

PROCESSING MEDIA

The Dominion of Her Instruments¹: Examining the Techniques of Digital Media

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INTRODUCTION

As the storm of Paradise propels the angel of *Angelus Novus* irresistibly into the future to which his back is turned, wreckage upon wreckage is hurled at his feet.² The storm that Walter Benjamin calls progress has deposited, amongst the latest detritus, triangles, rules, compasses, French curves, mylar, rapidiographs, electrical erasers, pounce... the entire means of architectural representation, its techniques and tools have gone through "great innovations" of the kind Paul Valéry warned us to expect.³ If indeed the printing press put architecture's privileged role in the production and dissemination of culture at risk, as Victor Hugo laments, it did so without impinging on the domain of architecture's own production. It accomplished its considerable effects⁴ still limited to the re-production of architectural drawings and treatises. The technological innovations of the digital revolution are perceptible not only in the realm of the means of storage, communication and distribution of culture but also in the domain of its production; they have effected specific techniques of production and manipulation of every art, including architecture.

As Robin Evans' formidable work on the relationship between drawings and buildings testifies, the role played by architectural drawings is "enormously generative".⁵ Drawing technique and the imagination work together, as in the convincing example of Philibert de l'Orme's use of parallel projection in the Dome of the Royal Chapel at Anet.⁶ And though the proposition that a work of architecture is more than the sum of its representations is made clear,⁷ the drawing remains its "one unailing communicant".⁸

The trajectory of technology through representation is inscribed in and by architectural drawings. Advances in mathematics, geometry in particular, have likewise been cited by both Evans and Alberto Perez-Gomez as having substantial impact on architecture and its representation. While Evans examines the productive relation between projective geometry and architecture (*The Projective Cast*), Perez-Gomez (*Architecture and the Crisis of Modern Science*) links the change in the meaning of geometry and number in the 17th and 18th

centuries to the identification of theory with process and discusses the results of this convergence.⁹

In 1936, Walter Benjamin addressed the effect of "technological reproducibility"¹⁰ on art. In the preface to the essay, he implies that there is "prognostic value" to his effort, calling it "a thesis about the developmental tendencies of art under the present conditions of production... [its concepts] useful for the formulation of revolutionary demands in the politics of art".¹¹ His seminal text concerning the effects of mass media on representation, "The Work of Art in the Age of Mechanical Reproduction",¹² is the touchstone for beginning a discussion of the effects of digital media on representation in architecture and its potential to formulate new inquiries and demands.

DRAWINGS

As Robin Evans points out in *Translations from Drawing to Building*, architects' relationship to the drawing is at once direct and distant; direct – immersive like that of a painter to a canvas, and distant – engaging a language of abstract signs closer to musical notes. To choose between these two orders of representation is to, on one hand, equate the drawing with the work of architecture, on the other, to forego the element of perceptual likeness to the work. Both miss an opportunity to recognize in the drawing "its peculiar powers in relation to its putative subject - the building"¹³ In fact, he sees that there exists an unnecessary and limiting opposition in architectural culture between two kinds of drawings: those that are produced and received as art in themselves and directly communicate their effects through resemblance or through the logic of their construction, and those that are notational and refer abstractly to a work outside themselves. Like the rational and intuitive forces at work in the creative process, these two aspects – the corporeal and the abstract, should be combined in such a way to enhance both.¹⁴ While this is clearly possible without using digital means, it is strikingly characteristic of the digital interface. If understood as a space of thinking and creation as Evans describes, and "not so much a work of art or a truck for pushing ideas from place to place,"¹⁵ the digital drawing emerges as a locus, the place to capture, store, transmit and display. The qualitative term "digital drawing" (or its corollary, "drawing by hand") necessarily enlarges the category of what we call drawing, from something that requires a support, like a piece of paper on which a repre-

sentation is fixed, to light on a computer screen.

The process of making a drawing using digital means is interactive; the screen constantly provides dynamic feedback that is judged visually. A digital drawing necessarily employs rational means (i.e. digital, numeric) but these means are so transparent as to be invisible to the user. Linear perspective is recast as a simple algorithm involving the division of the x- and y- coordinates by the z-coordinate to diminish shapes with their distance back from the picture plane.¹⁶ Like using Ozanam's Universal Geometrical Square or Casati's Proportional Compass, "all problems of geometry [are solved] without the use of calculations".¹⁷ The drawings are as Evans hoped, simultaneously corporeal and disembodied, tangible and measurable yet abstract and mediated. This is partly due to the universalizing principles of the Cartesian grid, and partly to the possibility of simultaneously engaging a multitude of strategies of representation, from photography to watercolor, scientific diagrams to cinema.

IMMATERIAL TECHNIQUES

Perez-Gomez elucidates the historical trajectory of the shift from "metaphor to math"¹⁸ as a model for thought that ends with the convergence of theory and process. After Galileo's invention of the telescope, "that epitome of the visual prosthesis"¹⁹ established the first visible proof of the Copernican theory of a heliocentric universe, perception was forever split between truth understood as science and reality as poetics.²⁰ The telescope provided visual proof that the lived world of perceptions was not consistent with scientific truth. As epistemology came to be dominated by scientific thought, geometry and number were no longer perceived as the link between the human and the divine. They became "purely formal disciplines, devoid of meaning, value or power except as tools of technological intentionality". For architects, this meant that, "they began to consider their discipline as a technical challenge whose problems could be solved with the aid of two conceptual tools, geometry and number."²¹ Architectural and other 3D software meets this challenge, making the manipulation of geometry accessible to architects with unprecedented speed and ease. The combination of graphic modeling software and the calculating power of the computer is the ultimate manifestation of these very tools. Its mathematical roots can be found in the work of 17th century architect and engineer, Girard Desargues, whose *manière universelle*—a geometric method for perspective and stereometric techniques, was described in two treatises not published until 1864. The mathematical lineage from Desargues can be followed through the 18th and 19th centuries in the work of Gaspard Monge and his student, General Jean-Victor Poncelet, respectively. With the publication of Gaspard Monge's *Descriptive Geometry* (1795), the joining of mathematics and geometry created the first possibility for

an effective and precise mathematical description of reality, "...a complete *theory and practice of the operations* that result from the combination of lines, planes and surfaces in space."²² Because the process was immaterial, it could be equally applicable to stonecutting, carpentry, fortification and perspective. It could translate all 3d space systematically into 2d space. The orthogonal planes and quadrants of modern descriptive geometry are encountered each time one opens up a 3D program. It is the "working space" of Form_Z. Desargues' contribution concerning the identification of a straight line as a segment of an infinitely large circle forms the mathematical basis for softwares like Alias Studio and Rhino3D. Poncelet's further development of work on the principle of continuity between forms—particularly volume to plane—allows for the accurate unfolding of 3D curves (Non-Uniform Rational B-Splines or NURBS) into a single plane of perspective projection. Exercises in projective and descriptive geometry, a long tradition in the training of architects, evidence that architects approached the complexities of multi-curved surfaces before. Stereotomic projections, for example the *traits* of the French Gothic tradition, were so difficult to conceive mentally that it is equally difficult to envisage their form from the *trait*, such as for the *trompe* at Anet by Philibert de l'Orme described by Evans. It is not that these complex forms are new, but that their visualization and manipulation has never before been so easy or so prone to reductive simplicity.

For Perez-Gomez, the loss of the "transcendental" which accompanied the shift from metaphor to math, and is well-demonstrated in the writings of 18th century "building scientist" Jean-Baptiste Rondelet, marks a crisis in the discipline of architecture to this day. Architectural software programs of the "Design your own House" genre, are nothing more than a technological manifestation of the "functionalization of architecture theory...its transformation into a set of operational rules, into a tool of an exclusively technological character."²³ This is characteristic of Kevin Kelly's contemporary analysis of all expert systems: "Almost never is an expert system larger than a few thousand pieces of knowledge...Experts are often shocked and startled to find out that in the end it amounted to just a few hundred rules. 'Is that all I learned? Is that what I'm doing every day? I'm really exercising just a few hundred rules?'"²⁴ As market-driven software designers customize tools, programs like 3D Studio VIZ come complete with libraries of building parts, windows, doors, kitchen and bathroom utilities. Design becomes a question of selection and assembly. With reference to Rondelet's textbook, *Traite; The;orique et Pratique de l'Art de Baſtir* (1802), Perez-Gomez laments, "The transcendent justification of architecture no longer mattered. Intended meaning was perceived as irrelevant. If it appeared at all, it would be as a result of a technological process."²⁵

CONTINUOUS AND HOMOGENOUS FORMAT : THE NATURE OF DIGITAL MEDIA

For Benjamin, the character of art as a whole was changed at the beginning of the 20th century in large part by the advent of reproduction techniques that had reached the standard of artistic processes in themselves. The substitution of a plurality of copies for a unique authenticity and the distribution and consumption of these copies mark a colossal break from the tradition which defined art as never entirely separated from the location of its original use, in ritual. He attributes the means by which this break is made to the innovations in technology, but not its cause: "To pry an object from its shell, to destroy its aura, is the mark of a perception whose sense of the universal equality of things has increased to such a degree that it extracts it even from a unique object by means of reproduction".²⁶ The digital format is marked by this same perception about the universal equality of things. Numerical representation in binary code depends on assumptions of homogeneity and continuity. It has therefore provided an unprecedented homogenization of media that allows for maximum interminglings. Rendering everything as information in bits eliminates the physical material that sometimes stands in the way of the interplay between the arts and sciences. There is no inherent particularity or character of an individual "bit" based on its content. On a mimetic level, software simulates specific media-based techniques, removing them from their material reality to an immaterial condition where the effects of material operations are reproduced abstractly: *PhotoShop* simulates the darkroom techniques of "dodge" and "burn", *Premiere* simulates film techniques "cut" and "splice". In contrast to the master-copy relationship to which Benjamin refers, where data is fixed in a material like photographic paper, the digital world is a world of "mediumlessness".²⁷ The digital has no tangible support, like paper or canvas and no specific medium like charcoal or paint. Also, the "bit" of data is not fixed, like sound on a magnetic tape, but dynamic, a programmable variable. The data may appear visually different through the use of simulated media. Older cultural forms act as representations, privileging some techniques at the expense of others. The use of different filters can make a single image visible as a watercolor, a sepia print or a mosaic. The filter reorganizes the data into a different format. This concept, called transcoding, can occur across media forms.²⁸ Artist Jason Salavon's Digital C-print, *The Top Grossing Film of All Time, 1x1* (2000) is a good example. He digitized the entire film, *Titanic*, from video and mathematically averaged the color of each of the 336,247 frames. The frames were then printed like text, in the narrative sequence of the film, to reveal its visual rhythm. Concept and construction, theoretical and practical concerns are rendered as data moving fluidly between the material and the immaterial. Taking this construct to the extreme, Hugo's book

and building are but two manifestations in different media of the same collected data. That our contemporary milieu has no equivalent to that particular book and building is a question of content.

The space of possibilities for architecture is being expanded in ways that have nothing to do with the actual use of computing, but with its implications as a culture form. If, as Erwin Panofsky describes, the linear perspective of the Renaissance was a "symbolic form" related to conventions of culture, then perhaps there is a corresponding form of the digital age.²⁹ Not dissimilar to the discussions Benjamin calls futile – about whether or not photography was art – are discussions in contemporary architectural circles about whether digital drawings are as good as hand drawings. "The primary question – whether the very invention of photography had not transformed the very nature of art – was not raised."³⁰ Traces of that transformation can be seen in painting and photography of the period. Many of De-gas' paintings, *The Millinery Shop* (1879/84) for instance, use techniques attendant to the "snapshot": the composition is close to framing, to the way of positioning the subject within the range of the viewfinder; the subject seems decentered, segmented, viewed from above in an artificial, somewhat harsh light, like the glare of reflectors used by photographers of the time.³¹ The figural content of the image is also consistent with the "frozen time" photographic experiments of French scientist, Etienne-Jules Marey; it is a highly gestural spatio-cut in time. The painting represents a stolen moment of intimacy, a view caught voyeuristically and then gone. A similar essence is palpable in the architectural drawings of Zaha Hadid, who describes her *Fire Station* on the Vitra Campus in Berlin: "The red lines of the fire engine appear to be written on the asphalt, so are the rituals of the firemen inside inscribed like choreographic notation... The whole building is frozen motion, suspending the tension of alertness, ready to explode at any moment."³²

THE COLLECTIVE IMPULSE

As Peter Bürger develops in his exegesis of "The Work of Art in the Age of Mechanical Reproduction", technical innovations are dependent on overall social development and are not autonomous. He is careful to underscore the argument against instrumentality, what he calls Benjamin's "second explanation" for the change in modes of reception – namely, a discernable impulse on the part of the artists.³³ The machines which objectify advances in technology are important, but so is the way these machines are used. Photography has an impact on the evolution of art, summarized in Bürger's critique as a "withering" of its mimetic function, but photography is not the cause for the transformation. The rise of "Art for Art's sake", to which Benjamin refers, is not merely a reaction to the technological advance of photography, but a condition brought about by the tendency for indi-

vidual works of art at that time to forego a social role for an aesthetic one. In his outdoor paintings of Chartres, and the *Haystacks* series, among others, Monet paints to capture the experience of the fleeting moment. Martin Jay comments that *what* was painted often seemed less important than *how* it was painted: brushstrokes were left unsmoothed with colors juxtaposed to create an experience of sight, a specific retinal effect. His production technique is proto-photographic: make many canvasses, each at different time, each with a different light condition. This aestheticism is characterized by Bürger as the loss of the political content in art work and seen in connection with the division of labor underway in bourgeois society.³⁴ Art breaks with practical life, and creates its own purposeless sphere. The tension between the practical and the aesthetic resonates particularly high in architecture, where the result of their total separation is either mute or banal. For Kenneth Frampton, this is when the question of *how* began, at a public level, to take precedence over the issue of *what*. *The Crystal Palace*, after all, was simplistically characterized by John Ruskin "...as nothing but a large greenhouse."³⁵

For Benjamin, the laws of reception for architecture are most instructive because architecture is the prototype for works of art whose reception is consummated by a collectivity. And, like film, it addresses a collectivity in a state of distraction. Benjamin posits that advances in reproduction techniques, including lithography, photography and most of all film, diminish the "aura" of the work of art, but that this a "symptomatic process whose significance points beyond the realm of art".³⁶ The change in the forms of reception – from contemplative individual to distracted mass – result in a change in the "character of art as a whole".

He points to the case of the Dadaists, where the "loss of aura" predates the technological advances and can be traced to a discernable impulse on the part of the artists:

*Dadaism attempted to create by pictorial – and literary – means the effects which the public today seeks in film... the work of the Dadaists became an instrument of ballistics. It hit the spectator like a bullet, it happened to him, thus acquiring a tactile quality. It promoted a demand for the film, the distracting element of which is also primarily tactile, being based on changes of place and focus which periodically assail the spectator.*³⁷

The early photographic experiments Marey and those of the British artist, Eadweard Muybridge, had a creative impact on art and perception similar to that of the proto-cinematic Dadaists Benjamin describes. The photographic images fostered a tangible desire to achieve motion in representation, a feat which would engage the concept of time in both its absolute and relative terms. Superimposition and serial repetition emerge as film-specific techniques for representing motion, due to the possibility to expose the media repeatedly and to

the relative ease (after the invention of the negative) to register the image. Photographic techniques, specifically those driven by a desire for *pure simulation*, and for *represented motion*, survive, flourish, and are codified in the digital media programs we use which simulate photography and film editing. Because there is no material limit to exposure, many more levels of superimposition are possible in *Photoshop*, allowing the viewer to see more images collapsed onto a single image than is possible with film. Other well known techniques of cinema include montage and *mise-en-scene*, both of which have been well documented by Beatriz Colomina with regard to their influence on the "promenade architectural" of Le Corbusier and the affinity between his thinking and that of Sergei Eisenstein on the concept of "intellectual montage".³⁸

The collective impulse towards technological progress is apparent in the arrival of the fixed photographic image. Hannah Arendt situates it philosophically, as an outcome of an epistemological change in perception: "fabrication which had hitherto disappeared into the product now became an end in itself since pure science was not interested in the appearance of objects, but in the capacity of objects to reveal the intrinsic structure lying behind all appearance."³⁹ While early reactions to the photograph were that it was a "mirror" of the world,⁴⁰ and "the pencil of nature" (William Fox Talbot), media-specific techniques soon evolved that represented the world at a speed – both accelerated and decelerated – and scale – microscopic and macroscopic – which revealed myriad unseen realities, from the spins of falling cats to the intricacies of insect's wings (Marey). Like perspective, where space seen through Alberti's window was broken down into the discreet units of the gridded veil, chronophotography broke down a homogeneously constructed time into discrete units as well. With his graphic recording devices and the camera, Marey extended vision into the spaces of "frozen time" and "microscopic scale", fulfilling the desire of pure science described by Arendt. Duchamp famously collapsed the motion-event in *Nude Descending A Stair No. 2*, 1912.⁴¹ A multimedia image translates time into space in a recent (1994) project at the Media Lab described by Negroponete: *Salient Stills*⁴² takes several seconds of video and prints them as a still in such a way that the still has a higher resolution than any single frame of the video. It is an image that never existed; it represents a still frame of many seconds, where the elements that do not move are registered in the image and the those that do move, drop out. Projects of contemporary architecture whose forms derive from generative forces such as the recording of pedestrian or other accumulated movements over time seem conceptually indebted to this way of thinking about time and space.

The change in representation techniques brought about by digital technology is contemporaneous with a fundamental change in

the forms of perception along this same trajectory : the desire to reveal the unseen. The image conceived as interface to data rather than as representation of a visibly perceptual reality. "In positivist histories which conflate artistic movements with image production... the computer and its screen falsely stand in as a mode of representation or depiction".⁴³ Indeed, the computer does not produce images through an indexical apparatus like the camera. Rather, it calculates data and makes it accessible through an interface. For example, advanced software programs with finite element and dynamic analysis capabilities like STAADPro⁴⁴ calculate the physical properties of simulated models and output the results through a numerical matrix or a synthesized codified visual interface. The recent extension for 3ds Max, reactor^ä, is an interactive system for creating physics-based animations of deformations such as cloth, rope, or fluids driven by natural forces like wind, gravity and the density of an object.⁴⁵ Each simulated material provides appropriate and accurate resistances to equally accurate simulated forces using fully associative models.⁴⁶ Furthermore, the desire to model fluid physical phenomena, including simulating turbulence, was made possible by the application of supercomputers to the Navier-Stokes equations. This created the contemporary field of Computational Fluid Dynamics (CFD).⁴⁷ The digital images created from these various applications are the result of equations applied to a computational grid of variable resolution. The image is the *interface* to those results.

Similar advances have made possible the visualization of sound to create animations from acoustical models, and other kinds of dynamic simulations. These have been applied towards performance-based evaluations and refinements of particular forms, for instance in Sir Norman Foster's *Greater London Authority Headquarters* in Southwark, London (1998-2002).⁴⁸ While *formal* applications of parametric design are by now familiar⁴⁹, parametric design has more expansive potential. Rem Koolhaas/OMA⁵⁰ has applied it as a theoretical strategy in the winning project for the Downsview Parc International Design Competition, Toronto. The submission, *Tree City*, began by stating the problem that the city of Toronto had as an economic financing problem, a city competing to maintain its status as a "Global City". It then offered a remedy for the entire city that would, associatively, drive the design of the park. *Tree City* laid out the strategies for managing the use of the land, action plans for public space and park management. The proposal was a kind of *intellectual parametry* where a set of associative rules was designed and put in place that would over time address the issues that the desire for the park represented. The actual submission was a simulation: one possible scenario resulting from the set of designed rules. No specific drawings for the park were submitted.

CONCLUSION

The instruments of architecture now include immaterial techniques and strategies. Blur, montage, superimposition, and zoom are imported camera/filmic techniques. Algorithmic geometries, parametric modeling, and Boolean operations are just some of the mathematical techniques intrinsic in modeling software. Besides these, there are the innumerable simulated material techniques of graphic design, painting and other arts, as well as scientific visualization techniques and data modeling. As with photography and the movie camera, initial simulation will give way to the discovery of techniques specific to the media, provided that the characteristic immateriality of the digital allows some specificity. The architectural drawing is simultaneously measurable and abstract. An emerging visual sensibility along with all these elements will perhaps engender in the notion of architecture the "amazing change" to which Paul Valery refers.

The architectural project exists in a state of becoming, between the theoretical building and the constructed one, between its generative strategies and their representations, between digital representations and material ones, and in practice, between the physical models and drawings and the buildings themselves. Questions about the impact of representation on design persist. Are the products of Architecture defined, as Alberti said, as the result of the union of representation, *lineamenta* and construction, *structura*, or are the processes of creativity and learning quite algorithmic in nature after all?⁵¹ Will algorithmically generated complexities replace ideas that can be held in a designer's mind? For example, the idea of a procedurally expanded genome replacing that of a traditional parti.⁵² How is the structure of representation altered by the use of new media (including the use of sound)? What are the latent ideologies of digital techniques and how do they inform architecture? The provocations of digital media can be very productive for architecture if considered carefully. For one, they arouse anew the researches into architecture's autonomy, understood historically, as K. Michael Hays concludes in his introduction to the *Oppositions Reader* as "nothing quite so much as attempts to recode, to re-territorialize, to reinvent the boundaries and specificities that delimit the discipline."⁵³

NOTES

¹In Bernard Palissy, *Recepte V;eritable* (1563) 118-119, Palissy describes a midnight dialog among his instruments where the compass, the ruler, the plummet, the level, the astrolabe and the fixed and adjustable triangle all eulogize their embodied metaphors the roles they play in construction. The competition for primacy is ended by Palissy who reminds the instruments that they were all given form by man, who is therefore the only just occupant of the

place of primacy. The story is cited and summarized by Alberto Perez-Gomez, *Architecture and the Crisis of Modern Science* (Cambridge, Mass: MIT Press, 1983) 221-222.

²...A Klee painting named *Angelus Novus* shows an angel looking as though he is about to move away from something he is fixedly contemplating. His eyes are staring, his mouth is open, his wings are spread. This is how one pictures the angel of history. His face is turned toward the past. Where we perceive a chain of events, he sees one single catastrophe which keeps piling wreckage upon wreckage and hurls it in front of his feet. The angel would like to stay, awaken the dead, and make whole what has been smashed. But a storm is blowing from paradise; it has got caught in his wings with such violence that the angel can no longer close them. This storm irresistibly propels him into the future to which his back is turned, while the pile of debris before him grows skyward. The storm is what we call progress.

—Walter Benjamin, *Theses on the Philosophy of History*, 1940.

³Paul Valery, *Pieces sur L'Art* "La Conquete de L'ubiquite," Paris, quoted in Walter Benjamin, Preface to "The Work of Art in the Age of Mechanical Reproduction," trans. Harry Zorn, *Illuminations* ed. Hannah Arendt (New York: Schocken Books, 1969) 217. The full sentence is as follows: "We must expect great innovations to transform the entire technique of the arts, thereby affecting artistic invention itself and perhaps even bringing about an amazing change in our very notion of art."

⁴Marco Carpo, *Architecture in the Age of Printing* trans. Sarah Benson (Cambridge, MA : MIT Press 2001).

⁵Robin Evans, *Translations from Drawing to Building and Other Essays*, Architectural Association Publications (London and Janet Evans, 1997)156.

⁶...ibid, 173-188.

⁷Robin Evans, *The Projective Cast : Architecture and its Three Geometries* (Cambridge, MA : MIT Press 1995).

⁸Evans, *Translations*, 155.

⁹Alberto Perez-Gomez, *Architecture and the Crisis of Modern Science* (Cambridge, Mass: MIT Press, 1983) 227- 303.

¹⁰Originally published in German, the literal translation of the title of Benjamin's article was "The Artwork in the Age of its Technological Reproducibility". see Susan Buck-Morss, "Aesthetics and Anaesthetics: Walter Benjamin's Artwork Essay Reconsidered" in *October: The Second Decade, 1986-1996*. (Cambridge, MA : MIT Press, 1997), 375. note 1.

¹¹Benjamin, "The Work of Art in the Age of Mechanical Reproduction", 217-218.

¹²...ibid, 217-251.

¹³Robin Evans, *Translations*, 154.

¹⁴...ibid, 161.

¹⁵...ibid, 186.

¹⁶William J. Mitchell, *The Reconfigured Eye: The Visual Truth in the post-photographic Era*, (Cambridge, MA:MIT Press, 1992) 126.

¹⁷J. Ozanam, *Usage de l'Instrument Universel* (Paris, 1688). Quoted in Perez-Gomez, 222.

¹⁸Perez-Gomez, 7.

¹⁹Paul Virilio, *The Vision Machine* trans. Julie Rose (London: British Film Institute, Indiana: Indiana University Press, 1994) 4.

²⁰Perez-Gomez, 5.

²¹...ibid, 11.

²²...ibid, 280. emphasis mine

²³Alberto Perez-Gomez, *Architecture and the Crisis of Modern Science* (Cambridge, Mass: MIT Press, 1983) 4.

²⁴Kelly, Kevin *Out of Control*, (Reading, MA: Addison-Wesley Publishing, 1994)

²⁵Perez-Gomez, 287.

²⁶Benjamin, "The Work of Art in the Age of Mechanical Reproduction", 223.

²⁷Nicholas Negroponte, *Being Digital* (New York: Knopf, 1995) 71.

²⁸Lev Manovich, *The Language of New Media*, (Cambridge, MA : MIT Press, 2001) 47.

²⁹...ibid, Manovich makes this observation regarding the Database, 219.

³⁰Walter Benjamin, "The Work of Art in the Age of Mechanical Reproduction", 227.

³¹Virilio, 15.

³²Zaha Hadid, *Zaha Hadid :The Complete Buildings and Projects* (London: Thames & Hudson, 1998)64.

³³Peter Bürger, *Theory of the Avant-Garde*, trans.by Michael Shaw. *Theory and History of Literature*, Volume 4, (Minneapolis: University of Minnesota Press 1984) 27-34.

³⁴Burger, 32.

³⁵Kenneth Frampton, "Industrialization and the Crises in Architecture" *Oppositions Reader*, ed. K. Micheal Hays (New York: Princeton University Press, 1998) 47.

³⁶Benjamin, "The Work of Art in the Age of Mechanical Reproduction", 221.

³⁷...ibid, 238.

³⁸Beatriz Colomina, *Privacy and Publicity: Architecture as Mass Media*, (Cambridge, Mass: MIT Press, 1994)

³⁹Frampton, 40.

⁴⁰Martin Jay, *Downcast Eyes: The Denigration of Vision in Twentieth Century French Thought* (Berkeley and Los Angeles, CA: University of California Press, 1994) 126.

⁴¹diagrammatic dots at the center of the composition NDS 2, recall the silver buttons Marey put on his subjects to be able to measure their movement with precision.

⁴²Negroponte, 73.

⁴³Gloria Sutton, "Voiceover" *AfterImage* 29 (2002) : 10.

⁴⁴STAAD.Pro 2002 is a copyrighted software product produced by REI, Research Engineers International for the generation, analysis, design and verification of steel, concrete, timber, aluminum and cold-formed steel structures.

⁴⁵Discreet Products, www.discreet.com. 2002

⁴⁶Fully associative modeling software provides the ability to design "parametrically", that is, to control and alter forms based on other forms or on a set of associated rules.

⁴⁷the numerical solution, using computational methods, of the governing equations which describe fluid flow. FloMotion and FloTherm by FloMetrics, 1997 and FieldView by Intelligent Light, Bell Labs, Lucent Technologies and MIT, 1994 are examples of CFD post processing software.

⁴⁸<http://www.fosterandpartners.com/internetsite/Flash.html> has some excellent movies which describe the processes for manipulating the form and for evaluating its solar gain and the acoustical performance of an interior auditorium.

⁴⁹Meta-ball manipulations and uses of inverse kinematics resulting in blobs and warped spaces.

⁵⁰Rem Koolhaas/OMA Bruce Mau Design, Oleson Worland Architect Inside/Outside Project

⁵¹Roger C. Schank, *Explanation Patterns: Understanding Mechanically and Creatively*, (Hillsdale, NJ: Erlbaum, 1986) 230.

⁵²William Mitchell, "Antitectonics: The Poetics of Virtuality" in *The Virtual Dimension: Architecture, Representation and Crash Culture*, ed. John Beckman (Princeton Architectural Press, 1998) 211.

⁵³K. Micheal Hays, Introduction, *Oppositions Reader*, ed. K. Micheal Hays (New York: Princeton University Press, 1998) xii.