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Architecture, Technology and the Body: From the Prehuman to the Posthuman

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> Visible and mobile, my body is a thing among things; it is caught in the fabric of the world, and its cohesion is that of a thing. But because it moves itself and sees, it holds things in a circle around itself. Things are an annex or prolongation of itself; they are encrusted into its flesh, they are part of its full definition; the world is made of the same stuff as the body.
>
> (Merleau-Ponty 1964, 163)

A discussion of technology in architecture might usefully begin with a redefinition of 'architecture as technology'. Rather than apparently diminishing design to a mechanical process governed by utility, efficiency and economy, this redefinition should also involve a much broader and possibly unfamiliar understanding of technology itself – one that includes its social, cultural and psychological implications. That it has such wide-ranging and yet often neglected dimensions is perhaps more obvious if we include within the category of technology the sum total of all the things that we produce in the pursuit of a better life. For example: our clothes, furniture, equipment, buildings, cities and even landscapes (to the extent that they are actively organized and productive) – in fact anything made, managed, configured, or transformed in the process of modifying the environment for human habitation. This broad definition should also include less tangible tools such as social structures, conventions, habits, forms of entertainment, styles of behaviour – and even language itself. All of these activities and artefacts should be seen first and foremost as tools for reaching out and engaging with the world. As the anthropologist Tim Ingold has defined the term: 'A tool, in the most general sense, is an object that extends the capacity of an agent to operate within a given environment' (1993, 433).

As Heidegger suggests (1977, 12–14) we live in the space opened up and revealed by technology. As human self-consciousness brings with it the realization of what he describes as *Dasein's* 'thrown-ness' into the world (1962, 223), the fact of our being fundamentally not at home in our so-called natural environment forces upon us the need to fashion a 'third space' in which we are firstly to survive, and secondly to thrive. Focusing on the philosophical and cognitive implications of this technology-created zone of habitation between the body and a hostile world, we might conclude that it is actually constitutive of our fundamental sense of self. To be human – and hence to be embodied – is to be already extended into the world, into what Maurice Merleau-Ponty memorably labelled the 'flesh of the world' (1968): a liminal realm where it becomes more and more difficult to say categorically what belongs to the self and what belongs to the environment. Merleau-Ponty's notion of an intertwining of the body and its perceptual field is based on the fact that we perceive the world through the medium of the experiencing body. Hence it might also be said that we experience the world through the 'technologies' of the body's sensory systems. In perceptual terms this means that it is impossible to make a meaningful distinction between our experience of the objects around us and our experience of the body itself in the act of experiencing. As Taylor Carmen has recently explained (2008, 133): 'Flesh is the *identity* of perception and perceptibility, even below the threshold of conscious awareness. As bodily perceivers we are necessarily part of the perceptible world we perceive; we are not just *in* the world, but *of* it.' Apart from recalling the biblical suggestion of the body's organic continuity with the world ('for dust thou art and unto dust shalt thou return'), this statement also throws into question the idea of a fixed and stable boundary between the self and the environment. A more concrete illustration of this idea of a shifting zone of interchange spanning the body–world boundary is provided by Merleau-Ponty in one of his earlier essays on the painter Paul Cezanne: 'The painter "takes his body with him" says Valéry. Indeed we cannot imagine how a *mind* could paint. It is by lending his body to the world that the artist changes the world into paintings' (1964, 162).

By extending this idea of a continuum linking mind, body and world, it becomes possible to question the simplistic received distinction between nature and society, which – as both Bruno Latour (2007 [1993]) and Félix Guattari (1995 [1992]) have suggested – is an artificial, post-rationalized and highly misleading convention. As an alternative to this restrictive binary logic, in the book *Chaosmosis* Guattari posits a new ontological category to describe the merging of the organic and the mechanical that he labels the 'machinic phylum'. Based in part on a statement by the anthropologist André Leroi-Gourhan that the 'technical object was nothing outside the technical ensemble to which it belonged', Guattari (1995 [1992], 36) extended the notion of the ensemble to include the social, cultural and material networks within which technologies are embedded. The principle of the human 'becoming machine' and the machine 'becoming human' was also suggested by Delueze and Guattari in their now famous example of the symbiotic relationship between wasps and orchids. As the orchid is able to mimic the colouring, scent and texture of the female wasp, the male wasp's frustrated acts of mating inadvertently result in the successful pollination of the flower – creating a moment of temporary hybridization across the boundary of plant and animal kingdoms (1988, 10–11).

What Latour describes as technology's tendency to 'mix humans and non-humans' together involves a process of delegating particular acts of human agency onto technical devices – for example where the corporate concierge is replaced by the humble overhead hydraulic door-closer. While the history of industrialization contains numerous examples of machines replicating ever more complex human functions, this process is really only a continuation of the much longer trajectory hinted at already – the desire to extend the capacity of the body to act in the world through the construction of ever more sophisticated tools. We can therefore conclude that all technologies should be seen in terms of their prosthetic relationship with the body, and – more fundamentally – we might agree with Bernard Stiegler that: 'The prosthesis is not a mere extension of the human body; it is the constitution of this body *qua* "human"' (1998, 152–153).

Despite the seeming inevitability of this hybrid human–machine condition, much of the twentieth-century discourse on the prosthetic has been haunted by its apparent threat to our 'true' nature as human beings. As one notable recent collection (Smith and Morra 2006) has recalled, Sigmund Freud saw it as one of the sources of a curiously modern malaise:

> With every tool man is perfecting his own organs, whether motor or sensory, or is removing the limits to their functioning … Man has, as it were, become a kind of prosthetic God. When he puts on all his auxiliary organs, he is truly magnificent; but these organs have not grown on to him, and they still give him trouble at times … [P]resent day man does not feel happy in his Godlike character. (1961, 43–44)

Writing on this theme in the 1960s, Marshall McLuhan adopted an apparently more celebratory tone, describing technological devices as the external organs of the body and media as 'the extensions of man' (1964). Later, in *The Medium is the Massage* – that surprisingly postmodern assemblage of iconic images, aphorisms and typographical games – he enthusiastically proclaimed that: 'All media are extensions of some human faculty – psychic or physical' (1967, 26). His examples included the wheel as an extension of the foot; clothing, of the skin; radio, of the ear; print of the eye. Even 'electric circuitry – an extension of the central nervous system' (1967, 40). This last reference hints at the darker side of McLuhan's prognosis as already set out in *Understanding Media*. One response to the technological enhancement of any one of the body's sensory systems is the recalibration of the other senses in a compensatory act of suppression. McLuhan coined the term 'auto-amputation' to describe the negative consequences of this process, as the nervous system moves to protect itself against the dangers of overstimulation. The ultimate consequence of the gradual technological invasion of the body according to McLuhan is summed up in a memorable chapter entitled 'The Gadget Lover', where he effectively reversed the traditional hierarchy between the body and technology as suggested by Freud's statement quoted above – also anticipating Deleuze and Guattari's reference to the uncanny relationship between the wasp and the orchid:

> By continuously embracing technologies, we relate ourselves to them as servomechanisms. That is why we must, to use them at all, serve these objects, these extensions of ourselves, as gods or minor religions … Physiologically, man in the normal use of technology (or his variously extended body) is perpetually modified by it and in turn finds ever new ways of modifying his technology. Man becomes as it were, the sex organs of the machine world, as the bee of the plant world, enabling it to fecundate and to evolve ever new forms. (1964, 46)

FROM THE EXTENDED BODY TO THE EXTENDED MIND

Before attempting to assess the architectural implications of this apparently apocalyptic scenario, it is worth considering in more measured terms the underlying principles at work over a broader historical trajectory. To better understand the phenomenon of technological embodiment we might first consider examples of the simplest hand-operated tools. Heidegger refers to the use of a hammer, describing how – when skillfully handled – it effectively 'disappears' or retreats from the user's view (1962, 98–107). Perception shifts from the immediate tactile contact between the hand and the wooden shaft of the hammer, out towards the metal surface which is striking the head of the nail. Awareness is soon dominated by the task rather than the tool, which with practice quickly becomes incorporated into an extended body-image.[1] This is perhaps more clearly evident in the use of tools that directly augment sensory awareness, such as wearing glasses to improve vision or, in Merleau-Ponty's famous example, a blind person navigating with the aid of a white cane

(1964, 143–144). In each case it becomes easier to imagine the technology less as a barrier between the body and the world and more as a means to bring the world even closer. As Merleau-Ponty's concept of 'flesh' implies in its intertwining of body and world, its 'thickness' is 'not an obstacle between them, it is their means of communication' (1968, 135).

This notion of the body being physically extended through the use of prosthetic technologies is also echoed in the writings of the American philosopher John Dewey. While highlighting an organic continuity between the body and the 'outside' world, he also hints at an ethical dimension to the relationship between the organism and its environment:

> The epidermis is only in the most superficial way an indication of where an organism ends and its environment begins. There are things inside the body that are foreign to it, and there are things outside of it that belong to it *de jure* if not *de facto*; that must, that is, be taken possession of if life is to continue. On the lower scale, air and food materials are such things; on the higher, tools, whether the pen of the writer or the anvil of the blacksmith, utensils and furnishings, property, friends and institutions – all the supports and sustenances without which a civilised life cannot be. The need that is manifest in the urgent impulsions that demand completion through what the environment – and it alone – can supply, is a dynamic acknowledgment of this dependence of the self for wholeness upon its surroundings. (1980 [1934], 59)

Dewey's reference to the 'higher scale' of property, friends and institutions reminds us just how dependent we are for our sense of self-identity on a whole network of tools and techniques involving both physical and intellectual functions. Of the latter category, an important analysis has recently emerged within the discipline of cognitive science, exemplified in the work of Andy Clark and David Chalmers and their concept of the 'extended mind' (1998). The authors extrapolate from examples of the most mundane experiences, such as wearing a wristwatch or carrying a diary, which like countless similar everyday objects provide a vital support and prompt to our behaviour. Like our clothing and our cars, these objects quickly become integral to our personality and social standing – part of the definition and representation of who we are and what we are capable of. From notepads to photograph albums these external memory-aids act like computer hard-drives onto which we upload important data to be retrieved when the moment demands. The increasingly familiar and distressing experience of losing one's laptop, wallet, address book or mobile phone provides a vivid example of the acute sense of personal loss involved in even a temporary denial of access to what Clark elsewhere has labelled our 'intellectual scaffolding' (2003, 6–11). Clark's ideas also serve as a reminder that the apparently recent appearance of the hybrid human–machine 'cyborg' entity is hardly a new phenomenon. Ever since the first random rock was used as a hammer to smash a nut, bodies have been merging with technologies in even the most basic technical tasks.

The notion of an externalized and distributed intelligence exemplified in the simple act of recording a thought in a notebook also provokes consideration of the evolutionary implications of historically 'primitive' technical activities. Much as a contemporary archeologist might look on the discovery of ancient tool fragments as a store of information about the material culture of a lost society, it is becoming clearer that early human cultures derived considerable cognitive benefits from the developing capacity to exploit external objects as both embodied tools and carriers of technical knowledge. As archaeologists, ethologists and paleoanthropologists argue over the chronology of early innovations in the realms of language and technology, one likely scenario is that tool-use came first. The ability to imagine, plan and execute an ordered sequence of actions in the making of simple tools could form the basis of the core skills needed to communicate through ordered patterns of sound. This conclusion is also supported by recent advances in brain imaging research which show clear evidence of overlapping areas of specialization within the brain for both language and manual skill – a correspondence also previously suggested by Leroi-Gourhan in the 1960s (1993, 86–89). Clusters of neurons in the left cerebral hemisphere, such as Broca's area, dealing with language comprehension may also be involved in the control of the vocal muscles. These areas are also heavily implicated in the so-called mirror-neuron system which is used for both perceiving and executing our generally right-hand dominated manual activities (Rizzolatti and Sinigaglia 2008, 118–123). These new findings are going some way towards alleviating the problems of speculating upon scant archaeological evidence, of which Leroi-Gourhan was all too aware:

> From this starting point, a paleontology of language could perhaps be attempted, but it would only be a skeleton of a science, for there is little hope of ever recovering the living flesh of fossil languages. One essential point that we can establish, however, is that as soon as there are prehistoric tools, there is the possibility of a prehistoric language, for tools and language are neurologically linked and cannot be dissociated within the social structure of humankind. (1993, 114)

This scenario has been recently extended by the cognitive psychologist Michael Corballis in his book *From Hand to Mouth* to help provide a foundation for his controversial account of the origin of spoken language (2002). Looking back approximately two million years to the appearance of the genus *homo* following the genetic divergence of ape and human species, Corballis imagines the gradual emergence of an embodied gestural language of visual signs and symbols.[2] Based on the archaeological evidence of tool-use among early hominid species it is suggested that the increase in levels of manual skill could have facilitated a more articulate form of visual language. This is in the period prior to the anatomical changes necessary for the production of articulate speech. The development of a gestural language could therefore have produced a kind of generalized 'linguistic competence', creating the ideal conditions – as well as a selective evolutionary pressure – driving the development of other, more sophisticated, forms of communication. An embodied language of manual gestures perhaps assisted by secondary emotional vocalizations would later come to be dominated by the more precise articulations of spoken language as we know it today. This process would also have gradually freed the hands for the subsequently more intense process of technical and artistic innovation. In Corballis' view this is only likely to have occurred among anatomically modern humans, beginning sometime around a hundred thousand years ago with the appearance in the fossil record of the species *Homo sapiens*. Evidence for what has been called a 'big bang' of cognitive and cultural evolution begins to appear in the cave art of the upper-paleolithic period (around 40,000–30,000 years ago) which clearly suggests sophisticated social and ritual behaviour (Klein and Edgar 2002; Lewis Williams 2002; Mithen 1996).

The much debated question of whether technical, social or linguistic intelligence is primary in human development (Mithen 1996) overlooks the fact that language itself involves an inherently technical dimension (Ingold 1993). As a means to reach out beyond the body and manipulate elements of the physical – and social – environment, language reminds us of the embodied origins of technology in the effort to extend our human capacities. As the anthropologist Marcel Mauss has also suggested, technology may be seen to originate with the development of 'techniques of the body': 'The body is man's first and most natural instrument. Or more accurately, not to speak of instruments, man's first and most natural technical object, and at the same time technical means, is his body' (2006 [1935], 83). What Aristotle had previously called the 'tool of tools', the hand was to the nineteenth-century anatomist Sir Charles Bell 'the consummation of all perfection as an instrument' (1834, 231). More recently Raymond Tallis in his book

The Hand: A Philosophical Enquiry into Human Being (2003) has described the process by which the emergence of the earliest technologies might actually have been the catalyst for the slow dawning of human self-consciousness. The growing realization of the instrumentality of the hand as the first proto-technology may well have been the stimulus for the development of a cognitive feedback-loop from which what we now call intelligence emerges. As bodily techniques become gradually extended, solidified and communicated in the form of durable material artefacts, these external deposits of human agency become what Levi-Strauss has called 'tools to think'. This dialectical process by which the human is both 'inventor of' and 'invented by' technology was earlier referred to in Friedrich Engels' discussion of the evolutionary function of labour: 'Thus the hand is not only the organ of labour, it is also the product of labour' (1940, 281). The notion of a mutual reinforcement created by the co-development of technology and consciousness, has also been employed by Jacques Derrida (again with reference to Leroi-Gourhan[3]) in his analysis of the archaic impulse of mark-making as a form of externalized memory:

> If the expression ventured by Leroi-Gourhan is accepted, one could speak of a 'liberation of memory,' of an exteriorization always already begun but always larger than the trace which, beginning from the elementary programs of so-called 'instinctive' behavior up to the constitution of electronic card-indexes and reading machines, enlarges difference and the possibility of putting it in reserve: it at once and in the same movement constitutes and effaces so-called conscious subjectivity, its logos and its theological attributes. (1976, 84)

So, to turn a now familiar idea of technology-as-prosthesis around: instead of thinking of technology as an extension of the body, it might be more enlightening to claim that thinking of the body is an extension of technology. That is, the process of becoming self-aware – or becoming aware of 'having' a body and having a choice as to what to do with it – may ultimately be seen as a consequence of the extension of the body through technology.

(DIS-) EMBODIMENT IN ARCHITECTURE

Having established the human and the technological as mutually co-constitutive, it would be reasonable to consider what kind of consciousness – indeed what kind of human – is currently being constructed by the new tools at our disposal? Or at the very least to ask ourselves as architects – as Peter McCleary has suggested: 'What are the characteristics of knowledge derived during the production of the built environment?' (2007, 326). McCleary takes up Heidegger's analysis of the ready-to-hand relationship with tools and equipment and describes a gradual historical transformation from 'transparent' to 'opaque' technologies. As with Heidegger's description of using a hammer, transparency refers to the withdrawal of the tool from the user's conscious awareness – in favour of what Don Ihde has also called an 'embodiment relation' (1990, 72–80). As perception shifts to the task, the user experiences the characteristic resistance of the material being worked, and hence the accumulation of an embodied knowledge about its possibilities and limitations. As technology becomes more sophisticated, more of the human input is delegated to the tool, first, typically, the power source and then gradually the controls, until we arrive at the fully automated black-box machine from which – at the touch of a button – 'finished products' magically appear. At this point awareness is dominated by the experience of the opaque device, with the human input reduced to consulting numerical gauges and digital read-outs in what Ihde has described as a merely intellectual or 'hermeneutic relation'. Embodied knowledge of material reality is thus reduced to an interpretation of data – a linguistic abstraction of reality that we might today describe as digitisation. Another way of framing this trajectory is provided in McCleary's dialectical model of 'amplification and reduction' which also highlights the experiential consequences of an apparent increase in technological efficiency. One of the clearest examples of this comes from the world of communication technologies, where the telephone (and now, of course, the internet) has created a state of instantaneous real-time contact or telepresence – the realisation of what McLuhan famously predicted as the coming of the 'global village' (1967, 63). If we stop to consider the nature of the exchanges made possible by these advances it is easy to see the sacrifices made in terms of the quality of the communication. Where face-to-face contact provides multiple 'channels' of vocal, gestural and contextual information, by contrast the typically crackling, staccato and often interrupted mobile phone call offers only an impoverished form of contact restricted to the audio channel.

The historical shift from transparent towards opaque technologies happens in large part because of the tendency to offload to other agents more and more of what might be called preparatory activities. Contemporary cooking habits provide a useful illustration of this, with the attraction and convenience of the pre-packaged meal. In this case the preparation of the food has already been delegated to another (unseen) human 'actor' (Latour 1987, 1–17; Cockburn 1992, 32–47). The meal itself – like the microwave oven that is used to re-heat it – has thereby become a 'black-box' technology: its design, ingredients, preparation and packaging are no longer an issue for the impatient consumer. No questions are asked of it other than the recommended length of radiation exposure and the appropriate setting of the oven's power-level. The loss here could be seen in terms of Albert Borgmann's notion of 'focal practices' where both the bodily and social dimensions of cooking and eating are apparently being gradually eroded (1984, 196–210). Even a cursory survey of the various processes involved in growing, harvesting and cooking food provides a useful indication of the kind of knowledge that is becoming less and less familiar. According to Borgmann: 'We are disenfranchised from world citizenship when the foods we eat are mere commodities. Being essentially opaque surfaces, they repel all efforts at extending our sensibility and competence …' (204–205).

As the day to day experience of designing buildings is gradually reduced to the selection of prefabricated components from product catalogues – and as architects become, somewhat like Adolf Loos' plumbers, simply the 'quartermasters of culture' (1982, 45–49) – a void begins to open in the traditional conception of the designer as creator and author. The position of the designer in relation to the builder of buildings is already one of alienation, in the sense that a division of labour has long since taken place in the professionalization of the architect's role. The history of the architectural profession from the Rennaissance to the nineteenth century involved the creation of a protected and rarefied realm of intellectual activity that separated the art from the craft of building. What Antoine Picon has recently described as a contemporary 'crisis of tectonics' is perhaps just the latest consequence of the progressive distancing of the designer from the process of construction. As less and less embodied knowledge is produced during both the educational and professional experience of the practising architect, it is no surprise that the designer now looks elsewhere than the process of building for the sources of formal invention. Given that all architecture must deal – as Kenneth Frampton has suggested – with the tension between its 'representational' and its 'ontological' dimensions it could be argued that the balance has shifted in recent years decisively in favour of the former (Frampton 1990). It is certainly the case that the modernist link between function and expression has been decisively broken in favour of a Saussurean arbitrariness in the relationship between signifier and signified. As both the building's programme and the tectonic systems are no longer expressively embodied in spatial and material form, Venturi's 'decorated shed' has become one of the dominant architectural paradigms – a supposedly functional but anonymous box wrapped in a slick and seamless signifying skin.

The process of bringing an architectural idea to expression in material reality could usefully be seen in terms of the philosopher Andrew Pickering's concept of the 'mangle' (1995). Pickering has described the process of devising and testing a scientific hypothesis through the construction of increasingly sophisticated technological devices as a kind of collision and interaction between human goals and material resistance. He calls this process the 'dance of agency' – an ongoing, open-ended and temporally structured operation involving a dialectic of resistance and accommodation out of which scientific knowledge ultimately emerges. In the act of constructing a building, a similar process can be observed, whereby the tectonic character of a raw material emerges from its resistance to being shaped and transformed into a building component. This notion could also be applied to the architectural design process itself and the way in which concepts are gradually 'worked out' in the material forms of models and drawings. The visual media of architectural representation also possess their own refractory qualities, and thus new formal and spatial opportunities appear unexpectedly through the exploratory process of graphical presentation, simulation and testing.

Pickering describes how the dialectical nature of the dance of agency allows these new possibilities to emerge through an iterative sequence of actions, as each attempted realization is followed by the designer/scientist accommodating their ideas to the limitations of material reality. He also questions the traditional dichotomy between human and non-human agency, referring directly to Bruno Latour's notion of 'mixing humans and non-humans together'. He is, however, critical of the semiotic emphasis of Latour's model because it seems to imply an equivalence and interchangeability between the human and non-human actors – another echo of Saussure's principle of the arbitrariness of the sign. Pickering instead suggests that the materialities in each case are fundamentally different, in the sense that so-called raw materials possess resistance and inertia but not intentionality. The argument turns on the question of the conscious human intention implied by the use of the word 'agency', such that Pickering's use of the term 'non-human agency' seems to be little more than a metaphor.

The concept of 'material agency' might be more accurately applied to those materials that have already been transformed into products, and thereby already taken on a form of embedded or delegated human intention based on their original designer's agency. In this case, materials are no longer natural but already cultural phenomena, and hence arrive already loaded with a set of preconceptions about how they might be employed. Whether in science or in architecture most so-called 'raw' materials are actually already technological objects and hence the designer/experimental scientist has to grapple with multiple levels of agency. This is generally the situation that most architects confront when selecting materials for construction projects, as even apparently natural materials like brick and stone carry both physical and cultural properties. Given the ghostly presence of human intention in even the most mundane constructional component, even Louis Kahn's famous invitation to 'ask the brick what it wants to be' may not now seem so uncanny. The only difficulty with applying Kahn's principle in a world of ever more miniaturized digital technologies is whether the answer will have any significant architectural consequences when addressed to embedded sensors, microprocessors and optical fibres.

In the last great period of rapid technological development towards the end of the nineteenth century, the major architectural innovations were still mainly concerned with structural components that possessed obvious tectonic and formal characteristics. As the masonry wall gave way to frame-and-infill systems, architects looked to engineers for guidance on how best to employ them and it could be argued that it has taken almost a hundred years to achieve their successful assimilation. Today the engineer is still seen as the ultimate source of guidance in coming to terms with the latest technologies, although the rapid pace of change has made it much harder for architects to keep up. Another difference now is that the focus of innovation has shifted, away from visible structure and towards 'invisible' servicing systems. With environmental performance now taking precedence over the visual articulation of structure and materiality, designers are still struggling to find a coherent formal language for what Reyner Banham called the 'well-tempered environment' (1969).

DEMATERIALIZATION

The widespread use of CAD in architectural practice could be blamed for further deepening the divisions between the designer as a maker of drawings and the messy realities of the material world. Paradoxically perhaps, one area in which this technology might also bring them closer together is in the area of environmental performance simulation and its ability to visualize normally invisible processes. This has led some designers towards a greater awareness of the relation between internal and external environmental forces, theorized by the Malaysian architect Ken Yeang (1999) as a reciprocal exchange of energies, in a clear echo of John Dewey's description of the organism being 'completed' by its relationship with its surroundings. The effects of climate on architecture – during both design and occupation – have also been described as a form of material agency in both a literal and a metaphorical sense. In Jonathan Hill's discussion of 'weather architecture' climatic forces are given a similar status to the actions of the creative user (2001). Following the philosopher Henri Lefebvre's example, these unpredictable actors are considered alongside the designer as equally important participants in the ongoing 'production of space' (Lefebvre 1991). Likewise the broader status of architectural practice as contingent upon a multitude of uncontrollable real-world phenomena has been powerfully and precisely reformulated in Jeremy Till's book *Architecture Depends* (2009).

These attempts to expose architectural design to factors beyond the designer's control have also led to a greater use of computational modelling in order to process the potentially vast amounts of additional information at the designer's disposal. One consequence of this is that unpredictable patterns of user behaviour resulting from the decisions of conscious human agents are treated as equivalent to the physical characteristics of 'material agency', with predictably problematic results. One of the best known examples of the recent use of the computer to generate three-dimensional architectural design proposals is in the work of Greg Lynn as described in the book *Animate Form* (1999). Through a series of case studies of apparently live projects, Lynn describes his approach to design from the starting point of a seemingly conventional site analysis. Beginning by mapping the site according to degrees of attraction and repulsion, factors such as traffic noise, pedestrian movement and views out to the landscape are captured as forces or vectors which are then allowed to play out against a generic form:

> The forces were allowed to act in free space and interact with one another in a gradient fashion, as they emanate a field of influence without any distinct contour or boundary. The shapes of these forces included linear, vortex and radial directions along with various parameters for decay, acceleration and turbulence. As there was no way to read these invisible forces except in their ability to affect

> objects, we introduced a 3-dimensional grid of particles onto the site. (1999, 144)

A further stage in the materialization of this 'dance of agency' involved a more or less literal solidification of the movements of these particles into a folded surface laid over the site:

> After capturing the particle trails as spline elements, we attempted to generate a massing strategy for the site. This involved constructing an accordion-like surface and placing it within the field of forces. We gave the pleated surface varying elasticity at its vertices and intersections of polygons. These elastic vertex connections were assigned based on the density of particles at any given area. (1999, 146)

The range of forms resulting from these carefully orchestrated processes shares many formal similarities with much contemporary 'organic' architecture. This is curious given the apparent care involved in mapping the unique characteristics of each individual context, which suggests that behind the rhetoric of individuality and site-specificity there is actually another stronger force influencing the outcome. In this case it appears that the chosen tools are having a decisive effect on the design, which leads to a similar question about the role of the architect's agency in relation to the agency of the tool designer. On the one hand there is the possibility that the designer may be attempting to step back from the position of author – delegating the decision-making power to the 'black-box' of the computer software. On the other hand, given that Lynn is working with programmes and algorithms of his own devising, this may also allow the architect to tighten his grip on the design process. While presenting the outcome as the result of an apparently impersonal and objective set of pseudo-scientific operations, the designer has actually reinstated his own agency, albeit distributed amongst his tools. Michael Speaks highlights another of the paradoxes inherent in Lynn's approach to design in its reliance on a thematic of movement expressed in ultimately static forms. Formally this seems to situate the work almost too comfortably within the canon of recent architectural history, without questioning whether this technology might also make possible fundamentally new approaches to architectural practice (Speaks 2001).

The origin of Lynn's and other similar generative methods of design (De Landa 2002) can be traced back to the early development of computer technology and the emergence of cybernetics as a discipline from around 1950 onwards. What Norbert Wiener famously labelled the 'science of control and communication in the animal and the machine' began during World War II in the search for a more accurate means of guiding anti-aircraft guns. Katherine Hayles in her book on the 'posthuman' (1999) has given a thorough account of these developments, structured around a narrative of digitisation – the gradual reduction of the living organism to disembodied information and the reciprocal elevation of the machine to an apparently sentient form of nature. The model of the human as information processor is succinctly if somewhat chillingly expressed by Wiener in the introduction to his attempted popularisation of cybernetics called *The Human Use of Human Beings*: 'Man is immersed in a world which he perceives through his sense organs. Information that he receives is coordinated through his brain and nervous system until, after the proper process of storage, collation, and selection it emerges through effector organs, generally his muscles' (1954, 17). One can also see in this formulation a paradoxically nostalgic yearning to return to an age of unself-conscious human awareness – a kind of utopian primal bliss when all organisms apparently lived in an instinctive harmony with nature. In this scenario the human being is reduced to the level of W. Ross Ashby's famous *homeostat* – an adaptive electrical device able to respond to changes in its environment in order to maintain its own internal 'ultrastability' (Ashby 1960, 100–121; Cannon 1963).

Attempts to model architectural design as a disembodied process of information handling soon began to proliferate during the growth of the 'design methods' movement in the 1960s. Christopher Alexander's explicit attempts to mathematize the design process in *Notes on the Synthesis of Form* (1964) were actually soon abandoned by the author in favour of an approach based on typological design 'patterns' – returning to the more familiar language of three-dimensional spatial organization. The success of Alexander's later work in inspiring greater user-participation in design highlights another paradoxical aspect of the computerization process. Both user-engagement (or 'community architecture' as it came to be known in the 1970s) and the current use of generative design algorithms betray a nostalgic yearning to return to a time of so-called unselfconscious design (Alexander 1964, 46–70). When vernacular buildings were produced without architects through the gradual development of craft traditions, architecture resulted from an instinctive process that could be compared with the making of birds' nests and termite mounds (Rudofsky 1964; Turner 2000; Hansell 2007).

Continuing Alexander's project of vernacularization with the aid of today's computing power, contemporary designers are currently pursuing similar ends at both extremes of the construction process – by digitizing the processes of architectural design and production at the same time as automating the finished building's environmental control systems. The fact that neither of these endeavours has so far been totally successful is probably due to the fact that the only realistic way to achieve these goals – given the messy complexity of real-world situations – is to massively restrict the number of variables to be taken into account by any one system. By creating highly artificial design scenarios such as in Lynn's work described above – or by building hermetically sealed enclaves that shut out external disturbance (Banham 1969) – it may be possible to create the illusion of perfectly homeostatic and seamlessly responsive architectural environments. These situations are reminiscent of John Searle's infamous 'Chinese Room' experiment, (Dennett 1991) which was intended as a critique of the current claims of artificial intelligence. The coded messages that are being received and processed through the mailboxes of Searle's sealed-off chamber are meant to create an illusion of equivalence between the 'intelligence' of man and machine. It is clear that this effect is actually created by restricting the information input-output capacity to a ludicrously low level.

REMATERIALIZATION

The process of digitization in architecture follows the principles of coding and decoding: by reducing the world to disembodied data it becomes easier to manipulate it within the virtual realm without the inconvenience of material constraints. As an attempt to avoid the consequences of the 'dance of agency' as described by Pickering, this allows various design operations to be executed and tested without dealing with all the complexities of real-world conditions. Once the designer is satisfied with the solution this is then followed by a reversal of the process: the building is constructed by following the instructions contained in the graphical and textual specification – converting the digital model back into material reality. Accepting that this allows the exploration of a realm of abstract geometric, formal or diagrammatic characteristics (Eisenman 1999) it also seems reasonable to ask how much of the world is trapped or lost in these passages through the digital bottleneck? To put this question into context it also worth recalling that architectural practice as a discipline is predicated on the notion that architects create drawings rather than buildings as such, and have therefore always operated via a form of graphic coding. Historically the arcane operations of geometrical projection have allowed architects to cultivate a quasi-mystical persona, and the curious tools of set-square, rule and compass have been seen to possess an almost magical status (Frascari 1993). Architectural drawings likewise come to be seen as mystical artefacts existing on the boundary between the possible and the actual, even to the extent that buildings can be described as 'representations of the drawings that preceded them' (Frascari 1991, 93). The carving out of a special niche for design within the construction process therefore involves a necessary degree of alienation between thinking and building, which is at the same time both liberating and troubling. Marco Frascari traces this tension through the etymology of the word *technology* and its intertwining of the two Greek terms *techne* and *logos*. By reversing the two parts we go from 'knowledge of construction' to the more intriguing 'construction of knowledge', which Frascari also claims explains the links between thinking and making implied by the common root of the words *constructing* and *construing*:

> Drawings must become technographies, which are graphic representations analogously related to the built world through a corporeal dimension and embodying in themselves the Janus-like presence of technology in architecture, where the *techne* of *logos* (*construing*) cannot be separated from the *logos* of *techne* (*constructing*). (1991, 107)

It is this same corporeal dimension of drawing that is celebrated by Juhani Pallasmaa in his book *The Thinking Hand* (2009). He argues that the 'false precision and apparent finiteness of the computer drawing' suggest a misleading correspondence between representation and reality, whereas the vagueness of the hand-drawn sketch actually allows a deeper cognitive connection to be developed through the medium of the designer's body:

> The hand with a charcoal, pencil or pen creates a direct haptic connection between the object, its representation and the designer's mind; the manual sketch, drawing or physical model is moulded in the same flesh of physical materiality that the material object being designed and the architect himself embody, whereas computer operations and imagery take place in a mathematised and abstracted immaterial world. (2009, 95–96)

Both Frascari's and Pallasmaa's interest in the instruments of drawing is echoed in the writing of Malcolm McCullough who has also tried to re-situate and re-materialize the new digital technologies within the broader history of design tools (1996). Focusing on the nature of the human-computer interface and the concept of what has been labelled 'embodied interaction' (Dourish 2004), McCullogh concludes that the success of the computer as a design tool will depend on its achieving a greater continuity with the material world: 'Virtual craft still seems like an oxymoron; any fool can tell you that a craftsperson needs to touch his or her work. This touch can be indirect – indeed no glassblower lays a hand on molten material – but it must be physical and continual, and it must provide control of whole processes' (McCullough 1996, x). Citing Michael Polanyi's *Personal Knowledge* and Henri Focillon's *Life of Forms in Art*, McCullough makes much of the notion of embodied learning and – like McLuhan – the idea of the tool as a *medium* of experience. The key point for McCullough is the way in which the tool feeds back knowledge of the world through the interface of the designer's body and it is this shortcoming in the current computer modelling process that he is keen to rectify. As the rapid simulation of building performance is beginning to allow the architect a more intuitive grasp of environmental design, it becomes conceivable that more of the tectonic qualities of materials will also become possible to simulate – what could be seen as a gradual widening of the digital bottleneck. This point has also been made persuasively by Bob Sheil in the introduction to an issue of the journal *Architectural Design* in which he described the combined use of analogue and digital modeling in the work of a number of young practitioners (2008, 6–11).

The resistance of materials under conditions of transformation is what gives rise to their tectonic qualities, and, as both Bergson (1988 [1890]) and Dewey have suggested, the body's encounter with material resistance is also the ultimate source of our experience of the world: 'Nor without resistance from surroundings would the self become aware of itself.' (Dewey 1980 [1934], 59). Within the residual physicality of the digital realm it may well be possible to identify useful analogues to the material world – perhaps through a more detailed analysis of the technical composition of digital media at the micro- or even nano-scale. Similar studies in related disciplines that could perhaps be mirrored in architecture include Vivian Sobchack's studies of the materiality of film (1992; 2004) and Laura Marks' work on digital video (2002).

The other development which suggests a stronger continuity between the screen and the physical world is the realm of digital fabrication which is gradually restoring some of the lost links between thinking and making. By linking the computer of the designer to that of the manufacturer it allows a kind of mass-customisation of components, offering the prospect of a reunification of design and construction in what could be seen as a 'new middle-ages' (Abel 2004, 61–89; Kieran and Timberlake 2004). Rather than simply selecting ready-made construction products in the role of a specifier or 'quartermaster', the use of CAD-CAM technologies potentially extends the designer's control from the structure to the smallest detail. As Mark Goulthorpe has stated in an interview from 2004:

> We should look to expand material imagination through digital media in more abstract ways. Increasingly I think of a project as a distribution of material in space, not as the assemblage of preformed elements. We're moving from collage to morphing, looking to deploy material as material for its spatial and surface effects. As yet, digital technologies do not facilitate the deployment of material-in-space, but they do instigate a reinvention of material process, in that we're not just inventing 'an architecture' but *the possibility of an architecture*'. (Goulthorpe 2008, 131)

We are not yet at the stage of 'printing' buildings, as we are equally not quite ready to print transplant organs, although biomedical scientists are developing bio-polymer 'scaffoldings' that can be used to help seed and support the growth of new tissue structures – Stelarc's 'Third Ear' project being just one high-profile demonstration (Massumi 1998, 341). These developments are beginning to bring about a change in the status of the architectural drawing which is losing some of its rhetorical functions in favour of a return to the medieval idea of the drawing as template (Anstey 2007, 29). Along with this may come a further move away from the traditional idea of architectural authorship brought about by new collaborative models of practice, such as that suggested by the work of SHoP Architects and others working in flexible networks of international partners and consultants (Coren et al. 2003). This shift provides an interesting echo of the notion of distributed bodily agency explored in several of Stelarc's performance projects, where the artist relinquishes control over his own movements through an array of remotely triggered body attachments.

CONCLUSION

In the apparent distance that all new tools create between our bodies and our surroundings lies the beginning of that process of alienation so memorably theorized by Marx and Engels in the nineteenth century. The resulting tension between thinking and making in the theory and practice of design can be traced back through the evolutionary emergence of technology, which, as suggested above, is also closely intertwined with the dawning of human consciousness itself. The fact that some form of alienation is an inevitable component of this development should not foreclose an examination of the current impact of new technologies on the construction – and continual reconstruction – of our basic sense of self.

Theorists and philosophers of technology as diverse as Michel Foucault (1994) and Jonathan Crary (1999) have charted in considerable and convincing detail the contribution of technical equipment, processes and theories to what might be called the restructuring of the modern subject. As each new technology is designed around an idealized pattern of use, so the users must adjust themselves to fit in with these preconceived forms of behaviour. It is here where questions of technology take us from the aesthetic to the ethical realm, as the embedding of human agency within an increasing number of technical objects can unwittingly offer opportunities for the insidious exercise of political power. This scenario was memorably described by Gilles Deleuze as the coming of the 'society of control', in which modes of resistance to political domination disappear behind the 'opacity' of ever more invisible technologies (Leach 1997, 309–313).

For all the potential dangers of what Heidegger described as modern technology's tendency towards 'enframing', it is not yet clear whether we should go as far as Leroi-Gourhan in describing our current condition as a progressive and inevitable 'loss of the hand' (1993, 255). Given that so much of our productive life is spent in front of a computer screen, it may be that a newly re-embodied digital interface may yet allow us to rediscover it. However they may be enhanced, augmented, redefined and reconfigured, our bodies are – as Merleau-Ponty has suggested – the only means we have to go to the 'heart of things' (1968, 135).

NOTES

1 See also recent experimental observations of neural activity during tool use in primates, e.g., Maravita and Iriki (2004).

2 Corballis is continuing a tradition initiated in the eighteenth century by the French philosopher Etienne Bonnot de Condillac (2001 [1746], 113–137).

3 I am grateful to Chris Johnson for pointing out this connection (Johnson 1997).

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