THE DIGITAL SLEDGEHAMMER AND OTHER USEFUL IMPLEMENTS

Nat Goodden
Faculty of Media, Art and Communications
University of Gloucestershire
Albert Road
Cheltenham
Gloucestershire GL52 3JG
United Kingdom
ngoodden@glos.ac.uk
http://www.glos.ac.uk/faculties/mac

Abstract – Sometimes it is frightening the amount of 'steer' a good research project can give to the way things get done. When an exciting innovative digital approach is proposed, it is all too easy for the alternative low-cost nuts-and-bolts solution to get elbowed aside without anyone noticing. The author, with a diverse sculptural/material/digital background, calls for our instinctive excitement about new-tech innovation to be tempered by a hands-on awareness of other, perhaps simpler or less obviously seductive, technologies; and reminds us that effective and imaginative critical perspectives provide an essential antidote to more narrowly specialised viewpoints.

INTRODUCTION

There is a story that when NASA realised that ballpoint pens (innovative and new-technology-driven when aviation called the shots) would not work in zero gravity, they invested a million dollars to research and develop a writing instrument that would work in space, any way up, on almost any surface, in freezing to super-hot environments. The Russians gave the cosmonauts pencils.

Of course the story is just too good to be true in the version that was popularly circulated. The space-pen was indeed developed with a million-dollar research budget, though by an independent company, then taken up by NASA: the American and Russian space programmes had both issued pencils before (the American ones being ridiculously expensive — even NASA thought so). Nonetheless, the story and the way it was enthusiastically picked up it does highlight critical issues of determinism — cultural, technological, sociological, institutional, financial, etc. — that arise every time we get to work on finding a solution to a new problem.

This paper is offered as a pause for thought. It was initially stimulated by some presentations at a previous digital-visualisation conference, where from my hybrid sculptor/handyman/academic perspective I found myself agitated by the thought "but you could do it much more simply than that" — meaning, non-digitally, using the simplest of tools, including those we are born with. Hushing the rude sceptic in me, and putting on my paid-up-academic hat, I realised quickly that doing it the low-cost low-tech (and quite likely more imaginative) way, would of course be to jettison the opportunity to join in on an institutional research programme. The opportunity to demonstrate 'innovation', to write it up and present at a prestigious international conference would be lost. So, reuniting hand and mind, I began thinking about a paper.

This is it. It represents a plea for the longer and broader perspective, informed by hand and eye as well as mind; making a place for empirically-gained knowledge, as well as for more theoretically-based (and perhaps narrower) specialist expertise. It invites the ‘shoestring’ alternative to be considered, at least as a corrective to the cutting-edge approach. And by deliberately straying from the straight and narrow path, through digressions into territories that may seem only tenuously connected with the digital, it hopes to act as a reminder that stimulus may come from the most unexpected sources, including what we may think of as redundant technologies.

In the interface between intention and action, it seems important that materially-based knowledge, as much as digital knowledge, plays a full part. But because we increasingly embed in our machines the material skills we previously employed ourselves, we continually lessen our chances of acquiring the adaptive can-do instincts that spring from practised use of them. As I see it, we thereby increase the risk that when we seek solutions to particular problems, we overlook the simpler ones; we easily find our thinking seduced by ‘big’ or ‘hands-off’ technology of the sort characteristically favoured by institutions and industry. Yet as the space-agency counter-example above suggests, and as our enthusiasm for cross-disciplinary activity might also indicate, we do value critical perspectives that provide alternative points of view, that are informed by disparate ideas about ‘doing’, and that are not afraid to open the door and let in the unanticipated — along with the fresh air of everyday common-sense.

TOOLS AND TECHNOLOGICAL DETERMINISM

This call to the involvement of hand, eye and what we might characterise as ‘can-do intelligence’ suggests some thought about tools, technologies, and the ways we go about doing things. In common usage, the terms ‘tool’ and ‘technology’ naturally overlap. By ‘tool’, I mean more the singular implement or device; by ‘technology’, I mean more the systematic practice and theory by which tools are put to work for identified purposes. By this definition, the spade, the lathe, the pencil and the desktop scanner are tools; digging, turning, drawing or writing, and the digitisation of visual material are technologies. Or again (because not every tool is an artefact), the voice is a tool and speech is a technology.

It is now generally accepted that tools evolve deterministically; partly in response, of course, to environmental influences. The idea that manufactured artefacts (including tools) do not come out of nowhere, but have a demonstrable history and set of family relationships, derives from the second half of the nineteenth century, and in particular the work of the soldier and ethnologist Pitt-Rivers [1]. More recently the philosopher and historian Manuel de Landa has gone further and proposed an “independent evolutionary track for tools as part of a machinic phylum.” Any understanding of the way that tools evolve and are used must therefore engage with ideas about causality and determinism.

The specific doctrine of technological determinism — that a society’s technology determines its cultural values, social structure, or history, to take one definition — brings a second set of ideas into play. Without espousing a ‘hard’ view of technological determinism (which would suggest that all future developments are pre-determined), it is difficult to argue against the view that successful tools and technologies exert a strong influence on the ways we subsequently do things and think about things. To take an obvious example, the invention and diffusion of photography is conventionally linked (among many other things) with the subsequent development of the cinema, the evolution of non-mimetic art, the espousal of new modes of scientific observation, and a sea-change in the way we conceptualise memory and time. Much of that seems unlikely to have been anticipated by the photographic pioneers Niépce, Daguerre or Fox Talbot, all of whom strove to make permanent the transitory images of the camera obscura. (Fox Talbot was strongly driven by his feelings of inadequacy at drawing compared with his womenfolk, though Daguerre was perceptive about the implications of his idea for scientific practice.) To take a less well publicised example of the development of a technology and its outcomes, the packaging of oil-paints in squeezable tubes from the 1840s was an absolutely key determinant in the development of open-air (as opposed to studio-bound) landscape painting, leading directly to Impressionism. Interestingly, conventional art-historical accounts, more concerned perhaps with grander narratives, tend not to point this out; yet it is hard to think of anything in its way more significant.

TOOLS, META TOOLS AND VIRTUAL TOOLS

There are tools (and technologies) that act on matter, and others that do not. The first class of tools is quite easy to define — at first sight, anyway: saws, pliers, kitchen knives, the garden mower. We might then propose a generally more recently-developed class of ‘meta’ tools — tools that act, not on matter, but on information: typewriter, camera, calculator [2]. But we should not forget that this discussion started with the example of writing or drawing implements — pens and pencils, which act both materially and informatically; so we immediately see that some of our commonest and oldest tools provide a bridge between those two, perhaps too hurriedly-defined, categories. Leaving that question aside, I want to propose one further category: the virtual or metaphorical tool, the tool that effectively acts on thought. A classic example is Occam’s razor (the tool for reducing an argument to its essentials by paring away any excess), though Nietzsche’s hammer (with which to smash false idols) surely also belongs in this category. Tools of this virtual or metaphorical kind appear to derive from the nineteenth century — just as do many of the consciously informatic and proto-digital tools (camera, telegraph apparatus, typewriter) considered above [3]. Whether the concurrency of these developments is coincidental or not — the nineteenth century was a great pioneering age for the materialising of informatics, as it was for the abstracting as well as internalisation of ideas about ‘doing’ — I do not know; it is a question deserving more attention. The idea of the virtual tool, meanwhile, is something we will return to later.

A DIGRESSION: RIVETS, MATERIAL AND MIND

It is hard to think of a more ‘material’ and less ‘digital’ technology than riveting. We might think of it as characteristically nineteenth century, and in the sense of large-scale riveted structures, we would have a point. But in fact the technology is astonishingly old, and premised in ‘process’ terms on nothing more than availability of a hammer, forge and malleable metal. While the much more recent development of the humble wood-screw has rightly attracted substantial attention in histories of technology (it has been elevated almost to the status of an exemplary case), the rivet has been very little written about [4][5]. Yet from the Bronze Age to the early twentieth century, it was in most respects the dominant technology for metal-to-metal jointing, and for conjoining metal with other materials such as leather, wood and bone. It was a mainstay of metal-smithing, and was brought to a high state of precision in the art of the armourer, enabling pivoting, sliding, hinged as well as rigid joints to be made. It developed into the dominant metal-joining technology of the great industrial age of the nineteenth and early twentieth century, when increasingly heavy demands of pressure, tension, etc. were made on structures of all sorts, and when an empirical awareness of how far you could push materials and processes was first complemented by a mathematically-based theoretical understanding of those things. Locomotives, iron ships and bridges, boilers and girders were all designed and riveted together using that knowledge. In an interesting aesthetic aside, some late nineteenth-century Arts and Crafts designers such as Christopher Dresser practically fetishised the rivet (in dual role as fastener and decorative punctuation) in the production of copper and brass household wares. In the pre-digital spirit of the age, Jacquard-card automation of hole-punching for riveting arrived in the mid-nineteenth century, powered rivet-guns from the cusp of the twentieth, and then suddenly the technology was (with some significant exceptions) on the wane [6].

Perhaps it is a sign of a successful technology when it becomes a metaphor, as for example the way rivets grip metal has become a metaphor for the way a story can grip the imagination. Riveting remains a compelling example of an approach to ‘doing’ that is as clear to the eye as to the mind. Every rivet is a punctuation mark in the narrative of assembly and structural behaviour of the artefact in question; a riveted bridge or ship is effectively a Braille text for the sighted. Will we ever learn to read lines of code as expressively as this? And if not — if the beauty of the products of digital technologies lies partly in their sublimation of what holds them together and dictates their behaviour — will that matter?

DIGRESSION 2: EIFFEL AND TOLERANCES

One of the high points of iron-and-rivet technology as an embodiment of materialised knowledge is in the bridges and viaducts designed by Gustave Eiffel: functional rather than celebratory, they are not as widely noted as his famous tower that evolved out of them, but as consummate in their realisation and advancement of an idea. Brilliant engineer that he was, Eiffel was not just good at well-crafted form, but at understanding material behaviour. Among other things, this means having an acute appreciation of tolerances. In his bridges, at the time the tallest known, he was a pioneer of production design, pre-fabricating sections in his workshops that were assembled on site in several continents, all to tenth-millimetre tolerances — extraordinary in an age before laser measurement. But tolerances are not just about accuracy of fit or linear expansion and contraction. They are also about letting a structure ‘breath’, designing and building it with the understanding that it is in its own way an organism.

Eiffel’s part in the construction of the Statue of Liberty is interesting. As a monument, Liberty Enlightening the World (its full name) is an intriguing example of the industrialisation of sculpture and at the same time of the revisitation of ancient techniques. The sculptor Bartholdi modelled the monument in Paris, and engaged Eiffel to build a wrought-iron latticed girder skeleton framework over which the beaten copper sheets that make up the skin were fitted [7]. The whole was built temporarily in a Paris yard, then disassembled into 350 pieces for shipment across the Atlantic and final reconstruction. Among the advantages of this procedure were weight-reduction, transportability and ease of reassembly, quite apart from the avoidance of problems in conventional foundry-cast bronze monumental sculpture of material distortion and 'fit' of the parts. This curious amalgam of advanced engineering, academic art, ancient technique and artisanal skill may appear to belong very much to its own era. But it is mentioned here for its wonderful demonstration of material compliances and tolerances. Along with Eiffel's tenth-millimetre girder-skeleton tolerances went the much more generous (5mm) tolerances needed for the hand-formed iron ribs sprung out from the central armature, and the 2.5mm beaten and riveted copper skin, which has to be able to flex to withstand wind pressures and extremes of temperature. Working with digital tools, it is easy to assume that micro-millimetre accuracy is all, but it is not. Poised on the cusp of manually-gained and theoretically-based knowledge, Eiffel — a pioneer of wind-testing in his final years — came up with the kind of tolerances, and understanding of 'fit' and 'flex', still used in building construction [8][9].

DIGRESSION 3: HOW WE GOT HIGH-RISE

Closely contemporary with the Statue of Liberty (finished in 1886) was the Otis elevator (first used commercially in 1857, widespread in electrically-powered form from the 1880s, and indeed installed in the Eiffel Tower's first stage soon after it opened in 1889). It was not the world's first passenger lift; that honour is often given to the 'chaise volante' that Louis XV had built at Versailles in 1743, to enable him to go undetected to his mistress's chambers, although rudimentary lifts in mine workings almost certainly predate them all. Critically however, the Otis elevator was the first to incorporate a failsafe device in the event of cable failure, a sort of mechanical equivalent to the feedback loops and other self-monitoring circuitry so critical to later analogue and digital electronics [10].

Histories of architecture often now explicitly acknowledge what, when I was a student, they tended at best to glide over, which is that the development of high-rise buildings, initially in Chicago then New York, was a classic case of technological determinism (and not simply a question of tight space and high style). The development of the Otis elevator coincided with regulations brought in after the great Chicago fire of 1871, which led to a radical structural innovation: iron (then steel) frame construction, whereby the outer walls of a building ceased to be load-bearing, but were instead suspended from the girders of the frame [11]. This enabled the walls of even very tall buildings to be made much thinner than was possible with brick or masonry construction, which in turn meant that even narrow plots of land could carry tall structures without interior space being squeezed out by increasingly thick walls at the lowest levels. The Otis elevator made it amenable to build higher than 5 or 6 storeys: by 1903 (the year of the Wright brothers' first powered flight), lift design had evolved to the point that buildings in excess of one hundred storeys could be dreamed of. Iron and steel girder construction (riveted, of course) made such heights possible — by the end of the nineteenth century, 20 to 30 storeys were being achieved, and by 1930, over 100 storeys [12]. In architecture as in aviation, aspiration and elevation were strongly linked: as inevitably as aspiration and digitisation are today.

DIGRESSION 4: CLASSIFICATION AND CARDBOARD

Perhaps, like the small hirsute mammals that first appeared alongside the dinosaurs, dominant technologies are always accompanied by others so low-profile that their full significance can easily be overlooked. Almost as ubiquitous in its period, yet as low-key as iron-framed bridges and skyscrapers were high, was the humble technology of the file-card and card catalogue; a ‘soft’ technology that was never dependent on mechanical advances (though it was certainly driven by a proliferation of library stock as well as by ideas about systematic classification, both very much of their time). Its origins are interesting: in post-Revolutionary France there was an urgent need for the state to have a central record of what was held in the many private and monastic libraries recently sequestered. In a classic case of a need engendering an invention, of the invention appropriating an existing technology, and of the earlier technology determining the characteristic dimensions of the new, playing cards were used to write down the details of individual books, and reinvented as file cards. By the 1840s, the British Library was moving to a system of paper slips representing individual books — and recognising that their irregular proportions presented practical problems to efficient searching. By the 1860s, systematised drawers-full of machine-cut cardboard cards (initially for staff use only) were becoming conventional in major libraries in the Western world. By their segmentation of information into discrete hand- and eye-sized chunks, what we can now recognise as a significant step in information engineering was well under way [13].

The case of the file-card and card catalogue is interesting in many other ways. It can now be seen as a critical transitional technology — advanced low-tech informatics before computerised systems superseded it [14]. In retrospect, it had many disadvantages (the space an extensive card catalogue occupied, its resistance to systemic reconfiguration, its locational specificity, its lack of back-up security). Against that, its unsurpassed ability to accommodate cumulative detail and its potential to act as a meta-narrative on what it indexes has been well noted. So has its character as information in material form, a topic essentially antithetical to digital informatics, but whose informational, cultural and psychological importance is still writ large in most museum collections, art galleries, and books.

DIGRESSION 5: OBSOLESCENCE AND AFTER

Is it in the nature of things that they become most interesting when they are novel (and entirely un-accommodated in our mental armoury) or when they are on the point of obsolescence (and we belatedly tune in to the attributes we had not fully exploited)? The file-card and card catalogue (and their obsolescence) invite a detour into a minor by-way of material determinism within culture.

More or less at the point of its obsolescence, the file-card was interestingly picked up and utilised, whether as form, idea or formalised idea, by a number of artists, writers and musicians. For example, the avant-garde film-maker Robert Breer built an influential career on the imaginative use of file-cards. With a background in painting, he was naturally keen to circumvent where possible the technological paraphernalia of film-making, and evolved what he called a ‘five-and-dime’ approach that capitalised on what could be found in any high street. Rather like the equally-influential composer and musician John Zorn, he developed ways of using stationery-store file cards as compositional generators: permutating the component parts to build new or impromptu imaginative structures, and (in Breer’s case) shuffling them unpredictably like the playing cards from which they descend. Breer has also taken advantage of the six-inch by four-inch file-card’s replication of cine film’s 3×2 aspect ratio, and made a body of imaginative and witty animated films drawn and painted directly onto them, frame by frame; an exemplary espousal of ‘home-made’ technique [15].

At broadly the same time, one of the founding works of conceptual art was Robert Morris’s *Card File* of 1966, a card file literally but also wittily describing its conception and making, and contextualising itself in detailed cross-reference (entries include ‘accidents’, ‘decisions’, ‘materials’, ‘mistakes’, ‘prices’). In serious-yet-playful spirit, an entire (and also highly influential) art movement of the 1970s, Fluxus, was premised on the availability throughout the industrialised world of low-cost semi-standardised stationery-shop paraphernalia: rubber stamps, file-cards, paper-clips, cheap reprographics, etc. The writer Georges Perec — of great interest to ideas of a digital culture because of the informatic constraints and mathematical-rule-based dynamics of his influential novels addressing memory and loss — in his daytime job as neurophysiological archivist, famously developed advanced versions of commercial card-file systems enabling cross-referencing to an extraordinary degree of complexity, meanwhile making sure that they and his creative practice were mutual cross-pollinators. Novels of his such as the 1978 Life A User’s Manual (La vie mode d’emploi) exemplify what is generally accepted as a significant and innovative literary imagination, intriguingly inflected by this world of systematised informatics [16].

USEFUL THINGS AND GETTING IT RIGHT

How did we get here? File-cards, information, rivets, lifts, … Material or technological determinism are topics that remain largely peripheral to histories of (for example) art and literature, which generally persist in pursuing the grand narrative or abstract idea, rather than asking for instance what effect the typewriter or cheap paper had on literature, or the availability of sheet metal upon twentieth-century sculpture. Yet I cannot help thinking that something important is lost when such viewpoints are excluded [17]. Material culture as a coherent field of study is of course a relatively recent idea (though some of its roots can easily be traced back, for example, to Diderot and d’Alembert and their luminous democratisation of practical knowledge in pre-Revolutionary France). Our penchant for denigrating the utilitarian is well illustrated by the cultural historian George Kubler’s observation that “useful things disappear more completely than meaningful or decorative things,” noting how in our museum collections, we keep paintings, decorative and ‘precious’ items of jewellery and the like far more than we do tools and other artefacts of everyday culture [18].

The thought of ‘useful things’ naturally leads us back to research projects. The suggestion was made at the outset that the directional integrity of these can sometimes fall prey to a crude form of techno-cultural determinism. In particular, I want to suggest that a problem encapsulated in some research projects — including those that stimulated these words — is that we love innovating, especially with new technologies, but do not love waiting to accommodate ideas, and especially ideas-in-things and other materially-based knowledge; yet these are exactly the kinds of knowledge we need in order to be able to formulate sound judgements as we step into territories too new for us to have established a full set of bearings. The architects Peter and Alison Smithson made the remarkably simple-sounding point that “it takes a very long time for a useful thing to become an idea,” and it is well-known how the real significance of a new technology is often misunderstood even by its inventors when it first emerges. If the innovative urge cannot wait until all of the relevant tools, processes and technologies have become absorbed into our everyday practical awareness, we have to recognise the potential for some of our critical judgements to be flawed. Our attempts to innovate are often out of sync with a sound understanding of the ideas and native skills that, ideally, should inform the innovation.

There is a wonderful idiomatic expression in English: reinventing the wheel. It is meant as a caution: to reinvent the wheel is to have failed to understand that what you were doing had already been done; your project was essentially redundant, and you managed not to notice. It is interesting how often the expression is still used, suggesting that some of us never learn. As an idiom, it is compelling — the wheel is of course held out as one of the defining technologies of its era, if not *the* defining technology [19]. There are two important points here. Firstly, the wheel became an idea a very long time ago (hence the validity of the expression). As such, it exemplifies technological ‘things’ that we can adapt, generalise from, think laterally and creatively with, and (if you like) appropriate as mental tools. Secondly, it makes a silent point about our need to possess a critical perspective, because without an effective way of standing back from what we are doing, we would never be in a good position to see that what amounted to the same thing had already been developed.

THE DIGITAL SLEDGEHAMMER

When there is something to be done, making the assumption that one way to go is innately superior — be it pencil or pen, wheel or camel, tape-measure or its digital laser equivalent — is plainly short-sighted. My instinct is to suggest that a lot of the time, we *do* choose reasonably appropriate ways to do things (that we do not always act so intelligently is nicely illustrated by another English expression, using a sledgehammer to crack a nut — a sledgehammer being a particularly large and not very subtle implement normally reserved for driving in stakes or cracking concrete). But research institutions tend not to invest in inventive but down-home solutions to our problems, so they and we easily find ourselves pursuing alternative kinds of answers, and thus it is that — occasionally and maybe more often — we find ourselves doing things in needlessly over-complicated ways. An interesting illustration of the way we tend to ‘expect’ complex solutions is provided by one of the lesser-known achievements of Stanley Milgram, the innovative and influential sociologist. Milgram, an imaginative deployer of everyday technologies, invented in the 1960s the use of the dropped envelope as a strategy for gauging the man or woman in the street’s response to particular things (such as their political tolerance). The idea was as beautiful in its simplicity and economy, as in its subtle appreciation of the way the human psyche works. The strategy is still used, but what is revealing is that 40 years on, it is still being remarked upon for its low-cost, low-tech effectiveness [20].

Our best tools and technologies do much more than fulfil our basic functional expectations of them. For instance, in the mechanical age, the form a well-evolved device took tended to tell you what it did; the hammer and hacksaw, the bicycle and bridge, were diagrams of their own functionality. If a particular example was misconceived or over-elaborated, the fact could readily be seen: so there was less chance of it happening in the first place. But in the digital age, you can make a thing pretty much any shape you like, and that makes it much more resistant to a clear reading of its rationale. And thus it is that the digital sledgehammer, which has found its way into a fair number of toolboxes without previously being graced with a name, and which

I propose as the latest addition to our armoury of virtual or metaphorical tools, is doubly insidious. It is undeniably impressive-looking, and well capable of giving a project a desirable aura of businesslike intent. But in fact, it is hard to see exactly what its finer points (or indeed its weaknesses) are. And the cruel fact is that, unless you are involved in digital demolition-work, it is almost certainly the wrong tool for the job.

So my plea to the digital-research ‘doer’ is this: do everything you can to keep a broad perspective, do not ignore stimulus from ‘obsolete’ or other unlikely sources, do not despise home-brewed solutions, and make sure your toolbox is appropriately equipped for adaptive and imaginative approaches to the job in hand. But leave that sledge-hammer and any of its smoother-talking siblings at home, and see if ingenuity and imagination cannot do the job more effectively. If cracking digital nuts is what you really have to do, there has got to be a smarter way.

References

[1] That everyday objects have ancestries may seem a commonplace idea, but was radical when first articulated in the 1850s by Pitt-Rivers, not uninfluenced by his contemporary Darwin’s notions of biological evolution (though he himself put it that Darwin’s ideas on the organic world simply confirmed his own on the world of artefacts).

[2] The term is my own. There is of course an established specialised use of the term software tools that work on meta-data. My suggestion is for a more generalised usage.

[3] Although Occam (or Ockham) himself lived in the late thirteenth and early fourteenth centuries, the phrase ‘Occam’s razor’ first appeared in 1852.

[4] MUMFORD, S: 1934, *Technics and Civilization*. London, Routledge.
RYBCZYNSKI, W: 2001, *One Good Turn*. London, Scribner.
These are characteristically eloquent about the development of the screw.

[5] Rudyard Kipling (who appears to have understood structures well) in his 1895 short story *The Ship That Found Herself* provides one of the very few literary references — describing the rivet (slightly tongue-in-cheek) as “really the one indispensable part of the ship.” Rybczynski, for example, provides passing reference to the rivet (op. cit.), Mumford, in his seminal study, not at all.

[6] Richard Roberts, a significant pioneer in the development of machines that, acting upon information, produced other machines, designed a device for punching variable patterns of multiple rivet-holes in 1847 for George Stephenson’s tubular iron bridge over the Menai Straits in North Wales. Compression-powered rivet guns appeared around 1900. Aircraft manufacture provides the salient example of the continued survival of riveting, not least because of the warping that welding temperatures engender in sheet alloys, and the relative ease of inspection of riveted joints.

[7] Eiffel’s and Bartholdi’s methods were a sophisticated reinvention most obviously of ancient Greek methods. Small-scale riveted sculpture, where an outer metal skin lies over an inner former, dates back to ancient Greece (700 BC), where it was superseded by the more refined process of lost-wax casting (around 500 BC). Intriguingly, the Colossus of Rhodes (third century BC) appears to have been constructed of sheet bronze, probably riveted over an iron and stone skeleton: accounts are however unreliable.

[8] For details of construction, see for example http://www.corrosion-doctors.org/Landmarks/statue-construction.htm.
Eiffel was a pioneer in studying the effects of wind upon structures, used the Eiffel Tower's top platform to perform tests, and built what is now recognised as the world's first wind-tunnel.

[9] Modern computer-aided building design and construction works typically to 4–5 mm tolerances, relying upon shims — updated adaptations of an age-old principle — to get both fit and flex right.

[10] The history of interactive control and feedback still (rather surprisingly) awaits comprehensive treatment. Devices that mechanically monitored and governed their own condition had been around at least since the seventeenth century, in windmill technology; and as part of self-contained systems (steam engines, particularly) since the eighteenth, James Watt being a leading exponent of such developments.

[11] Earlier use of iron in buildings was still based on the outer brick or stone walls carrying much of the weight. Matthew Boulton and James Watt were responsible for the most radical design of this era (1801).

[12] The accepted height limit for load-bearing brick or stone construction was around 15 storeys.

[13] Nicholson Baker's extended essay *Discards* (1994) is intriguing on the history of the library file-card. BAKER, N: 1996, *The Size of Thoughts*. London, Chatto & Windus.

[14] However in the context of file-card cataloguing, the ultimately short-lived age of the microfilm and microfiche should not be forgotten: a brave stab at miniaturisation, though with hindsight appearing something of an evolutionary dead end.

[15] Zorn in fact points out that cinema 'greats' such as Hitchcock, Welles, Lang and Lynch have used file-cards more conventionally to store ideas.

[16] See David Bellos' biography: BELLOS, D: 1993, *Georges Perec: a life in words*. London, Harvill, e.g., pp. 254–8.

[17] The obvious counterexamples of fields like archaeology and the history of science and technology point up such anomalies.

[18] Quoted in EDGERTON, D: 2006, *The Shock of the Old*, London, Profile Books, p.29.

[19] Interestingly, the wheel — or rather, wheeled transport — was effectively un-invented in the Middle East, where it is generally taken to have been invented, and in North Africa, for around a thousand years, only re-appearing as late as the nineteenth century. The reason? That pack-animal par excellence, the camel, proved faster, cheaper, lighter, and was un-reliant on paved or even firm surfaces.

[20] This very recent example, from WISEMAN, R: A quirky look at our quirky species. *New Scientist*, 9 May 2007.