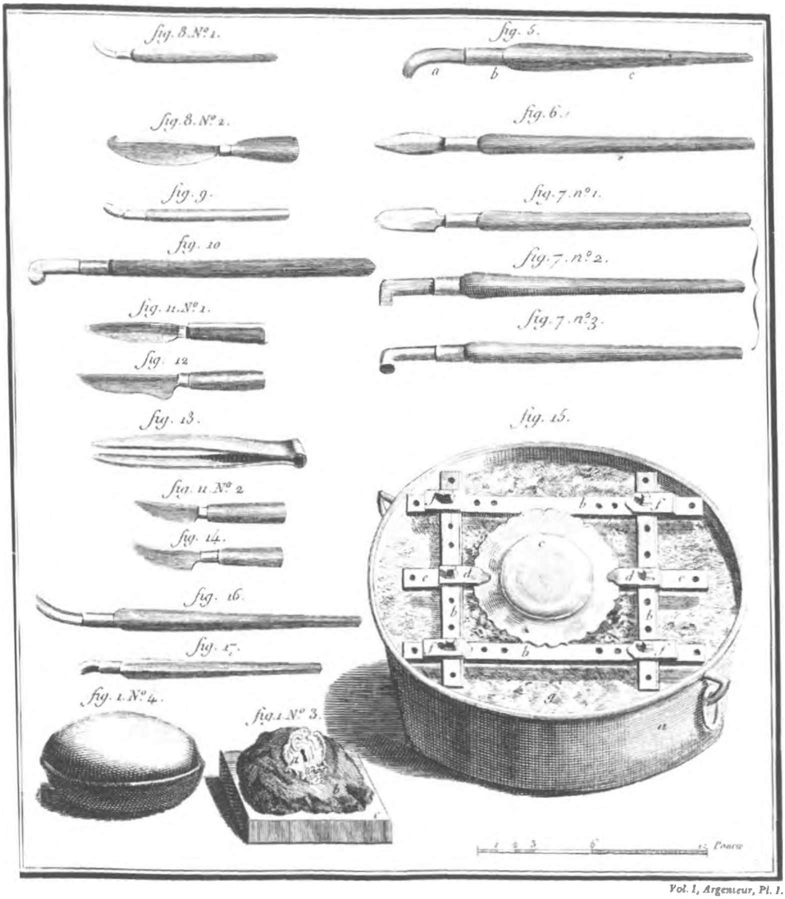
3 Tools

You probably think of a tool as something to hold in your hand. It is something to extend your powers: a piece of technology, or applied intelligence, for overcoming the limitations of the body. The hand-held tool comes to mind because more than any other it demands an especially active sort of skill. It requires your participation, and for that reason it engages your imagination.

A tool directs your attention. Its function becomes your focus: as the saying goes, when you hold a hammer, all the world looks like nails. Its function extends some powers of your hand, and prevents the use of others. In other words, it serves a specialization.

A tool usually belongs to a set, which implies a hierarchy of specializations. A toolkit provides every function needed for a single specialization by means of its members' many different specializations. Its effectiveness for a single purpose emerges from the combined or alternative effects of its differentiated members. Multiple tools may provide alternatives of scale, like a set of socket wrenches, or incremental differences of hardness or weight, like a set of pencils. Multiple tools may work in



3.1 Silversmith's tool set from Diderot's *Encyclopédie*

specific combinations, like a knife and a fork. Instruments for measuring complement implements for forming, and tools for clamping and guiding complement tools for action.

A tool or toolkit normally benefits from the context of a studio or shop. For example, surfaces and lighting support particular tasks. Multiple collections of tools and kits for a variety of related purposes distinguish a practice. A shop supports and gives place to that practice.

Above all else, tools take practice. You must learn how to bring skills and intentions together. You must learn how each tool works, how one tool works with another, and how all are maintained. You must know what tools are for. A well-equipped woodshop might make you feel like building something, but only if you are so inclined—only if you are in practice.

If you feel satisfaction in using a well-practiced tool, you probably do so on several levels. Tool usage simultaneously involves direct sensation, provides a channel for creative will, and affirms a commitment to practice. The latter is quite important: only practice produces the most lasting and satisfying form of knowing. Practiced mastery is something we crave in itself. Aquinas said that we cannot live well without working well.[1] Most anthropologists would affirm a fundamental relation between tools and humanity. Deep in our very nature, we are tool users.

A tool may not only perform some action, but may also come to represent that action.[2] A tool is inscribed in your imagination not only as an activity, but also as a symbol. An oar, if you are a skilled boatsman, is not just for plying the water, it is *about* plying the water. It may evoke memories, it may have romance. This is important to us, as reflected in the way we prize our favorite tools. Furthermore, a particular tool may represent not only an action but also an approach. In this manner, a French kitchen knife is quite different from a Japanese kitchen knife, even if both are used to cut fresh vegetables. Such implicit differences in approach are especially evident in toolkits, which more effectively represent whole structures of tasks. For example, the cookware in a fine restaurant differs from the cookware in an institutional cafeteria. The tools come to stand for the processes. This symbolic aspect of tools may help you clarify your work. Choosing the right tool is not only about completing a task, but also about establishing and focusing that task. Holding a tool helps you inhabit a task.

Tools may also work *upon* symbols. A clock, for example, although a piece of power machinery, produces abstract measure of hours, minutes, and seconds.[3] A book is hand-held, but is mainly the object of symbolic skills. A computer, part clock and part book, thus far allows insufficient physical control: although it involves a lot of pointing, computer usage is mainly mental. That is, not all tools are prosthetic. These various tools that introduce abstractions do not so much extend the powers of the body as those of the mind. They are for processing symbols. We use these tools of abstraction every bit as much as any others, because deep in our nature we are also symbol users.

History has taught that we might do well to divide our tools into those that transmit power and those that transform information. This division is fundamental enough to have formed a basis for social classes. Although humankind has used both of these classes of tools from the very outset, historically the information tool users—scholars, statesmen, and clergy—have dominated the mechanical tool users—the farmers, traders, and craftsmen. New thinking and new tools have often shifted the roles, but seldom the balance. But today the information tools take on a physical dimension, and may begin to unite skill and intellect in new ways. To understand how this potential might develop, we need to understand the symbolic processor not only as a form of tool, but also as a medium.

Tool and Medium

We have noted that the hand works in two directions: part effector and part probe. When enhanced by a tool, the hand remains such a two-way conductor, but its powers become narrowed and intensified. That is, when using a tool we can sense some things better, and we can alter some things better, but others not at all.

Normally this specialization occurs in terms of a medium. Tools are means for working a medium. A particular tool may indeed be the only way to work a particular medium, and it may only be for working that medium. Thus a medium is likely to distinguish a particular class of tools. For example, a material that is workable by chipping it away incrementally gives rise to chisels. The nature of that material will determine the nature of the tools: thus a carpenter's wood chisels are different from a stonemason's chisels.

Sometimes a medium implies such a unique set of tools that the whole is referred to without differentiation. Painting is a medium, but it is also the use of specific tools and the resulting artifact: a painting. The artifact, more than the medium in which or tools by which it is produced, becomes the object of our work. The presence of an artifact is more important than any clear-cut distinction between tool and medium. Artifact, tool, and medium are just different ways of focusing our attention on the process of giving form.

Many tools, especially tools that operate on symbols, do not work a medium so much as they assist observations, make measurements, or interpret scores. We usually refer to such tools as instruments. Although there may be a craft of scientific measurement or musical performance, let us focus on tools that work a medium to produce a lasting artifact. As mentioned earlier, it is the craft that involves continuous operations on a workable medium which is most compelling. But this does not rule out our consideration of an abstract medium: our scope includes abstract artifacts produced by means of continuous operations (e.g., direct manipulation) in symbolic media. Nor does it eliminate consideration of instruments, for many form-giving tools that demand highly refined practices are understood as instruments. We are simply limiting the focus to the interplay of the effecting tool and the workable medium.

In many refined practices, the perception of a medium surpasses any perception of tools. If a medium is a realm of possibilities for a set of tools, then any immediate awareness of the tools may become subsidiary to a more abstract awareness of the medium. Although a tool focuses your work, it should also let you focus on your work—in this sense it should go largely unnoticed. Cognitive psychologists agree that some sensory-motor activities can be learned to the point that they become automatic. This normally takes practice. Even for a known process, it may also require some adjustment of a tool's performance and to its subtleties—breaking it in. But with practice you should be able subconsciously to handle your tools without interfering with your active intent.

In this case, the tool may be said to have become transparent. When you use a hammer, you focus on the hammer striking the nail, and remain only secondarily aware of the feeling of its handle meeting your hand.[4] Indeed you think you feel the hammer striking the nail itself. Interestingly, tools far more sophisticated or abstract can be just as transparent as a simple hammer. When painting in watercolor, for example, you should mostly be looking at the light bathing your subject; you should be able to subjugate any awareness of your control of paint streaming off your brush; and the fact that you are holding a brush at all should be completely transparent.

Tool, Machine, and Technology

The experience of transparency is hardly limited to unitary, hand-held tools. Adjustable tools fit better than monolithic tools under a greater variety of conditions. Mechanical tools extend the possibilities of the hand to a far greater range of applications than can monolithic tools. Even machines can behave as tools under the appropriate circumstances. In the loose sense that a tool is a human extension as means to an end, all machines are tools, and all tools are a kind of technology, even if in the case of an ancient device such as an ax, it is difficult to think of them as engineering.

Given the abundance of mechanical tools, some definitions are in order. A mechanism is a device with multiple moving parts for the transfer of motion. For example, a pair of gears is a mechanism for the transfer of rotation from one axis to another. A machine is a mechanism for the transfer of power. Power may be the force of the hand or the body, or it may come from outside sources. For example, an engine is a machine powered by combustion. Motive power may assist or replace human guidance, and this is an important distinction.

Transparency depends on the effectiveness of an extension as a conductor. Like the hand itself, this extension may be two-way: part effector, part probe. So long as it is driven by the hand, this extension may be a crude implement, an elegant machine, or a complex, baroque world of technology—what makes it a tool is the hand. Although no tool will be as rich a conductor as the bare hand, it may compensate by working under a greater range of conditions. For example, it may overcome the interference of one undesirable sensation to provide a clearer perception of another, just as a fork in a skillet bypasses overwhelming heat to let you test the firmness of cooking food. It may translate the scale or reach of the hand so that it may work in tight spots, or at very large scales. Such magnifications, large or small, are accomplished with mechanisms. Well-fitted mechanisms, and mechanisms augmented with high-resolution sensors, may be more than adequately transparent. Or at least the surgeons doing teleoperations think so.

To this way of thinking it seems fairly meaningless to ask what, if anything, is truly made by hand.[5] Only in a few exceptionally simple cases such as pottery or basketweaving do the hands work in direct contact with a material. The word medium intrinsically suggests the mediating action of tools. Beside tools mediating the hand, guides such as jigs and templates mediate the tools; wheels or clamps handle the material; and motors assist in providing power. A *machine tool,* such as a lathe, couples mechanical precision and motive power with direct manual operation. Does it matter whether an expert machinist is truly doing hand work? In his study of workmanship, Thorstein Veblen observed:

> But in these more primitive industrial systems—as also in the days of handicraft—the workman is forever in constant control of his tools and materials; the movements made use of in the work are essentially of the nature of manipulation, in which the workman adroitly coerces the materials into shapes and relations that will answer his purpose, and in which also nothing (typically) takes place

> beyond the manual reach of the workman as extended by the tools which his hands make use of. Under these conditions it is a matter of relatively slight effect whether the workman does or does not rate the objects which he uses as tools and material in quasi-personal terms or imputes to them a degree of self-direction, since they are at no point allowed to escape his manual reach and are by direct communication of his force, dexterity, and judgment coerced into the forms, motions, and spatial dispositions aimed at by him . . .
>
> The matter lies differently in machine industry . . . [where] the operative's work supplements the machine process, rather than makes use of it. On the contrary the machine process makes use of the workman.[6]

The matter is mainly an issue of impetus. Continuous control of process is at the heart of tool usage and craft practice. Processes may be indirect, and mechanical and powered, so long as they are under manual guidance. Furthermore some operations that reduce the role of the hand (substituting motorized power for brute-force activity) may contribute to an overall process that increases human impetus. Master craftsman Gustav Stickley raised this same point:

> An expert carpenter or cabinet-maker will save much time that can be used to better advantage, and will lose nothing of artistic quality in his work, if he makes use of all the modern machines, for sawing, planing, boring, mortising, scraping, sandpapering, and otherwise preparing his material for use, instead of insisting that all these things be done by hand.[7]

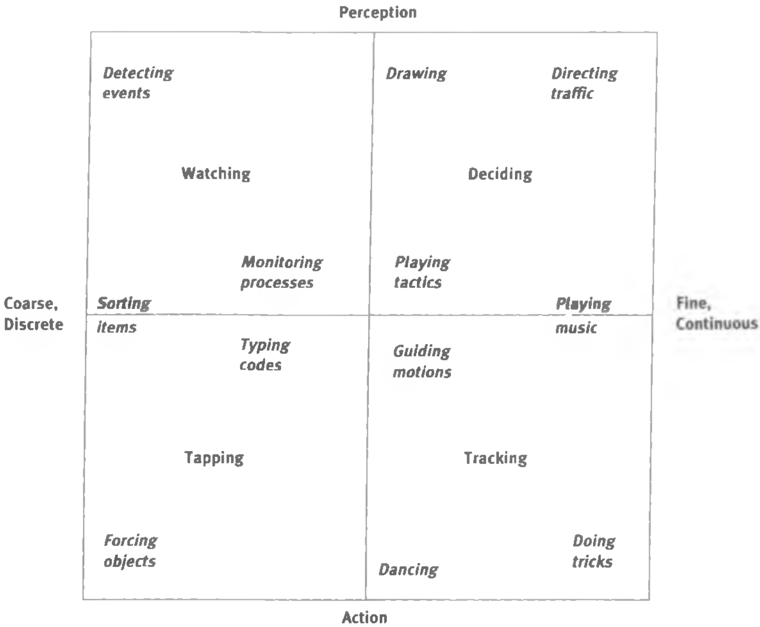
Or to take a more recent example, master stonecarvers at New York's Cathedral of St. John the Divine use CAD/CAM machining to do their rough cuts, plywood templates to frame their initial carving, and power grinders to polish up their finished chisel work. Is the result handmade? A lot depends on your attitude toward technology.

Technology has a Promethean quality, like the mastering of fire, for study renders skills more powerful than the societal forces that harness them. Technology in its more usual modern usage means the applied results of such study: powered mechanisms, sophisticated capital equipment—hardly traditional tools. But let us adopt a hybrid meaning. The important thing is that technology has both intellectual and physical elements. Let us use the word "technology" to refer to the *means* of engineering: both study and implementation. If to engineer is to design and to economize as asystem, then to accomplish this takes not only equipment but principles. In other words, technology is hardly limited to machines—it is a philosophy.

"Technique has taken over all of man's activities, not just his productive activity," warned the sociologist Jacques Ellul in 1964.[8] The more sophisticated the techniques, the more people become intrigued by them, and the less anyone cares to focus on other aspects of the human condition less conveniently subject to exactitude and method. Ellul seems to have anticipated computing very well in this regard. The majority of books about computers are simply technical instruction manuals. The more time people spend learning about and tinkering with computers, the less time they spend setting goals or applying existing skills. And at a most general level, the more we learn *how* to do, the less we know *what* to do.

Like Ellul, many people feel that the tyranny of technique is wrong, yet they are unclear on how much technology to accept. Few seem happy without electricity, for instance, and most still want to drive cars. Few people benefit from having categorical opinions for or against a largely undifferentiated Technology. There is certainly no advantage in blurring light switches and Walkmans and jumbo jets into one big wrong turn in human history.[9] Despite the examples set by many well-meaning people such as Ellul, there is no point in uncritically accepting or categorially rejecting Computers. Nor does imagining handwork fundamentally as a rejection of Technology lead one very far.

Here then is the pivotal importance of studying tools. A right approach to tools may help lead us toward more measured positions on



3.2 Hand-eye guidance: a chart of tracking skills

technology. There may be not always be a clear cutoff between tool and medium, between manual and mechanized, or between traditional and digital. We are likely to explore this middle ground.

So here is an inclusive definition: *A tool is a moving entity whose use is initiated and actively guided by a human being, for whom it acts as an extension, toward a specific purpose.* This definition is explicitly kinetic, yet it is open to abstraction: the entity may be physical or conceptual; the motion may be manual or machine powered; the guidance may be manual or by indirect control.[10] It reflects that condition that tools may suggest new uses for themselves, but unlike some other technologies, they remain subject to our intent. A tool depends on us to control the scope, the pace, and the focus of its work; merely attended machinery does not.

It clarifies a distinction very useful to discussions of craft, namely: *The degree of personal participation, more than any degree of independence from machine technology, influences perceptions of craft in work.*

The Abstraction of Work

Individual guidance of process participation in outcomes of work was of course the very condition upended by industrialization. Today amid increasing technology we may naturally despair of the prospects for such work. Yet the symbolic tools, abstract media, and intellectual technologies of our time are not necessarily direct projections of what has gone before. Rapid industrialization did have such an impact on working and thinking that even today, as much as two centuries later in some places, we cannot escape its influence. Theories on the relation of technology and work remain heavily weighted by the industrial age. As a result, we must constantly struggle to rethink production, and we often draw parallels from the past to help us do so—hence all the pronouncements about a revolution.

There is no question that technology accompanies social change, but there is much question about which comes first. As an example of change, consider just a few details from one of the clearest transformations, namely a fifty-year span in England culminating in the Great Exhibition of 1851. Remarkably, having been reasonably stable for three hundred years, the country's population proceeded to double; in several new industrial cities such as Manchester it quadrupled. But economic growth was greater still: between 1800 and 1850 iron production grew by a factor of 100 (or 10,000 percent), and cotton imports to feed the textile mills grew by a factor of close to 150. Moreover, these patterns of economic growth were indicators of general social structural change. Although industry grew fastest, commercial and professional activities also rose dramatically. Agriculture thus declined relatively over this period; later it would decline absolutely, and land ceased to be the main source of wealth. Thus by 1851, for the first time in the modern world, the majority of the population lived in the cities. There, at the site of machine-powered industry, the nature of work itself was transformed, particularly in its tools.[11]

It is pertinent to recite this old story, for among the changes wrought by industrialization, none seems more significant than the abstraction of craft. From a technical standpoint the change was a twofold transformation in tools. First, the tools' motion became machine powered; their control became indirect; and they incorporated a greater conceptual component, which often surpassed the scale of the individual. Next the tools' very pace and position became governed by independent mechanisms (at which point they no longer fit our definition of tools). From a social standpoint, however, the change was more singular: the means of production had become too elaborate, too extensive, and too centralized to be owned and operated by an independent craftsman. This too was a consequence of abstraction: if time was money, then work was labor. This famous abstraction was a near-fatal blow to artisanry, for it quickly moved power from the traditional tool users to the innovative symbol users—financiers, engineers, and factory managers. This situation has been at the crux of critical theory ever since. Marx insisted that the replacement of human skill was more significant than the application of motive power.[12] Veblen noted later that "Producer" had come to mean the owner of the industrial plant, rather than the workmen or the apparatus.[13] Productivity became best measured in capital infrastructure per worker, as opposed to the skill of the individual worker. Under these conditions semiskilled workers were good enough. So in the face of new abstraction, traditional skills waned.

As we know, technical change was accompanied by aesthetic and intellectual change. Declining skills led to a loss of innate design sense and a deprival of workmanship. Machine production led to a proliferation of cheap objects, which were marketed to precisely those classes whose self-sufficiency (and natural sense of design) had been debased by the new division of labor.[14] "Our work has constantly the look of money's worth," decried Ruskin.[15] Victorian households became cluttered with things needlessly ornate and expensive. This situation eventually led to aesthetic reactions and counterreactions such as the movements known as Craftsman and Bauhaus.

But also during this time, abstract scientific thinking about visual things accelerated. More systematic understanding led to more functional invention, and therefore unprecedented possibilities, some of which had long-term innovative consequences. Consider just four: the camera, as we have seen, transformed visual communication; telecommunications freed communication from transportation; powered machinery expanded the range of practical fabrications; and descriptive geometry increased the capacity and predictability of design. Note that each of these four is a germ of what by now has become an element of the contemporary CAD/CAM system—a new technology with old roots.

As technology and aesthetics entwined, design changed accordingly. Consider the case of architecture, where mechanization led to new materials, new economies of scale, and many unprecedented practicalities. New kinds of buildings began to incorporate steel and glass, large complex functional programs, and a range of specific inventions from elevators to balloon-frame construction. As a result of technological change, architecture emerged as a distinct profession. Engineering, and many other disciplines, followed a similar trajectory. At least as many creative practices arose as declined, the roles changing with the technology.

But from the artisan's perspective, any control over the pace and scope of practical work had been lost irrevocably. Powered factories took away the artisan's freedom to own the necessary tools and hire oneself out by the job. Organized labor such as piecework also removed the opportunity to work continuously, at one's own rate, with oversight of the process. This in turn discouraged practice, involvement, and care. And here technology struck right at the personal nature of work.

Today the abstraction is information. In our lifetime, symbolic processing has been tooled up very seriously. "Industrial Revolution" is a coinage attributed to the historian Arnold Toynbee, who toward the end of the nineteenth century had the hindsight to comprehend the many economic, social, and intellectual changes accompanying the rise of machine-powered industry as a major historical divide.[16] Today, as we are constantly assured, the growth and change associated with electronic information technology constitute a "Second Industrial Revolution," as Norbert Wiener called this one as early as 1948.[17]

This state of technological change began about fifty years ago, when the challenges of organizing a war effort had strained traditional notations, calculations, and transmittals to their limits. Not only military command-and-control practices, but also large-scale manufacturing, New Deal social record keeping, and with the end of the war, burgeoning capital trading each faced catastrophe unless abetted by new tools and methods. In this same decade, Claude Shannon's work at Bell Labs showed how to quantify information and how signals carry that information, and John Von Neuman's work at MIT showed how to store and process information—how to implement Turing machines. Norbert Wiener's work, also at MIT, suggested the social consequences. Wiener expressed the difference of the dawning era quite concisely: "*The preoccupation of modern engineering is not the economy of energy but the accurate reproduction of a signal.*"[18]

Technology for the abstract processes of computing and global telecommunication took only a few decades to materialize: technical change was at least as explosive as English industrialization. For example, in the mid-1950s, a then-young IBM estimated there would be a market for as many as 100 computers in the world; less than forty years later there were more like a 100 million—without counting the ones in everybody's automobiles, microwaves, and watches, in which case it has been estimated that microprocessors now outnumber people. Compared to the first transatlantic cable of 1866, recently installed fiber-optic ones have increased communications capacity by a factor of 2 billion. The explosive growth of processing power has been greater still: as processing technology has evolved from tubes to transistors to integrated circuits to microprocessors, its power, measured in bits per second per dollar, has increased by an order of magnitude approximately once every three years for the last thirty, or by a factor of at least a trillion.

By the 1970s, sociologists had begun to proclaim an information economy, two of the more notable documents being Daniel Bell's *The Coming of Post-Industrial Society* (1973), and Marc Porat's *The Information Economy* (1976–78). By the 1980s, the practicality of tools was accelerating fast enough that the value added by the computer industry surpassed even that of the darling of the machine age—the automobile industry. The potential of the technology (artificial intelligence in particular) seemed especially boundless then. Today in the 1990s, the concept of an information economy is the norm: the media hype, the fashion accessory, the government policy, the way to work. The tool on every desk, in many homes, in almost every hand, is a computer. If we describe information according to Gregory Bateson's criterion of "any difference that makes a difference,"[19] then information has value, *by definition.*

Of course, this fact has major consequences for skilled work. Where two centuries ago the middle-class worker lost first-hand artisanry, now he or she is losing first-hand subjectivity. Norbert Wiener cautioned: "The machine plays no favorites between manual labor and white collar labor. Thus the possible fields into which the new industrial revolution is likely to penetrate are very extensive, and include all labor performing judgements of a low level, in much the same way as the displaced labor of the earlier industrial revolution included every aspect of human power."[20]

This is to say that deskilling is now mental. The relief the computer provides from tedious thinking corresponds to the relief machine power provided from strenuous work. Besides reduced physical exertion, we now have reduced mental exertion. Regrettably, just as artisans had become laborers, now citizens became mere consumers. The allegation is that thanks to the pervasiveness of media and the complexity of issues, people are losing the tendency to form their own opinions.[21] We might say that postmodern consumers are ceasing to spin their own yarns, figuratively, every bit as much as the artisans of industrializing Britain stopped spinning their own yarns, literally.

But there is a positive side. Consider the situation in anthropological terms. It appears that the species whose specialization (brain) happens to best coincide with the direction of evolution (consciousness) has finally used its particular habits (tool making) to support its strength (thought). A generation ago, the biologist and theologian Teilhard de Chardin, from whom the above is paraphrased, expressed a vision for a *noosphere* (literally, thought-sphere) supplementing lithosphere, atmosphere, biosphere, etc., as a new skin of the living earth.[22]

So we will undoubtedly think globally; the question is, what does it mean to act locally? How do we uphold subjectivity and personal skill? In comparison to the situation wrought by earlier industrialization, the possibilities are a bit more difficult to grasp this time.

Cultural Lag

There exists a tendency to label an era by its most advanced technologies, whatever their pervasiveness. We know very well, however, that not everyone in a new technological age lives by its advances. For example, most people don't even understand their own computer, much less planetary networks. Most people don't even have a computer. From a technological perspective, then, we might refer to this condition as cultural lag.

Consider a parable. Say "books" and "inventions" and most people will say "Gutenberg": the printing press is the oldest cliché on the power of new technology to propagate knowledge and reshape civilization. Part of the fame of this example is that the printed page was the first completely standardized product—it faithfully reproduced typographers' errors, even. More specifically, what Gutenberg invented was a method for casting movable type blocks. Although the Chinese had mastered the printing press five hundred years earlier, the alphabetic languages of the West were ultimately better suited to the economies and precision of practical, large-scale printing. A pictographic language such as Chinese might allow printers to cut blocks for frequently used words, but it would always require the addition of further symbols. By contrast, an alphabet's finite number of simple characters could all be punched and cut once, after which great numbers of pieces could be cast from the resulting forms as needed. Note that the letter forms of the Roman alphabet, designed for carving in stone, would have been the most sensible for being cut in these dies, but early applications of the technology attempted to mimic the current Gothic alphabets whose forms were shaped by the strokes of the monastic calligrapher. To appearances, then, the new technology did not change the presentation or purpose of the book, only the production. What Gutenberg really did with the printing press was essentially what people did before, which was to produce commissioned, monumental bibles—he just did it more efficiently.

To a Medieval way of thinking, a book was a huge undertaking—about on the scale of putting up a building today. By the end of the Renaissance, all this had changed, but only after quite a bit of delay between the arrival of the altogether new tool and the practice of the altogether new task. Technology hardly drove the change; other factors came into play. Mercantile wealth challenged the power of the scholastic clergy. Levantine trade and teaching made paper cheap and plentiful where it had been unknown for centuries. The conquest of Constantinople sent precious texts from classical antiquity westward to Venice. It was there that Erasmus, who translated many of these works, and his employer Aldus Manutius, became the first to understand new potentials of typography for publishing an inexpensive, portable book. Together they were the first modern editors. Acting in this altogether new role they soon had the surviving work of every major known classical Greek author circulating about the streets of Europe.[23] Aldus is the new cliché: compared to automating commissioned books, redefining the audience for text was more the revolution.

New thinking and new tools may go together, but only rarely are an altogether new tool and an altogether new task invented simultaneously. More often a cultural lag occurs. Usually a new tool is used to do things pretty much as they always had been done; usually a new task is done for quite some time by means of adapting existing tools. Thus invention and innovation are most often gradual.

Given enough cultural lag—or advance—the very idea of industrial revolutions falls into question. Much recent scholarship supports the position that technological change is hardly revolutionary, or even the primary

3.3 Redefining the role of information technology: Aldus Manutius, a portable book of Virgil

social force. Even British industrial history gets revised. Economists note considerable organizational change—proto-industrialization—preceding overt technological change by as much as a century: early eighteenth-century wares were produced and marketed in a distinctly modern manner. Sociologists note that capitalized factory methods may have reached their zenith alongside mechanical technology, but they predated the rise of power machinery and assembly lines, which came much later, after electrification. Where temporary social injustices arose, often they were mitigated later with infrastructures built on the new prosperity. The same went for aesthetic problems: for example, the Arts and Crafts movement shifted tastes away from the crude objects of new industry. Manufactured objects improved in any case, as a new breed of industrial craftsmen emerged as mediators between design and the machine.[24]

Developments in our time may not be so technology-driven themselves. Scholars have identified how theoretical shifts predate technical development in our century, following the familiar pattern. More than ever, contemporary technologies depend on increasingly complex needs and the establishment of sophisticated theoretical underpinnings. Thus cultural lag is evident. Too often computers are pervasive in businesses, factories, and schools without changing what the businesses, factories, and schools actually do. Television too may be so pervasive because it has made efforts to comfort popular culture, rather than challenge or threaten it. The deep convictions that universal adoption of information technology will produce universal access to information and a better world for all seem confined to those who have a stake in the technology.[25]

To its critics, the new technology is actually a conservative force. In some regard, social change has equally often been said to be technology-obstructed. Dissenting computer scientist Joseph Weizenbaum wrote: "The computer saved societal institutions which were otherwise threatened with collapse under the weight of a rapidly growing population; computers were only necessary to a world already shaped by computers."[26] Lewis Mumford once said that "too often information technology appears employed in the service of institutions and values belonging to an earlier and more selfish era."[27] The intellectual left essentially accused the enormous electronic marketing-consumerist-entertainment-newsmaking apparatus of the Reagan era of being a public opinion factory—straightforward distraction engineering. It has also been said that: "Only a very small part of any ordinary person's knowledge has been the produce of his own observation and reflection, all the rest has been purchased in the same manner as his shoes or his stockings, from those whose business it is to make up and prepare for the market that particular species of goods . . . (including) religion, morals, philosophy, science, and art."[28] But this was Adam Smith two centuries ago; information economics is not so new.

Whatever their outlook, each of these critics suggests more gradual transitions and prolonged coexistence of conditions than the term "revolution" implies. Predictions about the impact of new technologies have known fallacies: that new technologies totally replace earlier ones; that technologies alone will change the world; that limiting our work to only whatever shows up on our instruments is at all appropriate. Toynbee's progressivist expression does seem outmoded. Our own time carries a fundamentally different idea of progress, limited by experiences of technology's destructiveness. We understand better that societies and their technologies reconstruct one another constantly, and that one set of freedoms just gets exchanged for another. Thus at the scope of individual practice we should acknowledge that if indeed such exchange must occur, the best response is to not to jettison the old freedoms, but to calmly, conscientiously explore the new ones.

Computer as Tool

It is with some healthy skepticism and amid considerable dissension, then, that most people approach computer technology. Although some people advocate change based on new possibilities, others actively resist it; if some advance their work, others retreat; even if the majority accepts new technology, only a minority truly adopts new practices. We see this today in that "computer ownership doesn't guarantee computer literacy."[29]

If there is a middle-of-the-road stance, it is that the computer is "just a tool." We are now in a position to explore what this means. In the legacy of industrialism we see an immediate source of the tool mentality in the psychological desire for containment, the wish for comprehensibility and control. A tool is for serving intent, whereas a medium might create intent, and a machine might work on its own. A tool does only what you tell it to do; it is never out of control. This is a reassuring viewpoint to those concerned about runaway technology.

In addition, even advanced industrial technologies such as assembly lines have been easier to understand as tools of a sort than as a medium. Because of their cost and rigidity, industrial technologies generally have been applied only to known problems and processes with foreseeable outcomes. For example, the way industrial engineers have had to "tool up" production lines has prevented much use of machine tools in any improvisatory or exploratory manner. Furthermore, the rigidity of production lines has caused use of the technology to become equated with unimaginative, semiskilled labor such as attending machines.

These same outlooks about industrial automation have been carried over to computer technology—a clear-cut case of cultural lag. In essence, the computer has been treated as a mere machine, in the mechanical sense of a device that determines its own scope and pace once set in motion by a programmer/attendant. This mindset tends to regard the whole computer as a single tool.

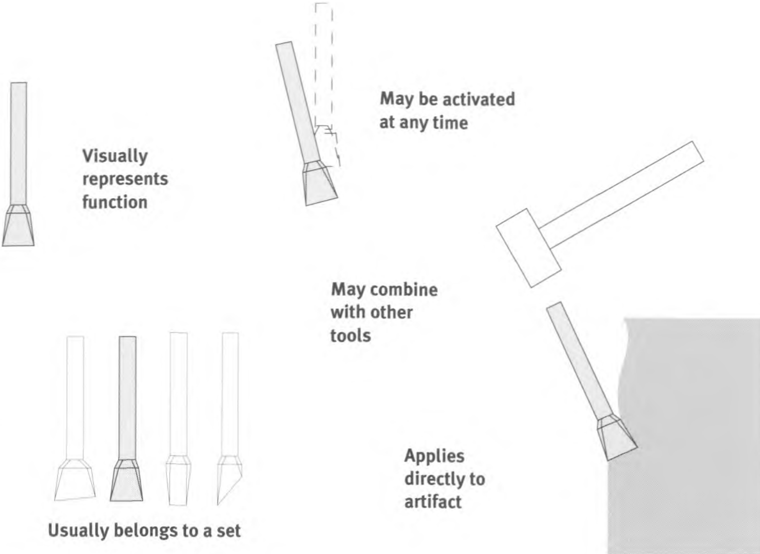
Yet computing is not at all monolithic: information tools are multiple. In hardware alone there is a spectrum of tools from institutional mainframes to office computers to wireless personal organizers to home entertainment equipment to incredible varieties of input and output peripherals. In software, tool metaphors are usually the main interaction strategy, and toolkits the main organizational schema. Even the data are increasingly tools of a sort: object-oriented data structures incorporate information about what operations are meaningful to conduct on them. Altogether, it would be more accurate to say that the computer is not a tool so much as hundreds of tools.

This single-tool mentality is especially pervasive with respect to the use of personal computers in large organizations, where it takes the form of a management practice known as task automation. Task automation is the use of computers to perform known processes more efficiently—as opposed to replacing those with different, higher-level processes. One good indictor of this familiar state is the use of just one piece of application software per computer—using the computer to do just one thing all day long. One prevalent case is drafting systems. For example, architecture and engineering firms have been prone to regard CAD as equipment, which they then hire paraprofessionals to "operate," work that consists in putting sketches already completed by hand onto the computer. Such drafting automation is a natural outgrowth of leftover industrial-era attitudes about technology.

There is a more accurate current source of the tool mentality, and that is the representation of individual software processes as tools.[30] Many programmers tend to refer to any independent module of code created for a particular purpose as a tool, but this is not very helpful. Let us stick to our kinetic definition. A software tool gives visible form and physical action to a logical operation. Like a physical tool, it modifies the effect of your hand, which it accomplishes by modifying the function of the nonphysical but visible cursor that you operate with the physical pointing device (i.e., the mouse). For example, a paint system offers pencils, brushes, airbrushes, etc., for applying color to a surface. This plays on the fact that a tool can be conceptual, and indirectly controlled. Whether direct or indirect, what matters is manipulation. Note also that like a physical tool, software becomes a symbol for the operations it performs. To employ any particular tool, you have to look around for it, pick it up, and move it into relation with the objects to which it will be applied. Its use is initiated and guided by your intentions—and by your hand.

Software tools introduce great power. It is the singular advantage of the software tool to give visible form and physical action to a logical operation otherwise lacking any physical correspondence, let alone traditional counterparts. To accomplish this, software designers rely on our skills by analogy. Human-computer interaction methods use tools as a metaphor for developing some comprehension of abstractly conceived activities.

Many software designers believe that the tool metaphor appeals not only to ingrained outlooks about work, but also to deeper fundamentals of human psychology. Research proceedings on human-computer interaction include numerous works on cognition, mental mapping, psychological loads, and psychomotor skills.[31] Representing particular abstract operations as tools is the best way yet developed for engaging the kinds of actions and intents that have traditionally motivated the craftsman. All this suggests that software tool makers would do well to place more value on tacit knowledge: the best tools will account for levels of mastery and psychology of participation, and conversely tool users should get more leverage from software's formal constructions.



3.4 Properties of a software tool

Ultimately the computer is a means for combining the skillful hand with the reasoning mind. We never had such a tool. If designed and used properly, this already lets us apply something about what we know of symbolic processing to using tools, and this alone should become more enjoyable than industrial automation. But at the same time computers let us turn the tables—to apply something of what we know about using tools to achieve richer symbolic processing. Metaphorically, they let us get a hold of our ideas. Concepts become things. We can't touch them yet, but already we can look at them, point at them, and work on them as though with hand-held tools. All this is ultimately more interesting than automation. Our use of computers ought not be so much for automating tasks as for abstracting craft.