with a digital space through some physical object or movement. Increasingly the physical and the digital become woven together into new spaces with their own properties; blended spaces. The term 'blend' here is borrowed from blending theory which is a theory of cognition that highlights the importance of cross domain mappings and conceptual integration to our thought process that are grounded in physically-based spatial schemas. The concept of a blended space is developed by recognizing that physical space and digital space can both be described in terms of the objects and agents who inhabit the space, the structure of the objects' relationships (the topology of the space) and the changes that take place in the space (the volatility, or dynamics of the space). The blended space will be more effective if the physical and digital spaces have some recognizable and understandable correspondences. The concept of blended spaces aims to take the design of mixed reality experiences to the next level of understanding. People will move through these spaces, following trajectories that weave in and out of physical and digital space. They will navigate to new places in both the physical and digital worlds and fell present with the other people who are also living in the blended space.

APPROACH

People will be present in these blended spaces, engaging in experiences. They will move between and within blended spaces. They will move up and down the layers of experience. Support for navigation of spaces is a critical aspect of designing spaces. How people come to understand what they can do in blended spaces, what they can feel and how they can express themselves will depend on the designer's skill in allowing people to conceptualize the blend. Principles from blending theory points to integration as a key feature; "integrated blends is an overarching principle of human cognition" ([4] p.328). In investigating a semiotics of information spaces Benyon and O'Neil [5] draw on de Certeau's ideas that people walking in the city create the city. ' the mouse clicks, scrolling, button presses and sliders, … the swipes, taps, pinch and spread and other gestures in our multi-touch interfaces are the way we create the blended space'. People create meanings as they negotiate and contribute to the blended space. People use the rhetoric of physical and digital spaces to be present in a blended space.

IMPACT

Blended spaces provide a new medium within which people reside and through which they interact and form ideas and relationships. The degree to which people will feel really present in the blended space is a measure of the quality of the user experience;

of the naturalness of the blended medium, the appropriateness of digital content and the spatial and aesthetic characteristics of the physical space.

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Computational behavior science: towards open-endedness

Daniel Roggen

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

VISION

There are many domains where mobile assistants, by being aware of our activities, context and preferences through ubiquitous computing technologies, could advise us in our daily life. A few examples as consumer application could be: A mobile assistant could advise us on how to minimize our energetic impact. It could find behavioral patterns to optimize, at home or on the move; a mobile assistant could help us spare money by suggesting better shopping patterns; managing one's weight could be supported by small changes in daily habits, advised at the right moment, such as taking stairs instead of elevator.

A key requirement for all these motivating applications is to recognize complex human activities in real-world environments over long time periods and in unconstrained environments. We refer to this as open-ended activity recognition.
Activity recognition is tackled as a problem of learning by demonstration. The user is put into a situation where he performs the activities and gestures of interest, with selected sensors in the environment or on body. The sensor data are acquired with ground-truth annotations describing what the user performs or experiences. The resulting dataset is used to train the recognition system and test its performance. The training process consists of identifying the mapping between the user's activities and the corresponding sensor signals. The mapping of the sensor-signals to activity-classes or context-classes is carried out by an "activity recognition chain".

This approach implies a number of consequences which are problematic when dealing with complex activities over long time periods in unconstrained environments.
— Pre-defined set of activities. The set of "relevant activities" that is required with current approaches may only be partially known at design time. This is for instance the case for a memory prosthesis: while there are definitely some activities relevant to most, there is also a vast majority of activities that will highly depend on one's person lifestyle and may be almost unique to that person
— Limited scaling up. Collecting datasets for long-term activities thus becomes even more challenging for time-reasons (long-term), and for privacy reasons: video annotations are hard to envision in such settings. Method-wise, reasoning applied to activity primitives shows a way to scale up, however there is still the need of benchmark datasets to evaluate the method performance over long time scales. Furthermore, reasoning methods also assume known activity primitives on which to reason.
— Static models. User habits and way of executing activities changes over time due to ageing, injuries, or changing preferences. Thus, activity models cannot be solely statically trained on design-time data.

Systems beyond the state of the art must be radically more open-ended:
— In the general case of activity recognition, the set of relevant activities is not necessarily known at design-time.
— It is an open-ended set of activities, depending on the specific user, and evolving over time following changes in the user's habits, and growing as additional relevant situations are discovered.
— Open-ended activity recognition must be realized with limited design-time assumptions, and smart run-time supervision, following unsupervised and semi-supervised principles, capitalizing on similar examples from peers when available, and drawing from autonomous operation principles seen in artificial intelligence.

APPROACH

An open-ended system achieves lifelong learning of an unbounded set of activities with minimal design-time training effort and in a wide range of sensor configurations [1,2]. It must reduce the need to collect large training set for each sensor configurations and each pre-defined activities. Thus it can offer activity recognition of complex human activities in open-ended daily life environments, where the activities of interest and the sensors available are hard to predict at design-time. An open-ended system must be adaptive, continuously tracking changes in the way activities map to sensor signals, in order to adapt to change in sensor characteristics, and in changes in the way a user executes activities. Overall, an open-ended system must autonomously adapt to new, likely unforeseen, situations encountered at run-time, such as the appearance of new sensors, new activities, or new sources of knowledge. Two pillars are combined to achieve this goal.

High-level activity recognition is based on unsupervised hierarchical clustering and semi-supervised techniques. This runs on user-specific systems and uses collective activity models provided by a cloud server to identify the activities. Semi-supervised learning is used to let the system's user, or other data sources, provide sporadic information about the activity taking place, thus allowing the system to refine the activity model for the specific user of the system (adaptation from user independent models to user specific activity models). Unsupervised hierarchical clustering allows to discover repeating sensor data patterns corresponding to re-occurring patterns of daily life activities. This results in a symbol string which can be later identified to a specific activity as more information becomes available. This supports the semi-supervised learning, by allowing to label activities at the proper timescale (e.g. activity primitives or higher-level activities). It also supports a crowd sourcing approach by allowing to link the activity of a user with those of another user. For instance, when the system of another user discover a similar hierarchical data structure to the first user, both systems hypothesize they correspond to similar high-level user activities. Activity labels provided by either user can thus be used interchangeably.

Effort in acquiring training data can be reduced by crowd sourcing it. A back-end cloud server comprises collective (user independent) activity models. These models are shared with each user's system that performs local activity recognition. The collective models can be refined as more data related to an activity becomes available. This occurs with incremental lifelong learning. Activities are hierarchically organized, as labels concerning different timescales of events are provided. A key research question for the robust crowd-sourcing of activity models is to allow users to provide sporadic activity labels with minimal disturbance and cognitive load. Thus, “likely” activities are suggested by exploiting the fact that other persons may already have labeled a similar activity. The system must also cope with imprecise, missing, or even incorrect user-provided labels (e.g. because hastily provided by the user). We develop methods that efficiently use such “noisy” labels by a combination of temporally localized clustering to identify the temporal activity boundaries, and semi-supervised learning method, as well as investigating trade-offs in levels of user feedback from minimalistic to accurate labeling. The user can provide custom label to achieve a growing set of recognized activities. A challenge is to identify synonymous labels and label hierarchies (e.g. running is a specific instance of sport, providing one or the other label should be tolerated and appropriately managed by the system). This is achieved by analysis of statistically significant re-occurrence of labels, distributed word clustering (also using web resources), or probabilistic latent semantic analysis.

IMPACT

Activity and context aware systems will be able to truly understand users: besides simple behaviors, this means the intentionality behind their actions, which is key to enable the next generation of context-aware assistance. For instance: systems that understand what a person with dementia that became disoriented truly had in mind, and should be reminded about, in order for her to seamlessly carry on her daily activities.

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VI — Disappearing Interfaces

Connecting to the Emerging Nervous System of Ubiquitous Sensing

Joseph A. Paradiso

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

VISION

All notions of ubiquitous computing assume sensate environments. Without these, the cognitive engines of ubicomp are deaf, dumb, and blind, and can't respond relevantly to the real world events that they aim to augment. The past decade in many ways belongs to these sensors. Advances have been rampant as sensors tend to exploit Moore's Law. Accordingly, sensors of all sorts now seem to be increasingly in everything, indicating an approaching phase transition once they are properly networked, like we saw when web browsers appeared and our interaction with computers fundamentally changed. This shift will create a seamless electronic nervous system that covers the planet – and one of the main challenges for our community now is in how to merge the rapidly evolving electronic sensoria onto humans. I see this challenge splitting into two basic conceptual categories – namely something I broadly term a digital omniscience, where a series of 'browsers' (for lack of a better word), seamlessly graft this information onto multimodal human perception, and another being more in the actuation space, where these systems extend our physical bodies (e.g., HVAC systems responding to personal sense of comfort, lighting systems that help you see, smart robotic tools that are extensions of the hand, etc.).

APPROACH

This vision hinges on several research areas. One is ultralow-power or passively-powered wireless sensing, which is a key technology in acquiring this data to begin with, as not everything can be wired. Technologies involving adaptive power management, low power analog and digital processing, low-power radio (e.g., backscatter), and energy harvesting are the major pieces of this advance, and are all active research areas. Going further, standards need to be developed and adopted to allow all this sensor information to be easily appropriated across devices. At this point, this is a crucial endeavor in which to involve industry, as such capability needs to be in commercial products before we see the world change. Existing protocols such as DLNA and Qualcomm's AllJoin are focused more on remote control and data piping between heavier devices – lighter weight protocols need to be in place to allow low power sensors to be part of this infrastructure. Bringing all this information together into cloud-based context engines are another big piece of the picture, which will retain a research edge, as context in unstructured environments involves elements of AI. Finally, intuitive user interfaces through which people touch this data are crucial – e.g., leveraging attention and estimated user intent to seamlessly make this new 'electronic' sense an intuitive part of being human, rather than a device that distracts you with focused effort needed to run its user interface. Finally, privacy concerns are paramount here – going beyond today's worries about people and governments hacking into your documents and online communication, this will be hacking into your daily life – individuals will be able to virtually hang at your shoulder, creating something of a parasitic presence that can also interfere with your real-time perception of events. Clearly, devices in our environment need to be properly secured and validated – certainly an enormous challenge, especially in a world where the device and software manufactures themselves aren't trustable.

IMPACT

Augmenting the human thorough ubiquitous sensing and actuation will have profound societal and economic impact. The major service industries of the next decade will be based around brokering, supplying, and securing context. As networks merge, this information will be used for everything, from conserving energy while keeping you comfortable to automatically assembling your photos from ubiquitous cameras that you encountered on your vacation. A new emerging art form will be based upon the notion of presence, as what it means to be in one place at one time will be fundamentally redefined. Clearly, this future is full of promise, yet to our 20'th century perspective is also fraught with peril, a potential delight for prying totalitarian eyes. Clearly we need to chart the course now that will take us into this unavoidable era that maximizes the opportunities for new kinds of human expression, creativity, and endeavor, while minimizing the threat of malicious control and the inability to escape oppression.

VISION

Imagine you want that your computer assistant performs a specific action, like selecting a TV channel or grasping for the water bottle. But before you have to get up and interact with it, the device is already doing it! Your intention is identified from the brain signals and the corresponding action is directly executed.

We can imagine that more and more physical interfaces will disappear, and cognitive or neuroprosthetic interfaces will allow us to control external devices directly. Furthermore, they may even sent information into our sensory neural pathways, so that we can start feeling and embody them, like if you would know when you touch a bottle or how heavy it is.

Would such a novel interaction technique be of interest for us or would it be too scary? How far is the technology already towards the line of such direct brain-controlled or brain-responsive devices? Can we envision that heavily disable-people can overcome their restrictions with such a technology?

APPROACH

A brain-computer interface (BCI) system monitors the user's brain activity [1], extracts specific subject-dependent features from the brain signals that reflect the intent of the subject, and translates them into actions, e.g. writing messages, playing games, controlling robots or wheelchairs without the generation of any active motor output [2], and even allowing stroke patients to partially recover motor functions. Furthermore, cognitive signals or metal states are possible sources of interaction. Whenever our brain identified an error performed by the system, we could automatically correct it. Or based on our attention or other mental states the interaction system could adapt itself towards our current needs in speed, support or autonomy. Therefore, BCI technology offers a natural way to augment human capabilities by providing a new interaction link with the outside world.

Especially hybrid BCI architectures, where a brain channel is combined with other physiological signals and assistive technology devices in order to augment the interaction and control capabilities, seems to be reliable and robust to use over long periods of time [3]. Furthermore, context awareness and adaptive human-computer interaction allows a brain-controlled device to interpret the user's mental commands given the current context and thereby translate the low-capacity output of the BCI into complex actions, while reducing the cognitive workload of the user.

An emerging area of BCI research with a large commercial potential is neurorehabilitation, especially stroke rehabilitation. BCI-based rehabilitation

Brain Computer Confluence

Robert Leeb and José del R. Millán

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

intervention shows evidence for positive changes in brain plasticity and functional improvements.

The benefits of BCI, once developed to its full potential, are not only limited to severely disabled people and their relatives: they also open up new possibilities in human-machine interaction for elderly and able-bodied people. This promise might still take some time to materialize thoroughly, but first steps are being taken.

IMPACT

The invisible, embodied or even implanted interaction between humans and system will influence the way how we are able to see and interact with our world. Brain-computer interfaces are just one possible option to achieve such a goal, but how would we or our brain embody such external devices into our body schema?

Life-time functionality with minimum intervention, similar to heart pacemakers, is the biggest challenge for BCIs at the moment. A system which has biocompatible electronics and sensors, is working 24 hours a day, using ultra-low power and wireless technology is the goal for recording stable signals at the non-invasive or invasive level. Thereby, we would enable patients to operate such a BCI all day long and giving them back the freedom to perform actions on their own.

Furthermore, identification of brain correlates associated to different aspects of voluntary behavior or cognitive states (e.g., attention and fatigue) could be crucial for a purposeful interaction of everybody. Like if your car is adapting its behavior based on your level of fatigue and attentiveness to drive.

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VISION

Robots have formed part of the advanced industrial environment for over 50 years, but these first industrial robots were very far removed from their human co-workers, both physically (through large safety barriers), and intellectually. The past 10-15 years has seen a development away from solely factory based robots to encompass the first domestic, medical and service robots. In this developing scenario, the robots form part of the human living and working space, but still there is a divide between the robots and the human. In essence, the robot and the human do may be co-located, but they not co-exist, do not co-operate and do not achieve any substantive level of interaction either physically or intellectually. However, the next 5-20 years will see a paradigm shift in the nature of Human-Robot Interaction with the machine and the human interacting physically on factory floors, in hospitals, and in homes [1,2].

To move robotics to the next phase of its development there will be a need for a confluence of the human and the robot, and this will require advances that merge engineered systems, based on large heavy motors, stiff gear boxes and inflexible controllers, with a perhaps more biologically inspired approach were interactions remain fast and accurate but are "softer", more natural, materials are lighter, and controllers can adapt to the presence and actions of humans in close proximity (or even coupled – exoskeletons and wearable systems) to the robot.

APPROACH

While mimicking biological principles does not necessarily lead to the development of optimal systems, the core philosophy is that the confluence of multiple, diverse technologies will facilitate a transition from traditional (hard-bodied) robots which operate largely remote from humans towards a new generation of hybrid systems combining engineering principles such as speed, robustness, accuracy, and endurance with biologically inspired concepts that aim to emulate the 'softer' compliant structure of muscle, bone, tendons and skin to provide robots with the capacity for self-repair, regeneration, redundancy and intuitive learning [1].

This synergetic combination will require new advanced; Actuation and Energy/Power Systems, Interfaces and Interaction Technologies, Sensing, Intelligence and Control, and Structures, Materials and Mechanisms.

For actuation and energy/power systems, new approaches will be developed that ensure the interaction of a robot and a human, or even their physical coupling in devices such as exoskeletons and wearable haptics, will be safe, through the use of active and passive compliance that mimics natural muscle behavior (position and force/torque), and through increased energy efficiency in the total system (animals

Human Robot Confluences

Darwin G. Caldwell

Academic Contribution

indifferent (0) Agreement

mid term Duration

ground breaking (10) Importance

have power/weight performance that is magnitudes greater than robots) [3,4].

Current interfacing and programming techniques mean that in most instances only individuals with specialist training can interact with a robot. However, in a human context, learning is at its most simple level, “see it, copy it”. Future developments of learning and programming by demonstration (PbD) will call for robotic systems that can perceive human actions (using an array of sensory systems including but not limited to vision) and then copying this behavior. The robot will distill the essence of the task and learn in a manner that although very different in terms of neuroscience from biological learning nonetheless gives a level of end-goal functionality that is comparable [5].

The future generations of robot will be able to benefits from new advanced materials, structures and nanomaterials/structures that will produce lighter more robust mechanisms perhaps even with the capacity to self repair after damage in a manner not unlike biological tissues yet still have greater strength than skin or bone. The advances in rapid prototyping may allow for construction of mechanism with unparalleled complexity allowing sensory systems to be directly embedded within the physical structures.

At the sensor level, particular emphasis will be placed on developing new senses or enhancing the level of robustness and performance of current systems. Primary among these will be touch, which despite a low history of research does not provide the sensory needs for effective perception and learning coupled with long term reliability and robustness. At this time touch falls well short of human abilities at a functional level and more particular in robustness, reliability and the capacity of repair. This undoubtedly has a significant knock on effect on perception and learning. In addition it would not be unexpected for robots to develop smell and possibly taste and then to include capabilities beyond human experience. In the processing of these data the software to learn from and use this data will also have far reaching requirements and implications.

IMPACT

Fifty years of robot technology have brought tremendous advances in the capabilities of the systems in terms of their physical capacities but although they have added so much to society their remoteness has meant that they have failed to have a truly direct influence on the lives of most people. The next decades will see a revolution in the use of robots in human centered workspaces radically changing our homes, our workplaces, our medical care systems, transportation and methods of caring for the sick, and elderly.

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Moving Beyond Classic Interaction Models

Barnabas Takacs

Academic Contribution
indifferent (0) Agreement
mid term Duration
ground breaking (10) Importance

VISION

The wealth of human knowledge has grown exponentially through the last centuries and it is expected to further accelerate, while the human capacity to absorb that knowledge has remained practically unchanged. The basic problem in increasing the efficiency of the learning and training processes is that “information consumes the attention of its recipients, hence the wealth of information creates a poverty of attention and the need to allocate that attention efficiently among the sources that might consume it.” (Herb Simon, Nobel Prize Winner). Thus, the challenge for a new generation of HCC systems is not only to bombard its users with information alone, but rather to constantly and interactively track and enhance their performance and engagement in response to the multi-modal stimuli they are presented with for the purpose of increased information processing efficiency as well as ultimately turning information into useful and practical knowledge.

The interface between computers and humans will also migrate from the classical display-keyboad-mouse-and-gadgets-based setup to a set of tangible physical props, including high fidelity socially capable robots(1), inclusive projection surfaces and wireless sensors that make BCI and subliminal feedback readily available to the computer systems in a ubiquitous and wireless manner. Therefore bridging the gap and understanding the implications of this transition from the present virtual worlds to a mixed physical coexistence is of high importance to FET research. It will partly transform ICT as we know it today and require a truly interdisciplinary approach, which will provide us with new scientific insights.

(1) The cost of socially capable robots with advanced facial animation and communication skill are expected to drop to \$5-\$10K within the next five years making them not much more expensive than a plasma TV. There are already full body animated models on the market place available today for as little as \$8K.

APPROACH

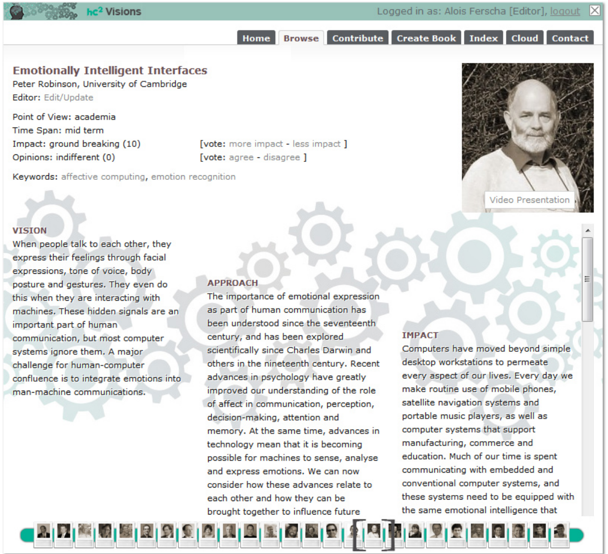
While the roots and seeds of the above outlined near term challenges partly exist today and integrated approach and the novel methodologies it will deliver will go 10-20 years beyond the state of the art. Specific ideas to pursue are as follows
— Development of novel devices: portable and wireless fMRI, 3D smart sensors to process and “translate” body-language for application control, non-contact BCI and biofeedback solutions, low-cost virtual locomotion and walking in-place solutions, subliminal interfaces, 3D 360º panoramic interfaces and projection solutions, advances in tactile/haptic feedback and smell.
— BCI Sensor fusion: There are many sources of subliminal and biological feedback that may be measured, however making sense of them for control and a directed,

convergent processes remains a challenge.
— Subtle Crowd-interface: The technology and art of architectural, interior and holographic video projections will penetrate public buildings and eventually people's homes and thereby shift from the screen-based and focused interaction model into an implicit interaction space, where the subtle actions of multiple people, even a crowd together influence the behavior of the system and what is being presented. Measures derived from the crowd's activity to influence a display process and control mechanisms that help achieve goals as a community are needed.
— From Knowledge to Skills and Abilities: Shifting ICT's focus from providing information and knowledge while at best stirring emotions via multi-media to a toolset that helps end-users to discover new skills and abilities within and to help developing and enhancing them via virtual training. Methods to measure emotional intelligence.

IMPACT

The specific outcome of research supported in this area would bring a set of novel and marketable devices as well as control and interaction methodologies that may be used in many disciplines of science and technology. These tools will in turn enabling people to absorb knowledge faster and learn more efficiently, provide competitive advantage to individuals and societies alike, and consequently speeding up overall technological development. Within the 10-20 years timeframe the computer interface as we know it will disappear emphasizing implicit and subliminal aspects.

HCC Visions on the web



All the research statements presented here are available online at **http://www.hcsquared.eu/visions/**

The HCC Research Roadmap is a "living document": Apart from the physical, printed release, it also exists in the digital realm. There it can continue to expand its body of contributions also in the future via submissions to the web portal, and generating the corresponding new printed release instantly - with a single click at “Create Book”.

The key features and services of the portal were motivated by the following principles:

— Ease of use: The solicitation process was expected to highly depend on the supportive will of the community. Therefore the portal was designed to be enjoyable, and to offer functionality at high levels of user convenience.

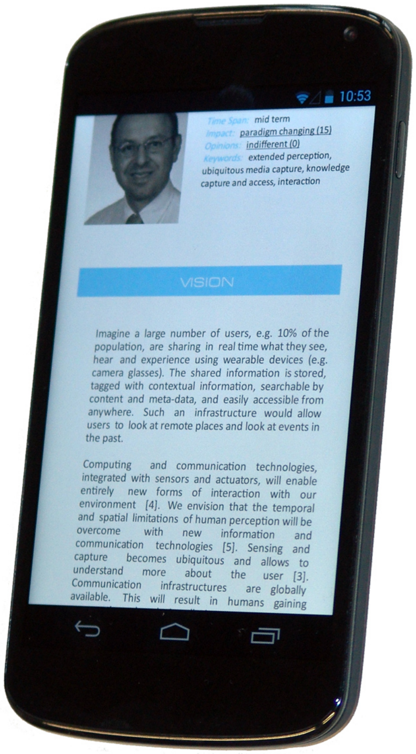
— Supporting the review and consolidation process: The portal enables the community not only to author mission statements, but also to provide feedback on others. This can be done verbally, by composing comments, similar to a classic forum, or by voting on the two properties "impact" and "opinion score". If several users give a positive vote to the opinion property of a statement, this indicates topicality and attraction, on the other hand, if many negative votes cumulate, a rework might be in order. The impact property is initialized with an assessment by the author (e.g. "challenging" or "ground breaking") and may change due to votes by others.

— Visualise semantic relations: We require authors to specify keywords, an importance assessment and a hint of the time frame the proposed statement would challenge research (e.g. short term, long term). Keywords are clustered by the power of their connections among each other and emphasized in relation to the number of mentions.

— Generate a printable book (PDF): To strengthen the association between the online articles with the printed version of the Research Agenda Book, it is always possible to download a PDF containing all the current articles in a printer-friendly format. A smart versioning system helps to tell if your book version is still up to date.

HCC Visions on the go

Already we live in a world dominated by smartphones and tablets. In particular for people travelling from one meeting to the next conference, this brings certain advantages with it, for example the possibility to bring a ton of books with you. We already support these devices quite well, simply by publishing a PDF version of this book along with the print version. By now PDF is a format universally known on all handhelds. However, this still removes a large portion of the interactive possibilities the web version has to offer. While it is possible to use the web version on a handheld, it is genuinely awkward, since it was specifically designed for personal computers and a fixed screen size. So we finally came up with yet another method to access the HCC Visions statements:



The HCC Visions Android App

For all Android handheld devices we offer a convenient reader application for the research statements. Apart from the obvious possibility to browse through the research statements, we provide several additional services:

— Offline reading: Data is updated online when possible and cached on the device. This allows you to continue reading when a network connection is no longer available, e.g. on a plane.

— Voting: As in the web version of the HCC Vision book, you can vote on the impact of a topic or how much you agree with a statement. Your voting will be instantly reflected in the attributes of the statement (impact and opinions).

— Dynamic scale: Handheld devices come in all kinds of shapes, sizes, and screen resolutions. The HCC Visions App is able to adapt to any screen size and orientation.

Author Index

Keyword Index

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