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Pervasive Socio-Technical Fabric

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Abstract

In 2011, now 20 years after M. Weiser's "The Computer for the 21st Century" (1991), the vision impacting the evolution of Pervasive Computing is still the claim for an intuitive, unobtrusive and distraction free interaction with omnipresent, technology-rich environments. In an attempt of bringing interaction "back to the real world" after an era of keyboard and screen interaction (Personal computing), computers are being understood as secondary artefacts, embedded and operating in the background, whereas the set of all physical objects present in the environment are understood as the primary artefacts, the "interface". Over it's more than two decades of evolution, the field has been undergoing three generations of research challenges fertilizing Pervasive Computing: The first generation aiming towards autonomic systems and their adaptation was driven by the availability of technology to connect literally everything to everything (Connectedness, 1991-2005). The second generation inherited from the upcoming context recognition and knowledge processing technologies (Awareness, 2000-2007), e.g. context-awareness, self-awareness, resource-awareness, etc. Finally, a third generation, building upon connectedness and awareness, attempts to exploit the (ontological) semantics of Pervasive Computing systems, services and interactions (i.e. giving meaning to situations and actions, and "intelligence" to systems) (Smartness, 2004-). While Pervasive Computing research has its success in the first, partly also in the second generation, the third generation is evolving as we speak.

The FP7 FET proactive project PANORAMA (FET proactive / Goal 8.3: Pervasive Adaptation) picked up on the challenge of identifying the new trails of Pervasive Computing research, involving some 240 of the most distinguished researchers in the field in a solicitation process that lasted for about three years. The result of this process is manifested in the Pervasive Adaptation Research Agenda Book (www.perada.eu/research-agenda), which is presented in this article and the respective fett11 session.

Keywords: Pervasive/Ubiquitous Computing; Socio-Technical Systems; Collective Adaptive Systems; Human Computer Interaction

1. The Evolution of Pervasive Computing Research

Quoting from Weiser's (1991) vision "The most profound technologies are those that disappear. They weave themselves into the fabric of every day life, until they are indistinguishable from it" [1] conveys the most common unerstanding of the origins of a computer science research branch today known as Pervasive and Ubiquitous Computing.

Preliminarily suffering from a plethora of unspecific, competitive terms like "Ubiquitous Computing", "Calm Computing", "Hidden or Invisible Computing", "Ambient Intelligence", "Sentient Computing", "Post-Personal Computing", "Universal Computing", "Autonomous Computing", "Everyday Computing", etc., the research field has over the past years consolidated and codified it's scientific concerns in technical journals, conferences, workshops and textbooks (e.g. the Journals on Personal and Ubiquitous Computing (Springer Verlag), Pervasive and Mobile Computing (Elsevier), IEEE Pervasive, IEEE Internet Computing, Int. Journal of Pervasive Computing and Communications (Emerald), or the annual conferences PERVASIVE (International Conference on Pervasive Computing), UBICOMP (International Conference on Ubiquitous Computing), MobiHoc (ACM International Symposium on Mobile Ad Hoc Networking and Computing), PerComp (IEEE Conference on Pervasive Computing and Communications), ISWC (International Symposium on Wearable Computing), IWSAC (International Workshop on Smart Appliances and Wearable Computing), MOBIQUITOUS (Conference on Mobile and Ubiquitous Systems), WMCSA (IEEE Workshop on Mobile Computing Systems and Applications), AmI (European Conference on Ambient Intelligence), etc. - These are only a few indicators for todays Pervasive Computing manifest, with a continued growth in the number of related research conferences all over the world. This process of consolidation is by far not settled today, and the focal question that raises after two decades of Pervasive Computing concerns it's future research challenges and roadmap.

Weiser's seminal vision was pathbreaking, and still represents the corner stone for what might be referred to as a first generation of Pervasive Computing research, aiming towards embedded, hidden, invisible and autonomic ICT systems. This **first generation** definitely gained from the technological progress momentum, and was driven by the upcoming availability of technology to connect literally everything to everything (**Connectedness,** 1991-2005). **Networks of 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 the ICT in this generation.

The **second generation** of autonomic ICT inherited from the then upcoming context recognition and knowledge processing technologies (**Awareness,** 2000-2007), where research issues like e.g. context and situation awareness, self-awareness, future-awareness or resource-awareness reframed the understanding of pervasive computing. Autonomy 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 and fertilized by the PhD work of Anind Dey [2], introducing the term "context": "*…is 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, and 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 behaviour grounded on "knowledge based" monitoring, analysing, planning and executing were proposed, shaping **ecologies of 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 autonomic ICT is approaching, 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 Artefacts" (FP7 FET). 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*." [3]. Ensembles of digital artefacts as compounds of huge numbers of possibly heterogeneous entities constitute a future generation ICT to which we refer to as **Socio-Technical Fabric** (2008-), 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. The respective research directions are thus more heading towards complex socio-technical systems, rather than focused along a single user or groups of users in the two previous generations.

The Session "Pervasive Socio-Technical Fabric" delivered within fet11 reflected on the evolution of Pervasive Computing research generations, starting with the challenge of the "Disappearing Computer" Initiative of the FP5 funding program of the EC at the beginning of the century (Speaker: Dr. Dr. Norbert Streitz, Head of the FP5 FETproactive "Disappearing Computer" Initiative, Pioneer in Generation 1 – Connected). Awareness and context related research themes, together with the upcoming interaction design space challenge were summarized and highlighted (Speaker: Prof. Albrecht Schmidt, Univ. of Stuttgart, Pioneer in Generation 2 – Aware), and an outlook into research challenges and methodology going for creating "systems with meaning", by that going way beyond lab based prototypes towards systems for the general public was given (Speaker: Prof. Nigel Davies, Editor in Chief, IEEE Pervasive Computing, CS at Lancaster University, Pioneer in Generation 3 – Meaning). The recorded Session with all the presentation material can be watched at [5].

2. The Next Generation Pervasive Computing Research Agenda

Within the FET (Future Emerging Technologies) work programme discussion on new directions for ICTs in FP7 of the European Commission, the question after the next generation Pervasive Computing research challenges has gained momentum. Specifically, the FP7 FET proactive project PANORAMA (Pervasive Adaptation Network for the Organisation of the Research Agenda and the Management of Activities, FP7 ICT Call-2, FET proactive / Goal 8.3: Pervasive Adaptation) picked up on the challenge of identifying the new trails of Pervasive Computing research. To this end, a structured "Research Roadmap" solicitation process involving some 240 top researchers in the field has been conducted over the past three years. The result of this process is manifested in the Pervasive Adaptation Research Agenda Book (www.perada.eu/research-agenda). In the frame of a special session "Pervasive Socio-Technical Fabric" at FET 2011 (The European Future Technologies Conference and Exhibition, 4-6 May 2011 Budapest, Hungary), the Research Agenda Book [4] was presented to a broad audience, and discussed and quality

controlled by invited, renowned research pioneers. The Research Agenda Book, while being created in a participatory style by the scientific community itself (note the authorship acronym: Th. Sc. Community) via the Pervasive Adaptation Research Agenda Book Web Contribution Portal (seamlessly integrated in the community platform www.perada.eu/research-agenda), also an automated generation of a print version of the book is permanently available as a versioned PDF download.

By June 2011, the Research Agenda Book Contribution Portal has collected about a hundred research challenges articulated by leading experts in the field - on a personal invitation basis, and discussed by the community via the web portal. The book is structured into collections of contributions along the chapters: (i) Autonomous Adaptation, (ii) Adaptive Pervasive Ensembles, (iii) Emergence and Evolvability, (iv) Societies of Artefacts, (v) Dependable Pervasive Systems, (vi) Pervasive Trust, (vii) Human-Centric Adaptation, (viii) Socio-Technical Systems and (ix) Quality of Life. Some selected, yet indicative voices raised by the scientific community towards the next generation research challenges are:

Intelligibility *"One particular usability aspect of interest is **intelligibility**, helping users to form an accurate mental model about how to use an application. This is important for allowing users to understand how the application works and to be able to predict what it will do in a future situation, and all of this will impact adoption and use."* (Anind K. Dey)

Social and Cultural Knowledge *"Advanced data analysis tools will allow spotting trends, observing their movement, their causes, and triggers. This platform, will allow researchers to … **explore social** and **cultural knowledge**. What do people **believe**? And how people **act**."* (Adrian D. Cheok)

Uncertainty *"Context-awareness is woefully limited in our computing devices and they rarely do the "right thing" or what we would prefer. We need to be able to teach them **how we want them** to work for us… What we need are the ability to tell if a user is interruptable, what information they likely to need next, what work/play they might be engaged in, and who might be engaged in it with them … **our models will never cover all possible activities in which humans may engage**."* (Gaetano Boriello)

Thinking *"Building on recent fMRI discoveries of common spatial patterns among subjects when thinking of the same word, there are numerous projects processing brain signals in an attempt to understand **what people** are **thinking**."* (Daniel P. Siewiorek)

Cognitive Adaptation *"One of the next grand challenges for adaptive pervasive computing will be to make devices that truly **understand** our **mental** and **emotional situation** and try to accommodate us."* (Jennifer Healey)

Social Values *"**Respect** for peoples' ability to judge for themselves and be assisted by machines where needed. Respect for peoples' desire for freedom of choice and be supported by automation and decision support where appropriate. And respect for fundamental human rights, such as privacy, security and safety. A key research area is thus how to build respect for **humans' social values** into the fabric of machines, to deepen our understanding of 'value sensitive design'."* (Sarah Spiekermann)

Energy Awareness *"… an important issue that will have great impact on how pervasive clouds will become is that of energy consumption. The development of **energy-conscious** and **power-aware** resource allocation protocols for cloud computing systems will open up more opportunities for the deployment of more pervasive technologies…"* (Albert Zomaya)

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References and Online Presence

[1] Weiser, M. The Computer for the 21st Century. Scientific American. September, 1991, 94-104.

[2] Dey, A. K. Understanding and Using Context. Personal and Ubiquitous Computing 2001. Vol. 5, No 1, 4-7.

[3] Castellani B, Hafferty FW. Sociology and complexity science: A new field of science. New York, NY: Springer; 2009.

[4] Community, Th. Sc. Pervasive Adaptation. The Next Gerneration Pervasive Computing Research Agenda. Institut for Pervasive Computing, University of Linz, *ISBN 978-3-200-02270-6*, 2011.

[5] Online Presence: www.pervasive.jku.at/fet11.