Digitalized Nature and mass customization

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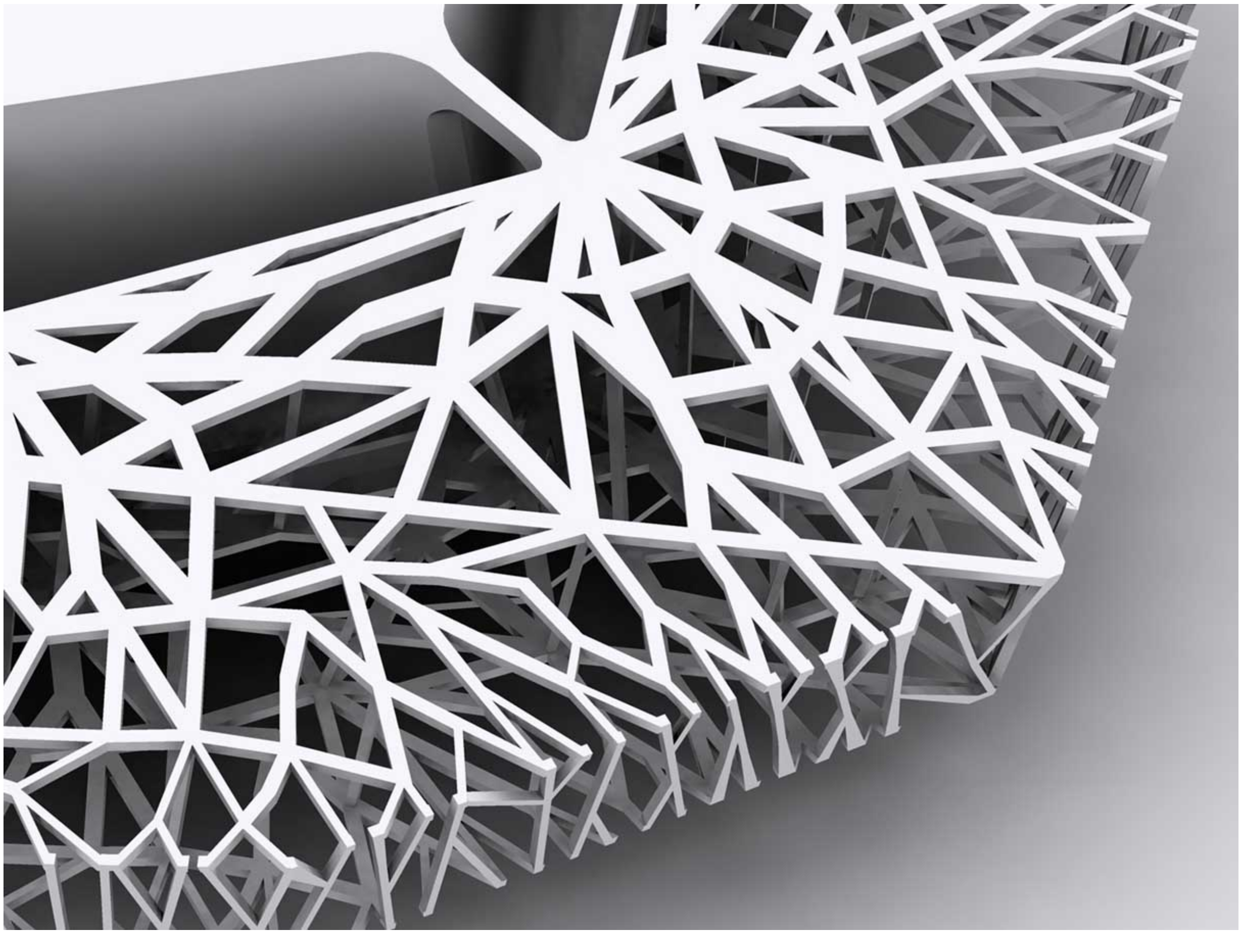


1.1 Nature's forms

"The straight line belongs to man, the curved line
belongs to God."
Antonio Gaudi

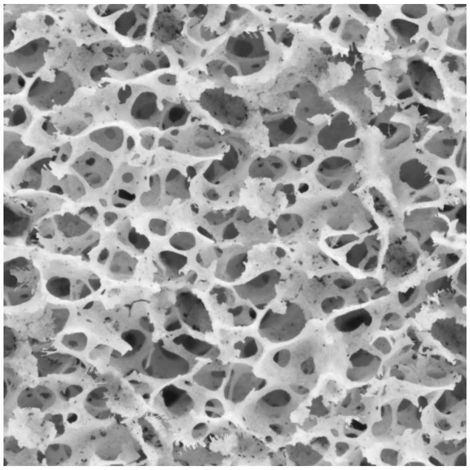
Inspiration in a design process often comes from Nature. Philosophically speaking, it is not possible for it to emerge from any other source .Everything we know about the world is derived from the perception the human being has of its surroundings. Every experience gets written into our brains over the 5-sense conductor, leaving us incapable to draw inspiration from something that is beyond our comprehension or our knowledge. If that is so, in order to talk about structural design, we have to start with the *structural characteristics* of the surrounding world. One look around will show us that Nature knows no right angle, nor does it use straight lines. Although there are lots of similarities between species of different life forms, it uses no repetition of basic structural elements for the sake of *production costs*. Actually every structural part of natural systems is unique, however big or small it is. One glance at the human history and structural design in architecture shows a constant use of straight lines, orthogonal connections and as much repetition of elements as possible. This contrast has a pretty straightforward and reasonable justification. Many systems people made were and still are inspired and influenced by Nature, but the degree of its simplification and abstraction always depended on knowledge, production ability and resources. Because of the lack of technology enabling the copying of Nature in an exact manner, the main principles were extracted and simplified. In order to use most of the tree trunks, they were cut longitudinal, thus producing straight wooden boards. Iron and steel were cast and rolled into straight beams because it was easier. In the XVII century *Renatus Cartesius*, better known as Rene Descartes, defines a *Cartesian coordinate system* for

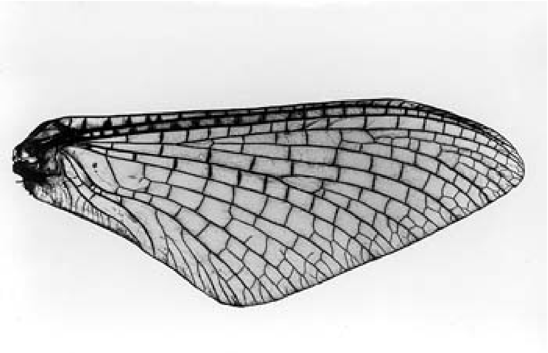
space representation, where the rectilinear convention was logical and easy to plan. Natural systems of primary and secondary structures were reproduced with simplified elements like columns, beams and ribs. Due to the uniform effect of gravitation, force slabs were built planar, for people to be able to walk on them. Experience and intuition indicated that longitudinal elements are best exploited when the gravity force acts
upon them parallel to their longer axis (causing axial pressure and tension, instead of bending), which made a logical development of vertical walls and columns as basic bearing structural elements. Everything fitted, and the complexity of building structures was mostly kept in those limits. Monumentality was achieved by varying
the number and size of the elements. Although rectilinear system evolved into a rule in design and architecture, there have always been exceptions throughout history , and as technology development progressed they became more frequent. Because we are born into geometrically *controlled* houses and cities, we are used to the idea that rectilinear solutions are optimal precisely due to their simplicity. If the simplicity is something desirable or if *"simplicity is the ultimate sophistication"* as Leonardo Da Vinci claimed , then the degree and level of simplification is where the problem lies and in the fact that its definition has constantly changed throughout history. As science goes from centimeters and millimeters over nanometers to unknown depths of elementary particles, in every field of research there is an expansion, branching and division into smaller, simpler elements that build the system. The definition of *simple* suddenly becomes blurry and it has to be carefully weighed up for each problem.

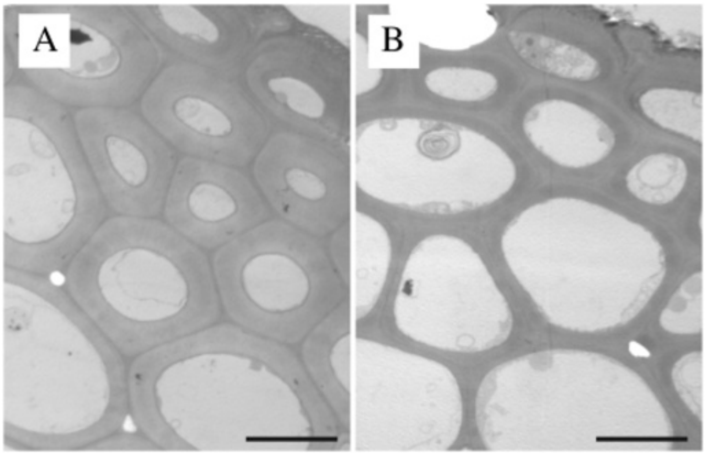
Following that principle of constant division, straight lines can be divided and combined into polylines. By letting lengths of polyline parts converge toward zero, smooth natural curves can be obtained. Similarly, we can connect plane surfaces, multiply them and
let their areas incline toward zero to form a continuous free-from surface We are expanding the range of our possibilities and we are always able to choose the degree of simplification at the cost of production expenses.

If everything in Nature is made out of free (irregular) forms, we can only ask ourselves why that is the case. The reason is that all structures are reactions to the forces in Nature acting upon them, or as D'Arcy phrased it, *"The form of an object is a diagram* *of forces"* . Since those forces are highly complex, irregular and non-uniform, structural systems adjusted themselves to resist those influences in the best possible way. In exploring what *the best possible way* means for Nature, it was realized that throughout the years of evolution it attempts to minimize material and minimize potential energy in its creations. When drawing a parallel to the structural design, it is important to mention that Nature's optimization of structures has a certain dimension of robustness and *safety coefficient*. An interesting thing is the actual *risk assessment* of Nature that can be further explored for structural optimization techniques. Challenges in design do have a parallel in Nature, since they are both trying to resolve the problem of optimal design for utilisation of human beings. In order to materialize these thoughts in terms of design objects, some of the criteria that should define form and structure have to be considered. First, there are external influences, like gravitation, sun, wind, snow, etc. Second, there are *user requirements*, expressed as different human functions or needs. Third, there is a creativity factor that is multiplied with free forms. Creativity is a term not known by Nature. Nature's variety is a searching technique to find a better solution according to different criteria, i.e., a solution that will survive. In order to describe this evolutionary process in Nature and draw a parallel to our mental processes that involve the discovery of new ideas, people defined the notion of creativity. But much more important, the notion of Beauty evolved into a science of proportions and design rules, whereas Beauty is also a term not known by Nature. We use it to describe something that gives us a perceptual experience of pleasure, hence something that is *optimal* for some specific set of conditions (objective or subjective). Combining external and internal, non-uniform influences, we have to agree that geometrical simplification principally doesn't lead to the minimal energy and minimal material solution. People inclined toward those spatial answers over the years for several reasons. An obvious one were the productions costs, followed by an extreme simplification of functional needs. Namely, gravity was one of the most important external forces and therefore considered as the dominant structural factor. Simplified functional organization fitted into the rectilinear system. That is how simple boxes were formed, whereas many other external or internal influences had to fit into those boundaries, defined by only a few factors which were taken into consideration. One of the ways to express creativity was the use of ornament, a pure decoration, made to imitate Nature’s complexity and achieve Beauty, thereby having no functional justification. There was still a lot of room for designers to express their creativity but the structural system was often there to limit the imagination.

So we are ready to climb one step up toward the natural systems. The technology exists and the principles that will enable us to use it in the best way possible have to be established.



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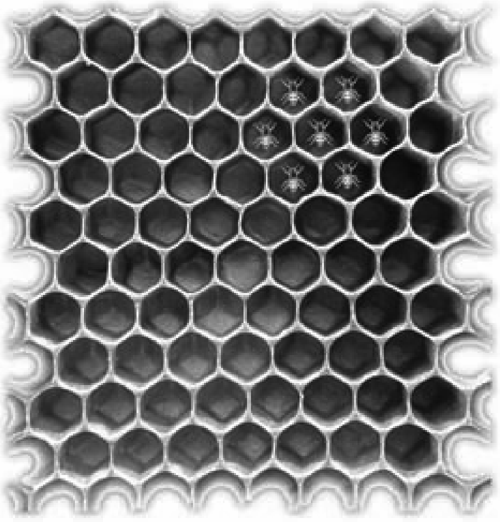

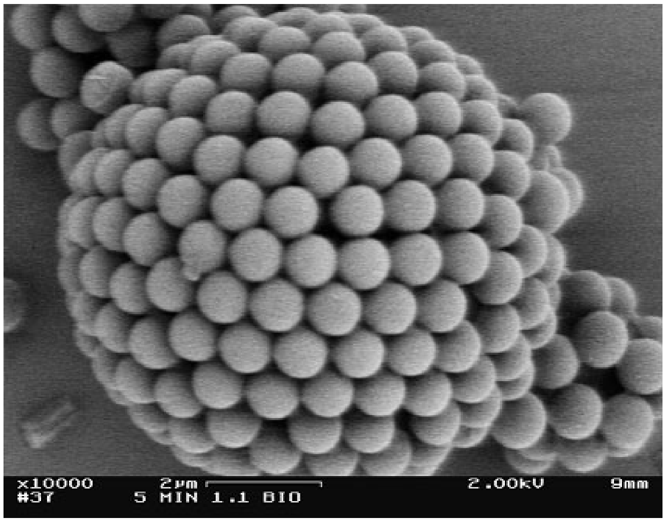
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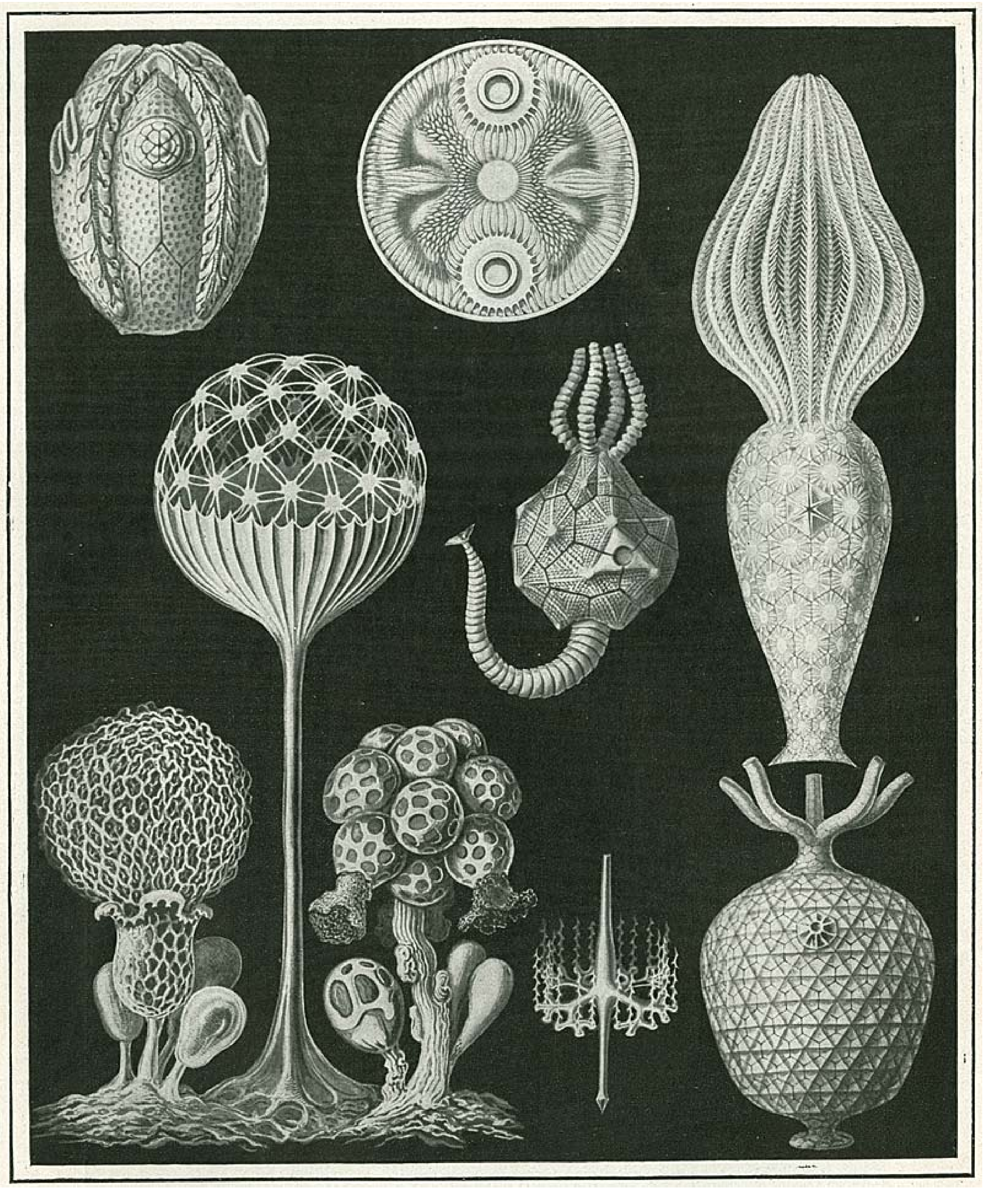
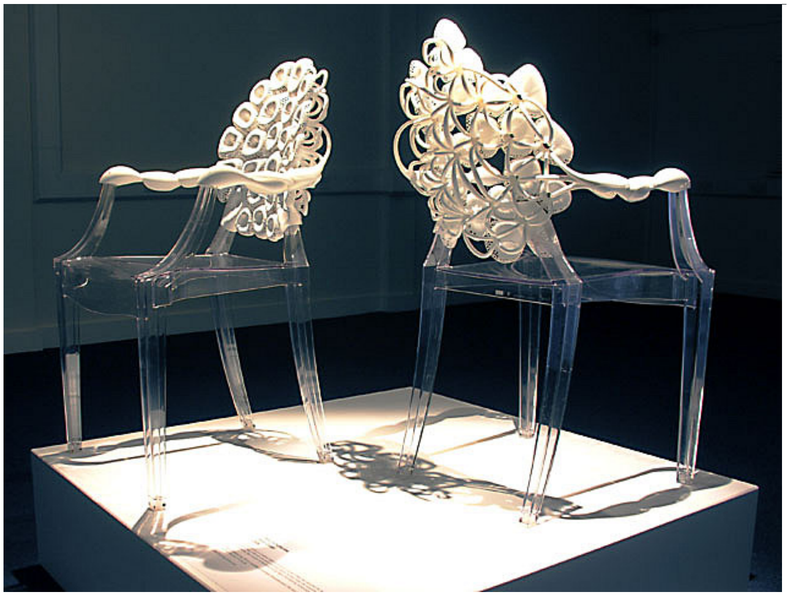


1.2 FINDING INSPIRATION IN NATURE

Over the last 3.6 billion years, nature has gone through a process of trial and error to refine the living organisms, processes, and materials on planet Earth. The emerging field of biomimetics has given rise to new technologies created from biologically inspired engineering at both the macro scale and nanoscale levels. Biomimetics is not a new idea. Humans have been looking at nature for answers to both complex and simple problems throughout our existence. Nature has allready solved many of today's engineering problems such as hydrophobicity, wind resistance, self-assembly, and harnessing solar energy through the evolutionary mechanics of selective advantages. But for centuries, men have been used natures elements only for decorative purposes. Straight line, or segment of an arc represented resistance to the nature's forces. Architectural thinking throughout centuries was based firmly on Euclidean thought and Platonic solids-The cylinder, pyramid, cube, prism and sphere were not only the essential forms of the Egyptian, Greek and Roman architecture, as observed by Le Corbusier, but were also universal geometric “primitives” of the digital solid modeling software of the late twentieth century. They are no longer seen, however, as some kind of unique, isolated archetypes, but as special cases of quadrie parametric surfaces. Euclid’s Elements proposed five basic postulates of geometry, of which all were considered self-evident except the fifth postulate of “parallelism,” which asserts that two lines are parallel, i.e. non-intersecting, if there is a third line that intersects both perpendicularly. The consequence of this postulate in Euclidean geometry is that through every point there is one and only one line parallel to any other line. Renaissance demanded straight lines in her structures, because it was directly related to Greek and roman principles, and perspective rules as well. As the science was developing, the idea of a curved surface was getting more and more accepted. In Baroque , that idea was considered on a philosophical level: . And with Leibniz, the curvature of the universe extends in accordance with three other fundamental notions: the fluidity of matter, the elasticity of bodies, the spring as mechanism. In the first place, it is certain that matter would not of itself move in a curved line: it would follow the tangent (Preface to the New Essays). But the universe is, as it Were, compressed by an active force which gives a curvilinear or swirling movement to matter, following to its end a curve with no tangent. And the infinite division of matter means that the compressive force relates each portion of matter to its surroundings, to the surrounding parts which bathe and penetrate the body in question, determining its curvature. Ceaselessly dividing, the parts of matter form little swirls within a swirl, and in them there are other, smaller ones, and still more in the concave intervals of the swirls which touch one another. Matter thus offers a texture that is infinitely porous, that is spongy or cavernous without empty parts, since there is always a cavern in the cavern: each body, however Small it may be, contains a World insofar as it is perforated by uneven passageways.

The contemporary digital architectures appear to reject any notion of urban and structural typology, continuity and morphology, and historic style and perspectical framework—they represent an ideological, conceptual and formal break much like Walter Gropius's Bauhaus in Dessau, Germany. They seem to prefigure an entirely new way of architectural thinking, one that ignores conventions of style or aesthetics altogether in favor of continuous experimentation based on digital generation and transformation of forms that respond to complex contextual or functional influences, both static and dynamic. The new digital architectures might be non-typological, discontinuous, amorphous, non-perspectical, historic... But they are not without a precedent. Since Baroque, architects have been trying to go beyond the Cartesian grid and the established norms of beauty and proportion in architecture. The parallels between contemporary and Baroque thought are indeed multiple, as contemporary reading of Deleuze's Fold shows, leading to labels such as "Neo-Baroque" being applied to new architectures. The biomorphic forms are, of course, not new, from the excesses of Baroque to organic design vocabularies of the early- and mid-twentieth century. Rafael Moneo speaks of "forgotten geometries lost to us because of the difficulties of their representation.“ The forms of Gehry's recent projects could be traced to the Expressionism of the 1920s; one could argue that there are ample precedents for Greg Lynn’s “blobs” in Surrealism. Earlier precedents could be found in the organic, biomorphic forms of Art Nouveau or, more specifically, in the sinuous curvilinear lines of Hector Guimard’s Metro Stations in Paris. And then there is Gaudi’s oeuvre of highly sculptural buildings with complex, organic geometric forms rigorously engineered through his own invented method of modeling curves by suspending linked chains.

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matter
workshop in
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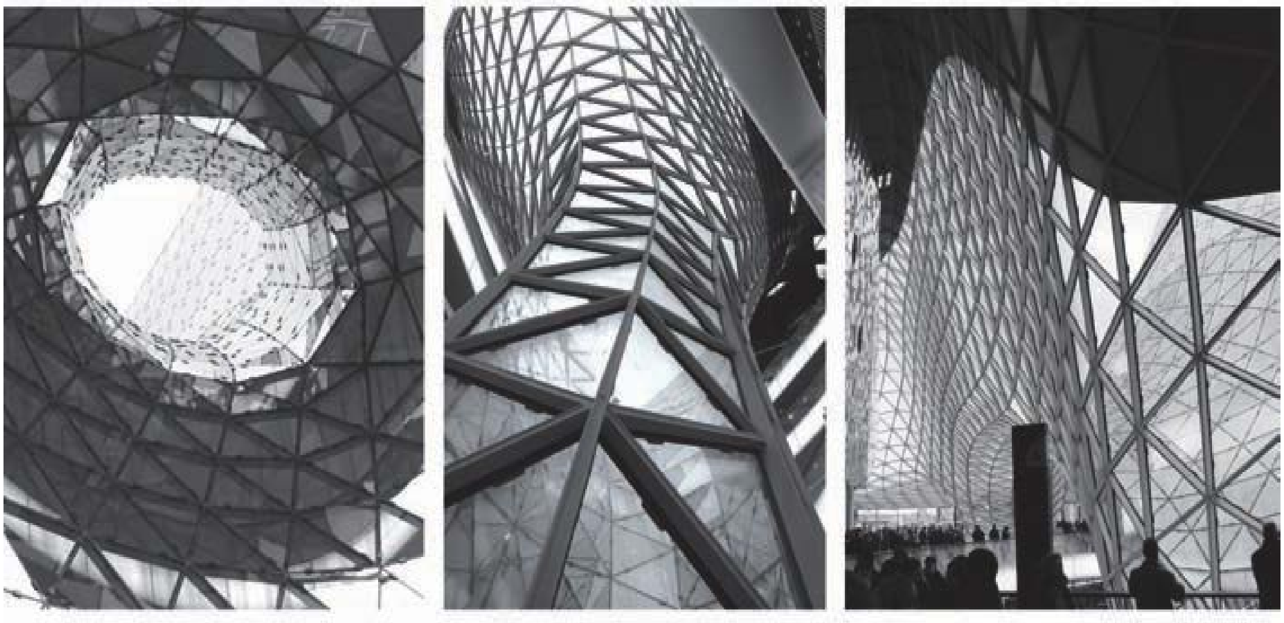
project title: 2 cewl 4 skewl
design team: Ehsaan "Adobix_255" Mesghali | Reza "Hi-Rez" Zia



2.1 CAD: COMPUTER AS A TOOL

For the last five decades, beginning with early CAD programs and continuing through high-end computer graphics, modeling, and animation systems, architects have been increasingly concerned with the possible loss of control over their own designs due to the powerful yet complicated, if not mysterious, nature of computers. This concern has led them to position themselves within a wide spectrum of speculations about the effect of computers on design that ranges from complete rejection, elitism, or demonization of their use as design generators to the complete antithesis, that of adoration, worship, or popularization of their use. When comparing avid computer users to those reluctant to engage with them it is necessary to overlook many significant and distinguishing differences in order to identify at least one common theme: the assessment that there is something different, unprecedented, and extraordinary about the computer as it compares to traditional manual tools.

Discretization of design by definition can be addressed, described, and codified using discrete processes executed today by discrete numerical machines (i.e. computers).However, the problem is that discrete/quantitative design provokes a fear of rationalistic determinism that is long considered to be a restraint to the designer's imagination and freedom.

Such resistances have attempted to discredit Computer Aided Design (CAD) products or processes as inadequate, irrelevant, or naïve. According to the humanistic position, design is considered a high-level intellectual endeavor constructed through uniquely human strategies, i.e. intuition, choice, or interpretation. Such theoretical design models negate computation as a possible means for design realization mainly because it is based on discrete processes that are finite and, as such, restrictive.

What should be the exact scope of the computer’s involvement with design?

This question has been present since the beginning of computer aided architecture. It played of course, a fundamental role in the first reflections and experiments regarding a possible computed or cybernetic architecture in the 1950s and 1960s.It did not disappear with the advent of post-modernism.

.It is only during the last decade, with the spectacular development of computer graphics and the fascination exerted by the strange forms, the blobs and others that began to float on the designers’ screens that this question was momentarily suspended. Now that this fascination is beginning to fade, the issue is back with all its complexity.

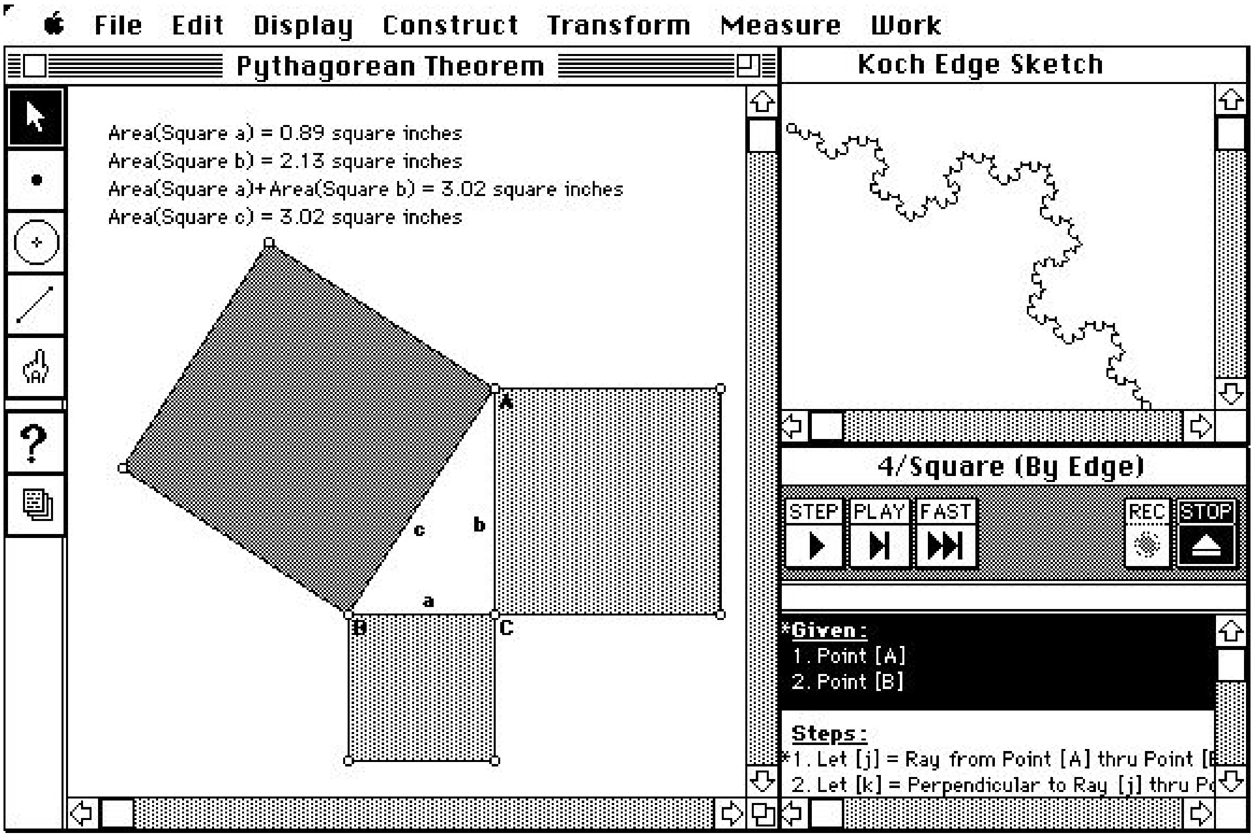
Typically, the positions regarding the role of the computer in architectural design fall into two categories. For many designers, the computer is just an advanced tool running programs that enable them to produce sophisticated forms and to control better their realization. For those designers, although the machine does alter significantly the nature of the architecture that is produced, it is not necessary or even desirable to enter into the details of its inner processes. Despite their claim to the contrary, the greatest part of the blob architects fall into this category.

There is the other group composed of those who think that it has become unavoidable to enter into the black box of programming in order to make a truly creative use of the computer.

CAD/CAM systems, used by designers, were actually developed for the consumer product industry. Animation software, such as Softimage, Alias, and Maya, were developed for the special effects needs of the film industry. This interest of architects in the re-use of technology and methods from other industries is nothing new. Designers have always looked beyond the boundaries of their discipline, appropriating materials, methods and processes from other industries as needed. Historically, these technology transfers have been at the core of many successful advances, widening the scope of innovation and continually affecting the prevalent norms of practice. Today, much of the innovation and change stems from the adoption of digital design and production processes based on CAD/CAM processes, and from new materials invented for, and widely used in, the product design, automotive, aerospace and shipbuilding industries. The impact of the adoption of innovative technologies in those industries was profound—there was a complete reinvention of how products were designed and made. Today, various appliances, cars, airplanes and ships are entirely designed, developed, analyzed and tested in a digital environment, and are then manufactured using digitally-driven technologies. Boeing 777, "the first 100% digitally designed aircraft," is probably one of the best-known examples . Buildings have that same potential to be digitally conceived and produced. While the CAD/CAM technological advances and the resulting changes in design and production techniques had an enormous impact on other industries, there has yet to be a similarly significant and industry-wide impact in the world of design and construction. The opportunities for the design, engineering and construction (ABC) industries are beckoning, and the benefits are already manifested in related fields.

I tend to believe that now, a designer/architect's creativity is limited by the very programs that are supposed to free their imagination. There is a finite amount of ideas that a brain can imagine or produce by using a CAD application. If a designer/architect doesn't find the tool/icon that they want they just can't translate that idea into form. And whenever they see a new icon (let's say "meta-balls") they think they are now able to do something cool. But are they really doing anything new? If a designer knew the mathematical principles and some of the programming behind the newest effects, they would be empowered to always keep expanding their knowledge and scholarship by always devising solutions un tackled by anybody else. By using a conventional program, and always relying on its design possibilities, the designer/architect's work is sooner or later at risk of being grossly imitated by lesser-devised solutions. By cluttering the field with imitations of a particular designer's style, one runs the risk of being associated not with the cutting-edge research, but with a mannerism of architectural style. In this light, there are many designers claiming to use the computer to design. But are they really creating a new design? Or are they just re-arranging existing information within a domain set by the programmer? If it is the programmer who is asking first all the questions, who is really setting the parameters and the outcome of a good design? We saw already the I-Generation (Internet-Generation). When are we going to see the C-Generation(Code-Generation) – the generation of designers/architects that can take its fate into their own hands?

What makes design problematic for scientists and engineers is that they have maintained a doctrine of rationalistic determinism in their fields. It is the theory that the exercise of reason provides the only valid basis for action or belief and that reason is the prime source of knowledge. Because of its clarity and efficiency, rationalistic determinism has traditionally been a dominant mode of thought in the world of science. The problem with this is that it assumes that all human activities abide to the same principles. In contrast, design, as defined in the arts and architecture, is based on quite different, if not opposite, principles. Rather than following a rationalistic model ,designers often employ the acceptance of empiricism, authority, spiritual revelation, metaphor or analogy as sources for their design inspiration. In addition, they quite often defy the rules of scientific planning and scheduling. This mode of thought, which we call here intuition, comes in contrast to the dominant model of science where rational, methodical, and systematic processes exist. More than ever now, as design enters the world of science, or as science enters the world of design, a complementing and harmonious mix of both thought processes is needed.



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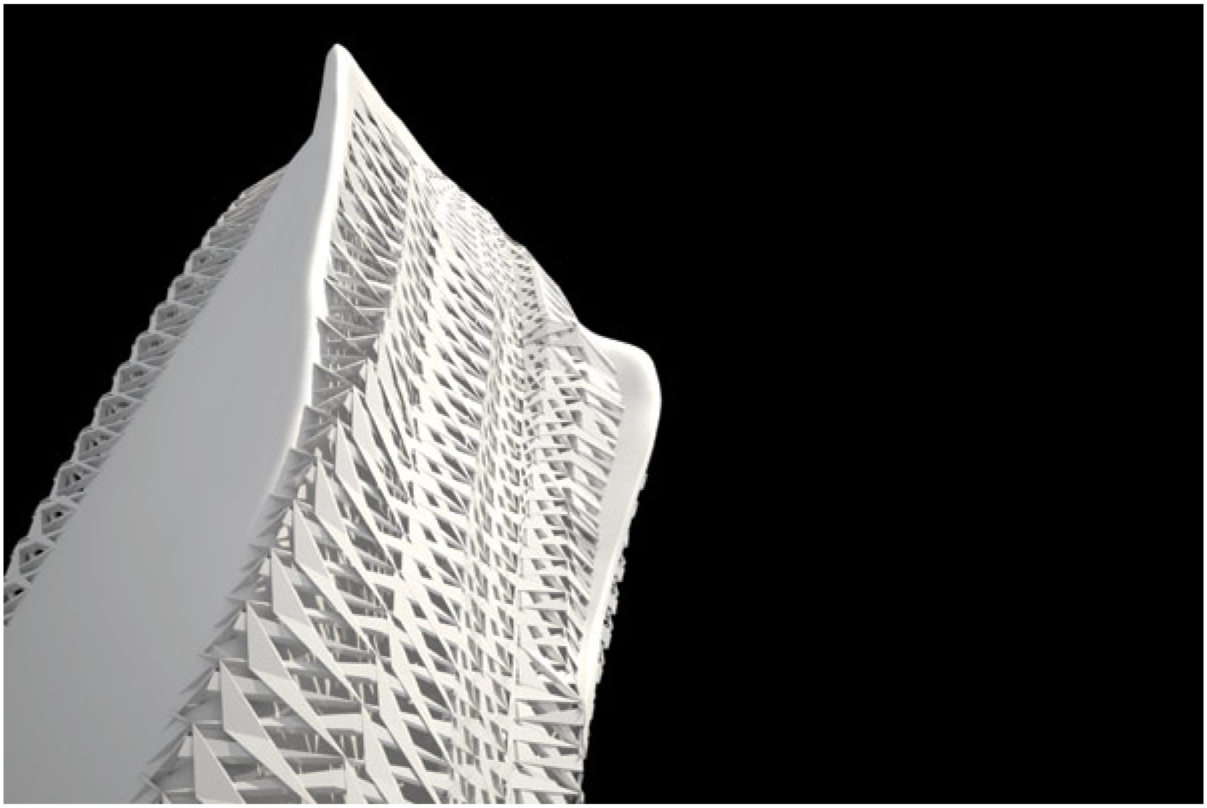
2.2 DIGITAL MORPHOGENESIS

In contemporary architectural design, digital media is increasingly being used not as a representational tool for visualization but as a generative tool for the derivation of form and its transformation—the digital morphogenesis. In a radical departure from centuries-old traditions and norms of architectural design, digitally -generated forms are not designed or drawn as the conventional understanding of these terms would have it, but they are calculated by the chosen generative computational method. Instead of modeling an external form, designers articulate an internal generative logic, which then produces, in an automatic fashion, a range of possibilities from which the designer could choose an appropriate formal proposition for further development. The predictable relationships between design and representations are abandoned in favor of computationally-generated complexities. Models of design capable of consistent ,continual and dynamic transformation are replacing the static norms of conventional processes. Complex curvilinear geometries are produced with the same ease as Euclidean geometries of planar shapes and cylindrical, spherical or conical forms. The plan no longer “generates” the design; sections attain a purely analytical role. Grids, repetitions and symmetries lose their past raison d ’étre, as infinite variability becomes as feasible as modularity, and as mass-customization presents alternatives to mass-production. The digital generative processes are opening up new teritories for conceptual, and tectonic exploration, articulating an architectural morphology. The emphasis shifts from the “making of form” to the “finding of form,” which various digitally-based generative techniques seem to bring about intentionally. In the realm of form, the stable is replaced by the variable, singularity by multiplicity.

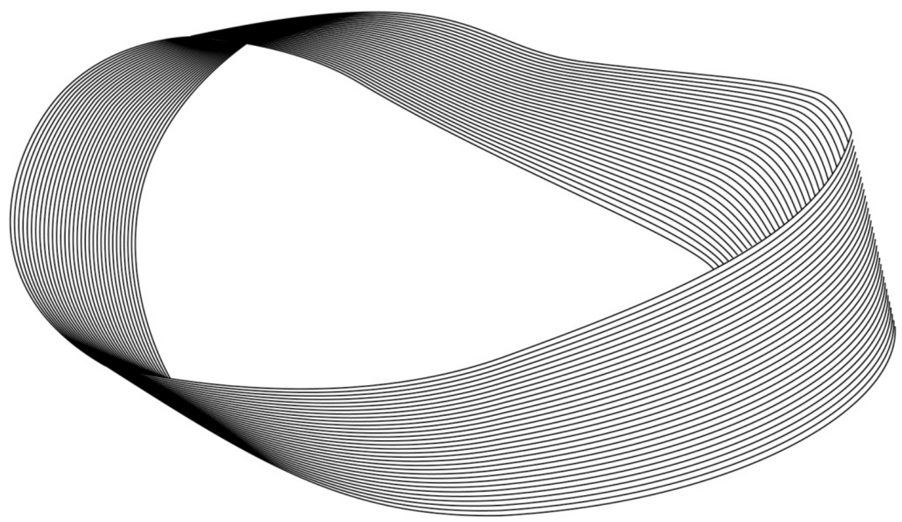


2.3 TOPOLOGY

Computational, digital architectures are defined by computationally-based processes of form origination and transformations, i.e. the processes of digital morphogenesis, where the plural (“architectures”) emphasizes multiplicities inherent in the logics of the underlying computational concepts, such as topological geometries, isomorphic polysurfaces (“blobs”), motion kinematics and dynamics, keyshape animation (metamorphosis), parametric design, genetic algorithms (evolutionary architectures), performance, etc., which are discussed in more detail in the following sections.

The notion of topology has particular potentiality in architecture, as emphasis shifis away from particular forms of expression to relations that exist between and within an existing site and the proposed program. These interdependences then become the structuring, organizing principle for the generation and transformation of form. According to its mathematical definition, topology is a study of intrinsic, qualitative properties of geometric forms that are not normally affected by changes in size or shape, i.e. which remain invariant through continuous one-to-one transformations or elastic deformations, such as stretching or twisting. A circle and an ellipse, for example, or a square and a rectangle, can be considered to be topologically equivalent, as both circle and square could be deformed by stretching them into an ellipsoid or rectangle, respectively. A square and a rectangle have the same number of edges and the same number of vertices, and are, therefore, topologically identical, or homeomorphic. This quality of homeomorphism is particularly interesting, as focus is on the relational structure of an object and not on its geometry—the same topological structure could be geometrically manifested in an infinite number of forms.

Topological transfomiations first and foremost, affect the relational structure and, thus the resulting forms. For example a rectangle could be transformed into a triangle with a single topological operation of deleting one of its vertices. Because of their intrinsic property of one sidedness, topological structures such as the Mobius strip have a potential for an architecture in which the boundaries between what is interior and what is exterior are blurred, an architecture that avoids the nonnative distinctions of “inside” and “outside.” What makes topology particularly appealing are not the complex forms, such as the Mobius strip, but the primacy over form of the structures of relations, interconnections or inherent qualities which exist internally and externally within the context of an architectural project.



2. 4 NURBS

Contemporary free form shaped buildings have manufacturing principles with the roots in the aeronautical and ship-building industry.The majority of construction methods in free form architecture today (taking Frank O. Gehry’s buildings as an example) is made with the help of vast experience in ship, aeronautical and car industry. Aside from manufacturing methods, the software able to represent free form surfaces, with mathematical precision, was initially developed for ship and car bodies. Pierre B´ezier, an employee of Renault, and Paul de Casteljau from Citroen, pioneered the principle in the 1950s with the polynomial representation of curves. From B´ezier splines the problem was generalized to create non uniform, rational B-Splines and was eventually developed into **N**on **U**niform **R**ational **B**asis **S**pline surfaces, or NURBS surfaces.

Due to the fact that it is possible to represent practically any shape with the use of NURBS, they entered the CAD world in the 80’s and prospered very fast to become the main tool today for the geometrical representation of free form in all fields of design.

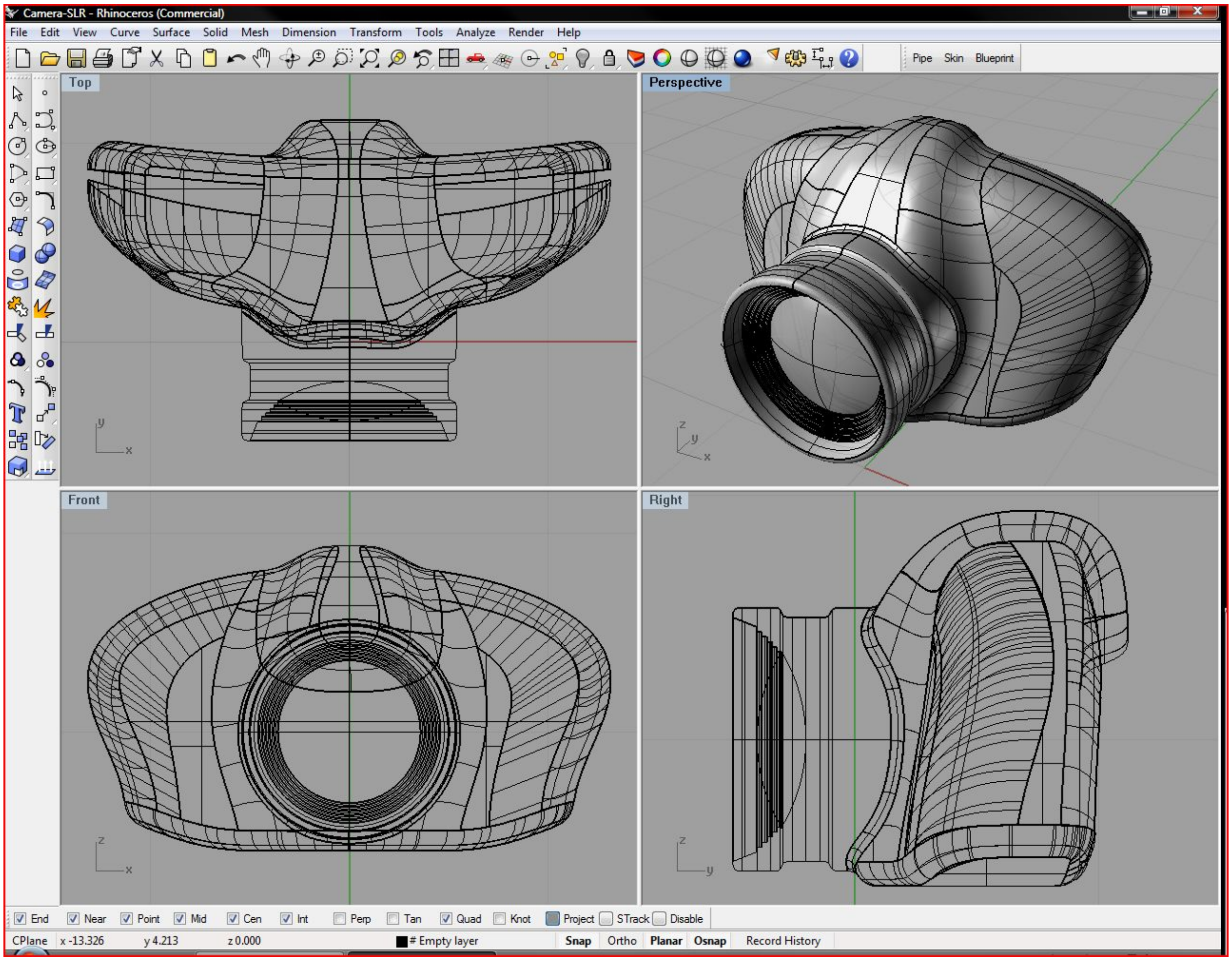
The research presented is made with the help of Rhinoceros 3D software, a commercial NURBS based 3D modeling tool.

. While the mathematical concept and software implementation of NURBS as surfaces is a prod-uct of applied numerical computation, the rearrangement of their control points through commercial software is simply an affine transformation, i.e. a translation. Presently, an alternative choice is being formulated that may escape these dialectically opposed strategies: algorithmic architecture. It involves the designation of software programs to generate space and form from the rule-based logic inherent in design programs, typologies, building code, and language itself. Instead of direct programming, the codification of design intention using scripting languages available in 3D packages (i.e. Maya EmbeddedLanguage (MEL), 3dMaxScript, and FormZ) can build consistency, structure, coherency, traceability, and intelligence into computerized 3D form. By using scripting languages designers can go beyond the mouse, transcending the factory-set limitations of current 3D software. Algorithmic design does not eradicate differences but incorporates both computational complexity and creative use of computers. For architects, algorithmic design enables the role of the designer to shift from “design programming” to “programming design.” Rather than investing in arrested conflicts, computational terms might be better exploited by this alternative choice. For the first time perhaps, industrial design might be aligned with neither formalism nor rationalism but with intelligent form and traceable creativity.

. The term spline in NURBS) actually has its origin in shipbuilding, where it was used to refer to a piece
of steamed wood shaped into a desired smooth curve and kept in shape with clamps and pegs. Mathematicians borrowed the term in a direct analogy to describe families of complex curves. The shape of a NURBS curve can be changed by manipulating its control points and associated weights, as well as the degree of the curve itself . The NURBS curves are shaped primarily by changing the location of control points, which do not have to lie on the curve itself, except for the endpoints. Each control point has an associated weight, which determines the extent of its influence over the curve, in a direct
analogy to drafting splines. Increasing the weight of a control point pulls the corresponding curve or surface toward that control point and vice versa. Each control point has an associated polynomial equation, commonly referred to as a basis function (the in NURBS, and in B-splines in general). A rational B-spline (the in NURBS) is defined mathematically as the ratio of two polynomial equations, i.e.
two basis functions. Each basis function affects only the curve section in the vicinity of the associated control point, and these sections are delimited by knots. A non-uniform rational B-spline is one in which the influence of a control point (i.e. the associated basis function) on a curvature can be varied by changing the location of the knots along the control segment that links two control points; in other words, a non-uniform rational B-spline is one with unequal knot spacing.

Other spline curves. as subcategories of NURBS. are typically available in modeling software. B-splines are actually NURBS with equally weighted control points (thus weights are not displayed). Bézier curves named after Pierre Bézier the French automotive engineer who invented them are B-splines with equal knot spacings (thus knots are not shown) Cubic curves are actually third-degree continuous Be'zier curves, and quadratic curves are second-degree continuous Bezier curves. In this pseudo-taxonomy of spline curves, at each level an additional set of controls over curvature is lost: weights in the case of B-splines, and both weights and knots in the case of Bézier curves.“ An important property of curves made by splines is that their curvature, i.e. the curve radius, changes continually along their length, in sharp contrast to curves made of tangent circular ares, which, despite their smooth appearance, have discrete points at which the curvature changes abruptly. Besides fluid dynamics, the curvature continuity also has important aesthetic and manufacturing implications, which is why most modeling programs provide

tools for the continuity analysis. The location of control points in a NURBS curve can affect its continuity locally. meaning that different segments can have different levels of continuity. For instance, two coincident control points in a NURBS curve would pronounce the curvature; three coincident control points would produce an angular cusp. This potentiality of NURBS curves of having varying continuity is referred to as multiplicity. The definition of NURBS surfaces is a straightforward extension of NURBS curves. A control lattice that connects control points surrounds the surface . Each control point has an associated weight parameter, and knots control the distribution of the local influence as in curves. In other words. the shape of a NURBS surface can be manipulated in the same ways as in curves.



☑ End ☑ Near ☑ Point ☑ Mid ☑ Cen ☑ Int ☐ Perp ☐ Tan ☑ Quad ☐ Knot ☐ Project ☐ STrack ☐ Disable

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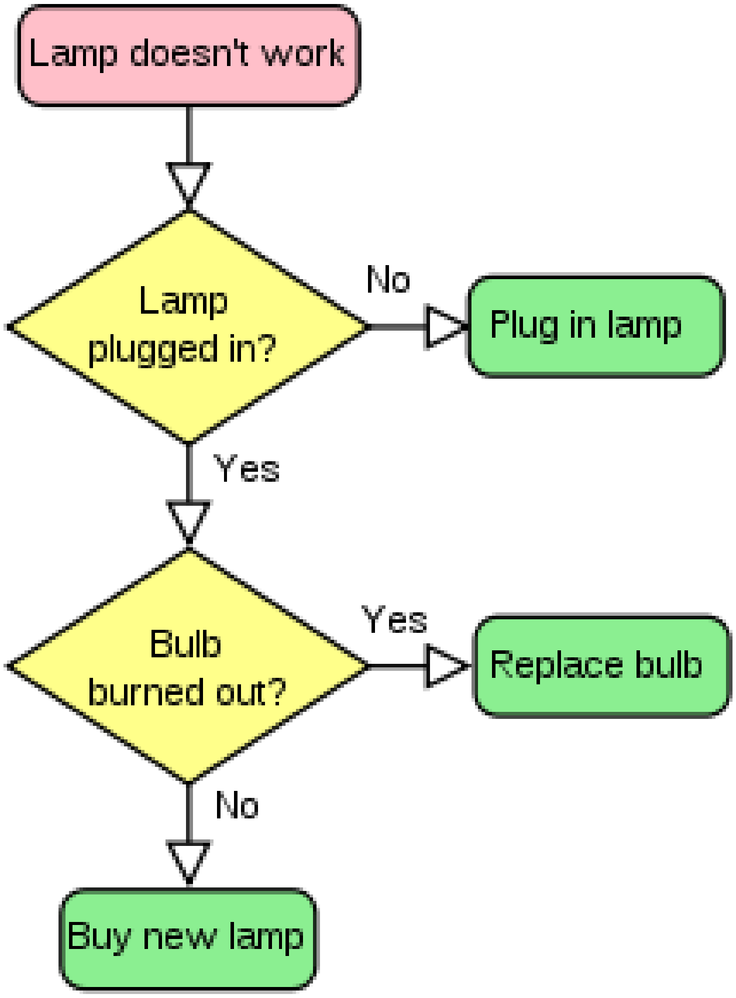
3.1 WHAT IS ALGORITHM ?

An algorithm is a process of addressing a problem in a finite number of steps. It is an articulation of either a strategic plan for solving a known problem or a stochastic search towards possible solutions to a partially known problem. In doing so, it serves as a codification of the problem through a series of finite, consistent, and rational steps. While most algorithms are designed with a specific solution in mind to a problem, there are some problems whose solution is unknown, vague, or ill-defined. In the latter case, algorithms become the means for exploring possible paths that may lead to potential solutions.

An algorithm can be seen as a mediator between the human mind and the computer's processing power. This ability of an algorithm to serve as a translator can be interpreted as bi-directional: either as a means of dictating to the computer how to go about solving the problem, or as a reflection of a human thought into the form of an algorithm.

In this case, the human programmer serves the purpose of translating a process external to the human mind to be compiled into machine language which is also external to the human mind. For instance, a genetic algorithm is a process that simulates the behavior and adaptation of a population of candidate solutions over time as generations are created, tested, and selected through repetitive mating and mutation. The algorithm uses a stochastic search based on the chance that a best solution is possible and that computer processing power is effortless, rapid, and precise from the viewpoint of the human programmer. Yet, nothing in the entire algorithm is about human invention; the process is called natural selection (a process occurring in nature regardless of the presence of humans) and the flow of the calculations is logical or arithmetic (both processes occurring in nature regardless of the presence of humans).Interestingly, algorithms can generate other algorithms; not only precise, identical, multiple copies of themselves but also structured text (i.e. code) that when executed will behave as an algorithm. In fact, the process of composing an algorithm is also an algorithm in itself, that is, the algorithm that created the algorithm. This selfreferential property (which may be referred to here as meta-algorithm ,i.e. the algorithm of an algorithm) is important in design for at least two reasons: first, like algorithms, design can be seen as a set of procedures that lead stochastically towards the accomplishment of a goal. In studying the articulation of algorithms one may be able to discern similarities with design. While such a study may lead to the development of procedures that may be useful in design, more importantly, it may reveal certain clues about design as a mental process. This possibility opens up a more intricate relationship between design and algorithm than has been previously possible. Rather than using algorithms to copy, simulate, or replace manual methods of design(while perhaps desirable), instead they can be studied as methodologies that operate in ways similar, parallel, or complementary to that of the human mind. Second, along the lines "we make a tool and the tool makes us", algorithms can be seen as design tools that lead towards the production of novel concepts, ideas, or forms, which, in turn, have an effect in the way designers think thereafter. That way of thinking is incorporated in the next generation of tools that will, in turn, affect the next generation of designers, and so on.


Lamp doesn't work
Lamp plugged in?
No
Plug in lamp
Yes
Bulb burned out?
Yes
Replace bulb
No
Buy new lamp

3.2 METAMORPHOSIS

Digital modeling software offers a rich repertoire of transfomations a designer could use to further explore formal potentialities of an already conceived geometry. Simple, topologically invariant transformations. such as twisting and bending are particularly effective means for creating alternative morphologies. For instance, Gehry's Uslra Oflice Building in Hanover. Germany (I999), has a simple prismatic form which twists in the direction of the nearby open park area. By adding a fourth. temporal dimension to the deformation processes, animation software adds a possibility to literally express the space and form of an object's metamorphosis. In keyshape (keyframe) animation. different states of an object are located at discrete points in time, and the software then computes through interpolation a smooth, animated. time-encoded transition between them. A designer could choose one of the interpolated states for further development, or could use the interpolation as an iterative modeling technique to produce instances of the object as it transitions, i.e. morphs from one state to another A particularly interesting temporal modeling technique is morphing, in which dissimilar forms are blended to produce a range of hybrid forms that combine formal attributes of the “base“ and “target” objects. Kolatan and Mac Donald used morphing in their projects. ln "Housing" a normative three-bedroom two-and-a-half bathroom colonial house was used as a "base" object that was then morphed into a range of every-day objects as "targets." producing a large range of which they call “chimerical" designs. In that way they digitally blended cross-referenced sectional profiles of common household furniture. such as a bed. sink, sofa, etc. to generate new hibrid forms that establish a "chimerical condition between furniture, space, and surface. Kolatan and Mac Donald intentionally employed digital generative processes whose outcomes were “unknown and impossible to preconceive or predict ". Other techniques for the metamorphic generation of form include deformations of the modeling space around an object using a bounding box (lattice deformation), a spline curve or one of the coordinate system axes or planes, whereby an objects shape conforms to the changes in geometry of the modeling space. In path animation, for example, an object is deformed as it moves along a selected path.

3.3 GENETIC ALGORITHM

The “rules” that direct the genesis of living organisms, that generate their form, are encoded in the strands of DNA. Variation within the same species is achieved through gene crossover and mutation, i.c. through the iterative exchange and change of information that governs the biological morphogenesis.

The concepts of biological growth and form. i.e. the evolutionary model of nature, can be applied as the generative process for design form as well. Architectural concepts are expressed as a set of generative rules, and their evolution and development can be digitally encoded. The generative script of instructions produces a large number of “prototypical forms which are then evaluated on the basis of their performance in a simulated environment.”-" According to Frazer, the emergent forms are often unexpected.

The key concept behind the evolutionary approach to architecture is that of the genetic algorithm, “a class of highly parallel evolutionary, adaptive search procedures. Their key characteristic is a “a string-like structure equivalent to the chromosomes of nature,“ to which the rules of reproduction, gene crossover and mutation are applied. Various parameters are encoded into “a string-like structure" and their values changed, often randomly, during the generative process. A number of similar forms, “pseudo-organisms," are generated , which are then selected from the generated populations based on a predefined “fitness” criteria. These "organisms," and the corresponding parameter values, are then crossbred, with the accompanying crossovers“ and “mutations“ thus passing “beneficial and survival-enhancing traits“. Optimum solutions are obtained by small incremental changes over several generations.

For example, architect and designer Karl Chu had approach to digital morphogenesis that is also known as the “proto-bionic" design, and it is a formal system based on the generative logic Landermayer system and its implementation in digital modeling software, where it is used for the simulation of plant growth. L-systems are based on a recursive rule-based branching system, conceived on the simple technique of rewriting in which complex objects are created by successively replacing parts of an initially constructed object using a set of simple rewriting rules. The generative rules of an L-system can be very succinctly expressed. A simple set of carefully defined rules can produce a very complex object in a recursive process consisting of only a few levels. In both approaches to generative design based on biological metaphors, the task of the designer is to define the common source of form, the genetic coding“ for a large family of similar objects, in which variety is achieved through different processes of reproduction.

3.4 ALGORITHM AND ARTIST

Genetic Algorithm is basicly piece of software that is relatively old now, invented in 60 which can mimic evolution (sort of virtual evolutionary process in the computer). Even though it sounds relatively new, it isn't. But what is new about it is it's utilisation by artists. These kind of programs allow us to treat forms like living organisms, to breed them (like people breed race horses) through successive generations which are programmed (instead of writing the program with head) they are actually steering the evolution. Artist can use the virtual evolutionary process as one more tool, not to replace the others but to add one more visualization to task of creating computer art.

Deleuze: last years of science, non linear dynamics, fractal theory, chaos theory, theory of self-organization and comlexity have demonstrated beyond any doubt is that matter is morphogeneticly charged, that it has power of morphogenesis of their own. And that this should somehow alter the position of an artist to respect the material that he uses. The artist can play the role of god oufcourse, where he can have an image or cerebral project of a form he wants to create, and then impose that form on the particular piece of material OR the artist can recognize that materials have creative powers of their own and enter into the partnership with the materials in the genesis of form.

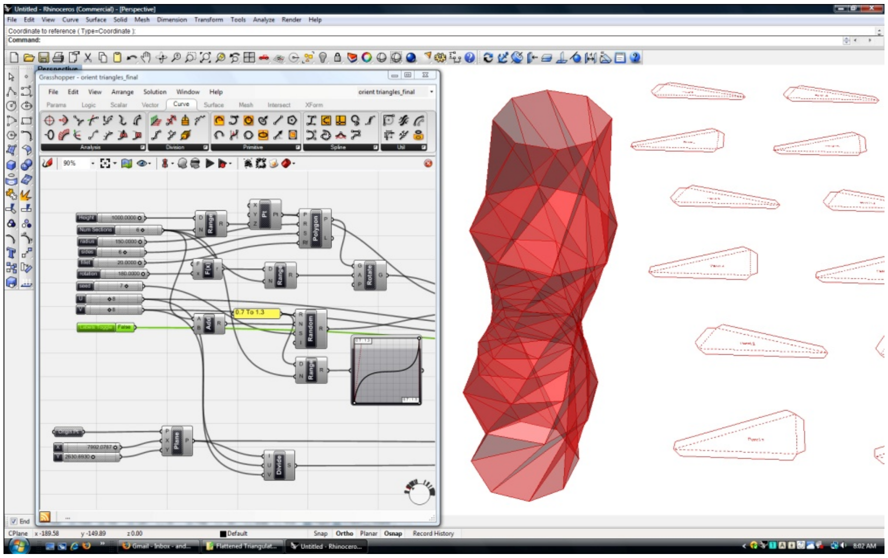
Example : Otto Frei

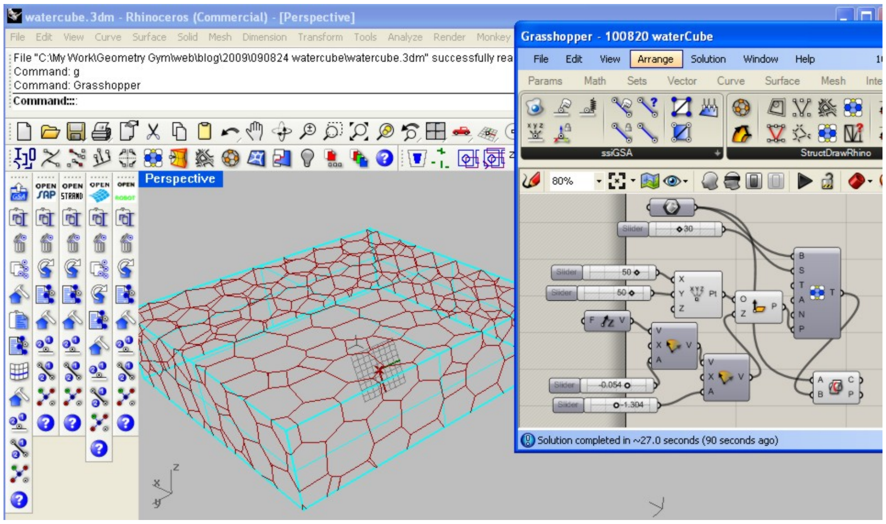
It can be applied in art in which artistic element (the sign element -the brush stroke- the basic form, motives are defined in a computer not by clicking with a mouse but procedurally . This profiles of approach to computer art is now becoming more and more well known in a sense that the software packages themselves come with this scripting capability. We can create works of art and then let them selves to performance since every single element of work of art is produced in the computer. It can let self to a wider variety of applications than just clicking and drawing a form with a mouse.

Genes tease out the form out of the material which have their own morphogenetic potential. Complexity can only be teased out of matter in certain ways so if that is necessary in nature, it is clearly necessary in a computer.

Evolution is automatic search process- the genetic algorithm in computer is classified as a search algorithm. Artist many times do searching themselves. They draw several variations or sketches, and they are trying to pick the best one, the fittest one. Gen. algorithm is not going to replace the artist clearly, it is just one more visualization tool to increasingly complex kit of tools that artist uses for creating new forms.

Algorithmic design In the world of design, the problems designers are called upon to solve are not necessarily solvable in the traditional sense of finding a path between A and B. Apart from specific quantitative localized sub problems that occur within some standardized patterns of construction, the general formal, aesthetic, or planning considerations are barely addressable as discrete solvable problems. Consequently, it may be more appropriate to use the term problem-addressing rather than problem-solving. Whatever the choice is, an algorithm serves as a means for articulating the problem whether solvable or addressable. More importantly, because of its translational power, an algorithm can carry out that articulation one step further and process it using a computer’s arithmetic and logical power. The combination of both systems, that is, that of the human and that of the computer, is where the true power of algorithms lies. An algorithm is not a game, a cool name, another tool, or an obscure engineers’ conspiracy but instead it is a way of thinking, and because of its newly introduced counter-part, the computer, it allows human thoughts to extend beyond their limitations. Because design is a way of thinking intrinsically weaved with the most existential human characteristics, that of logic, artificiality, creativity, and identity, algorithms serve as the means to explore beyond ,in parallel, or in lieu of traditional established ways of thinking. The notion of addressability versus solvability is important in design because it allows the algorithms to address a problem offering hints, suggestions, or alternatives which may never have occurred to the human designer. In such a synergetic relationship the unpredictable, impossible, or unknown are not factors of fear but rather invitations for exploration.





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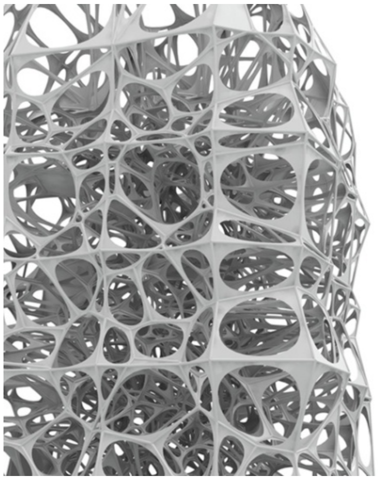

5.1 3D SCANNING: from physical to digital

For some designers such as Frank Gehry, the direct tactility of a physical model is a much preferred way of designing than a “flat' digital manipulation of surfaces on a computer screen. In Gehry’s case, the digital technologies are not used as a medium of conception but as a medium of‘ translation in a process that takes as its input the geometry of the physical model and produces as its output the digitally-encoded control information which is used to drive various fabrication machines. That means that

digital representations of geometry can be used in ways the original physical models cannot.

The process of translation from the physical to the digital realm is the inverse of computer-aided manufacturing. From a physical model a digital representation of its geometry can be created using various three-dimensional scanning techniques in a process often referred to as "reverse engineering.” A pattern of points called the "point cloud" is created from the physical model through scanning. and is then interpreted by the conversion software to produce a close approximation of the model’s geometry. Typically patterns of scanned points are used to generate profile NURBS (Non-Uniform Rational B-Splines) curves which are then used to generate lofted NURBS surfaces .The resulting surfaces can be compared to the scanned point cloud for an analysis of deviations from the original physical model . A common method for three-dimensional scanning involves the use of a digitizing position probe to trace surface features of the physical model. This procedure can be done manually using three-dimensional digitizing arms or automatically using a Coordinate Measuring Machine (CMM), which has a digitizing position sensor that is mechanically kept in contact with the surface of the scanned object. An alternative is to use mm-contact scanning methods which require more expensive scanning devices. but are faster and more accurate, less labor intensive and often more effective when scanning small-scale objects. These devices commonly use laser light to illuminate the surface of a scanned object in a step-by-step fashion producing patterns of bright dots or lines which ate captured by digital cameras (two are often used).

The recorded images are processed using optical recognition techniques to construct the three-dimensional geometric model of the scanned object which can then be exported in a desired data format for use in digital analysis or modeling applications. Three-dimensional scanning techniques can be used to digitally capture not only the physical models, but also existing or as-built conditions or even entire landscapes. Laser scanning technologies. based on different measurement techniques are commonly used in surveying on construction sites worldwide . In each of the different devices

available on the market. a laser beam is emitted by the scanner and the reflected beam is captured, and its properties analyzed to calculate the distances to the measured object. Four pieces of information are captured for each individual point measurement: X, Y and Z coordinates plus the intensity of the reflected beam which can be used to assign different light intensities or even colors to the point cloud.

Laser scanning technologies can create very' accurate three-dimensional models of existing objects . It is conceivable that the laser scanning will also be used to continuously scan the building's structure as it is erected and to immediately detect deviations from the geometry of digital model. The “point cloud"

is already Ill the designers vocabulary and the laser scanning has already rendered the tape measure obsolete on numerous design fields.

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5.2 ADDITIVE FABRICATION : from digital to physical

The use of additive manufacturing technologies for rapid prototyping takes as input virtual computer aided designed models and transforms them into thin, horizontal and successive cross-sections in the creation of physical three-dimensional objects .These processes assume, however, that such objects are geometrically defined without necessarily considering their material makeup and composition . The basic strategy behind additive manufacturing is typically to assign a constant material property to pre-shaped structural components defined as solids or closed surface polygons. Furthermore, both computer aided design tools as well as rapid prototyping processes are not set up to represent graduation and variation of properties within solids such as varied density or elasticity. As a result, the design process is constrained to the assignment of discrete and homogeneous material properties to a given shape. It is also characterised by a methodological partition between virtual modelling and physical prototyping . Overall, current approaches to virtual and physical prototyping lack the ability to model and fabricate continuously varying material properties as part of the modelling and production phases respectively, resulting in material waste and structurally non-efficient prototypes. Natural structures possess a high level of seamless integration and precision with which they serve their functions. A key distinguishing trait of nature’s designs is its capability in

the biological world to generate complex structures of organic, or inorganic, multifunctional composites such as shells, pearls, corals, teeth, wood, silk, horn, collagen, and muscle fibres. Combined with extracellular matrices, these structural biomaterials form microstructures engineered to adapt to prearranged external constraints. Such constraints generally include combinations of structural, environmental and corporeal performance criteria. Since many biological materials are made of fibrous heterogeneous compositions, their multi-functionality is typically achieved by mapping performance requirements to strategies of material structuring and allocation. The shape of matter is therefore directly linked to the influences of force acting upon it . Material is concentrated in regions of high strength and dispersed in areas where stiffness is not required. It is a well-known fact that in nature shape is cheaper than material, yet material is cheap because it is effectively shaped, heterogeneously distributed, and efficiently structured. Nature’s ability to gradually distribute material properties by way of locally optimizing regions of varied external requirements, such as the bone’s ability to remodel under altering mechanical loads or the wood’s capacity to modify its shape by way of containing moisture is facilitated fundamentally by its ability to simultaneously model, simulate and fabricate material structures .The structural properties of wood, for instance, not unlike most biological materials, can widely vary when measured with the growth grain or against it such that its hardness and strength may differ for a given sample as measured in different orientations . Compared to manmade materials, many natural materials, particularly in the plant kingdom, mechanically outperform some of the most common materials used by engineers and architects. Woods have strength per unit weight comparable with that of the strongest steels; shell, bone, and antler have toughness an order of magnitude greater than engineering ceramics; and mature bamboo stalks have slenderness ratios which are remarkable even by the standards of modern engineering . Yet Nature’s materials are less than half as dense as many of these artificial materials and are characterized by very low weight and are functional for the plant to sustain . What are the attributes that make natural materials so effective? In The Mechanical Properties of Natural Materials, Gibson explores various classes of natural materials in examining the relation between their composite microstructures and their exceptionally high values of mechanical performance . The function of these natural materials exploits their exceptional structural properties: woods and palms resist bending and buckling, silk stores elastic strain energy, muscle stores and releases elastic strain energy during locomotion, and so on. Such relations have significant implications for the design of mechanically efficient engineering materials: when considering beams and plates of a given stiffness or strength, or columns of a given buckling resistance, woods, palms and bamboo are among the most efficient materials. Gibson reviews four classes of natural materials: woods, palm and bamboo, stems and quills. The results of the analyses suggest novel microstructures for mechanically efficient engineering materials for bending stiffness and elastic buckling resistance achieved by optimizing micro-structural organization to fit performance requirements such that the cellular structure can enhance performance for loading parallel to the . Common to all these examples are the exceptional properties of natural materials arising mainly through novel cellular microstructures that make for efficient engineering materials . Nature's building blocks are therefore not as unique as their structuring in that it is not so much the material properties of the components as their arrangement within the natural composites, which give rise to such a vast range of properties. Thus we may postulate that Material Structure is an important design property of natural design as well as a significant body of design knowledge. A bio-inspired fabrication approach calls for a shift from shape-centric virtual and physical prototyping to material centric fabrication processes. In this approach, not unlike he bones' re-modeling process , the distribution of material properties is informed by structural and environmental performance criteria acting upon the component, and contributes to its internal physical makeup. It thus requires a set of virtual and physical prototyping tools and methods that support a variable-fabrication approach, not unlike Nature's.

Virtual prototyping

Layered manufacturing technologies work hand in hand with computer-aided design (CAD) software to allow engineers and designers to fabricate their designs. The process begins with a design or a sketch with set geometric parameters. Structural and behavioral characteristics of the design are taken into account by the geometry of the design from analysis and testing. Before the layered manufactured product is prototyped, however, the design must be reproduced in CAD software with all accompanying dimensional constraints to be sent out for fabrication. Traditional CAD software acts as a translator, converting a design on paper into a design understandable by a computer. The software application in this project, on the other hand, offers features that act as a platform for creative and structural design by allowing users to generate organic forms by mapping the distribution of various material properties across the expanse of the form. Designs are driven by its properties and material behaviors as opposed to its geometry. Layered manufacturing technologies have revolutionized the process of prototyping geometrically complex designs. And yet, the geometric modeling and CAD tools employed for such technologies have remained fairly traditional .Current limitations lie in the developments of structural materials for fabrication; however, beyond such anticipated improvements, and in light of reported advancements in material engineering, major opportunities lie in the designer's ability within the fabrication process to control the variation of material properties as a function of external constraints . This requires the re-appropriation of computational tools for modeling, simulation and fabrication. The VPM approach, coupled with the VPRP technology, makes use of voxel-based graphics methodologies as an alternative template for variable property rapid prototyping. Various advantages of this approach such as elimination of the artificial.STL format, easy accomplishments of tasks like estimation of errors in the physical parameters of the fabricated objects, tolerancing, interference detection etc. have been reviewed in the literature . This paper demonstrates an integrated approach to design and manufacturing promoting a direct link between virtual performance-based design and physical prototyping. In the following section we introduce some definitions considered essential to understanding the VPM approach and its corresponding VPRP technology, currently under development at MIT . Current CAD applications do not support the descriptions of internal material composition. However, some options exist which employ digital entities capable of describing micro-scale physical properties of materials and internal composition .

Physical prototyping

Layered manufacturing describes a method of manufacturing that uses information from CAD files to dissect a design into numerous thin layers and produce the item by successively depositing or bonding material to form these unique layers. Layered manufacturing is also known as rapid prototyping as produce time is short and objects of varying complexity can be formed without the design and production of a manufacturing system specifically for the object. Some examples of layered manufacturing include stereolithography (SLA), selective laser sintering (SLS), fused deposition modeling (FDM), laminated object manufacturing (LOM), 3D printing, and electron beam melting (EBM). Since materials in layered manufacturing are limited and vary with the method used, objects produced from layered manufacturing usually undergo various secondary processes. Rapid fabrication (RF) and rapid manufacturing (RM technologies have emerged, since the mid 1980s, as promising platforms for building construction automation . VPRP defers profoundly from such similar fabrication technologies in that it aims to produce material organizations of varied properties. Generally classified by the material phase used in their extrusion whether liquid based (i.e. stereolithography), powder-based (i.e. selective laser sintering), or solid-based processes (i.e. fused deposition modeling), consistent to all such technologies is the use of materials with homogeneous properties for prototyping and fabrication purposes.

Additive fabrication involves incremental forming by adding material in a layer-by-layer fashion, in a process which is the converse of milling. It is often referred to as layered manufacturing, solid freeform fabrication, rapid prototyping, or desktop manufacturing. All additive fabrication technologies share the same principle in that the digital (solid) model is sliced into two-dimensional layers (figure 3.18). The information of each layer is then transferred to the processing head of the manufacturing machine and the physical product is generated incrementally in a layer-by-layer fashion.

Since the first commercial system based on stereolithography was introduced by 3D systems in 1988 a number of competing technologies have emerged on the market, utilizing a variety of materials and a range of curing processes based on light heat or chemicals.“ Stereolithography (SLA) is based on liquid polymers that solidify when exposed to laser light. A laser beam traces a cross-section of the model in a vat of light-sensitive liquid polymer. A thin solid layer is produced in the areas hit by the laser light. The solified pan, which sits on a submerged platform, is then lowered by a small increment into the vat, and the laser beam then traces the next layer, i.e. the cross-section of the digital model. This process is repeated until the entire model is completed. At the end of the process, the platform with the solidified model is raised from the vat, and the model is then cured to remove extraneous liquid and to give it greater rigidity. In Selective Laser Sintering (SL S), the laser beam melts layer by layer of metal powder to create solid objects. In 3D Printing (3DP), layers of ceramic powder are glued to form objects . Sheets of material (paper or plastic), either precut or on a roll, are glued (laminated) together and laser cut in the Laminated Object Manufacture (L OM) process. In Fused Deposition Modeling (FDM), each cross-section is produced by melting aplastic filament that solidifies upon cooling. Multi-jet manufacture (MJM) uses a modified printing head to deposit melted thermoplastic wax material in very thin layers, one layer at a time, to create three-dimensional solids.

In one of her project in 2010, Neri Oxman have presented her project of the chair that has been completely generated by the CAD systems and fabricated by the 3d printer:

Example :

The chaise combines structural, environmental and corporeal performance by adapting its thickness, pattern density,stiffness, flexibility and translucency to load, curvature, and skin-pressured areas, respectively. A single continuous surface acting both as structure and as skin is locally modulated to cater for structural support on the one hand, and corporeal performance on the other. Multiple
algorithms were generated that correspond to these variables such that stability is mediated with pleasure, and structural integrity with visual and sensual experience. In this light, the chaise celebrates the negotiation between engineering and experiential performance. It is a method, as much as it is an object of pleasure that promotes material and structural integrity with the physical act of sitting and
lying down against a hardsoft surface. The traditional chaise is transformed here to promote lounging of a different kind. It is designed as a three dimensional object that provides for multiple seating positions each promoting a completely different experience. The cellular pattern applied to its entirety is designed to increase the ratio of surface area to volume in occupied areas where the body potentially rests. A pressure map study was conducted that matches the softness and hardness of the cells to cushion and support sensitive and high-pressured areas. By analyzing anatomical

structures that cause concentrated pressures, the chaise becomes softer and flexible where pressure needs to be relieved. The relative volume of each cellular cushion is locally informed by pressure data averaged with values representing structural support and flexibility. Its density is informed by global and local mean curvature values such that denser, smaller cells are organized in areas of steeper curvature whereas larger cells are found in areas of shallow curvature. The chaise’s natural relation of structural and sense datum is propagated in variable polymer composites offering a wide range of physical properties. Through these algorithms force conditions naturally propagate functionality. Stiffer materials are positioned in surface areas under compression and softer, more flexible materials are placed in surface areas under tension. State of the art technologies are applied here for the first time to cater for a large range of physical properties and behaviours. The surface patches are 3D printed using a new multi-jet matrix technology simultaneously depositing materials of different properties corresponding to structural and skin-pressure mappings. The traditional chaise is transformed to promote lounging of a different kind. By analyzing anatomical structures that cause concentrated pressures, the chaise becomes softer and flexible where pressure needs to be relieved. The relative volume of each cellular cushion is locally informed by pressure data averaged with values representing structural support and flexibility. Its density is informed by global and local mean curvature values such that denser, smaller cells are organized in areas of steeper curvature whereas larger cells are found in areas of shallow curvature.

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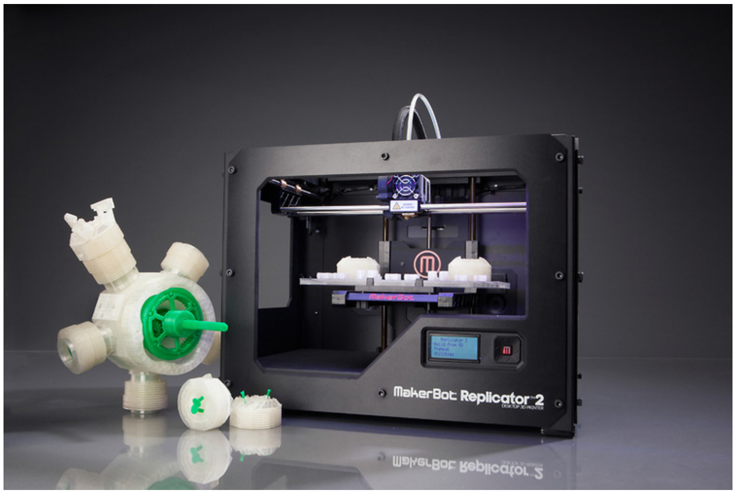

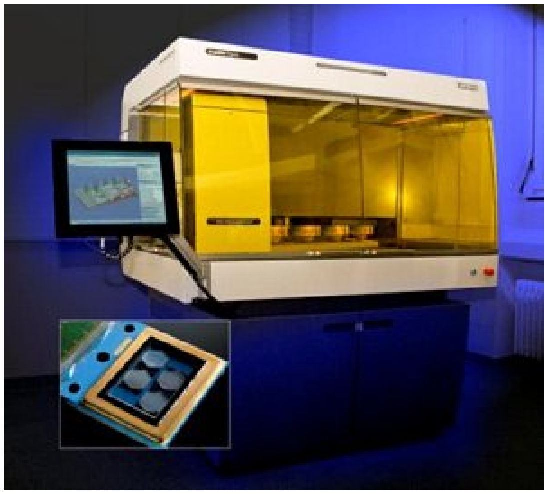

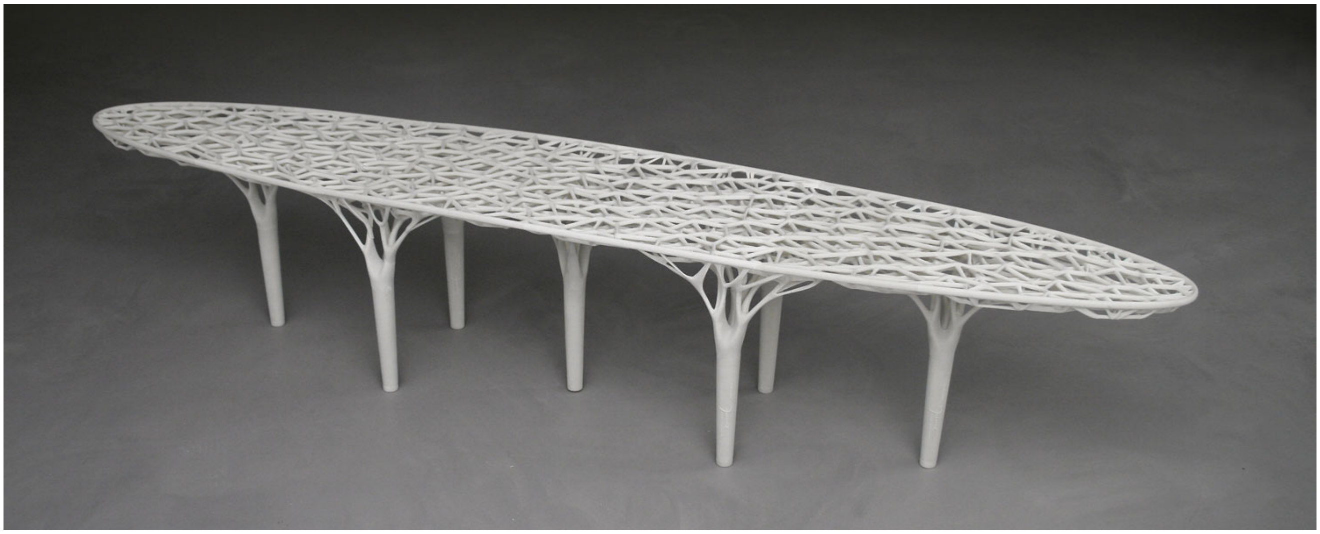


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5. 3 MASS-CUSTOMIZATION

The ability to mass-produce one-off, highly differentiated building components with the same facility as standardized parts. introduced the notion of "mass-customization" into building design and production (it is just as easy and cost-efective for a CNC milling machine to produce l,000 unique objects as to produce l,000 identical ones).

Almost every segment of the economy. and industrial production in particular. has been affected by mass-customization, sometimes in very radical ways. Levi’s, for example, offers customized jeans, manufactured from body measurements taken by a scanner in one of its stores at a cost slightly more than a standard pair. Motorola’s Paging Products Group lets its customers design their own pagers by choosing the desired frequency, tone, color, software, clips and other components (more than 29 million combinations are possible), and sells them at the same cost as their ofi'-the-shelf predecessors. In Japan, Panasonic sells bicycles that are built to individual rider‘s measurements, with customized color combinations and other options (with some ll million possible variations), creating truly mass-produced, built-to-fit, i.c. mass-customized machines.

Mass customization is a particularly suitable production paradigm for the building industry, since buildings are mostly one-off, highly customized products. A “custom” house will become available to a broader segment of society. Eventually, the technologies and “customization” methods that are developed in the consumer products industry will be applied to products as well. ln furniture industry, individual components could be mass-customized to allow for optimal variance in response to differing needs .The digitally-driven production processes will introduce a different logic of seriality in architecture and design, one that is based on local variation and differentiation in series. lt is now possible to produce “series-manufactured, mathematically coherent but dilferentiated objects, as well as elaborate, precise and relatively cheap one-off components.

Mass customization is the new frontier in business competition for both manufacturing and service industries. At its core is a tremendous increase in variety and customization without a corresponding increase in costs. At its limit, it is the mass production of individually customized goods and services. At its best, it provides strategic advantage and economic value.

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6. CONCLUSION

Originally the role of computers in design was to replicate human endeavors and to take the place of humans in the design process. Later the role shifted to create systems that would be intelligent assistants to designers, relieving them from the need to perform the more trivial tasks and augmenting their decision-making capabilities. Today, the roles of computers vary from drafting and modeling to form-based processing of architectural information. While the future of computers appears to include a variety of possible roles, it is worth exploring these roles in the context provided by the question: “Who designs?” If one takes the position that designing is note exclusively a human activity and that ideas exist independently of human beings, then it would be possible to design a computational mechanism which would associate those ideas.

“nothing comes out of nothing and nothing disappears into nothing” which, if true, signifies an inability to achieve something out of nothing, i.e. to create something new.

Nature

In previous chapters it was shown how Nature’s basic rule of selection can be combined with computers in order to get an answer to different questions that start with: *“What is the optimal . . . ”*. It will be useful to turn shortly to the forms generated in Nature in order to draw some parallels between natural and artificial structures. Direct comparison would not be an easy task, since the fitness functions in structural design of objects and living creatures can be quite different In deployable structures, GAs can be used as effectively, but the fitness functions would become more complex, and that is something that will surely be a part of future research. That will be another step forward to getting closer to the Nature’s *engineering skills and aesthetics.*

Natura non facit saltus

A very important characteristic of our natural environment is suitably summed up in: *Nature does not make a leap*. Nature doesn't *know* anything, it tries. Each and every one of its creations is influenced by a large number of factors from its environment, and therefore basically randomly (accidentally) altered. Natural selection preserves the better design and relies on inheritance. Now the big question is, whether we have surpassed Nature and do not use any random alteration, or whether our comprehensive knowledge and intelligence is just an illusion and we are basically using the same principle of inheritance? We rely on what we know and then try something new with small alterations, thus probably mistaking all the accumulated skills from the beginning of mankind for an illusion of conscious and comprehensive thinking. The basic principle of cell division at the microlevel, shows how every cell in Nature has its own centroid according to which it tries to define its form. The geometry is then influenced by its size and strength (material properties) and by the neighbouring particles and their centroid and volume.

The Future

Up until the recent past, FEM analysis of any structure was a complicated task that needed lots of preparation and calculation time. Today, with the exponential growth of the processor speed, not only can we calculate complicated structures in a matter of seconds, but we can create an iterative process that can do that millions of times.

In those iterative algorithms the future of structural design is being born. As mentioned before, our part will only be to ask the question right, and the answer will be given by a machine. It is irrelevant what kind of optimization algorithms will be used, but for now the stochastic ones, like Genetic Algorithms, promise a lot. One of the main reasons is their generality, i.e., applicability to practically any optimization problem. It was proven that, if they are set properly, they can be extremely efficient. Most of the possible applications of the merger of graphics and static analysis have not yet been investigated, and surely offer solutions beyond our imagination. It opens up huge possibilities, and represents the future of structural and formal design. Many procedures performed by designers and engineers *manually*, can now be automatized. Computers can be used to generate thousands or millions of possible combinations and solutions, something that we as human beings could never process. The only thing that we have to do is ask the question properly (which is not an easy task!) and then we can use different optimization methods to get the answers. As mentioned before, a large effort will be directed toward smart, parametric solution of the joint geometry. Parallel to that, new materials have to be tested and applied in the structural design.

As far as the optimization of product design object's structures with the use of Genetic Algorithms goes, this is just the beginning. Every single aspect of the application written is made in a way that it can be expanded easily. For example, the *coding* and *decoding* part can be altered to comprehend any kind of 3D structure. We can imagine an optimization of the structure for the entire free-formed skyscraper, or even an optimization of the fiber and molecular structure in materials (with the further development on nanotechnology). This can be done with simple alterations of the presented method. Deployable structures are becoming more popular, and with the proper set of dynamic fitness functions we can generate beautiful and efficient bio-structures, that will be able to transform and adjust to the environment conditions, as well as plants or animals can. The tools that we have today are slowly starting to get ahead of us. Breakthroughs in science are challenging our imagination every day. Buckminster Fuller wrote about new inventions and how they have to wait 50 years until they get applied in the fabrication process. I think that time-span is getting shorter and shorter now. New generations of designers and engineers, that have to know programming languages as well as they know mathematics or art history, are being educated right now. The future of design is in their hands.

And as for the conclusion, i would like to share the article from The Economist magazine (april 21st, 2012), in order to clarify the future idea of mass customization and it's direct relation to computer aided creation and fabrication:

" The third industrial evolution"

THE first industrial revolution began in Britain in the late 18th century, with the mechanisation of the textile industry. Tasks previously done laboriously by hand in hundreds of weavers' cottages were brought together in a single cotton mill, and the factory was born. The second industrial revolution came in the early 20th century, when Henry Ford mastered the moving assembly line and ushered in the age of mass production. The first two industrial revolutions made people richer and more urban. Now a third revolution is under way. Manufacturing is going digital. As this week's special report argues, this could change not just business, but much else besides.

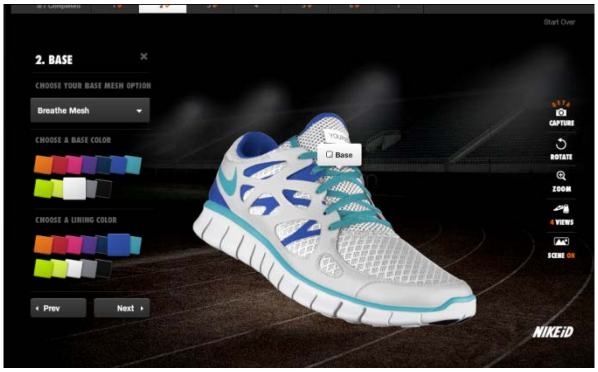
A number of remarkable technologies are converging: clever software, novel materials, more dexterous robots, new processes (notably three-dimensional printing) and a whole range of web-based services. The factory of the past was based on cranking out zillions of identical products: Ford famously said that car-buyers could have any colour they liked, as long as it was black. But the cost of producing much smaller batches of a wider variety, with each product tailored precisely to each customer's whims, is falling. The factory of the future will focus on mass customization—and may look more like those weavers' cottages than Ford's assembly line.

The old way of making things involved taking lots of parts and screwing or welding them together. Now a product can be designed on a computer and “printed” on a 3D printer, which creates a solid object by building up successive layers of material. The digital design can be tweaked with a few mouse clicks. The 3D printer can run unattended, and can make many things which are too complex for a traditional factory to handle. In time, these amazing machines may be able to make almost anything, anywhere—from your garage to an African village.

The applications of 3D printing are especially mind-boggling. Already, hearing aids and high-tech parts of military jets are being printed in customized shapes. The geography of supply chains will change. An engineer working in the middle of a desert who finds he lacks a certain tool no longer has to have it delivered from the nearest city. He can simply download the design and print it. The days when projects ground to a halt for want of a piece of kit, or when customers complained that they could no longer find spare parts for things they had bought, will one day seem quaint.

Other changes are nearly as momentous. New materials are lighter, stronger and more durable than the old ones. Carbon fibre is replacing steel and aluminium in products ranging from aeroplanes to mountain bikes. New techniques let engineers shape objects at a tiny scale. Nanotechnology is giving products enhanced features, such as bandages that help heal cuts, engines that run more efficiently and crockery that cleans more easily. Genetically engineered viruses are being developed to make items such as batteries. And with the internet allowing ever more designers to collaborate on new products, the barriers to entry are falling. Ford needed heaps of capital to build his colossal River Rouge factory; his modern equivalent can start with little besides a laptop and a hunger to invent.

Like all revolutions, this one will be disruptive. Digital technology has already rocked the media and retailing industries, just as cotton mills crushed hand looms and the Model T put farriers out of work. Many people will look at the factories of the future and shudder. They will not be full of grimy machines manned by men in oily overalls. Many will be squeaky clean—and almost deserted. Some carmakers already produce twice as many vehicles per employee as they did only a decade or so ago. Most jobs will not be on the factory floor but in the offices nearby, which will be full of designers, engineers, IT specialists, logistics experts, marketing staff and other professionals. The manufacturing jobs of the future will require more skills. Many dull, repetitive tasks will become obsolete: you no longer need riveters when a product has no rivets.



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