1

VARIABLE, IDENTICAL, DIFFERENTIAL

On the evening of Sunday, August 15, 1971, U.S. President Richard Nixon announced in a televised speech[1] a series of drastic economic measures, including the suspension of a fixed conversion rate between the dollar and gold. The end of the gold standard, which had been reinstated by the Bretton Woods Agreement in 1944, had momentous economic consequences.[2] Its cultural fallout was equally epochal. Only a few years later, the founding fathers of postmodernism saw in "the agony of strong referentials"[3] one of the symptoms of the postmodern condition, and Nixon's abolition of the dollar's gold parity should certainly rank among the most prominent harbingers of many postmodern "fragmentations of master narratives"[4] to follow. From what is known of him, chances are that Nixon (who died in 1994) was never fully aware of his inspirational hold on Deleuze and Guattari's rhizomatic theories of mutability.[5] But from the point of view of historians of images, the end of the dollar-gold standard should also be noted for tolling the knell of one of the most amazing and miraculous powers that images ever held in the history of the West—one that art historians have often neglected.

British banking history may illustrate the relationship of paper currency and precious metal over a longer period of time than the history of the dollar would allow. From 1704, when banknotes were declared negotiable in England and Wales, until—with minor interruptions—1931, when the Bank of England in fact defaulted, any banknote issued by the Bank of England could be converted into gold or sterling silver at a fixed rate: paper stood for metal and one could be exchanged for the other at the same rate at any time. After Bretton Woods the British pound was pegged to the American dollar, and the dollar to gold, which, if one reads this story in British history books (and in Ian Fleming's *Goldfinger*),[6] means that the pound was once again on a gold standard, and if one reads it in American books means that the British pound was pegged to the dollar. Either way, the statement that still appears in small print on British banknotes—"I promise to pay the bearer on demand the sum of" £10, for example—before 1971 meant that the bearer would be paid on demand an amount of metal conventionally equivalent to ten pounds of sterling silver; as of 1971 and to this day, the same phrase means, somewhat tautologically, that the Bank of England may replace that banknote, on demand, with another one.[7]

The almost magic power of transmutation whereby paper could be turned into gold was canceled, apparently forever, on that eventful late summer night in 1971. For centuries before Nixon's intervention that alchemical quality of legal tender was guaranteed by the solvency of an issuing institution, but bestowed upon paper by the act of printing. For that miraculous power of images did not pertain to just any icon, but only to very particular ones: those that are identically reproduced, and are visually recognizable as such. Identicality and its instant visual recognition are what used to turn paper into gold; and identicality still makes legal tender work the way it does. A banknote that is not visually identical to all others in the same mass-produced series (with the exception of its unique serial number) may be fake or worthless. And as we have seen plenty of identical banknotes, until very recently we were expected to be able to tell at first sight when one is different, or looks strange, and reject it. Before the age of banknotes, the same pattern of visual identification applied to coins and seals, whose value and identification depended on the sheer indexicality of a mechanical imprint, and on the cultural and technical assumption that all valid copies could and would be reproduced identically.

These instances of "indexical" sameness—a quintessential feature of the mechanical age, and of mechanical reproducibility itself—are in direct contrast with other paradigms of vision that both preceded and followed the age of mechanical copies. To keep to monetary examples, the variability of artisanal handmaking survives today in personal checks, where the authority of the bank is attested to by the part of the check that is printed, but the validity of the check is triggered only by the manuscript signature of the payer. Like all things handmade, a signature is a visually variable sign, hence all signatures made by the same person are more or less different; yet they must also be more or less similar, otherwise they could not be identified. The pattern of recognition here is based not on sameness, but on similarity. Similarity and resemblance, however, are complex cognitive notions, as proven by the history of mimesis in the classical tradition, both in the visual arts and in the arts of discourse. Even today's most advanced optical readers cannot yet identify nor authenticate personal signatures, and not surprisingly, personal checks are neither universal nor standard means of payment (unless the bearer can be identified by other means, or is known in person, and trusted).

In the world of hand-making that preceded the machine-made environment, imitation and visual similarity were the norm, replication and visual identicality were the exception. And in the digital world that is now rapidly overtaking the mechanical world, visual identicality is quickly becoming irrelevant. Credit cards may well be in the shape of a golden rectangle (or a fair approximation thereof: it is not known whether this happened by chance or by design), and still bear logos, trademarks, and some archaic machine-readable characters in relief—a reminder of the time when they were invented in the late fifties. But today the validity of a credit card depends almost exclusively on a unique string of sixteen digits that identifies it, regardless of its format, color, or the material of which the card is made.[8] Indeed, for online transactions the physical existence of the card is neither required nor verifiable. The first way to confirm the validity of a credit card is to run a check on the sixteen-digit sequence of its number using a simple algorithm, known as Luhn's formula, which in most cases (statistically, nine times out of ten) is enough to detect irregularities. No one would try to judge the creditworthiness of a credit card by looking at it, in the way one would peruse a banknote or inspect its watermark. Visual identification is now out of the game. In this instance, exactly transmissible but invisible algorithms have already replaced all visual and physical traces of authenticity.

Albeit anecdotal, these monetary examples illustrate three paradigms of visual identification, essentially related to three different ways of making things. The signature, the banknote, and the credit card: when objects are handmade, as a signature is, variability in the processes of production generates differences and similarities between copies, and identification is based on visual resemblance; when objects are machine-made, as a banknote is, mass-produced, exactly repeatable mechanical imprints generate standardized products, and identification is based on visual identicality; when objects are digitally made, as are the latest machine-readable or chip-based credit cards, identification is based on the recognition of hidden patterns, on computational algorithms, or on other nonvisual features. This loss of visuality, which is inherent in the mode of use of the latest generation of credit cards, may in turn be a prelude to the eventual disappearance of the physical object itself: credit cards are in most cases already obsolete, as many of their functions may soon be taken over by cell phones, for example.

The list of objects of daily use that have been phased out by digital technologies is already a long one: digital consumer appliances tend to merge on a single, often generic technical platform a variety of functions that, until recently, used to be performed by a panoply of different manual, mechanical, or even electronic devices (from address books to alarm clocks to video players). Industrial designers and critics have taken due notice, as is shown by the ongoing debate on the disappearance of the object (or at least of some objects).[9] However, alongside and unrelated to this seemingly inevitable wave of product obsolescence—or perhaps, more appropriately, product evanescence—digital tools are also key in the design and production of a growing range of technical objects, old and new alike—from marble sculptures to silicon chips. And the technical logic of digital design and production differs from the traditional modes of manufacturing and machinofacturing in some key aspects.

A mechanical machine (for example, a press) makes objects. A digital machine (for example, a computer) makes, in the first instance, a sequence of numbers—a digital file. This file must at some later point in time be converted into an object (or a media object) by other machines, applications, or interfaces, which may also in turn be digitally controlled. But their control may be in someone else's hands; and the process of instantiation (the conversion of the digital script into a physical object) may then be severed in space and time from the making and the makers of the original file. As a consequence, the author of the original script may not be the only author of the end product, and may not determine all the final features of it.

To go back to image theory, a comparison may help to make the point. Each print of a picture in the same print run looks the same. All mass-produced series include minor accidental variances, but by and large, all buyers of the same postcard (printed, for example, in one thousand copies) will buy the same picture. On the contrary, a digital postcard, e-mailed from a computer to an electronic mailing list of one thousand recipients, is sent as a sequence of numbers that will become a picture again only upon delivery—when it appears on one thousand different computer screens, or is printed out by as many different printers. The digital file is the same for all. But each eventuation of that file (in this instance, its conversion into a picture) is likely to differ from the others, either by chance (some recipients may have different machines and applications), or by design (some recipients may have customized their machines or may deliberately alter the picture for viewing or printing). Some of this customizable variability certainly existed in the good old days of radio and television, and even of mechanically recorded music. But the degree of variability (and indeed, interactivity) that is inherent in the transmission and manipulation of digital signals is incomparably higher. We may well send the same digital postcard to all our friends. Yet there is no way to anticipate what each of them will actually see on the screen of his or her computer or cell phone (and even less, what they will see if they decide to print that picture on paper—or on any other material of their choice, for that matter).

The loss of visual significance that is so striking in the instance of the credit card may simply be the terminal phase of the general regime of visual variability—or sensorial variability if we include other senses beyond sight—that characterizes all digital environments. Variability is also a diacritical mark of all things handmade, but artisanal and digital variability differ in another essential feature. Handmade objects can be made on demand,

and made to measure. This makes them more expensive than comparable mass-produced, standardized items, but in compensation for their extra cost, custom-made objects are as a rule a better fit for their individual user. In other instances, however, artisanal variability may be a problem, rather than a solution. As hand-making is notoriously ill suited to delivering identical copies, this tends to be the case whenever identical copies are needed. To take an obvious example: before the invention of print the transmission of texts and images was at the mercy of the will and whims of individual copyists, who could make mistakes and unpredictable changes at all stages of the copying process. The inevitable random drift of all manually reproduced texts and images was for centuries a major impediment to the recording and the transmission of all sorts of cultural artifacts—from poetry and music to science and technology.

Some degree of randomness is equally intrinsic to all digital processes. In most cases, we don't know which machines will read the digital file we are making, or when, or what technical constraints or personal idiosyncrasies will ultimately determine the conversion of our work from machine-readable documents into something readable (or otherwise perceptible) for humans. But, to a much greater extent than was conceivable at the time of manual technologies, when every case was dealt with on its own merit, and individual variations were discussed, negotiated, and custom-made on demand, the very same process of differentiation can now be scripted, programmed, and to some extent designed. Variability can now become a part of an automated design and production chain. Indeed, this is what the most alert users of digital technologies have been doing for the last fifteen years or so—artists and technologists as well as entrepreneurs and capitalists.

Both the notions of a manual drift in artisanal and script cultures, and of a digital drift in contemporary computer-based environments, will be discussed at length in the central chapters of this book. But a simpler instance of digital "differentiality" (a term introduced by Greg Lynn to describe the new forms of serial variations in the digital age)[10] may clarify the matter here. As is well known, various features of many web pages are now automatically customized based on what the page makers know of each individual page user. This is why the advertising (and increasingly, the content) which appears on some of the most popular web sites differs based on the computer, the browser, network, or protocol we use to access those pages, and varies according to the time of day, the geographical location of the user, and a number of other arcane factors that are well-protected trade secrets. This is, at its basis, the golden formula that has made Google a very rich company.[11] Variability, which could be an obstacle in a traditional mechanical environment, where identical copies were pursued, expected, and had intrinsic value, has been turned into an asset in the new digital environment—indeed, into one of its most profitable assets. As content customization seems to be, for the time being, almost the only way to make digital content pay for itself, web users are learning to cope with its side effects. Readers of the same online edition of the same newspaper often end up reading, at the same time and in the same place, a permanently self-transforming hodgepodge of different texts and images (sounds can be added at will). Following on the same logic, experiments are reportedly underway to replace conventional printed billboards in public places with electronic ones, capable of detecting certain features of the onlookers standing in front of them (through physical or electronic markers) and adapting their content accordingly.[12]

There was a time when daily newspapers published more than one local edition (and a few still do); but the notion that each reader may find his or her own custom-made newspaper (or web portal, or advertisement in a railway station) to match his or her unique profile goes far beyond technical variability, or digital differentiality, and induces a feeling of cultural instability that many may find disturbing. Over the course of the last five centuries the "typographical man" became increasingly dependent upon a high degree of visual predictability to facilitate the storage and retrieval of written information. Visual and graphic stability in the layout of texts and images arose with print technology, and thence spread to all tools and instruments that were mechanically mass-produced (again, printed from the same matrix or mold). These same patterns of graphic recognition are still at the basis of many cultural and social practices that play an important role in the ordinary conduct of our daily lives. We used to look for a certain column (or index, or price) in the same place on the same page of the same newspaper; similarly, certain electromechanical interfaces, such as analog instrument panels with dials and gauges, used to assign specific data sources to fixed, distinct, and memorable visual loci (as in all cars of the same make, for example, where a given warning signal always lights up in the same place, form, and color on the dashboard).

None of this applies to digital interfaces, where even the fonts and sizes of alphabetical texts may change anytime, often without warning, and the same piece of information may pop up anywhere on the isotropic surface of a muted LED display or of an interactive control panel, in all kinds of different sensorial species (as sounds, pictograms, drawings, diagrams, alphabetical warnings in a variety of different languages, perfectly impenetrable numerical error codes, etc.). Indeed, there is a certain logic in that the company that most contributed to the variability of digital images (Adobe Systems, the makers of Photoshop) should also have created new software specifically to counter this digital drift—to freeze images and force users to view visually identical graphic layouts. Adobe's PDF, or "portable document format," essentially uses web technologies to transmit electronic photocopies—faxes sent over the Internet. Not without success: clearly, in many instances our societies cannot yet do without the iron inflexibility of the typographical page—a mechanical attribute *par excellence*. Tax forms must be identical for all (even when downloaded from a web site, or, more recently, filled in online) because line 33A-14 must appear on page 7 on all tax returns. This clearly shows how income tax returns could not have existed before the age of printing: even in the electronic era the internal revenue services of most countries, when they go online, are forced to use the most sophisticated technologies to reduce the ectoplasmic variations of digital images to the mechanical fixity of printed pages. The web sites of various ministries and national services that deal with tax returns are true works of electronic art, and Marshall McLuhan would have delighted in the digital emulation of Gutenberg's machine recently perfected by modern state bureaucracies: the typographical man is so integral to the modern state that the modern state, even after adopting electronic technologies, is forced to perpetuate a mimesis of the typographical world.[13]

So it seems, to sum up, that in the long duration of historical time the age of mass-produced, standardized, mechanical, and identical copies should be seen as an interlude, and a relatively brief one—sandwiched between the age of hand-making, which preceded it, and the digital age that is now replacing it. Hand-making begets variations, as does digital making; but the capacity to design and mass-produce serial variations (or differentiality) is specific to the present digital environment. Unlimited visual variability, however, may entail a loss of visual relevance: signs that change too often or too randomly may mean less, individually taken, and may in the end lose all meaning.[14] This was already the case in the old age of handmade variability, when the economy of visual communication was dysfunctional because of a penury of recognizable images, and is again the case in the new age of digital differentiality, where the economy of visual communication is dysfunctional because of an oversupply of variable images.

The sequential chronology of these three technical ages (the ages of hand-making, of mechanical making, and of digital making) lends itself to various interpretations.[15] Some objects were still handmade well into the mechanical age, and some will still be handmade, or mechanically made, well into the age of digital making. But, by and large, the second break in this sequence, the passage from mechanically made identical copies to digitally generated differential variations, is happening now. The first break, the transition from artisanal variability to mechanical identicality, occurred at different times in the past—depending on the classes of objects and technologies one takes into account. The defining shift from artisanal hand-making to mechanical manufacturing (or machinofacturing) came with the industrial revolution. However, if next to traditional objects of manufacturing (rails, sewing machines, or automobiles) we also look at media objects (texts, images, sounds, and their modes of recording and transmission), we may encounter some slightly different chronologies.

New media theorists[16] tend to situate the transition from variable to identical copies in the nineteenth or twentieth century, as they associate the rise of identicality with indexical realism, which is often seen as the distinctive property of photography and of cinema. Unlike an artist's drawing, a photographic image is a machine-made, quasi-automatic imprint of light onto a photosensitive film: by the way it is made, it can only record something that really happened. Traditional media scholars[17] relate the rise of identically reproduced, mechanical images to the invention of print and—almost simultaneously—of geometrical perspective in the Renaissance. Well before modern photographic technologies, Alberti first and famously defined perspectival images as the trace of light rays on a surface.

The history of architecture features a conflation of different technological timelines. Built architecture depends on the production of material objects (bricks, nails, iron beams, etc.), hence its modern history is linked to the traditional chronology of the industrial revolution. On the other hand, architectural design is a purely informational operation, and its processes are defined by a specific range of cultural and media technologies. For centuries the classical tradition was based on the recording, transmission, and imitation of architectural models. In turn, this tradition, or transmission, was and still is dependent on the media technologies that are available, at any given point in time, to record a trace of such models and to transmit them across space and time. What cannot be recorded will not be transmitted, and what is neither recorded nor transmitted cannot be imitated. Additionally, and unrelated to the publication, circulation, and reception of architectural rules and models, building may also be dependent on the cultural technologies needed to notate specific design instructions that are conceived by some to be carried out by others, sometimes in the absence of the original designer. A key issue in the modern, notational theory of architectural design, this technical, point-to-point exchange of building and construction data is once again a matter of recording and transmission—a media problem.

1.1 Architecture and the Identical Copy: Timelines

The history of architecture in the machine age is well known. As it has been written and rewritten many times over by the militant historians of twentieth-century modernism and by their followers, it is a tale of sin and redemption. Architecture was slow in coming to terms with the industrial revolution. Throughout the nineteenth century, most architects either ignored or reacted against the new technologies of industrial mass production. Then came the pioneers of modern architecture, and their wake-up call. As Le Corbusier and others began to claim in the early twenties, mechanization was changing the world, and architecture had to rise to the challenge. Architects should invent new architectural forms, made to measure for the new tools of mechanical mass production; and town planners should invent new urban forms, made to measure for the new tools of mechanical mass transportation. For the rest of the twentieth century many architects and urbanists did just that. Oddly, many architects and urbanists are still doing that right now, as they ignore, or deny, that today's machines are no longer those that Le Corbusier and his friends celebrated and sublimated almost a century ago.

Well before the industrial revolution, however, another mechanical revolution had already changed the history of architecture. Printed books are a quintessentially industrial product. They are mass-produced. Mass production generates economies of scale, which makes them cheaper than manuscript copies. They are standardized—each copy is the imprint on paper of the same mechanical matrix. Early modern printed books were so much cheaper and better than coeval handmade books that they soon replaced them in all markets, and the new architectural books in print (manuals, treatises, pattern books, etc.) changed the course of architecture first and foremost because of the printed images they contained. Before the invention of print, manual copies of drawings were famously untrustworthy, and as a result, images were seldom used, or altogether avoided, whenever precise copies were required. In such cases, nonvisual media (alphabetical or alphanumerical) were deemed safer. For centuries in the classical tradition (from antiquity to the Middle Ages to the early Renaissance) most architectural descriptions were verbal, not visual.

The advent of print reversed this relationship between text and images. All printed images in the same print run are notionally the same, for all and in all places.[18] Both the makers and the users of images were quick to realize that, thanks to print, technical information could be recorded and safely transmitted in new visual formats. And a new architectural theory soon developed, made to measure for this new technical condition. In a typical technocultural feedback loop, machine-made identical copies prompted a cultural awareness of identical reproducibility: printed images were put to task to illustrate visual models of famous buildings, old and new alike, but also to disseminate new illustrated catalogs of architectural components, both structural and decorative. These new models were deliberately designed for identical copies in print, but in some cases also for reuse and replication in architectural drawings, design, and buildings. The most successful spin-off of this media revolution was the new "method" of the Renaissance architectural orders—the first international style in the history of world architecture.

As I have recounted at length elsewhere, this was the new architecture of, and for, the age of printing.[19] The early modern making of the "typographical architect" left an indelible mark on architecture, which henceforth has been permanently confronted with the paradigm of exact repeatability. The only parts of the design process that were actually machine-made and identically reproduced in the Renaissance were the images printed in books; the architects' designs and construction drawings were handmade, and so were the buildings themselves. But the paradigm of identicality spilled over from books to visuality at large, and prompted a culture of identical copies that became pervasive in the West well before the industrial revolution, and the actual rise of mechanical mass production. Standardized images preceded industrial assembly lines, and a culture of standardized architecture was already well established at a time when all visually standardized architectural parts (from moldings, columns, and capitals to windows, chimneys, etc.) had to be carefully handcrafted in order to *look* identical to one another.[20] In the process, standardized images standardized the craftsman's gesture: the free hands of artisans were coerced to iterate identical actions, working like machines that at the time no one could imagine or presage—but which would eventually come, churning out identical copies better and cheaper than any artisan could or would. This is where modern Taylorism and mechanization took over, Le Corbusier stepped in, and the second, and better-known part of the story began.

1.2 Allography and Notations

As it happens, at the very moment printed images were revolutionizing the transmission of architectural models, another media revolution was crucially changing the way architects work. Alongside the images of eminent buildings of the past or present, and the new sets of ready-made visual models that would characterize early modern architectural books in print, another class of architectural drawings and models was fast rising to prominence: the project documents that Renaissance architects produced in growing numbers and forwarded to increasingly distant building sites—a physical distance that went hand in hand with the growing intellectual and social estrangement between architects and builders. New reproduction technologies were of no consequence for project drawings, as these technical documents destined for builders were not meant to be mass-produced: each drawing could be hand-drafted as precisely as needed before being shipped to the site where it would be used, without any loss in precision or other risks that would have come with copies. The only technological innovation in Renaissance project drawings may well have been their very invention—or the invention of their mode of use.

According to Nelson Goodman, all arts were born autographic—handmade by their authors. Then, some arts became allographic: scripted by their authors in order to be materially executed by others.[21] When did architecture evolve from its pristine autographic status as a craft (conceived and made by artisan builders) to its modern allographic definition as an art (designed by one to be constructed by others)? The traditional view, which attributes to early modern humanism the invention of the modern architect, and of his new professional role, rests upon some famous narratives: Brunelleschi's legendary struggle for the recognition of his role as the sole conceiver and master of a major building program; Alberti's radical claim that architects should be not makers but designers, and his definition of a modern notational system of scaled architectural drawings in plan and elevation that were the indispensable means to this end.

Counter to these clear-cut stereotypes, it is easy to point out that the separation between design and building (and between designers and workers) is a matter of degrees. Architectural notations of some kind have almost always existed. It seems that at the beginning of historical time Egyptian architects already used fairly precise architectural construction drawings.[22] But the history of design processes in antiquity is a difficult and controversial subject, as archaeological scholarship on the matter must build on slender evidence. Indeed, the evidence is at times so thin that some archaeologists have concluded that Greek architects of the classical age did not use scaled drawings at all; other known ancient notational systems, such as textual instructions, three-dimensional models, templates, or full-size diagrams, sometimes incised on stones or walls or otherwise sketched on site, all imply or require some presence of the designer on the site of construction. The use of scaled project drawings would have arisen only in the Hellenistic period, alongside the growing estrangement between designers and craftsmen that the introduction of a more advanced notational system suggests.[23] The controversy is compounded by the ambiguity on this issue of the most important extant source, Vitruvius's treatise. Vitruvius's famously obscure definitions of three kinds of architectural drawings (*ichnographia, orthographia, scaenographia*) in his first book seem to take some practice of architectural drawings for granted. Yet his own design method never refers to, and does not require, any kind of scaled drawing.[24]

Beside archaeologists and classical scholars, medievalists have also weighed in on the matter. Something similar to proportionally drawn plans and elevations can be dated to the thirteenth century, and more convincingly to the fourteenth and fifteenth centuries (the famous drawings from the workshop of Peter Parler in Prague are coeval to Brunelleschi's work on the Florence dome). These, and other textual documents, have led some to suggest that "construction by remote control" was common among Gothic master builders, and that adequate notational tools, and social practices, already existed to support such design methods well before, and unrelated to, the new architectural theory of the Italian humanists. This thesis has been corroborated by an unusual blunder by the eminent scholar Wolfgang Lotz, who in his seminal 1956 essay on Renaissance architectural drawings misread a crucial passage in Alberti's *De re aedificatoria*, wrongly concluding that Alberti encouraged architects to draw in perspective, and that Raphael's "Letter to Leo X" (1519), rather than Alberti's treatise, should be credited with the modern "definition of the orthogonal projection."[25] Although Lotz eventually corrected himself, that essay is one of the sources of a persistent tradition according to which the pictorially oriented Renaissance architects of the South, far from having developed the "orthogonal" notational format, would in fact have delayed its rise due to their penchant for perspectival, illusionistic, nontechnical drawings.[26]

Recent scholarship has pointed out that Raphael's passages on architectural drawings are little more than an amplification of Alberti's theory on the matter,[27] but the idea that "orthogonal projections" may have been invented by Gothic builders, or even by Renaissance architects, is problematic on other counts. Orthogonal, or parallel projections, as defined by Gaspard Monge's descriptive geometry (1799), posit a center of projection located at infinity (the only possible point of origin for rays, beams, or vectors, that must all be parallel to each other on arrival): in today's projective geometry, central and parallel projections differ only in that the projection center is a proper point for the former, and an improper point (i.e., a point at infinity) for the latter. The drawing of "orthogonal" ground plans may not require projections of any kind, as the ground plan of a building may simply be seen as its imprint or trace on a real site (if necessary, redrawn to scale). But "orthogonal" front views, or elevations, are a trickier matter.

According to late medieval optics, and to Alberti's own geometrical perspective, "orthogonal" front views would have required an observer's eye to be physically pushed back to an infinite distance, which, as a Renaissance mathematician famously remarked, is actually "nowhere."[28] Late medieval and early modern geometries, owing to their Aristotelian framework, did not allow for such insouciant appropriations of infinity, nor could they supply the homogeneity and continuity of space that parallel projections from infinity would have demanded. Piero della Francesca drew at least one famous head in plan—actually, two plans, an elevation, and a side view, where all the views are connected by parallel projection lines, more than three centuries before Monge's *Descriptive Geometry*.[29] Likewise, late medieval and Renaissance architects used, and depended upon, simpler sets of "orthogonal" plans, elevations, and side views (and later, sections) which, however, no mathematician at the time could have defined, nor formalized, for lack of any workable notion of geometrical infinity. Parallel projections were for centuries a practice without a theory.[30]

Yet in this matter too Alberti scored a major breakthrough. Alberti could, and did, codify central projections, which represent infinity (as a vanishing point) without defining it; but he could not codify parallel projections, which would have posited a physical eye (the perspectival point of view) in a nonphysical place (infinity). However, precisely because he had already defined central projections in his treatise on painting, when a few years later he wrote his treatise on architecture Alberti could for the first time ever lay out precisely what architects should *not* do: architects should avoid perspective, as from foreshortened lines one cannot take precise measurements (in Raphael's slightly later wording). As Alberti mandates in a key passage in the second book of *De re aedificatoria*, architects' drawings, unlike painters' perspectival views, require "consistent lines," "true angles," and "real measurements, drawn to scale."[31]

One needs perspective to have been invented in order to tell architects not to use it. As a side effect of his invention of geometrical perspective, Alberti could provide the first (albeit negative) geometrical definition of modern proportional and orthogonal plans and elevations—at a time when geometry did not allow for any definition of parallel projections. This may appear to be a fine point of geometry (and it is, as it is tantamount to defining parallel projections as "noncentral" projections, without a corresponding center of projection at infinity); but, at a more practical level, Alberti's strategy was also consistent with the basic need to explain why scaled elevation drawings should not include foreshortened lines (as such drawings often did before Alberti, and occasionally kept doing after him).

Alberti's distinction between building and design (*lineamenta*) is spelled out in various but unequivocal terms in the first, second, and ninth books of *De re aedificatoria*, and it is one of the foundational principles of his entire architectural theory.[32] His new geometrical definition of architectural project drawings (and models) provided a consistent set of notational tools suited to his new, allographic way of building. As previously mentioned, the distance between designers and building sites is an historical variable, and it ebbed and flowed for centuries before (and after) Alberti's theoretical climax. With these ebbs and flows, the need for, and availability of, reliable notational tools varied over time, and the evidence that several ways of building by notation existed, and were variously implemented, before Alberti should not be discounted. But, in addition to the sharpness of its conceptual proclamation, the Albertian way differed from all precedents in another, essential aspect—one that has stayed to this day.

1.3 Authorship

As Alberti repeatedly emphasizes in his treatise, architects must work with drawings and three-dimensional models throughout the design process, as various aspects of the project cannot be verified unless they are visualized.[33] Drawings (albeit, apparently, not models)[34] will also be used as notational tools when the project is finalized and construction drawings are sent to the builders; but the two functions, visualization and notation, remain distinct. Designers first need drawings and models to explore, nurture, and develop the idea of the building that, as Alberti states at the outset of his treatise, is "conceived in the mind, made up of lines and angles, and perfected in the learned intellect and imagination."[35] Alberti insists that models should also be used to consult experts and seek their advice; as revisions, corrections, and new versions accumulate, the design changes over time; the whole project must be examined and reexamined "not two, but three, four, seven, ten times, and taking breaks in between."[36] The final and definitive version is attained only when each part has been so thoroughly examined that "any further addition, subtraction or change could only be for the worse."[37] This is when all revisions stop, and the final blueprint (as we would have said until recently, both literally and figuratively) is handed over to the builders. Thenceforward, no more changes may occur. The designer is no longer allowed to change his mind, and builders are not expected to have opinions on design matters. They must build the building as is—as it was designed and notated.

At various times and in different contexts Alberti insists on this ideal point of no return, where all design revisions should stop, and construction begin speedily and without hesitation (and, he adds, without any variation or change during the course of the works, regardless of who is in charge of the site).[38] Alberti famously advised architects against directing the actual construction: in his view, building should be left to the workers and to their supervisors.[39] He allows that "to have others' hands execute what you have conceived in your mind is a toilsome business,"[40] and indeed documents related to the building history of the Tempio Malatestiano in Rimini[41] prove that the throes of allography did not fail to take a toll on Alberti's career as an architect. Local workers, craftsmen, and master builders might not have been easily persuaded to comply with the drawings and models sent by an absentee designer. Building by design was most likely not an absolute novelty for the craftsmen of the time. Building by someone else's design may have been less common, but, crucially, Alberti's new way of building left the builders no leeway. Craftsmen in Rimini around the mid-fifteenth century may have resented Alberti's complaints as the caprice of a scholar dabbling in construction matters. In fact, much more was at stake.

At the close of the ninth book of *De re aedificatoria* Alberti muses that the lifespan of major building programs may be longer than that of any architect, and that many incidents may occur during the construction to alter or pervert the original design. Yet, he concludes, "the author's original intentions" should always be upheld.[42] This remark is slipped in, inconspicuously and seemingly inadvertently, at the end of the ninth book (which some scholars consider the real conclusion of the treatise, or at least of its systematic, theoretical part). By bestowing upon the architect this unprecedented "authorial" status, Alberti emphasizes the scope and ambition of his new vision of the architect's work—but he also raises new questions concerning the "authorship" of architecture's end product.

An original, autographic work (for example, a painting made and signed by the artist's hand) is the unmediated making of its author. But in the Albertian, allographic way of building the only work truly made by the author is the design of the building—not the building itself, which by definition is made by others. The only way for Alberti to claim an extension of authorship, so to speak, from the drawing to the building was to require that the building and its design should be *seen* as perfectly identical. This requirement, however, was bound to be difficult to enforce, and technically problematic. Until very recent times, scaled models were not used for notational purposes, due to the difficulty of measuring them (and Alberti himself implies they should not be, presumably for the same reason). Alberti's apparent preference for drawings, rather than models, as the primary notational tool marked a significant departure from the late medieval tradition.[43] But drawings, unlike buildings and models, are two-dimensional, and in most cases proportionally smaller than the building itself.[44] Consequently, a building and its design can only be *notationally* identical: their identicality depends on a notational system that determines how to translate one into the other. When this condition of *notational identicality* is satisfied, the author of the drawing becomes the author of the building, and the architect can claim some form of ownership over a building which in most cases he does not in fact own, and which he certainly did not build—indeed, which he may never even have touched. The transition from Brunelleschi's artisanal authorship ("this building is mine because I made it") to Alberti's intellectual authorship ("this building is mine because I designed it") is discussed in more detail in section 2.6 below. The notion of an architect's intellectual "ownership" of his work is not spelled out by Alberti in so many words, but it is inherent in the notion of authorship that Alberti borrowed from the humanists' arts of discourse and applied, for the first time ever, to the art of building.

Thus reformed, architecture ideally acquires a fully authorial, allographic, notational status. Insofar as a building and its design are considered notationally identical, one can identify an architectural work either with the design of the building or with the building itself (a step that Nelson Goodman still hesitated to take in 1968).[45] Around 1450 Alberti's claim to architectural authorship (as well as his new way of building by notation) must have appeared outlandish or worse, culturally as well as technically. Yet Alberti's authorial ambitions and concerns were common among writers, rhetoricians, and scholars of his time.

Alberti, the humanist, was painfully aware of the inevitable destiny that awaited all texts and images when severed from the hands of their authors and caught in the unpredictable drift of scribal production. Catullus could well "smooth with dry pumice" his brand-new papyrus roll of poems before presenting it to his first, and possibly fictional, dedicatee; but that original finishing touch was but a frail seal, and fifteenth-century humanists knew that most extant classical texts were mosaics of citations, interpolations, additions, subtractions, and plain copy errors. Modern philology was developed precisely to reconstruct, as much as possible, the original text of the author—the one the author would have "smoothed with dry pumice" on the day he considered his manuscript finished. Contemporary philologists and linguists have also suggested that in the late Middle Ages the awareness of the technical variability (*mouvance*, or drift) of scribal copies prompted new modes of textual interaction, where variances were not only tolerated, but actually expected, encouraged, and sometimes exploited.[46] The very notion of an "original" would hardly apply in such a context, as the so-called originals would be too many, and none more relevant than any other.

There is additional evidence that some of the early humanists (Poggio Bracciolini in particular) availed themselves of this potentially interactive format to circulate manuscripts that invited feedback, comments, and additions.[47] Alberti himself may have engaged in this practice—and indeed, it would be fascinating to see Poggio and Alberti as active wikipedists of the late scribal age.[48] This process of multiple revisions of, and possibly interactive feedback on, the successive drafts of a literary text corresponds to the fluid state of architectural design during the "versioning" phases of its development, on which Alberti insists so emphatically.[49] But Alberti also evidently thought that when revisions stop, they should stop for good—and forever. Alberti was so anxious about scribal errors that he took the unusual step of flagging passages where he thought that copyists of his manuscripts might be more at risk of being led astray, and devised some ploys (as well as some full-fledged and bizarre devices) to limit that risk, and contain potential damage.

A wealth of evidence proves that, when the final version of a given text was attained, Alberti aimed at having it copied and reproduced as faithfully as possible, and with as little external intervention as was conceivable at the time. The best technical means to this end would have been for Alberti to have his texts and illustrations printed—which, however, he could not or would not do, mostly for chronological reasons, although he may have considered the option toward the end of his life. Indeed, Alberti's pursuit of identical copies is exactly coeval to the development of print technologies, and this parallel chronology is certainly not a coincidence. Alberti's insistence on an ideal, but drastic, authorial cutoff—the point at which all revisions stop and identical replication starts—curiously anticipates a practice that eventually became common in the printing industry, and survives to this day in the technical term *bon à tirer* (good to print).[50] Originally, the author's *bon à tirer* (normally dated and signed) written on the last proofs validated the final version of his or her text, and "authorized" its identical replication in print. Thenceforward, readers could expect exactly the same words in each copy as in the author's original, even though the author never printed, nor necessarily signed, any individual book. Thanks to the cultural and technical logic of mechanical replication, authorship was extended from the author's original to all identical copies of it.

For intellectual and ideological reasons, which should be seen in the context of the humanists' invention of modern authorship, and perhaps in the larger context of the humanists' contribution to the shaping of the modern self and of the notion of individual responsibility, Alberti anticipated this division between an author's work and its mechanical reproduction. But Alberti tried to impose this authorial paradigm within the ambit of a manual production chain, where no machine would deliver identical copies, and scribes could be reasonably expected to produce just the opposite—randomly changing, individual variations. Also, but crucially for the history of architecture, Alberti extended his precocious *bon à tirer* paradigm from literary to architectural authorship, asserting that the same conditions and the same consequences should apply. The fact that in most cases the architect's design should beget only one building (and not a series of copies, as would a printing press, or a late medieval scriptorium) is irrelevant in this context.[51] What matters is the relation of identicality between the original and its reproduction. Alberti's entire architectural theory is predicated on the notational sameness between design and building, implying that drawings can, and must, be identically translated into three-dimensional objects. In Alberti's theory, *the design of a building is the original, and the building is its copy*.

1.4 The Early Modern Pursuit of Identical Reproduction

Between the end of the Middle Ages and the beginning of the Modern Age, two almost simultaneous media revolutions changed the course of European architecture. On the one hand, print transformed the modes of transmission of architectural information in space and time. For the first time in the West, texts and images could be protected from the permanent drift of scribal transmission and frozen as prints—mechanically reproduced, identical copies. On the other hand, a new notational format was then starting to reshape the transmission of architectural data from designers to builders: a development related to the rise of new forms of allography in building, and to the growing gap between thinkers and makers.

These changes in architectural notation were not related to the development of any printing technology, as they did not require any.[52] Yet right from the start the spirit of the Albertian design process, which aimed at the identical materialization of the architect's design of a building, was already, in a sense, mechanical. In today's terms, Alberti's authorial way of building by notation can be interpreted as an ideally indexical operation, where the architect's design acts like a matrix that is stamped out in its final three-dimensional result—the building itself. This metaphor may seem far-fetched, but it will sound familiar to those acquainted with today's tools for three-dimensional digital fabrication.[53]

The indexical nature of the Albertian design process also resonates with the design theory of one of the most prominent architectural thinkers of the late twentieth century, Peter Eisenman. Eisenman's theory of indexicality in design stems from the same premises as Alberti's. In both cases the authorial mark is inscribed in the project, and its expression in a constructed object matters only insofar as the end product is the identical trace (or index) of its conceptual matrix—all variation being irrelevant or erroneous. And in both cases, albeit in Eisenman's somewhat more deliberately, the built work can be seen as a probe or critique of the limits of allographic authorship. Given his pivotal role in the digital turn of the nineties, Eisenman's work is the ideal touchstone to assess the continuing relevance of the Albertian paradigm to the theory and practice of contemporary design.[54] This is even more true if, as I shall argue, the Albertian paradigm is now being reversed by the digital turn. A paradigm must be asserted prior to being reversed.

Alberti's new way of building by notation should be seen in the context of the quest for identical replication that is at the core of Alberti's work and theory, in all the diverse fields he tackled. And identicality is the common denominator to all new cultural technologies that crossed paths with, and transformed, the art of building in the Renaissance. In the case of books, identical copies in print were obtained from a mechanical matrix; in the case of building, identical construction was obtained from a notational matrix. The former process was induced by a new mechanical technology: print. The latter, albeit similar in its mechanical spirit, depended entirely upon cultural conventions: a reformed social practice (authorship), and a new cultural technology (a reliable notational format, or protocol, for architectural project drawings).

1.5 Geometry, Algorism, and the Notational Bottleneck

Alberti's design process relies on a system of notation whereby all aspects of a building must be scripted by one author and unambiguously understood by all builders.[55] Its principal notational means reside in the scaled and measured drawings of plans, elevations, and side views defined in the second book of *De re aedificatoria*. As mentioned above, Alberti's definition of such drawings as nonperspectival led him to describe them in terms that anticipate, for most practical purposes, today's theory of orthogonal or parallel projections.

The development of this new notational format was accompanied by a drastic transformation in the nature and function of the architect's mathematical tools. Vitruvius's design method was based on proportional modular systems, where each modular unit was a constituent part of the building, aptly chosen to be easily discernible and measurable while the building itself was being built.[56] The dimensions of most other parts were then defined as multiples or fractions of one of these modules, but except for the most straightforward cases (for example, "eight modules," or "half a module") these ratios were not indicated as numbers. Instead, Vitruvius narrated sequences of geometrical constructions that could be carried out "live," so to speak—on site and at full scale, with rulers and compasses. These mechanical operations could determine the real size of all relevant parts of the building without any need to measure them (except for the first one, the module itself), and crucially, without any need to follow scaled or measured construction drawings.

Vitruvius's design method may already have been outdated at the time of his writing (and was possibly inconsistent with other parts of his own theory).[57] Regardless, this is the method of quantification that Vitruvius, with his almost undisputed authority, bequeathed to Renaissance and early modern theoreticians. Not surprisingly, Renaissance architects soon found Vitruvius's text-based, narrational, and formulaic geometry odd and, at times, unwieldy. Vitruvius's modular system may have been a speedy way to *make* things (on site), but it was a cumbersome way to *design* them (off site). With the rising popularity of the modern way of building by design, and the concomitant rise of Hindu-Arabic numeracy in the West (then called "algorism"), Renaissance theoreticians gradually adapted Vitruvius's autographic and, in a sense, artisanal construction process to the new format of scaled and measured project drawings. The conversion from Vitruvius's geometrical constructions to modern computation was slow and laborious, but in time number-based operations phased out the manual, artisanal practice of ruler and compasses, and architectural measurements ceased to be geometrically determined by impromptu diagramming and real-size, on-site tracing and stonecutting.[58] Instead, it became increasingly common to expect that all dimensions should be precalculated and cleanly notated with numbers in the architect's construction drawings. These drawings would then be shipped to the building site complete with all the measurements needed for the workers to execute them. That, at least, was the idea.

If the old, Vitruvian, geometrical way was divisive, and used geometrical constructions mostly to divide segments (it is not by chance that compasses are also known in English as "dividers"), the architects' new geometry could be called, in a sense, pantographic[59] (even though the actual pantograph was not invented until the early seventeenth century): after a set of project drawings had been made, calculated, and carefully drawn to scale, another geometrical operation was ideally necessary to enlarge them homothetically to the actual scale of the building. In practice, before computer-aided design, this ideal scaling up was not performed by machines (architects seldom used mechanical pantographs, even long after they were invented), nor by way of geometrical projections.[60] Deriving the actual dimensions of a building from its scaled drawings is in most cases a much more pedestrian task.

Construction drawings generally contain some precalculated measurements in the form of digits inscribed in the drawing. All measurements that are not given as numbers, however, are shown only analogically by the length of segments drawn to a given scale. From these, the real measurements must, when necessary, be calculated arithmetically. A segment may be measured in the drawing and its length multiplied by a numerical scale ratio (for example, 1:50); alternatively, the length of the segment may be carried onto a graduated scale bar to read an approximation of its real size (or the same can be read on standardized, often multiscale straight rulers that are still in use in nondecimal countries). But the operation may become trickier when segments are not parallel to any of the projection plans in the drawing, because in that case their scales change. Architects soon realized that the new way of building from scaled drawings had a catch: if you cannot measure an object in a drawing, then no one can build it.

If all that is built is built from notations, and if the drawings (or models) must contain all of the necessary data for an object to be built identically to its design, it follows that in most cases what can be built is determined by what can be drawn and measured in drawings. And as the notational system that encodes and carries data in architectural design is mainly geometric, it also follows that the potency of some geometrical tools determines the universe of forms that may or may not be built at any given point in time (with some nuances based on costs and on the complexity of the geometrical operations).

This notational bottleneck was the inevitable companion of all allographic architecture from its very start. Forms that are difficult to draw and measure used to be difficult or impossible to build by notation. Robin Evans has shown how some well-known architects tried to dodge the issue. Parts of Le Corbusier's church at Ronchamp, for example, were meant to look like plastic, sculptural, and irregular volumes—hand-shaped, like the sketches and three-dimensional models from which they were derived. Behind the scenes, though, Le Corbusier's engineers had to cook the books so that the most sculptural parts of the building could be duly drawn and measured in orthogonal projections. The roof in particular was redesigned as a regular, albeit sophisticated, ruled surface. This high-tech geometrical construction was accurately and laboriously devised to approximate Le Corbusier's supposedly instinctive, unscripted gesture as closely as possible. Evans also suggests that Le Corbusier was aware of and complicit in this ploy.[61]

In the most extreme cases, when a form is too difficult to notate geometrically, the last resort of the designer may well be to abandon the modern design process altogether, and return to the traditional, pre-Albertian, autographic way of building. If you can't draw what you have in mind in order to have others make it for you, you can still try to make it yourself. For example, this is what Antoni Gaudí did, most famously in the church of the Sagrada Familia, not coincidentally reviving, together with architectural forms evocative of a Gothic cathedral, some of the technologies and the social organization of a late medieval building site.[62] Gaudí built some parts of the Sagrada Familia much as Brunelleschi had built his dome in Florence: without construction drawings, but supervising all and everything in person, as an artisan/author who explains *viva voce* or shapes with his hands what he has in mind. It is not by chance that Gaudí is a famous case study among contemporary digital designers: once again, new digital tools and preallographic, artisanal fabrication processes find themselves, sometimes unintentionally, on similar grounds.[63]

This apparent affinity between manual and digital technologies is further evidence of a deeper and vaster connection, which will be further discussed in the second part of this book. But from this historical narrative also follows another, preliminary but inescapable remark. Since the establishment of the modern, allographic way of building, a notational mediator has stood between the ideas of the architect and their expression in building. For centuries, this mediator was essentially geometric: architects had to use two-dimensional drawings to script the forms of three-dimensional objects. They did so using the conventions and under the constraints of a geometrical language that, like all languages, was never universal or neutral. Then came computer-aided design.

Early in the history of computer-aided design (the actual chronology varies with the development and releases of specific families of software) architects started to realize that, even though a computer screen is two-dimensional, all three-dimensional forms visualized through it may exist in a computational three-dimensional space right from the start. Regardless of the interfaces and the conventions chosen to represent them, all geometrical points controlled by recent 3D CAD or animation software are, at their root, a set of three coordinates that locate each point in a three-dimensional space. As a result, a coherent object designed on a computer screen is automatically measured and built informationally—and the computer can actually fabricate the same object for good, if necessary, via a suitable 3D printer.

Indeed, 3D printing, 3D scanning and reverse modeling have already made it possible to envisage a continuous design and production process where one or more designers may intervene, seamlessly, on a variety of two-dimensional visualizations and three-dimensional representations (or printouts) of the same object, and where all interventions or revisions can be incorporated into the same master file of the project. This way of operating evokes somehow an ideal state of original, autographical, artisanal hand-making, except that in a digitized production chain the primary object of design is now an informational model. The range of its possible eventuations, in two and three dimensions, at all scales, and in all formats, includes the fabrication of the object itself.

By bridging the gap between design and production, this mode of digital making also reduces the limits that previously applied under the notational regimes of descriptive and predescriptive geometries, and this may well mean the end of the "notational bottleneck" that was the uninvited guest of architectural design throughout most of its early modern and modern history. Under the former dominion of geometry, what was not measurable in a drawing was not buildable. Now all that is digitally designed is, by definition and from the start, measured, hence geometrically defined and buildable.[64] Yet a cautionary note may be in order here.

For all of its almost unlimited versatility, the computer is still a tool—a technical mediator that in this instance is interposed between a designer and an object of design. All tools feed back onto the actions of their users, and digital tools are no exception. All design software tends to favor some solutions to the detriment of others, and as a consequence most digitally designed or manufactured objects can easily reveal their software bloodline to educated observers. However, the scope of these new constraints should be seen in light of the old ones, which held sway for centuries.

Since its inception, the notational regime of geometry imposed upon architects a strict diet of straight lines, right angles, squares and circles, and some bland variations on similarly elementary Euclidean themes. The few significant exceptions that have marked the history of architecture were realized, for the most part, nonallographically (that is, in part or entirely without the mediation of scaled construction drawings). In 1925, Le Corbusier published an actual synopsis of primary-school geometry (a table of lines, regular surfaces, and elementarysolids as found "on the back of exercise books issued to the elementary schools of France"), proudly stating: "this is geometry."[65] The repertoire of forms available to architects today is so vast as to appear unlimited, and it includes nongeometrical forms (sometimes also called "free forms"), which can now be digitally scanned, measured, and built. Evidently, the old notational bottleneck has not disappeared; but for most practical purposes digital technologies have already made it almost unnoticeable, and often irrelevant.

Indeed, in many cases, today's digital designers are no longer working on notations of objects, but on interactive avatars (or informational models) of the objects themselves. Digital technologies for design and fabrication may in such cases still be seen as instrumental mediators, but functionally they are more akin to material utensils, like hammers and chisels, than to traditional notational vectors such as blueprints or construction drawings. CAD-CAM applications are responsive tools for designing and making at the same time, not recording tools for scripting a final but inert set of design instructions.

1.6 The Fall of the Identicals

In his first book, published in 1970, Nicholas Negroponte prophesied an "Architecture Machine" that could act as an all-purpose cybernetic design assistant, and make possible through digitally mediated collaboration a high-tech version of Bernard Rudofsky's "architecture without architects."[66] Remarkably, in 2009, some of the latest trends in digital design seem to hark back to Negroponte's earliest anticipations. On the purely technical side, distributed or "cloud" computing recalls aspects of the mainframe environment that Negroponte would have been familiar with in the sixties and seventies. And recent developments in information modeling software are giving new prominence to the collaborative, information-based, decision-making aspects of the design process, which had been jettisoned by the more tectonically oriented CAD-CAM technologies of the nineties.[67] Whether through revival or survival, some of the vintage cybernetic "architecturology" of the seventies appears to be staging a comeback—an odd vindication of sorts for a generation of prophets who, until recently, appeared to have gotten it all wrong. For when the digital revolution arrived for good, in the eighties (and, for architecture, in the nineties), it took a turn that none of its early advocates had anticipated.

In January 1982, *Time* magazine proclaimed the IBM PC to be "Man of the Year." Ten years later, in the fall term of 1992, Columbia University's Graduate School of Architecture, Planning and Preservation inaugurated its seminal "paperless studio." But the cultural relevance of this factual chronology is debatable. It is a well-known pattern in the history of technosocial change that new and potentially disruptive technologies are often first tasked to emulate preexisting ones.[68] Indeed, many in the early nineties (including some distinguished technologists) were persuaded that CAD software would serve primarily to make cheaper, faster renderings and project drawings—easier to edit, archive, and retrieve.

The idea that the new digital design tools could also serve to make something else—something that would not otherwise have been possible—may have occurred when architects began to realize that computer-aided design could eliminate many geometrical and notational limitations that were deeply ingrained in the history of architectural design. Almost overnight, a whole new universe of forms opened up to digital designers. Objects that, prior to the introduction of digital technologies, would have been exceedingly difficult to represent geometrically, and could have been produced only by hand, could now be easily designed and machine-made using computers. Perhaps, some claimed, too easily.

As a side effect of this technological upheaval, complex or irregular geometries, which throughout most of the twentieth century often stood for some form of technological aversion on the part of the architect (because they could not be geometrically notated, nor machine-made, but had to be laboriously handcrafted), suddenly acquired the opposite meaning. Intricate, knotted, and warped forms became a trademark of the new digital tools, and signs of a new wave of excitement about technological change. The nineties (like the twenties) were a decade of technological optimism. Some critics failed to take notice, and as a result many exuberantly irregular, digitally made forms of the nineties have been described as "expressionist"—uncanny or anxious.[69]

One of the most acclaimed digital designers of the nineties may have unintentionally contributed to this critical misunderstanding. More than anyone else's, Frank Gehry's buildings of the time (particularly the Guggenheim Bilbao) brought the digital turn to the architectural forefront, as a stunned and often admiring general public concluded that digital technologies were indeed triggering an architectural revolution. This may have been true, but in Gehry's case, appearances were misleading. As is well known, Gehry's design process at the time began with handmade, sculptural models. These were then handed over to a technical team to be converted into geometrical drawings, as per the good old notational paradigm.[70] As mentioned above, a similar situation in Le Corbusier's office in the early fifties (1952–1954) ended in a standstill, and Le Corbusier's engineers had to alter the original model for Ronchamp in order to make it geometrically measurable. But by the early nineties (1991–1994; the Guggenheim Bilbao was inaugurated in 1997), thanks to digital technologies, the geometrical representation of irregular (or "free-form") three-dimensional objects had become a relatively easy task.

At the time, several tools (some derived from medical instruments) were already available to scan and digitize all kinds of objects, regardless of their form, or formlessness. First, physical models had to be converted into their digital doppelgängers by scanning a sufficient number of their surface points. The digital process of design and manufacturing could then take over. After much further work (on the digital model as well as on new drawings and physical models and prototypes derived from it) the process culminated in the ideal "printout" of the digital model—at the real scale of the actual building. In practice, the final construction was much more laborious, as it involved the three-dimensional assembly of a large number of digitally fabricated components. In theory, however, digital technologies in this instance acted as little more than a virtual three-dimensional pantograph. They were used to measure a three-dimensional prototype and replicate it identically at another, usually enlarged, scale. The reference to Christoph Scheiner's pantograph is not metaphorical. Alongside his better-known planar pantograph, Scheiner had also devised a spatial one, which, however, he stopped short of applying to the homothetic magnification of three-dimensional objects. No stereographic pantograph seems ever to have been used for architectural purposes—before Frank Gehry, that is.[71]

Digital tools in Gehry's office were used to further, not to transcend, the architects' traditional pursuit of identical replications. For centuries, project drawings had to be laboriously translated into notationally identical constructed objects. Gehry's engineers could do this faster and better than their predecessors; apparently, they could notate project measurements straight out of three-dimensional models (an unprecedented feat), and measure, then fabricate, some very ungeometrical surfaces. For all of its complexity, this was an allographic strategy that Alberti could have understood, if not praised. Gehry's pantographical process did not mark the end, but the climax of the notational paradigm—carried over, through digital tools, from an older world of simpler geometries into a new universe of "free forms" and unprecedented formal complexity.

Nothing prevents digital technologies from being used to make identical (or homothetic) copies. Indeed, anyone can use a computer with a scanner and printer to emulate a photocopier. But this is neither the smartest nor the most cost-effective way to use a computer. Concurrent with the construction of the Guggenheim Bilbao, new theories were emerging to claim just that—namely, that digital technologies could be put to better use designing and building digitally variable objects, rather than making three-dimensional copies; and that digital design could be digital from the start (i.e., design could start from algorithms rather than from the scanning and scaling of physical models). As it happens, the discourse on digital variability in architecture was sparked, in the late eighties and early nineties, by a most unlikely conflation of thinkers and ideas: the seventeenth-century philosopher and mathematician Gottfried Wilhelm Leibniz; Gilles Deleuze's book *The Fold: Leibniz and the Baroque* (1988; and 1993 in translation); Bernard Cache's contribution to, and subsequent interpretation of, the latter; and Peter Eisenman's and Greg Lynn's creative adaptation of the Deleuzian fold to American postdeconstructivist architectural theory. These disparate sources somehow came together, blended and fused in a special issue of *Architectural Design*, "Folding in Architecture," published in 1993.

There were many reasons why Leibniz's mathematics of continuity should appeal to digital designers of the early nineties: the design software of the time could easily manipulate continuous functions, thus putting Leibniz's differential calculus within the reach of most architects, regardless of their mathematical skills; and the earlier devices for numerically controlled fabrication could mill or mold or otherwise print out a vast range of continuous and curvaceous lines with great facility and at little cost. Additionally, Deleuze's often nebulous definitions of the "fold" (originally, a point of inflection in a continuous function) and Deleuze and Cache's descriptions of the "objectile" (originally, the notation of a parametric function) were more enthralling than the mathematical formulas from which they derived. Without Deleuze's timely mediation, few architects would have found high school calculus so highly inspiring. Regardless, Deleuze's and Cache's objectile ranks to this day among the most apt definitions of the new technical object in the digital age: the objectile is not an object but an algorithm—a parametric function which may determine an infinite variety of objects, all different (one for each set of parameters) yet all similar (as the underlying function is the same for all).

Differential calculus deals more easily with continuous lines and points of inflection than with gaps and angles. Lynn's and Cache's writings of the mid-nineties emphasized the role of mathematics, calculus, and continuous functions as new tools of design,[72] and Lynn's 1996 essay on "Blobs" immediately captured the spirit of the time.[73] The blob itself quickly became a visual and notional trope of the end of the twentieth century. Toward the end of the decade the fling of digital architects with topological geometry further amplified this tendency toward formal continuity. By 1999, from car design to web design, from sex appeal to fashion magazines, curvaceousness was ubiquitous,[74] and from the Guggenheim Bilbao on, curvilinearity was often singled out as the diacritical sign of digital design. The new organicist and morphogenetic theories[75] that crossed paths with the mathematical ones around that time would eventually become staples of digital design theory. Technical factors clearly drove the tilt toward the curve that marked end-of-millennium digital design, but it is the deeper empathy between digital technologies and the more general postmodern and posthistorical aura of the nineties that best explains the spirit of the new culture of digital design that was then taking shape.

The first digital critics of the time were not at leisure to investigate the matter, due to the sudden disappearance of what was then called "the new economy." The dot-com bust of 2000–2002 had both direct and indirect consequences for digital designers,[76] and in the more sober environment that prevailed after 2001, digital theory often inclined toward a more restrained process-conscious approach, to the detriment of its earlier formal glamour. If the continuity between digital design and fabrication tools had been first exploited primarily to produce showcase pieces of unique and sometimes virtuosic formal difficulty, the accent now shifted toward the technical and social implications of a fully integrated design and production chain.

The capacity to mass-produce series of nonidentical items led to a new range of theoretical and practical issues. The idea of nonstandard seriality, as this mode of production is often called,[77] was already inherent in the original definitions of the objectile, but its economic implications were not. In its simplest formulation, the theory of nonstandard seriality posits that economies of scale are irrelevant in digital production processes: every item in a digitally produced series is a one-off. Industrial mass production used to depend on mechanical matrixes, molds, or casts of which the upfront cost had to be amortized by reusing them as many times as possible. But due to the elimination of mechanical matrixes, digital fabrication tools can produce variations at no extra cost, while product standardization, still a perfectly reasonable option in many cases, and still high in demand for a number of reasons, has nevertheless lost its main economic rationale. In a digital production process, standardization is no longer a money-saver. Likewise, customization is no longer a money-waster.

Nonstandard seriality, in turn, already contains the seeds of a potentially different authorial approach. As digital fabrication processes invite endless design variations (within given technical limits), and promise to deliver them at no extra cost, the question inevitably arises as to who is going to design them all. In a parametric design process, some parameters are by definition variable. This variability may be automated and machine-controlled: for example, a program may be instructed to generate any number of variations, randomly or as a function of some external factor. Alternatively, the designer may choose and fix all parameters that determine each individual item right from the start, thus "authorizing" only a given number of them—a closed series of different objects all designed by the same author. But a third possibility cannot be ruled out: some parameters may be chosen, at some point, by someone other than the "original" author, and possibly without his or her consent. Open-endedness and interactivity are inherent in the notion of digital variability, but this participatory approach to digital design has only recently gained wider recognition, in the new technocultural environment of the so-called Web 2.0,[78] and in the context of the current excitement for all forms of collaborative and "social" use of the new media.

Some earlier, pre-Web 2.0 experiments on interactive design formats have recently given way to heavyweight, full-fledged (and heavily advertised) software platforms aimed at design collaboration. Most such tools have been developed to facilitate the flow of technical information among teams of designers working on the same project, but the potential import of this participatory approach is vaster and deeper, and it suggests more imaginative modes of use.[79] Engineers already fret about the dilution of responsibilities that digitally supported collaborative design methods may entail. But what if the same tools were used to involve, at the opposite end of the chain, the patrons or owners, for example, as well as clients, end users, customers, or citizens? What if some parts of the design process itself could be made interactive and public?

Digital technologies inevitably break the indexical chain that, in the mechanical age, linked the matrix to its imprint. Digital photographs are no longer the indexical imprint of light onto a surface; digitally manufactured objects are no longer the indexical imprint of a mold pressed into a metal plate; and digital variability may equally cut loose the indexical link that, under the old authorial paradigm, tied design notations to their material result in an object. In a digitized design and production process, the Albertian cutoff line that used to separate conception and construction is already technically obsolete. But if Alberti's allographic model is phased out, the traditional control of the designer over the object of design (as well as the author's intellectual ownership of the end product) may be on the line, too. If variations may occur at any time in the design and production process, and if parts of the process are allowed to drift open-endedly, interactively, and collaboratively, who will "authorize" what in the end? Interactivity and participation imply, at some point, some form of almost collective decision-making. But the wisdom of the many is often anonymous; anonymity goes counter to authorship, and, since the inception of the Albertian model, authorship has been a precondition for the architect's work.

Yet we can already count plenty of instances where the new digital media are fast unmaking established traditions of authorship that, until a few years ago, would have been deemed indispensable—both intellectually and economically. Who could have anticipated the meteoric rise of a universal encyclopedia that has no author (because it has too many), and which everyone uses (with some precautions) but no one pays for? Open source software is developed in the same way. The music industry has already been upended by the sheer impossibility of enforcing copyright law in the digital domain. The bottom line seems to be that digital technologies are inherently and essentially averse to the authorial model that rose to power with mechanical reproduction, and is now declining with them.

The old authorial paradigm was predicated upon mechanical indexicality, and on the mark of authorship that mechanical reproduction carried over from archetypes to identical copies. The rise of architectural authorship may have been following the same trajectory. If this is the case, then chances are that, with the transition from mechanical to digital technologies, and from identical to variable reproductions, a recast of architectural agency will also be inevitable. In fact, the trend may already have started.

1.7 The Reversal of the Albertian Paradigm

At the beginning of the Modern Age, the power of identical copies arose from two parallel and almost simultaneous developments: on the one hand, identicality was an intellectual and cultural ambition of the Renaissance humanists; on the other, it would soon become the inevitable by-product of mechanical technologies, which it has remained to this day. It is Alberti's precocious and relentless quest for identical copies of all kinds that makes his work so revelatory in this context. Most of his inventions failed, but many of his ideas thrived. Predicated upon the same mandate of identical reproducibility (in this case, the identical translation from project to building),[80] Alberti's definition of architecture as an authorial, allographic, notational art held sway until very recently, and defines many if not all of the architectural principles that the digital turn is now unmaking.

The shaping of complex geometries and of irregular, ungeometrical or "free" forms, which was the first and most visible achievement of the digital turn in architecture, may have been a transient incident. But due to CAD-CAM integration, and counter to the Albertian principle of separation between notation and construction, digital architects today are increasingly designing and making at the same time. Acting almost like prosthetic extensions of the hands of the artisan, digital design and fabrication tools are creating a curiously high-tech analog of preindustrial artisanal practices. Traditional craftsmen, unlike designers, do not send blueprints to factories or building sites: they make with their hands what they have in their minds. The objection, so frequently raised, that this new mode of digital artisanship may apply only to small objects of manufacturing is theoretically irrelevant: any big object can be assembled from smaller, digitally fabricated parts.

Ultimately, Alberti's modern and humanistic authorial tenet, which called for the final notation of an object (its blueprint, in twentieth-century parlance) to be materially executed without any change, may also be doomed in a digital design environment. Projects (and not only for buildings: the principle can be generalized) are increasingly conceived as open-ended, generative scripts that may beget one or more different objects—redesigned, adapted, messed up, and tampered with by a variety of human and technical agents, some of them uncontrollable and unpredictable.

So it will be seen that, over the brief span of less than two decades, the digital turn may have already undermined many of the basic principles that defined modern Western architecture from its Albertian beginnings. In the course of the last five centuries, the power of exactly repeatable, mechanical imprints has gradually shaped a visual environment where identicality is the norm, similarity insignificant, and the cultural expectation of identical copies ultimately affects the functions and value of all signs. Under this semantic regime of modernity, only signs that are visually identical have identical meanings. This is the way modern logos, emblems, and trademarks work. They are recorded and protected by copyright laws, which register an original and all identical copies of it—but leave resemblance and similarity in limbo.

Similarity, imitation, and mimesis are essentially premodern, nonquantifiable notions, and as such are hard to appraise in a modern marketplace, and hard to defend in a modern court of law. Before the age of mechanical copies, more complex cognitive processes conferred steady meanings on variable visual signs. The Senate and People of Rome (SPQR) did not legislate the design of their legions' banners, on which fowls of various shapes easily fulfilled the same symbolic function: in any event, everyone knew that the banner of the Roman legion was meant to be an eagle. In ages of variable copies, the meaning of visual signs does not depend on sameness, but on similarity. This was the case in the West before the rise of print, and this is again the case now, in the vast and growing domain of variable digital media.[81]

As Erwin Panofsky claimed in a celebrated and controversial essay, the apparently random drift of late medieval architectural and decorative visual forms was nevertheless derived from, and inscribed within, a set of fixed normative genera. Panofsky famously interpreted this pattern of "differences within repetition" as an isomorphism between Gothic architecture and Scholastic philosophy, both based on a genus-species relation between stable general categories and variable singular events.[82] Equally famously and controversially, and almost at the same time, Richard Krautheimer examined the conspicuous and at times baffling variances between medieval monuments that were meant to be recognizable copies of the same famous archetypes, to conclude that their semantic function was eminently symbolic (or socially conventional), and unrelated to iconicity (or actual visual resemblance).[83] Both analyses aptly describe the visual environment that is being shaped by contemporary digital media. Each objectile is an exactly transmissible but nonvisual notation: it is a fixed normative genus, which may engender infinitely variable visual species. All singular eventuations of the same algorithmic code will be different from, but similar to, one another. They will expect from their beholder a capacity to read and discern similarities, and to use this ancestral cognitive skill to recognize meaningful patterns in a stream of endlessly variable visual signs.

We have reason to worry about, and possibly lament, the forthcoming demise of traditional architectural authorship. The recent spasms of authorial conceit (always an indelible part of the architect's trade, but recently risen to unprecedented levels) further reinforce the perception of an incipient crisis. Evidently, even among practitioners less inclined to theoretical speculation, the nagging feeling that something today is not quite right with architectural authorship has made some headway. But the likely victim of today's upheavals may not be the general, timeless notion of architectural agency. Once an esoteric modernist theory, now an ordinary postmodern practice, the death of the author affects today but one, particular, time-specific category of authors: the author of identical, mechanical copies—the modern, Albertian author. Modern objects (authorial, authorized, and identically reproduced) might also disappear in the process. But many other modes of agency remain, and the old ones that were in force before the rise of the Albertian paradigm could help anticipate the new ones that may come after it.

The Scholastic flavor of the objectile may be an accidental side effect of its Deleuzian, Leibnizian, and mathematical provenance. The objectile is to an object what a mathematical function (a script or notation) is to a family of curves, or the Aristotelian form is to an Aristotelian event: in Aristotelian terms, the objectile is a generic object. The theory of the objectile also implies that the object itself (or the "specific" object)[84] should fall outside the scope of design (much as the Aristotelian event falls outside the domain of science), since both the object and the event are seen as essentially variable entities. But insofar as the objectile is, technically, an open-ended algorithm, and a generative, incomplete notation, the objectile's designer will "authorize" some general norms to determine aspects common to a range of variable and individual events. Evidently, in an open-sourced environment, the algorithmic code itself may be open to aleatoric, nonauthorial variations, but this does not alter the bigger picture. Seen in terms of a genus-species hierarchy, objects are—ontologically—specific, whereas the objectile is the general category to which they belong. Hence the objectile's designer is a "general," or perhaps a "generic," author. This is not an unprecedented authorial model. It was in use for centuries, before Alberti came by.