DESIGN:
Between Pedagogy and Production

Technique and (re)Production:
The Shift from Script to Print to Hypermedia

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INTRODUCTION

The printed book, that gnawing worm of architecture, sucks her blood and devours her limbs. She strips off her robes, she sheds her leaves, she grows thinner and thinner to the eye. She is sickly, she is poor, she is null. She no longer expresses anything, not even the recollections of the art of by-gone days. Reduced to herself, abandoned by the other arts because abandoned by human thought, she calls on the laborer in default of artists. The pane of glass replaces the stained glass window: the stone cutter succeeds the sculptor. Fare well all vigor, all originality, all life, all intelligence! She drags herself, poor beggar of the studio, from copy to copy.

—Victor Hugo, "Ceci tuera cela," *Notre Dame de Paris*[1]

In 1832 Victor Hugo proclaimed, "architecture is dead, dead beyond recall, killed by the printed books, killed because she is less lasting, killed because she is too dear." Architecture was "the great book of humanity" written in stone. Architecture was the "handwriting of the human race" which was comprised of letters (pillars), syllables (arcades), and words (pyramids) set in motion by the laws of geometry and poetry. According to Hugo, the story of humanity had been incised within the stone walls of architecture until the invention of the printing press in the fifteenth century because the "book is soon made, costs little, and reaches far." In other words, the printed book is efficient, economical, and reproducible.

Jacques Ellul in the *Technological Society* describes technique as a complex of standardized means for attaining a predetermined result. Spontaneous and unreflective behavior is thus converted to that which is deliberate and rationalized. Formulas are developed to describe "the one best way" in search of the most economical and efficient. No longer is there an original copy. Technique reduces action to numerical calculation. The magic once associated with number is lost. Geometry and poetry no longer work together.

Today's computer is pure technique. History incised in stone has been replaced by the printed word that is now stored within the virtual world of hyperspace located within the logs of computer networks. History which once was shown through stone images to the illiterate masses now has become pure information: textual and graphic information that is part of a system of extensively cross-referenced catalogues, files and lists. Information that once was within the tactile realm of three dimensions and materiality now has become hypermedia, which is within no dimension at all and all dimensions simultaneously, displayed as temporal images on the computer screen.

THE SHIFT FROM SCRIPT TO PRINT

We should note the force, effect, and consequences of inventions which are nowhere more conspicuous than in those three which were unknown to the ancients, namely, printing, gunpowder, and the compass. For these three have changed the appearance and state of the whole world. . .

—Francis Bacon (1561-1626), *Novum Organum, Aphorism* 129

Developments in techniques of reproduction have brought about radical transformations in intellectual life. It is remarkable that over three hundred years ago, Francis Bacon could forecast so simply those key influences on our lives today with the naming of the three inventions printing, gunpowder and the compass. Of the three, printing has had an incredible effect and one of its ramifications is evident in its logical extension, the computer. Gutenberg's invention in the mid-fifteenth century of movable type with interchangeable letters is part of a continuously unfolding process that began with the "book revolution" of the twelfth century and continues in the "information age" of today. The art of printing marked a crucial break in the ability to convey information, both verbal and visual. The invention of the printing press altered the techniques of book production and consequently affected the way information was disseminated, people were educated, and society was structured.

The manuscript was traditionally scripted by hand from an oral transmission by a single reader somewhat like a stenographer might do in taking dictation. Multiple copies were achieved by assembling many scribes in one room, or scriptoria, within a monastery. A literary composition was published by being read aloud and book learning relied on the spoken word; both required listeners as well as readers. Books began to be mass-produced during the twelfth century when lay stationers under university supervision handled the making of books. No longer assembled in one room, the copyists would copy portions of a given text piecemeal, and would be paid by the stationer for each piece. Manuscript copies inevitably incorporated errors and changes, and were likely to get corrupted after being copied over and over again. This age-old process of corruption was aggravated and accelerated after print because one error in a printed book could then be repeated thousands of times.[2]

The first printed books were like the skeuomorph: a variant phase, or threshold device, which simultaneously looks toward the past and to the future.[3] In order to be accepted by their readers, the first printers were required to produce books that resembled manuscripts. Printing began with an imitation of the scribe's 'hand'. Early type consisted of many versions of the same individual letter so that a line of type might resemble the script techniques of the scribe with all the inconsistencies of hand lettering.[4] The shift from script to print affected methods of record-keeping, the flow of information, and patterns of thinking.

The scribe was concerned with the handiwork and the surface appearance of the manuscript. With the advent of printing, publishers and editors began to be more concerned with the organization of the printed material. Emphasis was placed on the title page to systematically index, catalogue and list information alphabetically (figure 1). Editorial decisions standardized, codified and even homogenized language which eventually marginalized provincial dialects. The use of typography for texts and xylography for illustrations made it possible to produce identical text and images, maps and diagrams which could be viewed simultaneously by scattered readers. This in itself constituted a communications revolution.[5]

The printed book made it possible to learn by reading thereby eclipsing the need for personal contact. Oral traditions that relied on mnemonic devices by which to learn became obsolete and apprenticeship training from a gifted master was replaced by the illustrated technical manual. Prior to printing, formulas, recipes, and even medical remedies were memorized by rhyme and through cadence. However, with the adoption of the title page to catalogue, index and cross-reference data, there was no longer a need for phonetic memory devices. Like the "picture that is worth a thousand words," technical literature with printed images became indispensable for describing the methods of craft production and for prodding memory.[6]

If the thoughts of readers are guided by the way books are arranged, then basic changes in book format might affect a change in readers' patterns of thought.[7] According to Lewis Mumford, the effects of printing have lead to changes in people's thought-patterns so that we have lost some of the ability to think in terms of the interrelationships encouraged through a scribal culture that relied on mnemonic devices and the oral transmission of information. Due to a proliferation of printed material that is highly organized and schematic, thought patterns have become abstract, verbal, linear, categorical, and stereotyped. He also credits the printed book with furthering the dissociation of medieval society by releasing people from local and immediate domination.[8] For example, prior to the newspaper, sermons were coupled with news about local and foreign affairs. Eventually the newspaper began to replace the pulpit and its forum for congregation, which allowed churchgoers to learn about local affairs in silence at home with the end result of weakening local community ties. The printed word sharpened the division between private life and public affairs, and paved the way for the access of infor-

Figure 1. Athanasius Kircher, Isis, Oedipus Aegyptiacus, *Rome 1652.*

mation without the need for a personal or collective memory.[9] In general, oral transmission brings people together, reading encourages individuals to draw apart, and the computer draws a person in and the world outside ceases to exist.

THE BOOK AND THE BUILDING

That architecture down to the fifteenth century was the principal register of humanity; that during this period there did not appear in the world a thought of any complexity which was not worked into a building; that every popular idea and every religious law had its monumental records; that, in fine, the human race had no important thoughts which it did not write in stone.

—Victor Hugo, "Ceci tuera cela," *Notre Dame de Paris*[10]

Gutenberg's invention of the printing press in the mid fifteenth century also coincides with a radical shift in the history of architecture. Although history can never reveal a precise demarcation of change, there can be seen a revolution in the production of architecture as the reproduction of text moved from the copyist's to the printer's workshop. The unique illuminated manuscript of the Middle Ages that was written and illustrated by hand with all its inconsistencies was replaced by the uniform, synchronized and reproducible printed book of the Renaissance. The un-reproducible hand-hewn medieval building which was also a book yielded as well to the renaissance work which, in relying on the imitation of classical architecture without "spring[ing] unconsciously to suit a present need,"[11] no longer had stories to tell.

The medieval church in itself was a book that fostered the telling of *historie*. The body of the building was adorned with stone sculptures which could be read as stories of God, creation, fables, and even astronomy and astrology. The sculptures were usually painted with watercolors and accompanied with explanatory inscriptions for the benefit of the literate and semi-literate. The medieval person, however, was generally illiterate or half-literate and required not only images to tell these stories, but also needed the translation of the abstract ideas inherent in the stories into terms of spatial relationships which is possible through the three-dimensional medium of sculpture. These stone sculptures allowed for multiple readings due to elements that could be interchangeable at will. Theoretically, the peasant could attain wisdom through an ambiguity that permitted countless identifications and equations in a kind of mystic algebra and geometry.[12] These stone images could also be used as mnemonic devices to aid in the transmission of oral histories. Rhyme and cadence were used to preserve stories, and stone figures and stained glass windows invested those stories with images to be stored in places of memory. According to Frances Yates in the *Art of Memory*, Hugo's concerns about the printed book destroying the building could also be applied to the destruction of the "invisible cathedrals of memory of the past"[13] because the printed book would make it unnecessary to have huge built-up memories of images. The printed book may have paved the way for the Christian iconoclasm that destroyed those stone graven images and substituted for them a literate, verbal, and abstract "image-less way of remembering."[14]

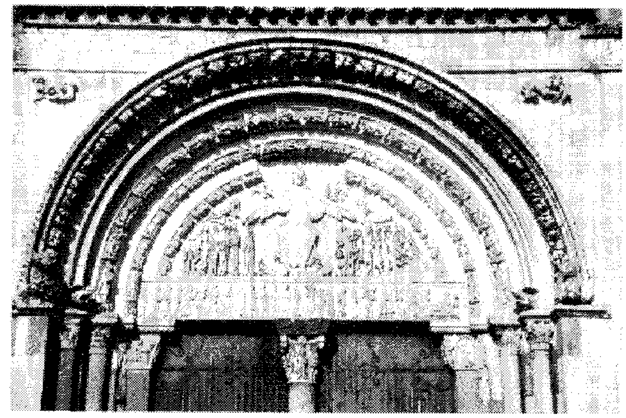

Figure 2. La Madeleine de Vezelay, The Last Judgment.

La Madeleine de Vezelay (figure 2) is one of "those marvelous books which were also marvelous edifices."[15] This basilica had been extensively damaged through pillage and desecration during the Wars of Religion in the sixteenth century and the Revolution of the eighteenth century when many of the sculptures were mutilated. La Madeleine was restored over a period of 20 years during the mid-nineteenth century by the architect Eugène-Emmanuel Viollet-le-Duc (1814-79) who also assisted with other medieval restorations that required the replacement, reconstruction and addition of elements. His techniques of restoration oftentimes resulted in the creation of entirely new forms: nineteenth-century architectural skeuomorphs. Notre Dame de Paris was another restoration project of this architect who was a contemporary of the author Victor Hugo (1802-85). It could be no coincidence that Hugo was aware of Viollet-le-Duc and the architectural debates of his time.[16]

This background in construction and restoration was influential to the development of Viollet-le-Duc's definition of architecture which was divided into two parts: *theory*, which deals with principles of geometry and laws of statics, and *practice*, which adapts these principles and laws through continued and familiar service by the hands in such material as is necessary for the purpose of a design. Ideally in architecture, practice would be the poetic manifestation of structure as in the original Greek sense of *poesis*, an act of making and revealing. Viollet-le-Duc's theory of rational architecture was that construction itself was the basis of design: 1) by knowing the nature of the materials; 2) by using these materials according to their nature; and 3) by utilizing a system of proportion to establish harmonious relations between all the parts.[17] He believed that these principles were founded upon the experience-based empirical science Roger Bacon defined in 1267 as "method, examination, and experiment,"[18] and not on theory alone. He was attracted to medieval architecture because to him it incorporated the eternal rational laws of art and of building science, or geometry and poetry. He sought to develop a new architecture by learning from the structural logic he believed to be inherent in Gothic architecture.[19] His admiration for the middle ages was shared by others of his time, most notably John Ruskin and Augustus Welby Pugin.

Common to these architects was the belief that originality comes through the *practice* of making and using materials, through spontaneous and unreflective behavior. To Viollet-le-Duc, practice went hand-in-hand with *theory*, or the laws which govern balance. These laws of balance were simply the apparent expression of the laws of statics, developed by calculation and geometry (figure 3). He cautioned, however, against reducing architecture to a "recipe applicable to every purpose and to every programme,—a common formula which all may apply without having recourse to reason."[20] His rational functionalism which tempered theory with practice could be viewed as a reaction to the influences on his architectural education: a professional training which began as a student of A. F. R. Leclère (1785-1853) whose own career had begun in the atelier of Jean-Nicolas-Louis Durand (1760-1834).[21]

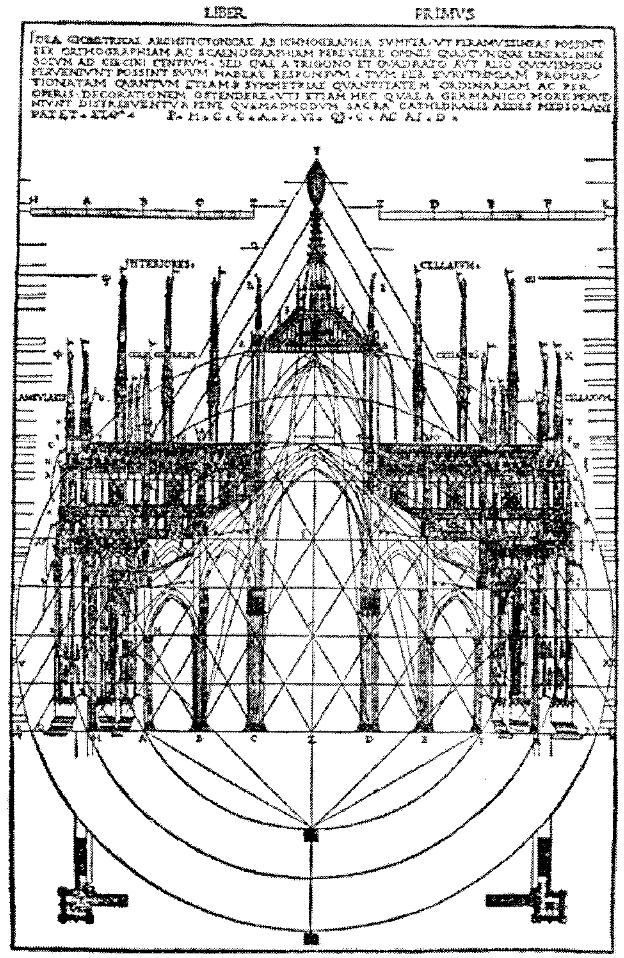

Figure 3. Cesariano, Cathedral of Milan, Como Vitruvius, *Milan, 1521. System of equilateral triangles that determined its various parts.*

NECROMANCING THE NET

A work of architecture may be significant, organic, dramatic, but it will fail of being a work of art unless it be also schematic. . . *a systematic disposition of parts according to some co-ordinating principle [which is] most easily effected by the use of what is called* profile paper, *a surface marked off into larger and lesser squares. . . This use of linear units as an aid to schematization . . . is the most obvious and easily achieved method of binding the elements of a work of architecture together in an invisible mathematical net.*

—Claude Bragdon, "Regulating Lines," *The Frozen Fountain*[22]

Durand is known for a rationalization and systemization of architecture which was governed by two inherent principles: (1) convenience, or efficiency of functional relationships and (2) economy. His attitudes toward efficiency and economy were directly influenced by Napoleon's distrust of architects who "should have been made responsible when they exceeded their estimates and put into debtors' prison for payment for this excess."[23] He served as an engineer in Napoleon's army and was aware of his preference for engineers who designed for an economy of means. He came out of a milieu of visionary dreamers who thought in metaphorical terms, architects like Ledoux, Boulée, and Lequeu who understood the imitation of nature as *mimesis*; whereas the rationalist Durand could only understand nature through a scientific quantification which substituted mathematical logic for metaphor as a model of thought. The principle of rationalism assumes that God/the creator has made the universe beautiful, harmonious and mathematical, and that through scientific experimentation the principles of creation could be discovered. The objective is to deduce the laws of nature, the general from which all the particulars may then be derived.[24] Since the Enlightenment, as a corollary to the work being done by scientists and philosophers, architectural theorists endeavored to bring architecture closer to a science by attempting to eliminate the irrational and personal in favor of a universally applicable system of principles and rules based

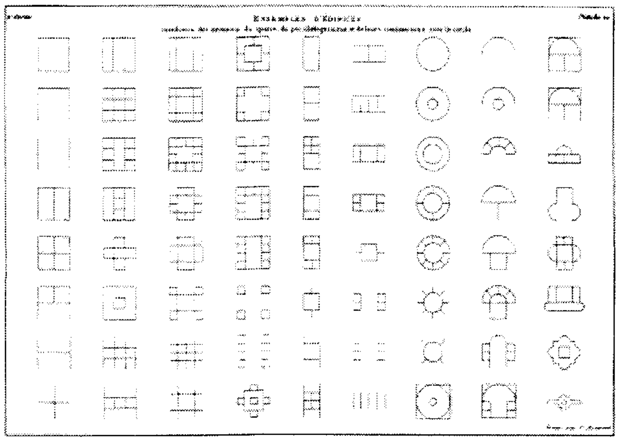

Figure 4. J.N.L. Durand, Table 20 of Précis des leçons d'architecture donnés à l'École polytechnique, *1802/5.*

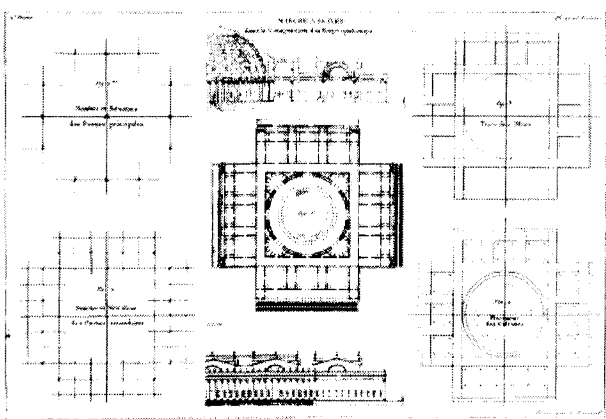

Figure 5. J.N.L. Durand, Plate 21 of Précis des leçons d'architecture donnés à l'École polytechnique, *1802/5.*

on absolute certainties. Durand was the first to formulate a complete early statement of this idea.[25]

He identified a set number of clearly definable principles, or formulas, upon which architecture was to be built. This rational attention to efficiency and economy led to his systemization of architecture and to the publication of two books: *Précis des leçons d'architecure donnés à l'Ecole polytechnique* in 1802/5 and *Recueil et Parallèl des édifices en tout genre, anciens et modernes* in 1809. The *Recueil* catalogues, in equal scale, buildings of the past and reduces them to a formal repertoire of two major groups: historical and functional. In the process, he consciously modified some of the plans to make them seem more systematic and geometric than they actually were in order to illustrate generic principles of architecture. The *Précis* became so popular it was used as the basic text for most architects working on public projects in France during the first half of

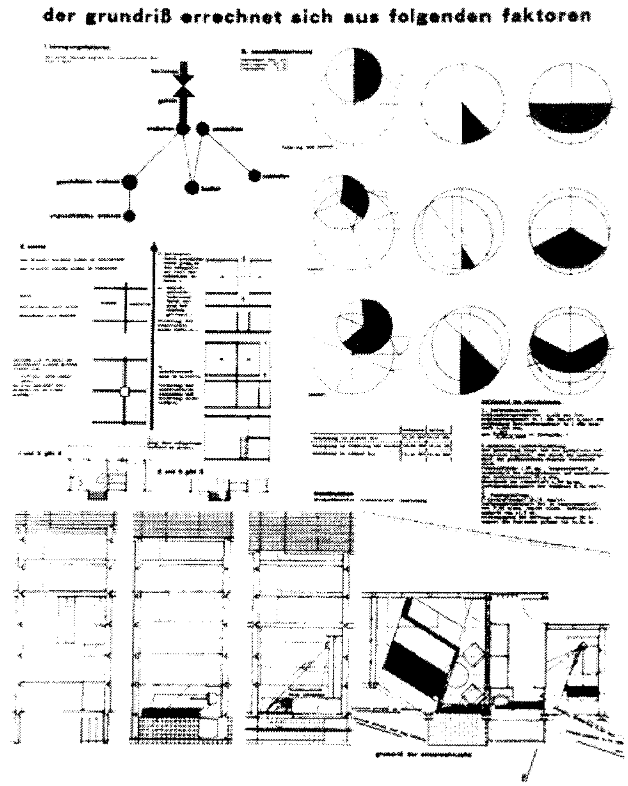

Figure 6. Hannes Meyer, The Plan Calculates Itself from the Following Factors, *Bauhaus, Dessau, 1930.*

the nineteenth century. In this work, he attempts to standardize construction by proposing rational prescriptive rules for the composition and assembly of basic elements of a structure (figure 4). This was an attempt to develop a codified system which began with gridded paper to which the various elements of architecture were added (figure 5). Economy of means was demonstrated through the use of grids, elementary geometric forms and simple building types. Durand boldly proposed that the design of a building could be the result of technical rules or formulas which could codify architectural knowledge in the form of methods, which could easily be passed on to other architects. Future architects could then learn about architecture through these abstract methods of design. In this way, architectural knowledge could become scientific.[26]

Large, illustrated printed books which systematically catalogued technological developments were nothing new to Durand. They originated in the engineers' notebooks of the fifteenth and sixteenth centuries and gradually developed into heavily illustrated printed works of machines called "theatres of machines." While Durand was working on his books, others at the École polytechnique, such as Jean N. Hachette, were classifying mechanical devices by function through schematic drawings arranged systematically in a chart.[27] The vast array of visual technical knowledge available at this time contributed to the notion that scientific processes could be made schematic and mathematic.

The chart as a visual aid and the grid as a generator of form is prevalent today in architectural education, arriving via a lineage which has continued from Durand's grid as a generator of the plan, to Le Corbusier's plan as a generator of form and Hannes Meyer's "the plan calculates itself" (figure 6). While Durand's grid was clad in the traditional clothing of the orders, the modernist grid was stripped naked, down to its basic geometry.[28] The Bauhaus tradition presently taught in our schools is based on measurable processes with codifiable causes and effects, from biological functions such as the act of seeing to psychological requirements; such that design itself has become a method of computation.[29]

Building upon this tradition of rational, scientific reasoning we have propelled ourselves headlong into the information era where value is no longer in the tangible, but exists simply as data stored within the logs of computer networks. If the computer could be programmed with a matrix of design variables similar to those found in the charts of Durand's *Précis* and *Recueil*, then the advantage of using a computer to design would be in its computational speed with the result of a more efficient and economical operation than could be done by hand.

The computer is able to count endlessly in an ideal realm, independently of any human presence, in a type of Platonic reality where language is ultimately nothing other than naming. In principle, the computer cannot be considered to be model of the human mind because it relies on the rule-based information-processing manipulation of symbols and formulas to mirror a preexisting reality. In contrast, human cognition is an embodied action such that thinking becomes more like "perception-in-action" which requires the situatedness of engaging directly with the world. This embodiment relies on the materiality of the counter who through interacting with the environment can count on "non-Euclidean fingers" and visualize non-programmed alternatives.[30] The ability to develop a plan, or strategy, stems from "*reasoning about* action, not as the generative *mechanism of* action."[31]

An important part of design thinking is the ability to form associations between ideas. Two forms of associative reasoning in computer-aided design are hypermedia and neural networks. Hypermedia is an interactive network which consists of units of information, both text and graphic ideas or pictures, connected by links. Hypermedia can catalogue images of historical buildings with textual annotations in a like manner to Durand's illustrated works, with the advantage of having all the images and textual information cross-referenced. One can navigate through a card catalogue of images which is organized by the visual association of similar ideas stored as discrete cards. The neural network model, on the other hand, simulates the neural connections in the human brain. Stored patterns are recalled from partial patterns which are stored in a data structure located at the nodes in a regular matrix in a computer system. It works as a net, information consists of both the node and the connection, its traversal a labyrinth in which every point is connected with every other point. Another method is the shape grammar model which involves parametric and schematic transformations. It is a computer program in the form of a shape-scripting language which recognizes shapes and transforms them through a series of permutations in order to arrive at a design.[32]

Through these types of uses of the computer, design can become more schematic and mathematic, the plan can calculate itself, generate its own form, and help students visualize what they cannot in their own minds. Perspective rendering programs with shadows, lighting and textures can produce fantastic images of mediocre designs. The emphasis in architectural production can become placed on the presentation of architecture rather than on the (re)presentation as an embodiment of an architectural idea.[33]

CONCLUSION

> *. . . invention no more depends on imagination than imagination has the ability to create anything whatever. The fact is, production of the new - and imagination - are only productions: by analogical connection and repetition, they bring to light what, without being there,* will have been *there. . . Imagination is what* retraces, *what produces as reproduction the lost object of perception. . .*
>
> Jacques Derrida, "Imagining"[34]

According to Jacques Ellul, magic is the first expression of technique and relies on ready-made formulas that yield precise results. Because these magical techniques are efficient and predictable, they are rapidly elaborated into a rigid, unchanging system. Reason also considers results in terms of the most efficient in its quest for the one best means, but in the absolute sense: in terms of numerical calculation. By abstracting the laws of nature, however, reason will not lead to an imitation of nature, only to ways of technique. The same is true of accomplishments that literally copy nature. Spontaneous and unreflective behavior through technique becomes deliberate and rationalized. The example Ellul cites is the swordsman who fabricates a sword, the form of which later could be justified through numerical calculation, however, formula had less to do with the technical operation of its making than with the swordsman's unconscious and spontaneous choice of form.[35] Therefore, the sword was a product of both the geometry of its form and the act of its making.

Pure technique *is* magical. Machines are magical: they perform marvelous, mysterious operations, the mechanisms of which are not fully understood by the people who use them. The computer can work so rapidly and efficiently, it almost works by itself: the Sorcerer's Apprentice' dream. This is the clever apprentice in Goethe's parable who repeated the sorcerer's magic formula in order to transform a broom into a servant to assist him in housecleaning. However, in the apprentice's desire to be free of all labor, he soon found himself overrun by the broom's automation. In this respect, students could regard the computer as a shortcut instead of a useful tool like the parallel bar and triangle. In necromancing the net, students can also easily get lost browsing through large, interconnected databases such as those created by hypermedia and neural networks. And unfortunately, in this ultimate striving for efficiency and economy, the patterns and diagrams produced through shape grammars are merely geometric designs that have little to do with functional requirements.[36] Even Durand's application of his method of design resulted in buildings that seem rather uniform due to standardized, repetitive, and economical forms that appear to be so unspecific in their primary geometries as to be interchangeable.

The computer is pure technique. When working on the computer results happen as if by magic, and like the magical technique its operations are hidden from view. Although the computer is "user-friendly," what began as a simple binary system of zeroes and ones, and on-and-off switches, is now encased within a technological system that is so complex it can only be understood by the systems analyst. Just like magical formulas that were kept within the select province of a few enlightened sages, operations on the computer are so mysterious that few know how they are performed.

Architectural production is the product of a mimetic process which copies, but copies the procedure of production rather than the product. For this reason, the computer as an instrument of production is ineffectual in architectural production because in producing the new in light of the old it manipulates patterns without imagining. The computer is only capable of rational thought based on the mathematical logic of the reasoning human mind and is incapable of "reflection-in-action"[37] which requires the situatedness of being in the world. It is difficult for design on the computer to embody an architectural idea because this procedure lacks the corporeal nature of the poetic logic inherent in drawing. Design on the computer via hypermedia, neural networks, and shape grammars is schematic and mathematic; the result is a simulation which is purely operational. The fantastic images produced on the computer easily confuse the difference between real and imaginary. Most importantly, critical thinking skills could be eclipsed through an architectural education that relies primarily on the computer. For it is the ability to think critically that allows students to see beyond the machine in order to continue learning as the technology rushes past them. Critical thinking can only be acquired through an architectural education that integrates both theory and practice, geometry and poetry.

NOTES

1. Victor Hugo, "Ceci tuera cela," *Notre Dame de Paris*, trans. Joseph L. Blamire (New York: George Routledge and Sons, 1881), 245. Note: All Hugo quotations are from this translation pp. 230-249.
2. Eugene S. Ferguson, *Engineering and the Mind's Eye* (Cambridge, MA: The MIT Press, 1992), 75-76 and Elizabeth L. Eisenstein, *The Printing Press as an Agent of Change*, vol. I (New York: Cambridge University Press, 1979), 10-12.
3. Skeuomorph is a term from archeological anthropology appropriated for use to describe developments within cybernetics by N. Katherine Hayles, "Boundary Disputes: Homeostasis, Reflexivity, and the Foundations of Cybernetics," *Configurations* 2/3 (Fall 1994): 446-447.
4. James Burke, *Connections* (Boston: Little, Brown and Company, 1978), 104.
5. Eisenstein, 52-53, 117.
6. Eisenstein, 65-69 and Burke, 104, 125-127.
7. Eisenstein, 88-89.
8. Lewis Mumford, *Technics and Civilization* (New York: Harcourt Brace Jovanovich, Inc., 1963), 136-137.
9. Eisenstein, 131-132.
10. Hugo, 240.
11. Geoffrey Scott, *The Architecture of Humanism* (New York: W.W. Norton & Company, 1974), 141-142.
12. Pamphlets, *The Basilica of Vezelay* (Bellegarde: Scop-Sadag, 1972), 11-14 and *La Madeleine de Vezeley* (Lyon: Lescuyer, 1985).
13. Frances Yates, *Art of Memory* (Chicago: University of Chicago Press), 131.
14. Yates, 271, see also Eisenstein, 66-67.
15. Hugo, 234.
16. For a thorough discussion of the relationship of the book to the building see Neil Levine, "The Book and the Building: Hugo's theory of architecture and Labrouste's Bibliothèque Ste-Geneviève," *The Beaux-Arts and nineteenth-century French architecture*, ed. Robin Middleton (Cambridge, MA: The MIT Press, 1982), 138-173.
17. Eugène-Emmanuel Viollet-le-Duc, "Lecture X: Importance of Method," *Lectures on Architecture*, trans. by Benjamin Bucknall (New York: Dover Publications, Inc., 1987), 462.
18. Ibid., 458.
19. For an excellent discussion on the rational laws of art and building science in Gothic architecture see James S. Ackerman, "'Ars Sine Scientia Nihil Est': Gothic Theory of Architecture at the Cathedral of Milan," *Art Bulletin* 31 (June 1949): 84-111.
20. Viollet-le-Duc, 475.

[21]For related discussions see Joseph Rykwert, "Necessity and Convention," *On Adam's House in Paradise* (Cambridge, MA: The MIT Press, 1981), 29-42 and Elizabeth Gilmore Holt, *From the Classicists to the Impressionists* (Garden City, New York: Doubleday & Co., Inc., 1966), 199-200, 212-214.

[22]Claude Bragdon, "Regulating Lines," *The Frozen Fountain* (New York: Alfred A. Knopf, 1932), 37-38.

[23]Antonio Hernandez, "J.N.L. Durand's Architectural Theory," *Perspecta* 12 (1969): 154.

[24]Stefan Polónyi, "The Concept of Science, Structural Design, Architecure," *Daidalos* 18 (15 December 1985): 33.

[25]Robert Bruegmann, "The Pencil and the Electronic Sketchboard: Architectural Representation and the Computer," *Architecture and Its Image*, ed. Eve Blau and Edward Kaufman (Cambridge, MA: The MIT Press,1989), 141.

[26]Leandro Madrazo, "Durand and the Science of Architecture," *JAE* 48/1 (September 1994): 12-24 and Hernandez, "J.N.L. Durand's Architectural Theory," 153-160. See also Joseph Rykwert, "The Nefarious Influence on Modern Architecture of the Neo-Classical Architects Boullée and Durand," *The Necessity of Artifice* (New York: Rizzoli, 1982), 60-65 and Alan Colquhoun, "Typology and Design Method" and "The Beaux-Arts Plan" in *Essays in Architectural Criticism* (Cambridge, MA: The MIT Press, 1981), 43-50 and 161-168. For a more comprehensive discussion see Alberto Pérez-Gómez, *Architecture and the Crisis of Modern Science* (Cambridge, MA: The MIT Press, 1983), 297-326.

[27]Ferguson, *Engineering and the Mind's Eye*, 115-152.

[28]Bruegmann, "The Pencil and the Electronic Sketchboard," 142.

[29]Klaus Herdeg, *The Decorated Diagram* (Cambridge, MA: The MIT Press, 1983), 78-97.

[30]Brian Rotman, "Exuberant Materiality—De-Minding the Store," *Configurations* 2/2 (Spring 1994): 257-274. See also Robert Markley, "Boundaries: Mathematics, Alienation, and the Metaphysics of Cyberspace," *Configurations* 2/3 (Fall 1994): 485-507.

[31]Lucy A. Suchman, *Plans and Situated Actions: The Problem of Human-Machine Communication* (New York: Cambridge University Press, 1987), 38-39.

[32]Richard D. Coyne, "Tools for Exploring Associative Reasoning in Design," and Takehiko Nagakura, "Shape Recognition and Transformation: A Script-Based Approach," in *The Electronic Design Studio*, ed. by McCullough, Mitchell, and Purcell (Cambridge, MA: The MIT Press, 1990), 91-106 and 149-170.

[33]Marco Frascari, "The Drafting Knife and Pen," *Implementing Architecture* (Atlanta: Nexus Press, 1988).

[34]Jacques Derrida, "Imagining," *The Archeology of the Frivolous: Reading Condillac* (Lincoln: University of Nebraska Press, 1980), 71.

[35]Jacques Ellul, *The Technological Society* (New York: Alfred A. Knopf, Inc., 1964), 3-27.

[36]Mark D. Gross, "Roles for Computing in Schools of Architecture and Planning," *JAE* 48/1 (September 1994): 56-64. See also Gary R. Bertoline, "The Role of Computers in the Design Process," *Engineering Design Graphics Journal* 52/2 (Spring 1988): 18-22, 30 who wrote, "In the hands of good designers, computers will become an effective tool. In the hands of others, computers will become the tool to create more visual garbage than the world has ever seen."

[37]Peter McCleary, "Some Characteristics of a New Concept of Technology," *JAE* 42/1 (Fall 1988): 4-9.