Interactivism at Work

Toward design heuristics for Ambient Intelligence

Extended abstract

Mikkel Holm Sørensen
IT University of Copenhagen
megel@itu.dk

This paper presents the promising perspectives in applying interactivist design heuristics on issues of development and organization in bio-mimetic Ambient Intelligence systems. Preliminary design principles for bio-mimetic AmbI are sketched on the basis of a general outline of the interactivist framework for adaptive systems.

Dynamic IT: Ambient Intelligence

Designing IT is facing more challenges than ever. The increasingly pervasive and complex IT systems risk loosing their overall value if not designed more robustly and autonomous. In addition the IT colonization of most everyday practices requires a more adaptive assistance from the technology if the proliferation of IT is to be rendered meaningful.

The challenges have been widely acknowledged within the IT research community and different disciplines call for a change of design strategy. Some point to the looming labor consuming maintenance of vast pervasive IT systems (Ganek, A. G. and Corbi, T. A 2003, Norman, D. A. et al. 2003) likely to dominate in the near future. Others to the need for IT that supports increasingly dynamic user practices (De-Bruijn and Stathis 2003, Ducatel, K. et al. 2001, Harris and Henderson 2000, Kaasgaard forthcoming, Rheingold 2002).

To meet both 'internal' (infrastructural and organizational) and 'external' (functional) challenges for improvements, IT has to be bestowed with adaptive capabilities – normally referred to as intelligent technology. Together with the growing embeddedness of IT into more parts of daily life this new technology is best captured as Ambient Intelligence (AmbI).[1]

The only plausible way to develop AmbI seems to involve the investigating phenomena characterized by intelligence, i.e. natural adaptive systems. The paper argues for a bio-mimetic design heuristic for AmbI, with a specific focus on organizational and developmental issues. Interactivism provides powerful tools for such AmbI design combining optimized infrastructural organization and improved functionality. Primarily by explaining how more adaptive assistance in AmbI would rise in concert with infrastructural and functional self-organizational capacities.

Bio-mimetic design heuristics

There are several reasons why a general bio-inspired tendency is growing within IT-research and it is worth taking a brief look at bio-mimetics.

Strictly speaking 'bio-mimetic design' seems somewhat incoherent, since design is normally conceived as a deliberate teleological practice whereas life is governed by inherently blind post hoc process. Besides the prime principle applied – variation and selection dynamics[2] – are not exclusively biological but an ubiquitous ordering

[1] AmbI denotes the interesting aspects by future IT: 1) In opposition to Pervasive or Ubiquitous Computing AmbI focuses on proper functionality – intelligent assistance – and not some means to obtain it, and denotes the highly distributed nature of IT. 2) 'Ambient' indicates the right sort of 'non-intruding but present at hand' assistance aimed for, captured under the slogan 'If there's to be computers everywhere they'd better get out of the way'. 3) 'Intelligence' not only denotes the behavior but the intrinsic characteristics of adaptive systems, i.e. their structural and functional development and organization.

[2] I refrain from using 'evolution' since this notion is (minimally) defined by 'heritability' besides variation and selection and the status of heritability in technology is an issue of controversy.

principle in self-organizing systems (Bickhard and Campbell in press, Gatherer 1999).

However the bio-mimetic heuristic suggested here is to enhance human designing capabilities with spontaneous development dynamics found in complex systems, because these mechanisms are fast, reliable and automatic. Bio-mimetics is a hybrid approach combining (human) global design norms with evolutionary self-organizing capabilities. The variant of bio-mimetics relevant for AmbI design does not concern specific materials or structures but adaptive processes. Bio-mimetics provides design heuristics not specific designs.

A looming issue for future technology is the development of-maintaining and self-repairing of IT systems. Nature is the only domain for adaptive dynamics we know of and since we already have got sciences - traditionally biology but also newer trans-disciplinary fields such as dynamic and complex systems theory - concerned with the organization of complex systems it is instructive to look to some of the models from these fields for inspiration.

Interactivism uses the same toolbox to describe the dynamics of both global complex systems and their constituents. Thus interactivism provides means for designing systems with great scaling and nesting capacities. Designing AmbI depend critically on an understanding of interaction on different levels (internal dynamics in devices over device-user interactions to the organization of whole networking societies). AmbI has to be designed to facilitate the rapidly changing practices and mobile, long-distance and trans-media interaction which increasingly characterizes use of IT.[3]

Self-organization in complex systems: An interactivist approach[4]

The self-maintaining robustness and developmental capabilities inherent in adaptive systems, stems from the structural and functional self-organization of the systems. Self-organization emerges from the interaction of system constituent guided by on-board functional norms. Norms rise in self-organizing open due to their thermodynamically non-equilibrium organization and dependence on a controlled input of energy, material and information to maintain functional coherence (autonomy). This openness creates a bias; some environmental features facilitate self-maintaining interaction others do not. Outcomes of interactions – success or failure – give rise to construction of internal cues for subsequent actions.

Adaptive complex systems have different means to adapt, facilitated by both short and long term dynamics. In short the term, systems adapt by learning. Learning is a process towards improving the anticipatory capabilities of the system, i.e. constructing better anticipations for possible outcomes of interactions. Anticipations are contextual and implicit at the lowest cognitive levels and in the beginning of growth in higher level systems, but become increasingly generic and universal as you ascend the hierarchy of intelligence or in the growth of higher level systems.

Adaptive systems do also (as species) adapt by procreative means. In reproduction, combinatorial (sexual) or/and reconfigurable (mutational) possibilities for adaptation rise which provide more radical changes. This is an advantage if the niche has changed drastically or just to explore other space in the fitness-landscape.

Both short and long term adaptation rest on the same ordering principle namely variation and selection cycles. This principle is mostly known in phylogenic processes, but it is also the driving force in ongoing interactive trial and error cycles in ontogenetic processes. Actually variation and selection cycles are the ordering principle of self-organizing processes tout court (Bickhard and Campbell in press).

AmbI: Interactivist architectural principles

According to interactivist design principles AmbI should be ecologically organized and constituted by heterogeneous devices (both applications and hardware devices) striving for self-maintenance by interacting with users and other devices in their functional domains. AmbI devices carries onboard value systems which relates to their functional coherence.[5] The overall

[3] See Bentley (1999) and Sørensen (2003b) for more motivations for deploying bio-mimetics.

[4] The interactivist approach I will use is in resonance with e.g. Bickhard 2001a, 2001b, Bickhard and Campbell in press, Bickhard and Richie 1983, Bickhard and Terveen 1995, Christensen and Bickhard 2002, Christensen and Hooker 2000a, 2000b, in press.

[5] Devices are organized in two levels: One relates to access to eternal computing support, ac-

fitness criteria for AmbI devices is to obtain positive feedback through interacting with their functional domain. Primarily with users but also other devices. Feedback equals time used but can also be modeled more specifically. Use is thus the prime resource for devices. Devices will gradually exploit mutual supportive or even symbiotic organizational dynamics to honor on-board functional norms.

Since artifacts are not thermodynamic non-equilibrium systems,[6] value constraints will not emerge autonomously but will have to be imposed as fitness-functions. Promising work in evolutionary robotics (e.g. Floreano & Mondada 1998) suggests that fitness functions on a simple "dynamically stable" neuronal-like architecture tend to give very good overall adaptation. In experiments with evolving control mechanisms for robots, simple fitness criteria used to evaluate the performance of strengths in the neural network gave rise to light-seeking behavior not specified by the fitness criteria. The robots constructed 'associations' of contingencies related to recharging when parked under a light source in a charging zone and obtaining positive feedback when outside the charging zone. Over generations the robots improved the behavior enabling them to reach the charging zone within a couple of time steps before total discharge and leaving the zone again immediately after recharging to maximize feedback.

Much of the success was due to the dynamic stability architecture of the robots which resembles an 'open' organization of non-equilibrium systems. Such architectures support learning as well as routine processes dynamically. The results are in agreement with the interactivist view on the autonomous development of functional norms and a sensitivity for contingencies relevant for self-maintenance in adaptive open systems.

Adaptive dynamics will mainly be provided by evolutionary computing methods. Since reliable and smooth functionality is critical, variation must facilitate developmental dynamics by mutations that are within an acceptable frame of deviance. Dysfunctional mutations are mostly unacceptable, (except in certain 'training' contexts). On the other hand variation is an important part of the adaptive dynamics and ways to strike the right balance has to be worked out.

The interactivist model provides a tool for designing open-ended but constrained variation by way of functional 'themes' (e.g. Bickhard and Richie 1983). Themes are aspects (not components) of interactions which together form relevant functionalities in given contexts. Trials happen within frames of creative but relevant outcomes dynamically determined by functional themes created by previous interactions. The dynamic stable architecture mentioned above could provide the right kind of 'deep' dynamic architecture required to achieve theme-like organization of interaction.

The artificiality of devices provides the opportunity to enhanced evolution by non-natural features. To speed up evolution and to maintain a low error tolerance for the sake of reliable functionality, 'thematic' learning functions (heuristics) could also be applied on selections at the evolutionary level as well, excluding mutations that showed lethal or dysfunctional beforehand.

Another non-natural mechanism which promote fast adaptation is to apply horizontal inheritability. Such double dimensional inheriting will promote a fast proliferation of successful traits across similar functional domains.

Selection frequencies will differ for different kinds of devices, such that micro- or swarm-based services (e.g. communication 'scouts' handling access and optimal bandwidth) will have a shorter lifespan than macro-services (e.g. OS's). Roughly lifespan are proportional to length of 'genom' and infra-structural complexity.

Services will be nested such that e.g. an OS acts as functional domain for simpler micro-services, struggling to enter a symbiotic cooperation with the OS. Users will act as functional domains for certain AmbI services and they will therefore stick to this (type of) user perfecting a tight adaptivity while others will inhabit more generic niches. This division of labor provides an extremely dynamic technology filling out every functional niche on the fly. The tight functional coupling between users and devices will be obtained through recursive variation and selection cycles providing adaptation and optimized assistance.

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cessible bandwidth, power supply and hardware error (lower level) and an upper level governed by learning mechanisms which provides most services and monitors the device.

[6] All though they most likely will depend on electricity, they will not disintegrate by lack of energy. Besides the process is reversible so that 'dead' cell phones can be recharged.

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