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FCJ–135 Feral Computing: From Ubiquitous Calculation to Wild Interactions

Matthew Fuller and Sónia Matos
Centre for Cultural Studies, Goldsmiths, University of London

Introduction

In ‘The Coming Age of Calm Technology’, Mark Weiser and John Seely Brown are clear in their assertions. What really ‘matters’ about technology is not technology in itself but rather its capacity to continuously recreate our relationship with the world at large (Brown and Weiser, 1996). Even though they promote such an idea under the banner of ‘calm technology’, what is central to their thesis is the mutational capacities brought into the world by the spillage of computation out from its customary boxes. What their work tends to occlude is that in setting the sinking of technology almost imperceptibly, but deeply into the ‘everyday’ as a target for ubiquitous computing, other possibilities are masked, for instance those of the greater hackability or interrogability of such technologies. Our contention is that making ubicomp seamless (MacColl et al, 2002) tends to obfuscate the potential of computation in reworking computational subjects, and thus societies, modes of life, and inter-relations with the dynamics of thought and the composition of experience and understanding.

Even though we might recognize this inherent demand in the bifurcation of ‘calm’ technology into the new feral logics, ubicomp’s reliance on the development of artificial intelligence – through techniques of identification, naming, tracking, sorting, monitoring and responding – has been precipitated, though if not always inspired by, a research agenda inherited from military programs inaugurated during World War II onwards (Heims, 1980; Agre 1997). This same 'military' heritage continues to define much of the research agendas of significant academic and industrial institutions, directly influencing their epistemological orientations. Doing 'calm' requires then an overemphasis on the machine, keeping the deployed human component stable and unexcited and focusing essentially on the development of artificial intelligence frameworks that in turn calmly interpret and act on the calmed user. Such an approach can be seen to operate in opposition to a deeper understanding of human-computer symbiosis, one that may even step out of this dyad to engage with a wider understanding of systems and ecologies. What is crucial to recognize here is that this agenda, infatuated with an ontological positivism simple enough to teach a machine, establishes distinct conceptions of ubiquity that ramify into computational technology, human action and cognition and the environments in which these occur. As it stands, many of the problems experienced by ubiquitous computing as a progressive research program can be found in the reliance on such an ontology and its apparently stable concatenations of misidentification and mismatched response, delimitating the potential of new logics into simplified models of calculation.

Despite its partial 'military' heritage, ubiquity is effectively bifurcating from this calculative approach, challenging much of the practice of computer programming and other layers of the ordering of computers. This is now diversified by: networks, embedded systems, new graphical user interfaces, the World Wide Web and wireless devices, networks of sensor-actuators, and the multi-form variations introduced to computing by its deep embedding in the social technical, biological, aesthetic and political dimensions of life. This renewed context has, particularly within the field of computer science, shifted from a view of 'computation as calculation' to one of 'computation as interaction' (Stein, 1999; Wegner, 1996; Murtaugh, 2008). It has deviated from the core of its first-order programming philosophy, from computation as 'number crunching' to an object based and distributed approach (Wegner, 1996; Gouldin and Wegner, 2003). The growth of computation into a new feral state has also affected the ways in which user relations with the new artifactual ecologies can be understood, extending previous research frames. Here, the emphasis on the ideal of 'computation as calculation' has not only affected the field of computer science, it has also influenced the field of cognitive science (Dupuy 2000) and those concerned with computation as metaphor, instrument, field or infrastructure.

Once again, ubiquitous computing and its propensity for distribution as part of environments, opening new space for variable kinds of users and contexts, has shifted the idea of cognition as analogous to the workings of computational devices to an idea of cognition as situated, embedded and distributed. This idea has much in parallel with the field that Heinz von Foerster and others named 'second-order cybernetics' (Poerkson and von Foerster, 2002). Indeed, amongst other contexts, this field has a lasting influence, or even undergoes a revival in some of today's laboratories of computational design, one example being in the development of robotics (Bishop and Nasuto, 2005). One of the main goals of second-order cybernetics was the attempt to study complex systems, including humans and machines, under a new light. It attended in particular to the way in which they formed patterns of reflexivity, gained a recursive sense of self and of the wider processes in which that self co-composed. Crucially, they also emphasized the study of systems that are analytically indecomposable, such as memory, or which grow as part of a 'conversation' (Pask, 1976), or other form of structural coupling (Maturana and Varela, 1998), making the neat distinction between subject and object, observer and the observed, simply a neat, but disabling perceptual gimmick.

One of the founders of the cybernetic movement, Norbert Wiener, posed the need to interlink the new worlds of 'automata' with distinct social interests and concerns, where the 'decentralization of authority should accompany the decentralization of computation'. This project would soon be obfuscated by scientists such as John von Neumann, whose vision of their use tended to relegate computational power exclusively to the interests of the 'military and industrial establishments'. This limitation inaugurated at the same time cybernetics' disengagement from domains – unfortunately – characterized as 'humanist', finally closing the computer into itself (Eglash 2000). As a consequence, the inherited 'military' agenda has contributed to the divide between cultural approaches to technology and the means for a technical imaginary and those that characterize themselves as 'scientific'. Today, an expansion of the scope of interdisciplinary approaches within the distinct domains that study human-computer interaction and computing cultures more widely is moving towards a reversal of this 'trend'. Here, ubiquitous computing has played a decisive role. Its propensity for distribution throughout the environment has opened space for a new range of contexts, users and artifacts, raising new complex questions that extend beyond the premise of perfecting artificial intelligence. What once was the concern of an engineering driven discipline is now delivered to a wider field of intelligences and skills beyond any discipline.

Interaction, the Extension of Computation beyond Calculation

Both the fact and ideation of ubiquitous computing and its characteristic embeddedness has driven the need for an exploration of new human-computer relations, shifting, in one description, the research *motto* from 'proactive computing' to 'proactive people' (Rogers et al., 2006). The shift arises not only from a new conception of human/machine symbiosis – of the sort originally theorized and supported by Licklider (1960), towards mutual proactivity – but also from a challenge from within the field of computer science itself. Essentially, this shift has been accompanied by a transformation of the understanding of what computation is and how it might be done, dislodging a model in which computation is seen as a series of fixed functions that are outlined to achieve a certain specified goal. Computation as something 'centralized, sequential and result-oriented' and primarily focused on the execution of calculation, moves tentatively or eagerly, but perhaps inexorably, towards an understanding of 'computation as interaction' (Stein, 1999: 1). Here, dynamic relations become key. A computation does not simply equal the achievement of a result, measured by an ever increasing metric of acceleration towards that result, but tends towards a collaboration with the user or other elements in a wider ecology, understood through a connective multiplication of the capacities of each entity in the computational composition.

Where the 'calculative' approach has persisted – in the disavowal of computational artifacts beyond their formal description as variations upon calculus – this has tended to make difficult or even prevent the recognition of any external influence, or of the multi-layeredness of computational situations. Concerning the embeddedness of computational gadgets throughout the environment, it has particularly influenced the ways in which certain dogmatic computational frames have pushed forward a 'result-oriented' rather than 'process-oriented' programming styles (Stein, 1999). Such imperatives have often dissuaded engaged professionals from elaborating any form of 'computer criticism' that could provide a richer frame for understanding computational artifacts and their contexts (Papert, 1990). At the core of such reluctance sits the bulk of our conceptions concerning the practice of programming, ideas that are embedded in strong cultural formations of thought and rationality. An example that throws light on both epistemological styles and their consequences for computation, the Logo programming environment for children – a pioneering project of its kind – was built upon the recognition that many computational environments, for the purpose of education still preserve canonical dogmas, such as the fixation on outcome or result achieved by predetermined means. On the contrary, the Logo environment has shown that many children favor a style that contradicts the formal canonical one identified with planning and reasoning, opting for a more 'intuitive' mode; both are conceptually valid (Papert, 1990). The example of Logo is problematic in the sense of its limited domain of actual use, but the way in which it opened the possibility for different programming idioms to come to fruition and to be recognized as being idiomatic, with different perspectival weightings and affordances, is significant. Today, different programming methodologies, scripting environments, frameworks, and the increasing sense of coding and computation as part of popular cultures and interesting subcultures open computation to a multiplication of conceptual and idiomatic registers (Mackenzie, 2006).

In fact, such conceptions of programming based on ratiocination have a long history in the development of the computational field itself. These find their philosophical legacy in a historic battle between rationalists and empiricists. Descartes' figuration of reasoning as the base of existence was followed by Kant's denial of the contingency of true knowledge, and in turn by those contemporaries who, in their most useful formulations, find the rational folded into and entangled with the aleatory, intuitive and experiential in ways that defy the capacities of expectation of either model. Still, much of modern Western science has been influenced by rationalist mathematical modes of thought, these even more intensified by the successes of technological development, the faith on the dependency of such rationality, and a corresponding ability to recognize a world which is increasingly reformatted into rationality's own image.

The history of Western thought, however, is also a history of successive collapses of total formalizations (Kline, 1980). Kurt Gödel's 'incompleteness theorem' that exposed the fissiparous faultiness of rationalism when turned upon itself is only an example, but a crucial one in the history of computing. The thesis opened the way for a new epistemological agenda where the idea of incompleteness would prevail, a decisive element in bringing the paradigm of interaction to centre stage for the development of computing. Alan Turing famously took up Gödel's 'incompleteness theorem' and in 1936 published a paper 'On Computable Numbers with an application to the *Entscheidungsproblem*', showing that 'mathematics could not be completely modeled by computers' (Goldin and Wegner, 2003: 1). However, whilst acknowledging its foundation in the tracing of limits to computability, the Turing machine was adopted by computer scientists at large, providing a seductive model with which to address problems. Computer science took the transformation of 'inputs into outputs' as a defining characteristic of computation, a transformative process already known to the mathematical field and best described by formal algorithmic operations (Goldin and Wegner, 2003: 1).

Approaching the 1990's, computer science faced new challenges. With a new logic of ubiquity, from the World Wide Web to wireless devices, phones and other more cranky assemblages, new questions appeared. Logical-axiomatic transformations (as understood through the 'inputs into outputs' of the Turing machine) as the sole answer to computational problems (those problems to which computing was addressed and distinct therefore from 'computable' ones) would no longer suffice. By that time, many already felt the need to extend computation into new paradigms, as the novelty of machinic formations evolving out into diverse ecological conjunctions allowed the exploration of, for instance, physical effects rather than solely logical ones. Today, one result of this is the development of 'interactive-identity machines', simple transducers characterized by non-algorithmic behavior that use the computing power available in the surrounding environment, substituting mathematical reasoning with empirical development (Wegner 1996). Here, the new 'interactive' paradigm appeared as most attractive, not only since it best explicated possible relations with 'real' environments that could not be completely predetermined by a list of configured inputs, but also because it provided the best extension for the already achieved capabilities of the Turing machine. The twist being that the 'incompleteness' now supplied by the interacting environment is a feature that is not under the machine's control, or not integral to its axiomatic nature, but generated out of its points of (intensive and extensive) conjunction with the world.

The new interactive ecologies could not rely on formal computable algorithms. These engaged in a constant switching back and forth, between the figure and ground of computation in the machine, and in the potential for computability within the environment. There was an increasing demand for developing new dynamical models (Stein, 1997) to new interactive algorithms (Mackenzie, 2009), extending to 'computation beyond calculation'. Most important, 'interactive computing' allowed the necessary resistance to the canonical style, rejecting computer science's legacy, finally leaving space for a new epistemological orientation. Of course, it is not that suddenly a computer becomes something more than a technically describable object, rather, computers were turned inside out. Their processes and affiliations routed themselves through non-computable processes producing new *moiré* patterns of resonance, interaction, and interference.

The Interactive Paradigm, a Cybernetic Revival

We can also trace the origins of interactive approaches to the 'Macy conferences' held between 1946 and 1953, in New York, when a group of researchers met with the goal of discussing 'Circular Causal and Feedback Mechanisms in Biological and Social Systems'. Here, the term cybernetics was taken on, following the title of mathematician Norbert Wiener's (1948) book on control and communication (Eglash, 2000). Two of the interdisciplinary researchers present, mathematician Norbert Wiener and neurophysiologist Warren McCulloch inaugurated what later became characterized as the 'first-order' cybernetic movement. The research *motto*: the idea that the dynamic entities, which maintain certain kinds of consistency over time, such as the human nervous system, can be characterized by internal feedback processes that maintain constant stability.

Part of the research agenda of cybernetics was an emphasis on inter-disciplinary applicability through the creation of meta-categorical concepts, such as feedback, that crossed both living and non-living entities. Cybernetic approaches, based on powerful degrees of abstraction, were later applied to the development of new kinds of artificial intelligence, now framed by a connectionist approach that emphasized structures of simpler but interconnected neural units (Bishop and Nasuto, 2005) instead of intelligence deriving from one main central processor. This 'bottom up approach' was applied to both machinic computation and human cognition. Aspects of this approach are paralleled by what is often recalled as 'second-order cybernetics', epitomized in, but not limited to the work of physicist and philosopher Heinz von

Foerster and participants in the Biological Computing Lab at the University of Illinois. Second-order cybernetics is characterized by finding ways in which feedback loops travel outside of the boundaries of an entity, affecting its behavior in reflexive and non-determinable ways. Here, von Foerster introduces the idea of 'subjective dynamic construction' (Poerksen and von Foerster, 2002: 23) into the complex web of feedback loops within a given system. This abstract framework relocates the position of the observer or agent of a given system into its dynamics. If for first-order cybernetics the agent was decoupled, with second-order cybernetics this would no longer be possible. Such a position re-describes, with a different scale of reference, the relevance of situating computational artifacts as 'external scaffoldings' (Griffiths and Stotz, 2000), where agent and environment are no longer fully separated but mutually articulating.

In more recent times, there has been a growing interest in using von Foerster's ideas in the field of robotics. Key factors have been the importance of environmental situatedness and non-representational embodiment as the driving forces in the development of intelligent behavior. Additionally, 'second-order cybernetics' opened the door for what later would be called a 'dynamic systems theory of cognition' and the 'enactive theory of perception' (Bishop and Nasuto, 2005). For both, cognition is a highly interactive process where agent and environment have important and active roles. Building on, but also questioning, earlier theories of environmental perception, such as those of James J. Gibson (1977), which are well-known in design, a dynamic systems theory of cognition recognizes the importance not only of the relation between an agent and its environment, but also the 'state-space' that relates such entities and the permutations of actions that compose them. 'Enactive perception' recognizes the role of embodiment in the process of cognition. The agent only perceives to the extent its perceptual system enables it to do so. For both approaches, cognitive processes are determined by agent-environment coupling dynamics (Bishop and Nasuto, 2005). Reality is no longer an established edifice but rather subject – but not reducible – to an individual's interpretation. In the case of research performed within ubiquitous computing and its dependence on artifacts that track, monitor and respond to a set of human activities, the idea of agent-based reality puts in question, once again, the idea of a predetermined computational entity.

The transformation of computation from 'calculation' to 'interaction' also has a direct relation to the development of some of the main ideas developed by von Foerster, Gordon Pask, Gregory Bateson and others associated with second-order cybernetics. Turning intelligence inside-out, this model opposed the idea of simple internal representation, proposing instead one of external and distributed pragmatics working with affordances. Such conceptions have in turn influenced computation itself, recomposing the idea of programming as a bottom up process, a move that returns to influence ideas about intelligence. Instead of something being sited in the 'head' (Noë, 2004), it has an emergent quality depending on high levels of interaction. Again, there are strong levels of filiation. The 'bottom up model' was first developed by cyberneticians such as Wiener, based on 'corresponding' connectionist approaches to cognition. Second-order cybernetics challenged this view, by locating the agent in relation to the same system (Bishop and Nasuto, 2005). This further promotes a 'constructivist epistemology' where the observer, perspectively and enactively, constructs her own experience and cognition becomes a continuous dynamic process.

At this point, it needs to be acknowledged that a new conceptual approach to the materiality of the world is also devised. First, this provides a means of recognizing the position of both agent and environment in a complex dynamic ecology, where the extensions or limits of either are not clear-cut, or are rendered effectively meaningless. Second, it provides a means of abstraction in which behaviors and patterns that cross categorically distinct entities can be recognized. Finally, it was a form of thinking, based strongly in practice, which opened up hybrid insights into forms of life, providing a new methodological approach when researching the 'social' and the 'natural' (Eglash, 2000), or let's rather say, with apprehension of their inadequacy as terms, the 'natural' and the 'artifactual'. Concerning the design of computational artifacts, such an agenda presupposes the relative importance of both user and artifact, now appearing in the light of more tricky, multivalent relations. It also presupposes that the user is as much responsible, or at least implicated – in multiple, non-predictable ways – in the construction of their own artifactual ecology. Such a constructive process calls for an approach that places computation in a new light, reemphasizing the importance of a research agenda that marks the expansion of computation through distinct layers of interactivity. This entails a transformation, not only for computer science itself, but also in the conception of new computational artifacts and environments.

The implication of the user in the expanded computational environment is however not a story of simple unfolding opportunity. The history of cybernetics is both a history of systems of control and of a mode of understanding and synthesizing systems of recursive self-organization. A society of extended interaction is certainly being put into place, the computer is spread out into the world, computation is enfolding itself into all layers of life: but in many cases as systems of control. Writing from an island whose society puts more faith in surveillance cameras than in the citizens they watch we have no reason to welcome the spread, distributed, or open arms of control. Instead, we might usefully look towards coupling an understanding of interaction with a critical and inventive politics. As an applied science, cybernetics became in part, like early strains of HCI, a means of integrating humans with machine systems (Hables Grey 1995) or those of the poetry of management (Beer 1975). In the nineteen-eighties, one of the resulting figures, that of the cyborg, became subject of wry critical celebration, most famously in the work of Donna Haraway (1991). The current wave of re-engagement with cybernetics tends to emphasize not so much its application in systems of control (Holmes 2007) but its empirical work amongst epistemic questions with the production of experimental devices (Haque 2007).

From Cybernetics to Interactive Designs

Such epistemic questions have instigated the need to understand interactive technologies in their actual use, blurring the modern divide between the 'social, symbolic and subjective from the material, real, objective and factual' (Latour, 2008: 6) avoiding any absolute bifurcation of interaction between users and artifacts and the relations between them. This has been the true contribution of the field of participatory design, one that opened the field of computation, finally setting up the interactive paradigm to reach out into the 'situated, interpretive and messy' aspects of human nature (Harrison et al., 2007). Forms of participatory design have long questioned modernity's formalism and rationality as raised on the research edifices of WWII and beyond. It has questioned computer science's formal approach and the rational structuring of cognition by incorporating user and environment, cultural, economical and political contexts. In this sense, participatory design makes possible, if it does not always deliver, a 'third and hybrid space' (Muller, 2003: 2) between users and artifacts, inaugurating a dialogical plane for action. As in 'distributed cognition' (Hutchins 1999, 2000), both user and artifact come to play determining roles in the mix of effects and interactions, with the explicit recognition of the processes of thought in relation to design. For designers at large this is of substantial relevance, since new forms of computation are bound up with the encouragement of new forms of sustainability, development and experimentation. Such considerations are especially potent when we consider the contexts in which users and technologies are embedded, along with the variable kinds of access different users have today – to the panoply of computational artifacts, processes and services (Crang et al., 2006).

In this same context, it seems pertinent to attempt to consider innovation. Here, the ideal still ostensibly driving most technological research agendas is not so much innovation anymore. Instead, it is uses (Shapin, 2007) or even misuses. For this same reason, participatory design philosophy and methods have been taken on by some companies in the development of user-centered approaches to innovation (von Hippel, 2005). Its principles have been applied, in different interpretations, in a number of ways and sites ranging from the development of industrial artifacts to that of software. However, these are not without their problems. Improvements that only travel inwards to a company will soon make users rightly cynical. The world of marketing is not innocent of simulating 'demand' in order to generate it and interaction will inevitably face many kinds of shaping by interested parties and social and libidinal forces (Lyotard, 1993). Nevertheless, distributed innovation as it articulates the reflexive extension of interaction is a potent feral force that proliferates on the outskirts of policies and regulations, amongst distinct communities of users/designers. This same shift has provided a new distributed conception of innovation and knowledge, with a significant move to test and extend the ways in which Free Software derived development methodologies and principles might produce effects in other domains of production and use, such as non-executable data. For reasons such as this, we use the term 'interactive designer' as much as that of 'interaction designer'.

As a counterattack to this potent feral force, many new approaches to the development of regulations and copyright policies have tended to 'imprison' the same users by relegating full control to corporations or owners of 'intellectual property'. These regulations, and sometimes the closure of designed objects, tend to retard innovation by limiting the scales and kinds of access to technological and cultural artifacts and processes. The rise of new computational technologies tends however to set this back, essentially by providing information and innovation opportunities to communities that may extend beyond 'traditional' geographical or economic constraints. The affordability – often at the cost of abusive forms of production, of computational gadgets and the ease with which people start to manipulate them, and thus perhaps break out of the role of simple user – is opening some space for a new era of technological innovators. Indeed several researchers have suggested that a democratic approach to technological design might have the tendency towards increasing opportunities, or instigating new forms of economic development (von Hippel, 2005). Approaches to ubiquitous computing that develop significant modes of interaction will necessarily also meet with the question of the way in which data of all kinds moves about, whether it is shared, sold, wrapped in protective seals, or is treated as simply part of the wider ecology of materials.

Feral Computation and Design

It now seems pertinent to ask: what might design facilitate or enter into combination with in this process? Can design catalyze a process of material reshaping, further influencing those described above? First, we need to extend this venture and consider relations between designer, the artifact and systems it engages with (that now might appear in a planned or unplanned manner). This is perhaps even more relevant when seeking feral qualities in the hardware domain. Here we note the recent and widespread increase in interest in tinkering, making idiosyncratic technical objects, and the extension of this into a renewed perhaps quasi-popular engagement with electronics through platforms such as Arduino (see http://www.arduino.cc/) and others that provide a means of recognizing and working with a quite palpable hunger for a more difficult, unpredictable, customizable and intelligent inter-relationship with electronic design, often that more commonly found at the level of prototyping. Such moves provide not only interesting options for design curricula but also for those engaged in design beyond formal education, as useful information and experiences move in ways that build self-organizing practices. This in turn establishes possibilities for a new generation of designers, and more broadly of designing practices. By such means, as machinic platforms, knowledge and skills, coupled with modes of thinking that provoke ubiquitous curiosity rather than calmness, certain principles of hackability are extended to a wider range of users who in turn modify them. We can only envisage potential future uses when bits and pieces become more robust, or usefully weak enough to make interesting connections, and are globally widespread, opening paths for new modes of commodity distribution, hackability and self-production. Here, design is involved in a more complex web of experimental devising, moving beyond the provision of simplified solutions, engaging in the construction of a system that continuously reshapes the questions that were initially waiting to be answered.

The qualities of ferality can also be found in applications such as ‘Squirrel’. Designed by Shannon Spanhake, (of the California Institute for Telecommunications and Information Technology) this small device incorporates a battery, sensor chip, Bluetooth and accompanying software, ‘Acorn’. The device allows users to monitor and read levels of carbon monoxide in the air through their cell-phones (Ramsey 2007). This extends the potential of pollution monitoring, once only in the hands of small public and private groups of specialized research enterprises. It is now opened up to users with the potential for hacking the politically enclosed debate. In a similar vein, Mexican artist-engineer Gilberto Esparza shows us the possibility of designing parasitical robotic artifacts, simple life forms that feed on power generated by human societies. The parasites ‘clgd’ (colgado) and ‘dblt’ (diablito) live suspended on telephone cables and re-circulate their energy while interacting with the surrounding environment through the emission of unusual sounds. The ‘ppndr-s’, a redaction of the name *pepenadores*, are small robot parasites that live amongst the accumulated remainders of human disposals, carrying out simple tasks such as removing, scattering and sweeping (for more information go to: www.parasitosurbanos.com). These artifacts live out of surpluses and engender a sense of the uncanny in urban situations, feral robots that couple with rickety media ecologies and the leakages and disarray of cities. Thinking of new forms of relation between natural processes and those that are deeply synthetic in a way that can open them up to wider understanding, or at least more tractable difficulty, Haque Design & Research presents ‘Natural Fuse’, an eco-physical network that employs the capacities within the environment, such as plant carbon-sinking, to create a recursive system where energy can only be derived from electricity networks if sufficient plant matter is present in the circuit to absorb the carbon produced by the energy used, (for more information see: www.haque.co.uk). In all these examples, hackability is taken into a new speculative dimension. Hackability itself becomes feral and no longer solely pertains to the material and infrastructural domain, in which it is measured by the relative technical openness of a system, but also to a performative one, in turn proposing new user modes for appropriating and experimenting with a wider sphere of interests. Finally, acquiring alternative sets of dimensions, scales and sizes of intervention, these new user modes call upon us to reinvent what the city is, what the ‘proper’ way of allocating energy might be and to circulate the capacity to know in new ways, demanding in turn new kinds of agency and knowledge circulation.

Rather tending to contradict mainstream perspectives on the sites of technological innovation, this call has been heard from economically impoverished countries, where salvaged machines imported from the West, or sourced direct from fabrication in the East, have, due to material scarcity, been incorporated into a tradition of maintenance and redesign. By transforming technologies in their own terms users come to generate a body of knowledge unforeseeable by the 'original' designer. The story of Morris Mbetsa, a self- taught inventor from Mombasa, seems pertinent. Mbetsa invented the 'Block & Track', an anti-theft device and vehicle tracking system based on mobile phone technology. The device uses a combination of voice, dual-tone multi-frequency (DTMF), signaling and SMS text messaging technology to control a vehicle's electrical system providing the user the ability to activate or disable the ignition in real time (AfriGadget 2008). Such ingenuity, in 'developing' countries, is not simply a means for survival, but a crucial resource for educational, economical and cultural development, which shapes its own conditions of emergence.

Interaction, Society and New Distributed Systems

To shift to another scale, such reflections become even more relevant if we consider the pace at which computational artifacts have become simple everyday objects for many children making ubiquitous or distributed forms of computing 'everyday' experiences in ways that test their stability. New forms of computational literacy suggest that the relation of users not only towards technology, but also to knowledge production itself, will change in unforeseeable ways. Not disinterestedly perhaps, Microsoft is amongst those keen to argue that developing forms of knowledge will increasingly require more and new forms of 'computational literacy' (Microsoft Research, 2005), to which new forms of critical and inventive intelligence will need to arise. There is a fundamental and pressing need for the design of research tools that might enable or constrain new forms of experimentation and knowledge production. Even though, for Microsoft's vision of the future, computationally literacy will imply profound mathematical thinking (Microsoft Research, 2005), it seems rather probable that computational literacy will also imply a form of 'concurrent' thinking (Stein, 1999) that is able to couple recognition and understanding of formal processes with their other experiential scales and dimensions. Computation, in the light of such an interactive conception, will of course have implications for education, challenging it with the evidence of new modes of experimentation. Here, materials will need to be modular and flexible, in order to elicit a constructive approach to both content and knowledge development. Finally, interactivity will imply novel forms of enquiry: by providing programmable and flexible tools that encourage ingenuity and reflexivity.

To achieve these goals much has to be done, for example when reflecting on the question concerning the implementation of information technology in school curricula. Whereas much effort has been directed towards the distribution of computers amongst pupils and ensuring fast connections to the World Wide Web, little has been discovered concerning the actual forms in which information technology might develop and enhance useful learning models (Gärdenfors and Johansson, 2005). We once more return to 'feral' understandings of computation, cognition and design, and it seems that the same kinds of thinking might usefully be applied to education. The sphere of knowledge production, and therefore also partially, perhaps rather too partially, of education, is relevant to the question of interactive design in the expanded sense. Education's involvement in the production of knowledge practices and of intellectual, organizational and spatial subjectivation has accompanied, if implicitly, much of the debates concerning the understanding of computation (specifically artificial intelligence and its figuration of the position and kinds of intelligence) and the studies of cognition sketched earlier in this paper. Add to this the commonplace that: 'there is nothing more political than education' and the models we choose in the development of knowledge will have implications for the development of design and of societies.

Now, if the capacities for thought are distributed between people, artifacts and the ecologies they are in, make and wreck, the question of learning becomes a crucial one in the imagination of what is computable as much as what is thinkable. The consideration of education and knowledge in society suggests that ubiquitous intelligence already forms an uneven and fissiparous challenge to the simple proliferation of ubiquitous computing on all levels of life, and will itself demand or instigate new social and organizational approaches. The interactive approach, in becoming feral, articulates not only computation, but modes of social organization, learning and alternative modes of collective innovation. Here, we recall a cybernetic approach to systems development where:

> *... one of the key ideas the general theory embodies is the principle of recursion. This says that all viable systems contain viable systems and are contained within viable systems. Then if we have a model of any viable system, it must be recursive. That is to say, at whatever level of aggregation we start, then the whole model is rewritten in each element of the original model, and so on indefinitely.' (Beer, 1973: 4)*

This would mean that a feral approach to technological development would entail less formalised approaches to society at large. It would at one scale perhaps imply the formation of cybernetically reflexive collectives, a 'recursive public' composed of modular, but ungridded, elements, where distinct modes of subjectivation, technicality and organization co-cooperate in the devising of their own infrastructural logics (Kelty, 2008). Finally, design and cybernetics might find a common path, design with its emphasis on 'participatory' approaches and cybernetics in its consideration for the development of complex systems where the system cannot be separated from acts of observation and involvement.

For designers, considering such a principle of recursion means accepting a major responsibility in the development of systems, and also the responsibility of constantly reflecting back to their own sphere of activity, accepting and testing the task of actually designing design, and in so doing accepting their rather more minor role. Doing so requires an acknowledgement that creations devised by distinct professions might actually slip out, escaping description by initial intentions (Fuller and Haque, 2008). This implies a deviation from formal and discipline-oriented professional approaches to a more multivalent view, encouraging design to become more than a purely sectional interest in the life of objects to actually consider and take part in the political, social and cultural implications of its activity (Wood, 2007). Such a position imagines an expanded role for design as an activity, but also, conversely, it suggests a recognition of the wild expansion of the scope of people, thoughts and things involved in the activity of design and the selection, development, deprecation and implementation of technological systems.

Some Closing Remarks

Throughout the present work we have moved rather too rapidly – but hopefully suggestively – between distinct fields of enquiry, from computation, cybernetics and finally design all under the rubric of an 'interactive paradigm'. We have attempted to argue that this paradigm, emerging from computation's enfolding into the world, has prompted conceptual developments leading to new questions and formulations. However, central to our theme is the fact that none of this would have been possible without accounting for the development of new artifactual, technical and ubiquitous realities, where distinct artifacts have gone feral, interweaving with the subjective, social and ecological fabrics of our cities, lives and societies. The idea of ubiquitous computing, its characteristic embeddedness, but also partial containment, within diverse multi-scalar settings of many different kinds, has suggested the exploration of human-computer relations in ways that can no longer be seen as simply calm, but also partially wild, if they do not drive us so.

By transforming our understanding of what computation is and how it might be done; shifting from a view of computation as 'centralized, sequential and result-oriented' or as 'computation as calculation', towards an understanding of 'computation as interaction' (Stein, 1999), we are able to alter preconceptions concerning the practice of programming and computing itself. This implies a shift from the views of a science that once took the transformation of 'inputs into outputs' as essential, to one that now emphasizes a process orientated view of computation that extends beyond prescriptive algorithmic understanding (Wegner, 2003). Due to its strong link to cognitive science, inaugurated through the behaviourist school during WWII, and vice-versa, such transformations have found wider implications for computation and beyond. For cognitive science particularly, this has meant the proliferation of new approaches to the study of the human mind. Starting from the premise that the idea of mind itself extends beyond the confinements of 'head and skull' (van Gelder, 1995; Chalmers and Clark 1998), the importance of the organism's environment can be recognized as crucial in establishing the complexities of any considered cognitive unit. The relations I establish with my surrounding world are as much relevant in the study of my cognitive capacities as the workings of my brain. By considering its extension beyond the single body of an organism, such an approach challenges the webs of rationality and formalism that can only be sustained when we consider the intellect as something separate from the world I am constantly immersed in. It does not mean however that such boundaries cannot themselves be effective when enforced or entrained by other, wider, means. All such boundaries, in themselves, have meaning.

Such conceptual workings, that transverse both computing and cognition are more readily understood by revisiting their filiations to a third approach: the works of second-order cybernetics and its study of complex systems, including both humans and machines. This is a field of study and practical experiment epitomized by the introduction of the idea of 'subjective dynamic construction' into the complex web of feedback loops within a given system. Such 'subjective construction' cannot be made an account of without considering the characteristic embeddedness of any organism, entity or practice. Ultimately, this has lead to the development of the recognition of human-computer relations as highly situated in a way that their cultural, subjective and political dimensions cannot be ignored.

A proper conceptualization of the message handed down from second-order cybernetics might finally open new approaches to the study of human-computer interaction at large. Essentially it allows us to recognize that this same relation extends beyond the tight formal coupling once devised by behaviorist and formalist approaches to both cognition and computation. By considering the messy and informal aspects ('subjective construction') of human computer interactions, previous Fordist models of design seem to become obsolete and the trajectory lead in part by the 'participatory' approach sheds new light into the design of alternative ecologies of computation and interaction where user, artifact and designer, play roles that are shiftingly determinant rather than fixed.

If we initiated our discussion by speaking of ubiquity as key instigator of a new interactive paradigm, one that brought novel approaches to computing, cognition and design itself, we have attempted to finalize this dicussion by considering how ubiquity might embody this same feral quality. In this light the feral artifact is one that has been able to escape a domesticated and captive state. It is not a sedative, exuding calmness for an already understood, tracked and pre-empted subject whose needs and requests have been mapped out and whose life as such corresponds to that of a finite state machine. To design for a feral context is to work with processes of subjectivation that are not simply described by input and output, no matter how far away they are from traditional sites of computation. Instead, such a design works with artifacts, processes, ecologies, people, computation and politics, in a way that is able to explore the multiple potentials of the fields of interaction, calculation, control and cognition. When computing escapes from being unable to recognize itself outside of the formalisable, becomes promiscuous, starts finding itself recomposed in combination with packs of other epistemic currents, it becomes feral. When design recognizes that its expertise is distributed amongst people, institutions, media, infrastructures and in the dissensus, joy and confusion of contemporary lives and their technological avidity and starts to find means of generating a rigor in the chaotic, it too starts to lose its domestication. In doing so, recursively, it promises to produce something that renders their complex artifactuality sensible and open – with all kinds of difficulty – to design: to think with things.

Authors' Biographies

Matthew Fuller is author of various books including *Media Ecologies, materialist energies in art and technoculture*, *Behind the Blip, essays on the culture of software* and the forthcoming *Elephant & Castle*. With Usman Haque, he is co-author of *Urban Versioning System v1.0* and with Andrew Goffey, co-author of the forthcoming *Evil Media*. Editor of *Software Studies, a lexicon*, and co-editor of the new Software Studies series from MIT Press, he is involved in a number of projects in art, media and software and works at the Centre for Cultural Studies, Goldsmiths, University of London. http://www.spc.org/fuller/

Sónia Matos is a designer and lecturer at Edinburgh College of Art who works at the intersection of ethnography, conceptual tool design, participatory interventions and writing. For the past five years, and as part of her doctoral studies at the Centre for Cultural Studies, Goldsmiths College, University of London, Sónia has dedicated her research to the study of a whistled form of language known as the Silbo Gomero, one that is still alive in the small island of La Gomera in the Canarian Archipelago – this body of research has culminated in the design of learning support materials for the Gomeran community. Her work has been presented at the 23rd British HCI Conference, the Chisenhale Gallery, London, as part of the '21st Century' research based program and more recently as part of the 'Prototypes for Transmission' organized by Constant – Association for Art and Media. She is currently preparing a new research project regarding food, design and ecology in the Azorean Archipelago.

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