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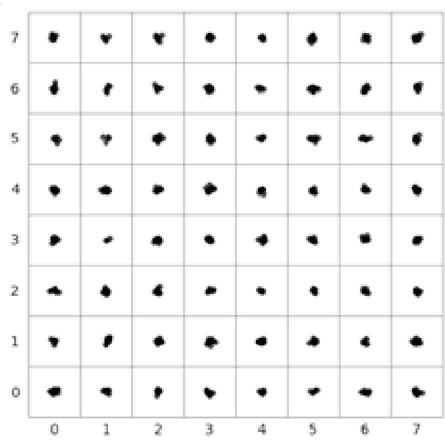
International Course on Architectural Design

master program | Systems and components design

DIGITAL TECHNOLOGY FOR ARCHITECTURAL FABRICATION

prof. Giuseppe Ridolfi, PhD



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Systems and Components Design and *Environmental Systems Design* represent the disciplinary contribution of «Technology of architecture» to the two integrated laboratories *Architecture and Structure Design Lab* (1st year) and *Building and Environmental Design lab* (2nd year).

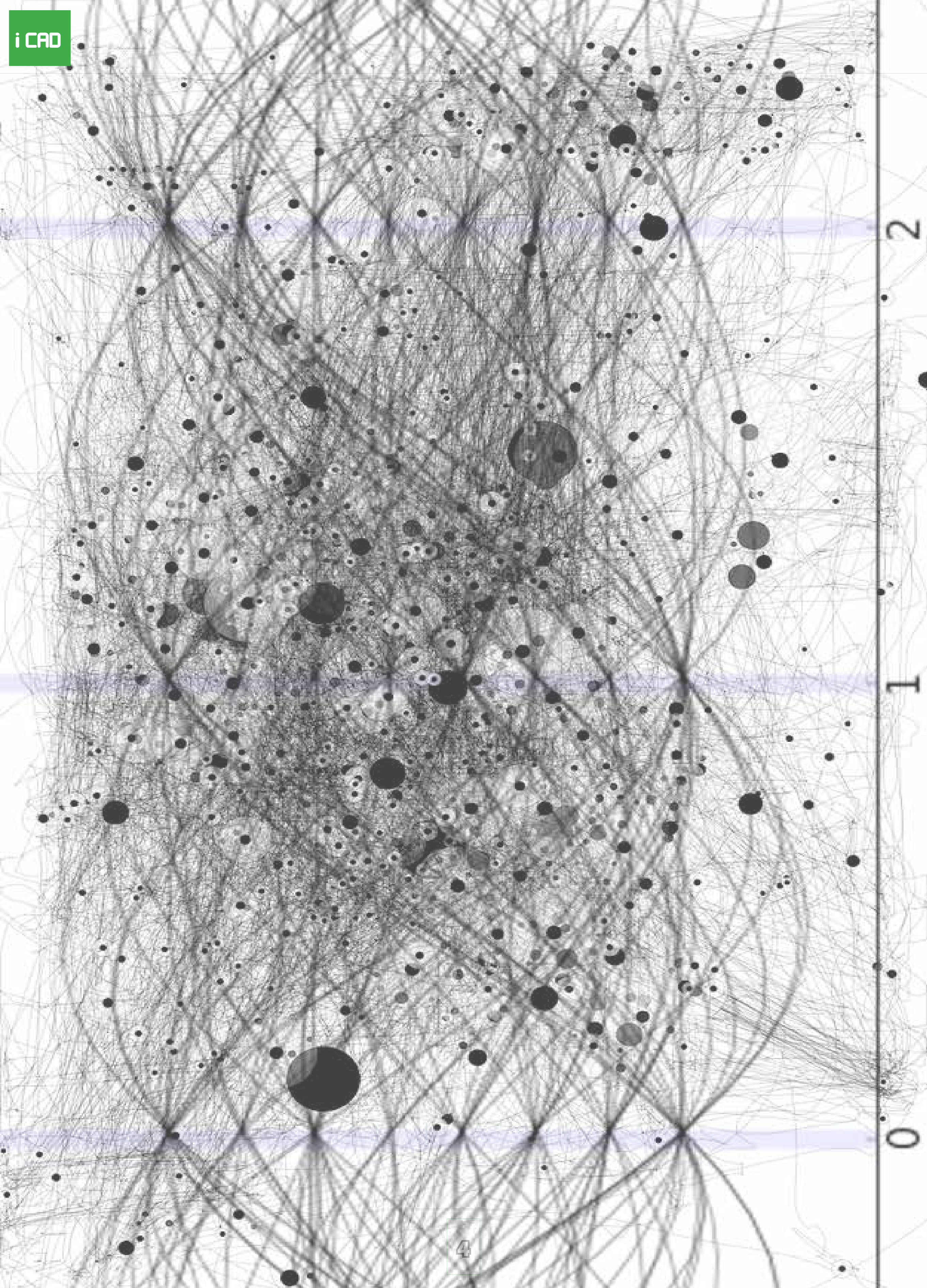
The aim of these two classes is to explore new technologies and related opportunities derived from digital computation and industrial automatic production in conceiving, designing and producing architecture.

The topic of *Systems and components design* is **Form manufacturing** in which students are asked to study forms and model materials to feed automatic manufacturing in order to fabricate a Structural System Prototype.

For these reasons, the class does not approach the building shaping as a mere invention of free-form and software is not intended and used as a tools for rendering, but as a coherent and interoperative process to address the real manufacture of buildings: a new *modus operandi* for architectural designers.

The class is introduced by the present lecture titled **Digital Technology for Architectural Fabrication**.

prof. Giuseppe Ridolfi, PhD | 2014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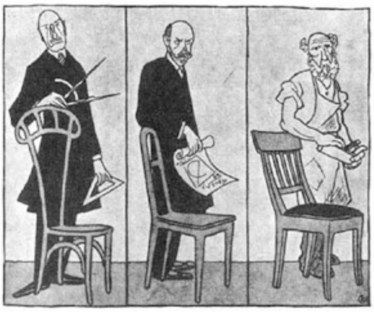
DIGITAL TECHNOLOGY FOR ARCHITECTURAL FABRICATION

Art and Crafts vs industrial manufacturing.

According to Renato De Fusco [cfr. 1990 – Renato De fusco, *Storia del Design*] Industrial Society started in the period from 1760 to 1830: the ages of the introduction and the refinement of steam power. After this beginning, the first significant manifestations of industry happened in the late 800s and the early 900s with a multitude of inventions that radically altered the way of life: the typewriter (1855), the car (1862) the plastic (1862) the reinforced concrete (1867), the celluloid (1869), the fridge and the electric light bulb (1879), the power plant (1881), the gasoline engine (1884), the bicycle and the motorcycle (1855), the linotype machine (1886), photography (1888), film (1894), the radio (1895), the Gillette razor (1901), the plane (1903), the electric washing machine (1906), neon lighting (1910).
An important milestone of the industrial manufacturing was the 1914 when the outbreak of the Great War created the condition for a massive production of goods for military purpose and established itself as the new productive and social system in opposition, often overlapping, craftsmanship. It was a new way of producing and consuming goods based on technologies and equipment systems, the result coming from the applications of science and research for military purpose. In fact, the Great War was a unique occasion to test this kind of production that made mass production its point of strength.

But 1914 was also an important date for another event. In this year the Deutscher Werkbund organized a meeting at Reinpark in Cologne, Germany. The Werkbund, a German association of artists, architects, designers founded in Munich in 1917, was a state-sponsored association to integrate traditional crafts and industrial mass-production techniques to put Germany on a competitive footing with England and the United States. Its motto *Vom Sofakissen zum Städtebau* (from sofa cushions to city-building) indicates its range of interest. Animator and one of the founders was Herman Muthesius, a cultural ambassador in England sent to research the reasons of the success and organization of the English industry and, eventually, how to transfer in Germany this new way of production.

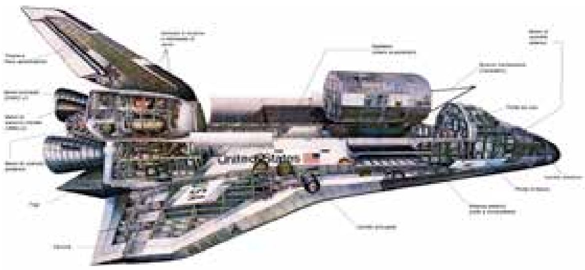
In this period the Industrial Revolution was entering an expansion phase showing its potential to establish a more democratic society. But, despite its advantages, critics emerged pointing out the brutal impact on workers, cities and lifestyle. Among others, English designers John Pugins and John Ruskin were the most recognized and influential critics discussing the degradation of man into a machine and affirming Art and Crafts as a way to save the world and preserve creativity.
The two positions on standardized industrial production versus creative craft manufacturing were the topic of this meeting, ironically synthesized by an illustration appeared in a newspaper of that time.



Typisierung was the word and the subject of the Muthesius's intervention where «...mass industrial production based on standardization was seen as the answer to the economic needs of the new era» [1989 – Helen Tatla, *Idea and Freedom*] and the way to reach a universal good taste. Against this position rose up Van de Velde leading a group of artists and young architects like Walter Gropius and Bruno Taut claiming for the individual creativity. The opposition between industrial production and crafting manufacturing became the heart of the question. The First World War was the test and the definitive overcoming of industrial manufacturing.

What differentiates industrial product from crafts?

If the querelle between Muthesius and Van de Velde is historically defined and documented how can we describe this contrast today? Which facts and aspects can be assumed as elements of differentiation between industry and crafts?
Some authors wrote that differences are, mainly, on the industrial capacity to produce a large number of products: to produce in assembly-line fashion versus craftsmen who are not able to reach such amount of products. Others point out that industry is a machinery-based production against the handmade fabrication of artists and craftsmen.
In reality, as history has shown, many examples demonstrate that these thesis are not comprehensive enough.



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3	99.9 – 99.99%	0.001 – 0.0001 (1E^{-3} to 1E^{-4})	1,000 – 10,000
2	99 – 99.9%	0.01 – 0.001 (1E^{-2} to 1E^{-3})	100 – 1,000
1	90 – 99%	0.1 – 0.01 (1E^{-1} to 1E^{-2})	10 - 100
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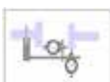
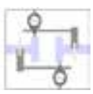
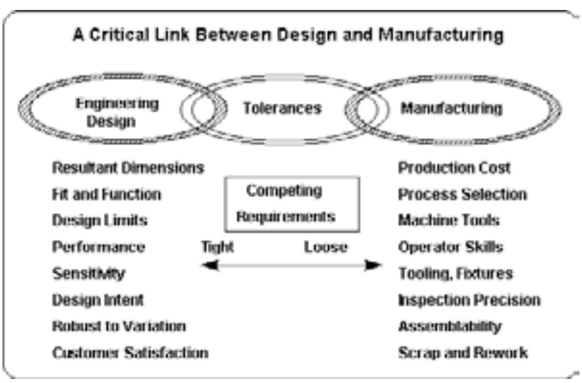






In past civilizations, workers were able to hand-make thousands of bricks; today the Space shuttle, a high technology industrial object, is released as a unique original product demonstrating how the above statements are wrong. It's also evident that artisans used and are widely using machinery in their works, sometimes very sophisticated.

So, what is the difference?

The difference is precision, exactitude or in other words, tolerance. In industrial manufacturing, precision is the counterpart of failure; risk and different products are classified in relation to the degree of errors allowed. An airplane admits margins of failures much more limited than a TV with a safety availability very close to 100%. Accuracy and tolerance control is the main key of industrial production affecting not only safety but also cost and quality in general. We can state that the keywords of this difference and the ontology of the industrial production are precision and *zero tolerance*.

PREVIOUS PAGE.
• K. Arnold's caricature on the 1914 Deutscher Werkbund querrelle

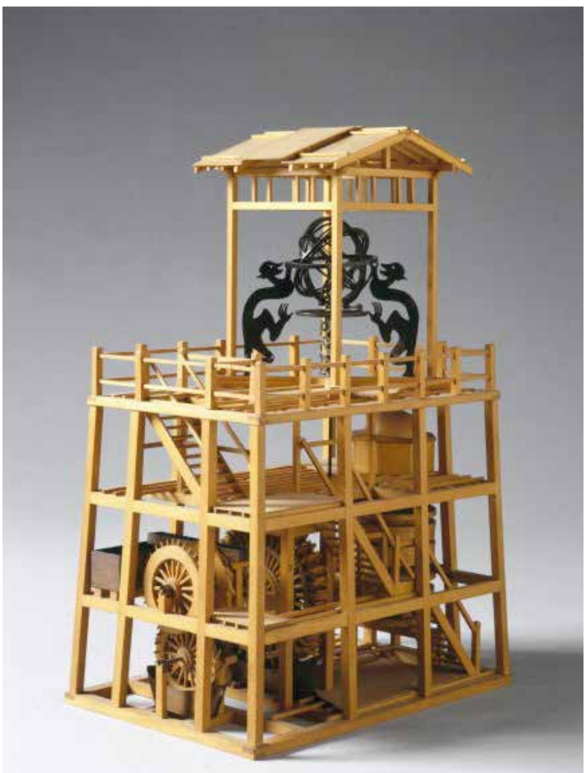
THIS PAGE.
• hand made bricks on drying process
• Space stuttle
• levels of safe for equipments
• tolerances in design and manufacturing

From the *more or less* to precision.

A seminal article wrote in 1948 by the russian philosopher Alexander Koyré *Du monde de l'a-peu-pres a l'universe de la precision* [From the world of the "more or less" to the universe of precision] summed up this core question showing one of the most important factors effecting the modern western society since the 17th century. According to the author, exactitude in the past was only related to the orbits of celestial bodies. Before Galileo Galilei, science, numbers and measurements were only used for the incorruptible heaven or for abstract geometry, not for the daily life where everything continued to be faced with the logic of the «more or less».

> «No one ever sought to go beyond the practical usage of number, weight, and measure in the imprecision of daily life – to count months and beasts, to measure distance and fields, to weigh gold and corn – in order to turn it into an element of precise knowledge». (Koyré, 1948)

According to this thesis, for Koyré, one of the remarkable inventions that changed the world was the pocket watch (today, we could say the personal watch) that reached its full functionality around the end of the XVIII century. Before this period watches were very huge, heavy and not really precise, built from wood and working using water or gravity with the pendulum.

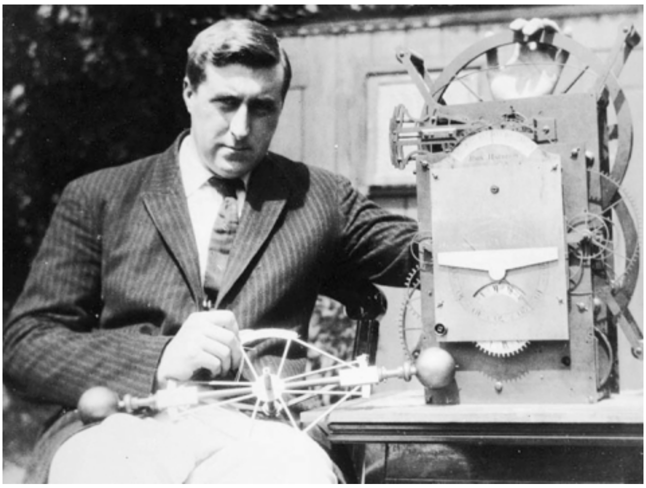


Only convents or public buildings could have one of these important machines.

All other people used qualitative instruments like hourglasses or seasons, sun and moon cycles to regulate their time, but with great approximation.

The invention of the pocket watch followed a competition, launched in 1714 by the Board of Longitude from an idea of the mathematician W. Whiston, in which was asked to realize a portable timekeeper to assist navigation.

The award was from 10,000 up to 20,000 pounds in relation of its precision that the winner John Harrison, according to the chronicles, had to struggle all his life to cash in. In 1735 after 5 years of trials, Harrison presented a model as the development of his first experimental pendulum watch – the *Number One* – that he made in 1713 entirely from wood and weighting 31 kg. The timekeeper he presented, the *H1*, was the first of a long series of improvements in which the pendulum was replaced with two springs. The marine chronometer with full functionality arrived after a life of experiments with the last two models, the *H4* (1759) and the *H5* (1769), that resized the watch to the diameter of only 12 cm.



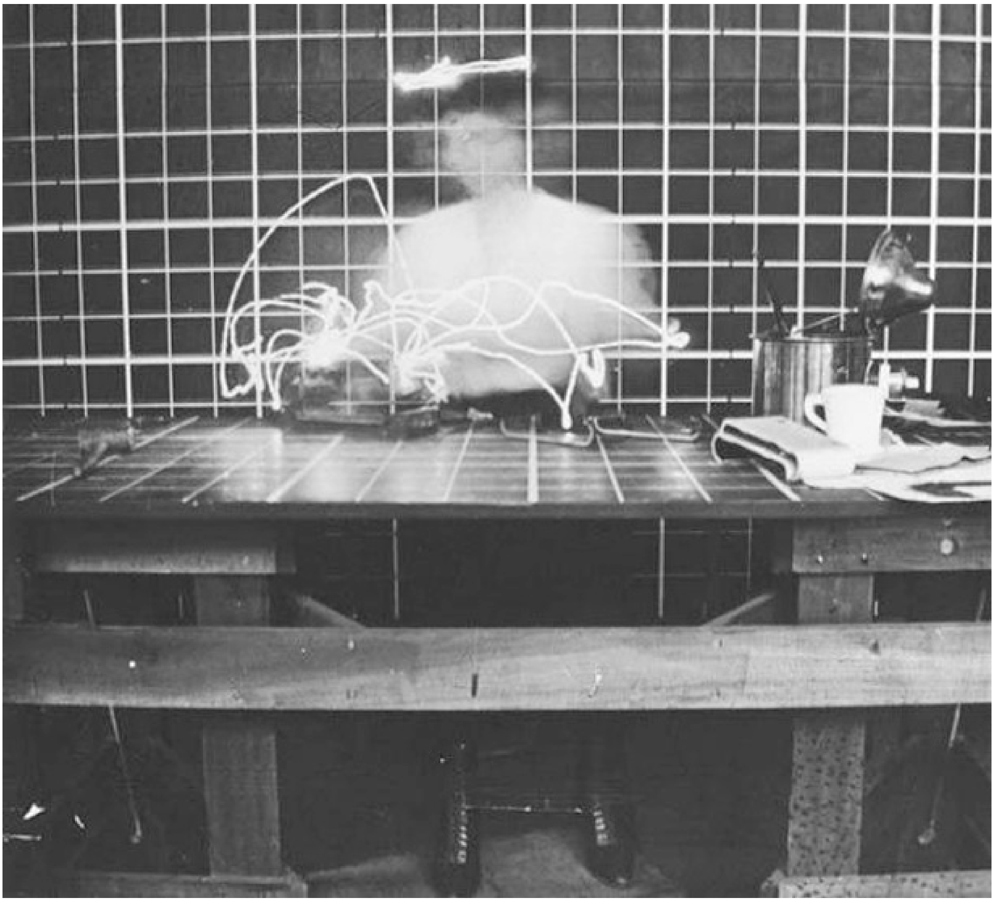
PREVIOUS PAGE.
Chinese wooden 1:48 scale model clock from 1092 A.C., moved by the pouring of water into small buckets on a giant wheel. The weight of the water in the buckets turned the wheel the distance of a spoke every 24 seconds. On the top of the tower he installed an instrument called an Armillary sphere that represented the paths of the Sun, the Moon and some important stars, as they crossed the sky.

THIS PAGE.
John Harrison's Marine Chronometer

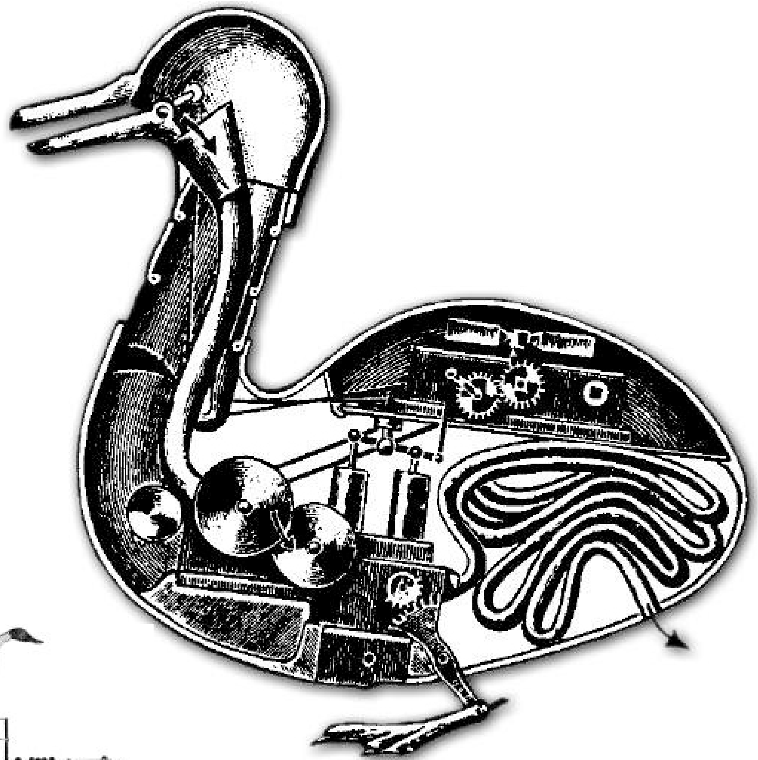
- Rupert Gould with 'H3' and one of the balances of 'H2',
- Model H3
- Model H4

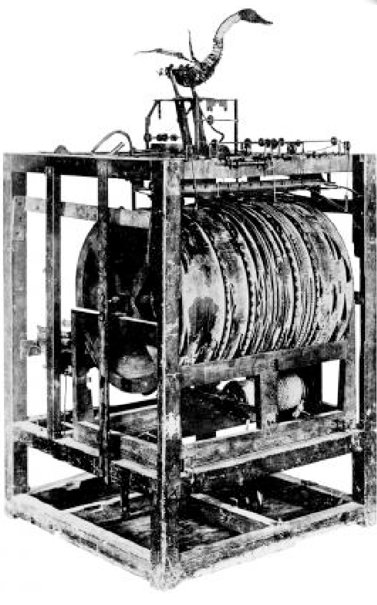
Time control.

It is curious that some centuries later, industrial production started the assembly line using the watch: the *Watch Book*.
The *Watch Book* was a book with a chronometer hidden into it introduced by Frederick Winslow Taylor, the father of Scientific management, to check the time required to make each elementary movements of the workers and to rationalize the process of the assembly line.



It is not a coincidence that around the same years of Koyré, also Lewis Mumford considered the watch and the scientific watch (the chronometer) as the most important machine for the affirmation of the industrial society, more than the steam machine. He stated that the chronometer provided the master model for many other automatic machines, setting the standard for other technological refinements and the interpretation of Nature and living organisms. It rose as the symbol of mechanization: a new prospective exemplified by the automata production flourished in the XVII and XVIII centuries. Above all, it made possible the programming and the subjugation of the world to the accuracy of time. In fact, as Mumford wrote, through time control we can live in a world ordered and predictable where trains, planes, ships arrive on time with accuracy comparable with heavenly bodies. Time quantification established conditions to regulate and objectify each task of production; it gave Henry Ford the opportunity to introduce the assembly line in car manufacturing: a system where workers didn't need specific or advanced expertise because the simplification of their actions. With a scientific and objectified approach to the production management, the «Model T» by Ford could be produced in one hour and half instead the original twelve hours and in the new factory in





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• Jacques Vaucanson, *Digesting Duck*, 1733-1734. A mechanical duck that was supposed to defecate, but with a fraude.

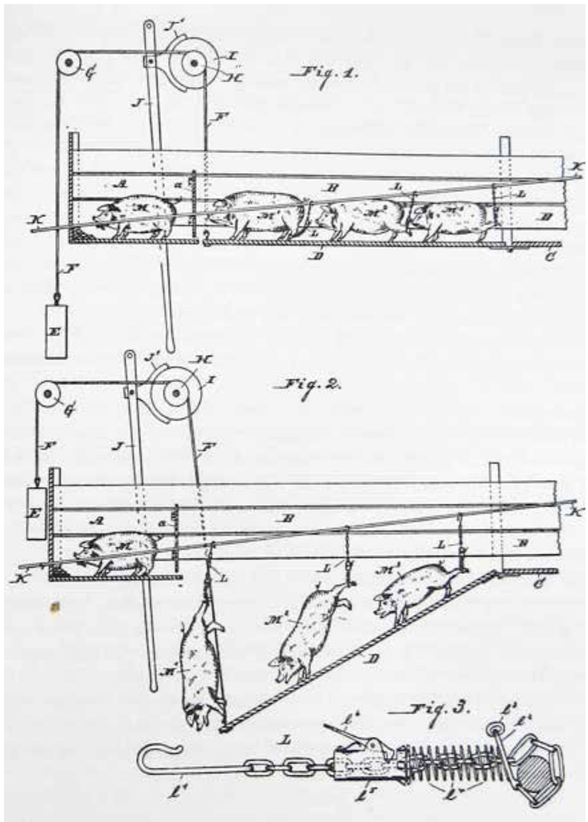
PREVIOUS PAGE

• Frank and his wife Lillian Gilbreth, *Worker movement tracking*, 1914. Analytical studies of the workers movements to maximize efficiency in factories and construction including the bricklaying. The studies were carried out with use of camera and lights to track movements.

Highland Park, designed to accomplish the assembly line, every 24 seconds a new car could be released on the market.
From 1908 to 1927 Ford produced 15 million *Model T's* with a cost that passed from 850 dollars (when the average cost of the competitors was around 2,000 dollars) to 260 dollars. As a result the *Model T* changed the life style of millions of Americans introducing mobility, the same product (invariably black) for everyone and populating the life of man with machines.

Mass production and well being for all.

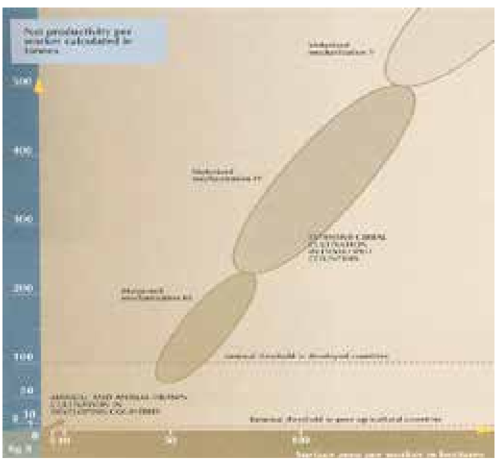
Industrialization is inextricably linked to the use of machines and more specifically to those machines equipped with an engine able to function without the contribution of animal energy and capable to repeat elementary operations tirelessly. For many observers, this operational mode, achieved using not only accidental, occasional or partial means but exclusively the machine represented the hallmark of industrial production and from which derive other corollaries such as repeatability, or serial reproducibility.



• Apparatus for Catching and Suspending Hogs (1882) that inspired H. Ford

In addition to scientific and technological development, another important reason that made possible the expansion of the machine was the introduction of the concept of «economies of scale» through which Capitalism was able to provide the necessary resources to realize complex tools of exceptional value (internal economy of scale), besides the fact that thanks to this large amount of money, Capitalists were also able to control the market (external economy of scale). Financial concentration with the ubiquity of the driving force, made possible by the first steam power (and electricity some years later), allowed to put to work a large number of people and machines in a single place: under the roof of the factory. The factory, landmark of the rising industry, was the place where work could be carried out under controlled conditions and away from the unpredictably of inclement weather.

In fact, the introduction of the steam engine by Watt and Bolton in 1769 and then electricity marked a radical change in the ways of producing not only for their potentialities to offer unimaginable power, but mainly because they offered the conditions in which the use of energy was no longer bound to the place of propellant supply: close to forests and woods when energy was given by charcoal, near the rivers when energy was hydraulic.
In term of power, the change in the curve of productivity in the agricultural sector is emblematic. With the advent of the machine agricultural productivity changed from few cultivated acres with some hundred pound of harvest per person to 100 acres with a performance that today (depending on the type of cultivation and cultivation techniques) may exceed even 500 tons of harvest. It was an example that industrialization and machineries can ensure well being for all.
These changes can be seen also in other sectors related to construction such as the logging industry where it is easy to detect the massive leap in productivity made possible by mechanization. A documented exposition in the transformation



• man per tonnes productivity

• trend of sugar price

process of logging due to the advent of the steam engine can be traced in *The Last Wilderness* by Murray Morgan published in 1980. Mechanization of the logging industry began with the introduction of the steam-engine «donkey» in 1882.

> This led to a logging technique called "high-lead" logging. High-lead logging required a steam-engine donkey, steel cables, a single, tall, standing "spar" tree. (M.Murray, 1980)

In addition to the detailed description of the new technique, the author documents the resulting boost in production capacity, cost reduction and increasing profits at the expense of a significant change in quality of life of employees. High-lead logging sped the harvest and meant increased profits for the operators, but not for the men who did this dangerous work. As mechanization continued, and fewer loggers were needed in the forest, many were laid off. Morgan reports that tensions increased in the camps as the economic gap between the operators and workers widened and injuries on the job multiplied. This was the price to pay to make possible the miracle of mechanization, to enable man to dramatically enhance their biological capacities that as Mumford wrote in the early 60s could now converse to 5,000 miles away, but can also kill at a distance of 5,000 yards.
The increasing human capacity could only be realized with a parallel transformation of his own life rhythms, increasingly regulated by the accelerated and tireless machine and subjugating its existence to the accuracy in a world fearful of unexpected and populated by objects rather than by men and natural elements.

Division of labor.

The labor regulation in the sheltered factory to protect workers from the unpredictable and seasonal weather also ensured that the work organization could suit more and more the operational manner of machines made of accuracy and rhythms transcending the limits of human endurance. The term which commonly identified this new way of organizing production is the «division of labor»: a breakdown into basic and low-expertise activities that expanded the availability of workers, including preschool children, as an efficient way to regulate the mechanisms of labor demand/supply in favour of the owners of the means of production. These are the negative aspects of industrialization combined with the ugliness of the working-class suburbs widely known and discussed since the analysis of sociologists such as Auguste Comte and Henri Saint-Simon, philosophers such as Karl Marx and Friedrich Engels and democratic theorists such as Alexis de Tocqueville.
This new way of organizing the work found its first systematic applications in the ceramic industry in the second half of 700, in the district of Staffordshire due to the activities of Josiah Wedgwood.
An eclectic person interested in science and technique, Wedgwood pushed as far as the times would permit a significant mechanization of all the operations of its plants by introducing, as a necessary complement, the precise division of labor that, in the past, was reunited in the artisan. With such innovations

and the rationalization of the forms of his ceramics (using neoclassical style) he was able to produce in large quantities and constant quality: considerable aspects that in a few years brought its brand to be appreciated and used in many British homes.

According to many observers, this new way of organizing production, and more precisely the social «division of labor», had already been used in some preindustrial organizations such as convents, the army, the bureaucratic structure of the rising nation-states and in the new way of conceiving the world triggered by the Cartesian analytical thinking. Ways of thinking that exploded the entirety and accelerated the processes of marginalization of figures such as craftsman and artist: men who live from their work, for their work and, thanks to it, drew reasons for their fullness of life.

Henry Ford is, undoubtedly, the historical reification, the icon of the success of this new way of production that will transform the studies on the division of labor in pragmatic organization of his factory: an organization based on the assembly line, that someone said he borrowed from the slaughter lines observed in Chicago. A solution that allowed him to reduce immediately the assembly time of a steering wheel from twenty to five minutes/man.

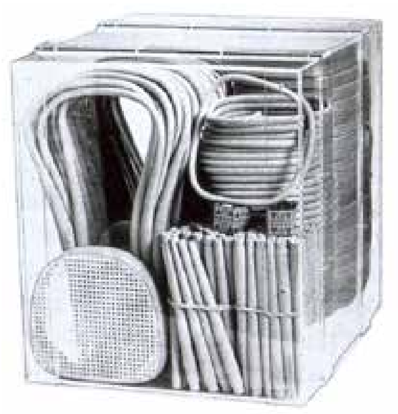
More prosaically, it was a maturation of a process that led to extend scientific knowledge from manufacturing machineries to procedures and organizations inside and outside the factories. It was the foregone conclusion of a historical moment where science and technology were seen as the way to achieve wealth and prosperity among the people and where the faith on divine entities was finally replaced by the more tangible, earthly and secular social progress.

Separation between mind and hand: the Scientific Management.

The taylorist division of labor concluded a long process of separation between mind and hand started in the Renaissance; between intellectual and manual laborer; between those who think and those who act. The final result was the emerging of programming as a distinct phase, anticipation and guide of rational action. Taylor confirm this idea applied to the cost reduction: «... the cost of production is lowered by separating the work of planning and the brain work as much as possible from the manual labor». [1911 – F. W.Taylor, *Shop Management*]. As a result, very quickly, the role and the figure of intellectuals will change to become, soon, professionals.

Walter Rathenau and Henry Ford required that artists and masters are experienced in the industrial system. The intellectual must engage in productive work or, conversely, he may rebel making useless machines, practicing the

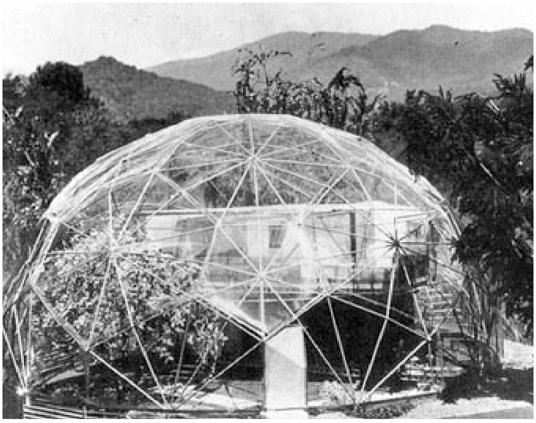
futility, the futuristic provocation, the nihilism dada, the surreal absurd or the formalist tautology as ways of asserting their independence and survival.
As a science of Capital, design will not cover only products, but also tasks to produce them in a way that a new specialized discipline rose: the management, strategic and indispensable element for the modern industry. Its specific result will be the so-called «One Best Way», the standard by which objectify the more fruitful way to produce or perform any activity, regardless rhythms, attitudes and competencies.
In the transition from a working way based on the skills of the worker-craftsman to the scientific organization of production, engineer and technician gradually assume an importance previously unknown. Their tasks are clearly separated from production. On the other hand, they deal with the conception, programming and control. Production shift from an empirical approach to a scientific organization where the decision-making power of the individual worker is lost. Procedures are now founded on objective rules which «specify not only what you should do, but also how it should be done, and determine exactly the time allocated for the execution. » [1911 – F. W.Taylor, *Scientific Management*].
What happens is the expropriation of the craftsman know-how, and its own power on salary negotiation, because the standardization of elementary functions and de-skilling every job will make them interchangeable.



In Taylor's words the model worker is «... an individual who has, to a greater or lesser degree, the characteristics of an ox, heavy in mind and body». [Ibidem] or, at best, a person incapable to manage knowledge «... so vast and numerous that the most suitable worker can not understand for lack of education or insufficient intellectual capacity» [Ibidem]. In this de-skilling of the worker, Ford will not be outdone. He highlighted not only a vision of the division of labor but also of the human race, based on «...a general inequality of human qualities [that] ...for certain types of brains to think it is a pain». [1922 – H. Ford, *My Life and Work*]

The birth of the Industrial Designer.

With the modern world a new kind of professional rose: the *designer*, a person that investigate the world and act for its transformation through the drawing. Leonardo da Vinci was the icon. Later, with the advent of industrialization, this figure turned slowly into the *industrial designer*. Michael Thonet was the fore-runner and Peter Behrens, working at the *Allgemeine Elektricitäts-Gesellschaft* (AEG), starred as the first recognized Industrial Designer.



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• M. Thonet, *Konsumstuhl Nr.14*, 1859
•P. Beherens, *AEG logo*, 1907
• A. Rodchenko, *Design for cup and saucer*, 1922

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• B. Fuller, *Autonomous living unit*, 1949
• Max Bill, *Kitchen watch with timer*, 1951

According to Mart Stam, industrial designers were the people who were studying new materials. Gui Bonsiepe wrote that the term industrial designer was employed for the first time in the U.S. in 1919 by Klivar [1979 – Klivar, M., *The dialect of industrial design and industrial art, in Czechoslovak Industrial design*].

Industrial designers were those that created the styling; and now who is designing communication, media, entertainment and information. All sectors that enhanced the specific field and ability of the designer: working with images. Early excellent interpreters were, as mentioned above, Peter Beherens and then El Lissitzky, Alexander Rodchenko; engineering designer Richard Buckminster Fuller; designer trainers Walter Gropius and Laszlo Moholy-Nagy at the Bauhaus, Emile Ruder at the Basle Kunstgeerbeschule, Josef Albers at Cranbrook, Max Bill and Tomas Maldonado at Ulm. These were characters motivated to think that the mass production would be the only opportunity for democracy and technology, joining design, would have produced solutions against social inequality. This was also the auspicious of Henry Cole, the curator of the famous1851 World Expo, that through the «Journal of Design» from 1849 to 1852 disclosing the industrial design and stated that designers had to serve humanity rather than gratify the élite.

Cross fertilization.

However, the methods of the first designers were very often borrowed from crafts and from the highly intuitive practices of art and more in particular of the applied arts. An extraordinary example of this mixing was the *Konsumstühl Nr.14*, where cleverness and empirical experiments on curved wood, allowed Michael Thonet to create a revolutionary object sold in more than 50 millions of copies form 1851 to the 1930.
Another and maybe the most famous example of the overlapping between crafting and industrialization was the Cristal Palace designed by Paxton (1851). An amazing architecture build in the industrialized fashion but conceived without the necessary knowledge of the elastic behaviour of materials and the scientific calculation available today. It was assembled in only four and half months putting together different elements from different factories and taken down after few years to be reassembled in another place.
Many examples show how designers and builders were using new materials and technologies looking back at past knowledge. One of them is the first iron cast Bridge on the River Severn (1871), where Abraham Darby III (the third of the famous dynasty that started the iron production in the near Coalbrookdale) in order to realize the bridge – according to Sigfried Giedion – conceived the structure copying past stone wedges organization, and – according to others – assembled the 378 tons differently casted pieces, adapting the woodworking-style joints.

The accuracy of science and technology and the methods of modern industry continued to be underutilized even in the Bauhaus: the school recognized as the cradle of the Modern Movement. «Building inventing and discovering observing» was the slogan through which the Bauhaus summed up its teaching methodology. Methodology according to which their students were making observations and experiments in order to recompose it into a theory that, especially at the beginning, was reluctant to be conceived in scientific ways and means.
The teaching criteria of their laboratories, close to the contemporary pedagogical ideas of Montessori and Steiner, were very far from what Descartes had hoped some centuries before.
As we can read from the Bauhaus Manifesto, Gropius expressly referred the centrality of the craftsman in the pedagogical program.

> Architects, painters, sculptors, we must all return to crafts! For there is no such thing as "professional art". There is no essential difference between the artist and the craftsman. The artist is an exalted craftsman. By the grace of Heaven and in rare moments of inspiration which transcend the will, art may unconsciously blossom from the labor of itshand, but a base in handicrafts

> is essential to every artist. It is there that the original source of creativity lies. Let us therefore create a new guild of craftsmen without the class-distinctions that raise an arrogant barrier between craftsmen and artists! Let us desire, conceive, and create the new building of the future together.» [1919 – W. Gropius, *Bauhaus Manifesto*]

We cannot forget that the «Sächsische Bauhaus», founded in 1919, was the result of the fusion of a historic Academy of Fine Arts with a school of crafts: the «Kunstgewerbe Schule» promoted by the last Grand Duke of Sachsen Weimar and founded in 1903 by Van de Velde. Basically and especially at the beginning, it was an academy innervated by a certain kind of crafts: cultured and refined on the model initiated few decades earlier in England.
In the beginning, also the taste that inspired the industrial products was taken from forms and styles of the past.
It was a long process that led to recognized new expressive potentiality. In the printing manufacture, the sector that experienced the first mechanization, it took over sixty years to see the release of a book finally free from the imitation of the Gothic manuscripts and the adoption of simple and linear fonts, printable in small bodies and suitable for economic editions. It was a landing point, which was accomplished after many years since the *DK type* forged in heavy shapes of the Germans Gothic manuscripts was introduced.

Simplification and Modularity.

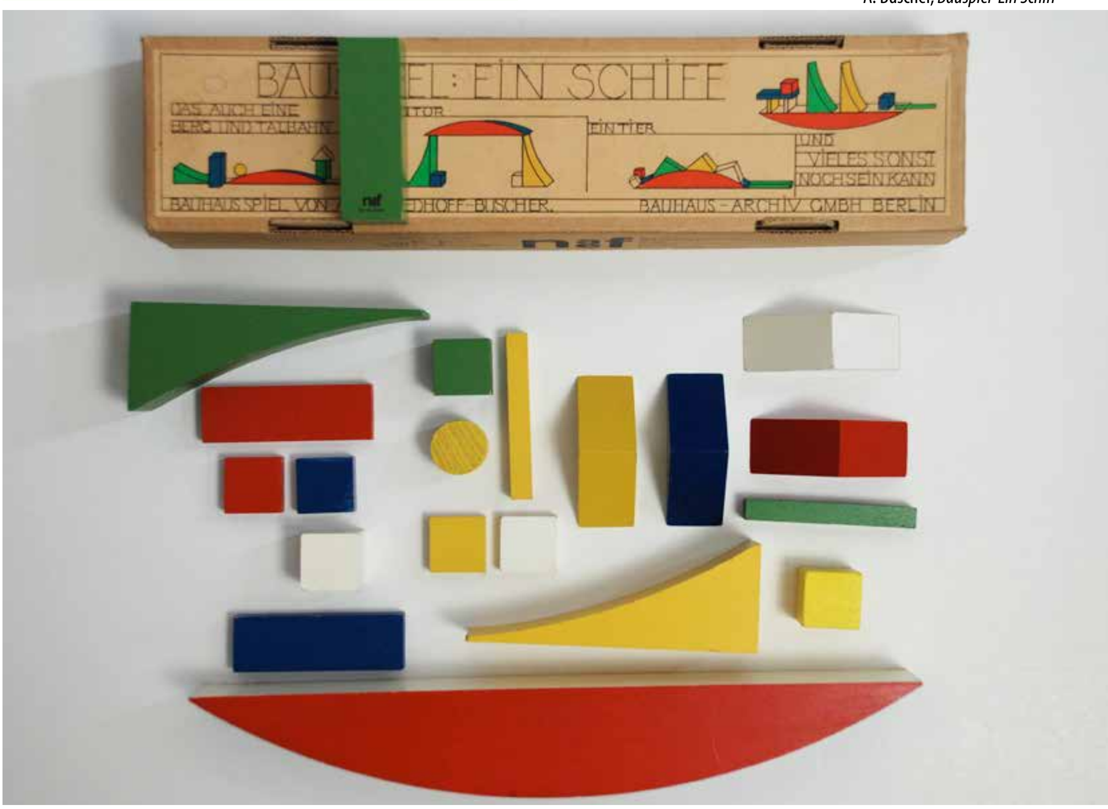
The Gutenberg's invention is to be considered the forerunner of industrial production. From the first 42- line Bible printed out on February 23, 1455 in 180 copies in few years the technology of the movable type allowed to press a page in 20 seconds and, later with the introduction of the steam power, to spread out thousands of economic copies across Europe. The new idea, anticipating industrial manufacturing, was using minimum units, repeatable and interchangeable: always the same regardless of the page to produce. Concepts and methodologies such as standardization, modularity, and product serialization are already those that, 400 years later, characterized the Industrial Revolution.
Many years later, typography is still the place where we can see the transition from craft and expressionistic approaches to the aesthetic forms of objectification and mechanization.
In 1922, as part of the publishing activities of the Bauhaus, Itten edited a book on the masters' works of antiquity receiving criticisms form Oskar Schlemmer due to the lack of readability of the pages.

The page composition strongly expressionist, designed by contrast of the design elements, printed on characters mixed with calligraphic notations certainly couldn't receive approval from the one who wished sobriety, minimalist and compositional colour control for the benefit of a clear usability and simplicity.
And one year later for the first Bauhaus exhibition all the promotional material was conformed to a style mainly using lower case and sans serif fonts. Pages were designed on a clear layout based on a precise compositional grid, geometric shapes and colours that, in history, will remain the recognizable Bauhaus style and identity.
This change of style wasn't so obvious and without criticism. In Germany the printing industry was still firmly anchored to the heavy richness of Gothic characters. The arrival of Moholy Nagy at the Bauhaus contributed greatly to the introduction of the new typographic style and to renovate the design approach. The machine and the industrial manufacturing potentialities became an indispensable reference for the designer. Besides the aim to give readability, the new characters advocated by Schlemmer and Moholy-Nagy, was also and certainly the intention to move towards the standardization as a means to reduce the cost of print production.

In the book *Die neue Typographie,* published for the Bauhaus in 1923 by Moholy-Nagy, it's possible to find many and varied experiments. *Sui generis* was the research of Kurt Schwitters and Jan Tschichold, in which the readability was achieved through the creation of an alphabet inspired by the phonetics. A solution that will be picked up by Bayer in 1959, when he was teaching at MIT, for the realization of the (today still in use) Fonetik alphabet of the English language
Most well-known and still used with minor adjustments in the world of digital publishing is the character *P22 Bayer Universal* commissioned by Gropius in 1925 in order to have a standard typeface Bauhaus. The character that finally could equally well be used for printing, but also for writing machine and handwriting saw the light in 1927 inside the Bauhaus by the collaboration of Herbert Bayer, Denis Kegler and Richard Kegler. For these reasons authors named it «Universal».
It was a geometric character, of course tiny and sans-serif, whose generative matrix was given by a mainly continuous line and designed using three arches in combination with horizontal and vertical segments. In a way it could be considered the normalization of the calligraphic characters studied by Itten and used in the first printing phase of the Bauhuas.
A research even more radical was the *Kombinationschrift* of Joseph Albers in which standardization is generated by the combination (hence the name) of characters of only ten primary elements arising from the forms of the circle and the rectangle.

Those experiments can be seen as diametrically opposed and seminal approaches in the Industrial Design practice: the *P22 Bayer Universal* font, where simplification is pursued in the first instance through the use of line that unifies; the *Kombinationschrift*, where simplification is pursued by combining a minimum number of standardized modules.
This new philosophy to approach design was reflected in many products designed in those years at the Bauhaus. Combination as a way to create objects is very clear in the *Bauspiel Ein Schiff,* a wooden children toy a for ships building designed by Alma Buscher that can be considered the precursor of Lego.

- H. Bayer, D.Kegler R. Kegler, *P22 Bayer Universal*
- J. Albers , *Kombinationschrift*
- A. Buscher, *Bauspiel Ein Schiff*



Towards a new Designers.

When finally the Bauhaus moved to Dessau the transition towards a designer that work for (and inside) industry was almost completed. In 1924 Gropius met for the first time the governor of the city Fritz Hesse. At that time Dessau was one of the few German cities still under the leadership of social democratic: the place where the largest industrial chemistry (IG Farben) and metallurgy had established their headquarters. It was the exact opposite of Weimar. The large employment opportunities had triggered a rapid and chaotic development where in only three years, from 1925 to 1928, the population grew from 50,000 to 80,000 inhabitants.
Here the powerful group of Junkers with their aircraft production plants and metal factories could be taken as a symbol of the city as well as Goethe could be of Weimar.
The theoretical writings of Gropius between 1923 and 1925 was addressed to redesign a new professional training, compatible with the industrial needs and promising a new technician free of any artistic affectation and anarchism. In Gropius's words the new designer, the industrial designer was supposed to be «a new type of designer, absent in the past, as contributor to the industry, for the trades and construction and, at the same time, with techniques and form expertise».
Words that sound like a denial of the artisan and antithetical to the first manifesto of the school where the identification with the craftsmanship was stated as the educational philosophy.
The emerging interest in the machine, absent in the early Bauhaus, and the identification of the designer into the industrial designer will find more space and a first systematic treatise in his book *Idee und Aufbau des Staatlichen Bauhauses, Weimar* written in the same year, 1923.
From this radical change of opinion, Gropius came out two years later with a brilliant intuition able to reach a reasonable mediation in his philosophy about industrial design.
This mediation that we can assume as an interesting definition of the industrial designer is shown in two sentences taken from the article *der Grundsätze Bauhausproduktion* of 1925 that can be summarized as follows:

> The craftsman of the past has changed, the craftsman of the future will result in a new unit of work, which will make him the exponent of experimentation to be applied in the industrial production. [...] The new training mission of the Bauhaus is therefore to form "model builders " with a broad culture , trained in laboratory practices and with accurate knowledge of the mechanical methods of reproduction. [1925 – W. Gropius, *der Grundsätze Bauhausproduktion*]

A brilliant definition able to recover intuitive methods, sometimes irrational and creative, inside the industrial manufacturing when seemed that exactness and mechanization had rejected because inadequate: these qualities were re-admitted in prototyping laboratories.

Following Gropius, we can therefore say that the industrial designer is a person with technical knowledge about materials, that is able to accomplish manufacture needs of industry and able to reunify everything, through experimental research and creativity, in a coherent form.

Science and Technology in Design.

With great pomp and celebration on December 4, 1926 the Bahuas moved to Dessau in the new headquarters designed by Gropius.
In the new school interests in the materials grew up with a particular reference to their physical and mechanical properties rather than their perception. Training was more based on research and objective methodologies.
With Josef Albers, who took over from 1928, the *Vorkurs* (the preparatory course) was updated with specific focus on materials. Lessons and exercises were held in an «objective» fashion and theory was accompanied by factories visits. The practical exercises will be conducted on three-dimensional investigations, more oriented to the construction process, based on form resistance and aimed to assess the physical capabilities of materials.

This orientation was also the reflection of new positions that had already started in the early Twenties by the members of the Costructivism and the De Stijl movent and that had gathered around the Hans Richter's magazine G-*Material zur elementaren Gestaltung*. In this magazine, Mies (seven years before he took over the leadership of the school) wrote:

> We refuse to recognize formal problems , we recognize only construction problems.
> The shape is not the purpose of our work, only the result .
> The form itself does not exist.
> The shape as purpose is pure formalism and we reject it. (1923 – M. van der Rohe)

As a result of this transformation the *Vorkurs* was supplemented by a new course taught by Oskar Schlemmer, whose aim was to examine some of the main components of man: the proportional relationships and the movements of his body; psychological aspects as the expression of his being; philosophy and history of the spirit as expression of his intellect.

A few years later Meyer, as a new director of the Bauhaus, invited psychologist Karlfried Graf Dürckheim to hold lectures; the art historian Karel Teige to disseminate the principles of the new theory of the *Wissenschaftliche Weltauffassung* (the scientific conception of the world); some of the leading exponents of the logical positivism from the Vienna Circle, including Otto Neurath, Herbert Feigl, Rudolf Carnap and Walter Dubislav.
All of these transformations had an important meaning on design showing how science started to enter art and technique and, as a result, that technology became an indispensable component of design from where Industrial Design emerged.

Concepts that were taken up and developed twenty years later in the teaching of the *Hochschule für Gestaltung* in Ulm (HfG), the most important design school of the Postwar. Opened in 1955 by the Scholl Brothers Foundation and commissioned by Inge Scholl in memory of her brothers killed by the Nazis in 1943, the school was the natural evolution of the scientific approach and the productivist commitment emerged into the Bauhaus and, more than there, in the Soviet *Vchutemas*. Teachers of the school were eminent figures of the industrial and graphic design such as: Max Bill (founder, director untill 1597 and student of the Bauhaus under Johannes Itten, Josef Albers, Walter Peterhans); Thomas Maldonado (his successor); Otl Aicher; Gui Bonsiepe; Hans Gugelot , Walter Zeischegg that, among the main innovations, introduced innovative teachings including history of culture, cybernetics, information theory, systems theory, semiotics, ergonomics; in short, the new sciences of the 50's giving the courses a strong epistemological foundation. New fields of research entered the design discipline: technical mathematics, physics, political science, psychology, semiotics, sociology, theory of science, product design, component design, visual communication, industrialized building, information and filmmaking.

Modeling research vs regulatory technique.

During these transformations, in which design evolved towards more formalized approaches it's possible to observe two opposite directions.
Jean-Pierre Epron, in his *Essai sur la formation d'un savoir technique* (1977) noted that in the formation of a «constructive knowledge», as a response to an increasing need for generalized control on the building processes, two different approaches emerged: one was the logical deductive method based on modeling; the other, the empirical inductive method based on the regulatory technique.

Under the modern point of view the first approach started with Galileo Galilei and the New Science, to flourish during the XVII century, especially with the work of René Descartes. The second with Francis Bacon and the Anglo-Saxon empiricism, but even with the French encyclopaedists to reach, in construction, the high level of the German technical manuals. But in the real applications of constructions these two opposite approaches were never used in their orthodox formulation.

Indeed in many cases, experimentation based on logical deductions or empirical observations of some clever practitioners had to clash strongly against strict regulation techniques produced by scientific calculations or widely shared and recognized.

Among many examples, we can highlight the battle that the George A. Fuller Company had to wage against the technical offices of New York to see accepted the framed structure steel, the technology that the company had already successfully employed in the majority of all the buildings known in the architectural history as the *Chicago School*. Another was the famous load tests that F.L. Wright had to lead on the pillars of Johnson Wax Administration Building in order to obtain all the permissions to build. Another relevant case is exemplified by Robert Maillart in a period in which German engineers and scientists had developed elaborate mathematical techniques that didn't need any load test to verify construction structures but, at the same time, that excluded any solution that cannot be verified with their calculation methods. Methods derived from the adaptation of the available techniques and from the previously built buildings.

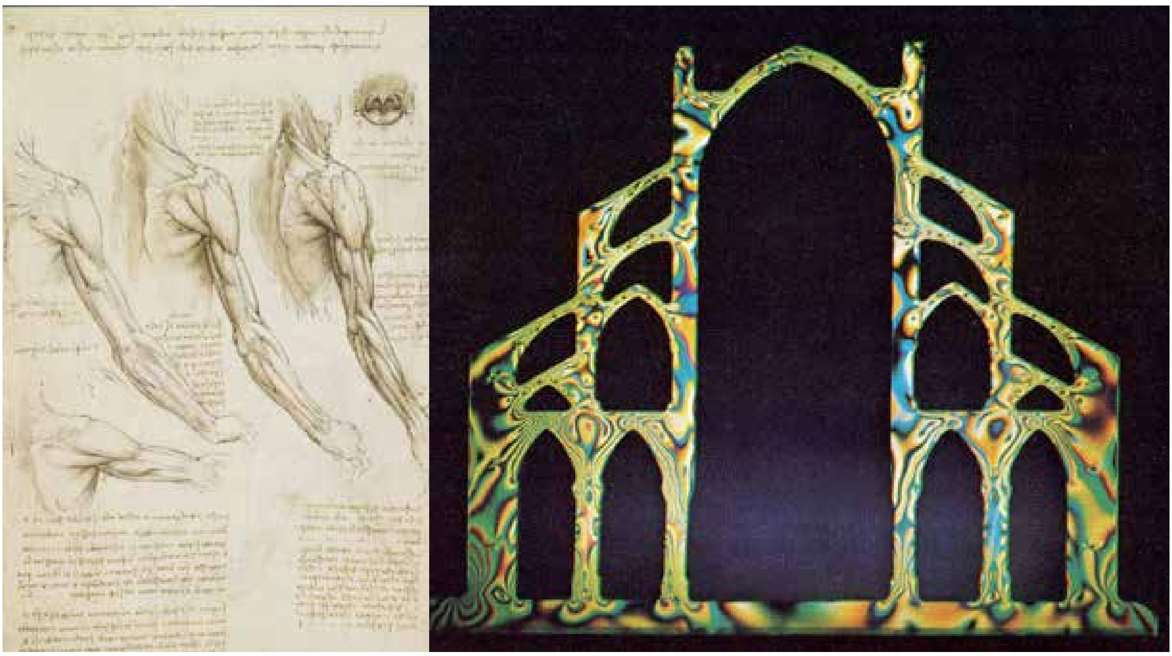
• R. Maillart, *Salginatobel Bridge* under construction, , at 1929 to 1930.

• F.L. Wright, *Johnson Wax Administration Building's* mushroom pillar load test, 1936

Using different methods based on the simplified calculation technique derived from his mentor Richter, but above all, using intuition, common sense and full scale experiment, Robert Maillart was able to conceive and build structures never seen before, considerably cheaper and more elegant, although often opposed because deviating from standard controls.

Drawing as an epistemological practice.

The forerunner who defied the norm and conventions and through rational experimentation tried the path of innovation is certainly Leonardo da Vinci. Among others, Leonardo will be the first to declare that art needed to be supported by scientific knowledge and even that science has to be founded on mathematical proof.

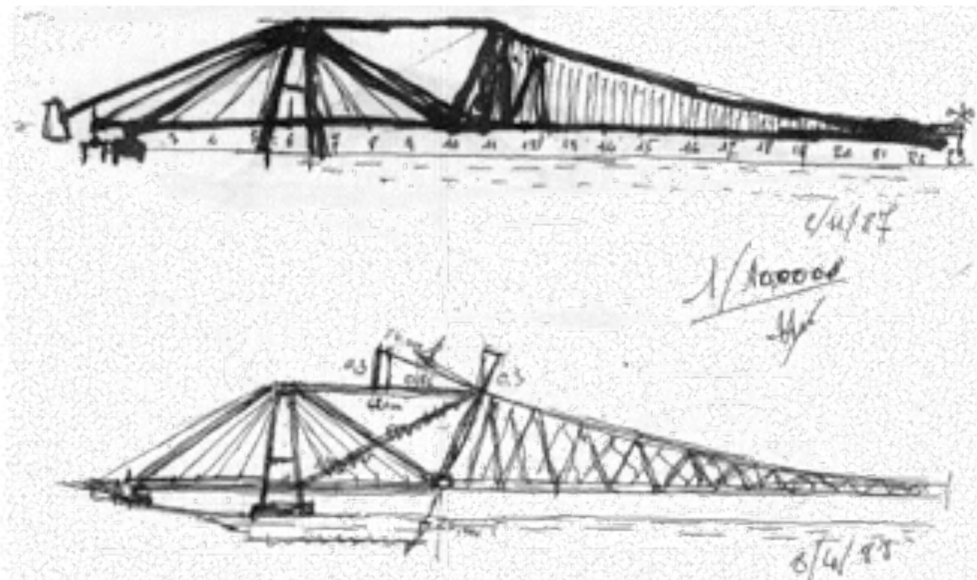


> «Nissuna umana investigazione si po' dimandare vera scienzia, se essa non passa per le matematiche dimostrazioni. E se tu dirai che le scienzie, che principiano e finiscano nella mente, abbiano verità, questo non si concede, ma si niega per molte ragioni; e prima, che in tali discorsi mentali non accade esperienzia, senza la quale nulla dà di sé certezza» (Leonardo da Vinci, LdP I, 1).

It is good to clarify that in his time mathematics was equivalent to geometry whose demonstrations and theoretical apparatus began to be used for the practical life applications.

Mathematics was therefore equivalent to the geometry where demonstrations were analogical, not analytical, carried out through graphical representations and drafting was the essential tool.
In fact, as many historians wrote, the Renaissance was the period where arose the awareness that drawing is not just a medium of representation, but an instrument of knowledge, an epistemological discipline.
In recent years, Edward Robbins in his book *Why architects draw* extends the concept with these words:

> Drawing in architecture is not done after nature but prior to construction, it is not so much produced by reflection on the reality outside drawing, as productive of a reality that will end drawing up outside.
> We can conclude affirming that drawing could be an instrument to investigate Nature in order to know it's internal laws and, in a more practical way, a tool to transform it. (E. Robbins, 1994)



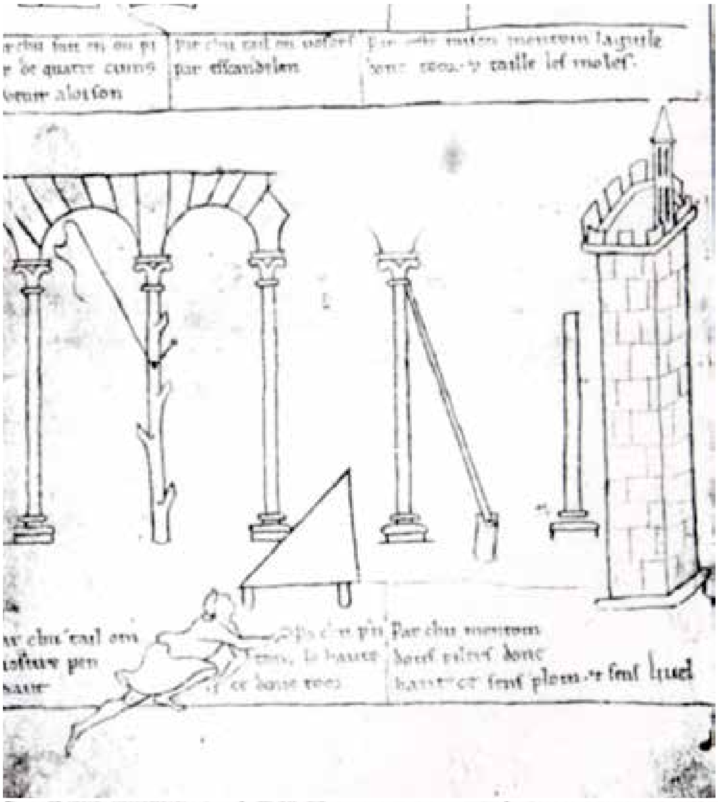
PREVIOUS PAGE.
• Leonardo da Vinci, Anotomical drawing, around 1510
• Force visualization on a Gothic cathedral using polarized light and plexiglass (R. Mark, '70s)

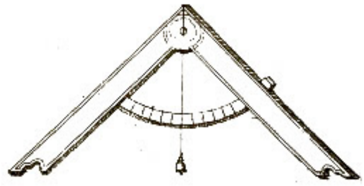
THIS PAGE.
• Riccardo Morandi's bridge studies, 1987/ 1989

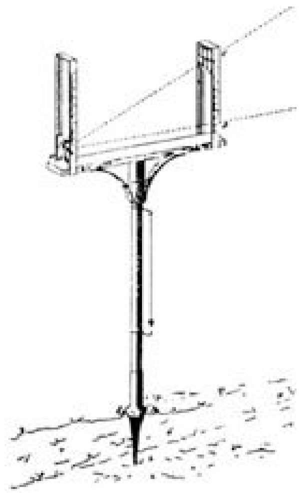
But if the Renaissance celebrated the primacy of drawing, this device, as operational practice, was certainly not born in that time. The lack of direct documentation of the periods that preceded the introduction of the paper-rags (1173) and paper in general is certainly one of the main causes of the lack of knowledge of this practice before the fifteenth century.
Parchment was a rare thing indeed, in a period when scarcity was widespread. It was reserved for official scriptures of some importance and/or solemnity. The technical design of the buildings was mainly carried out directly on site and, often, on whitewashed wooden tablets or plaster slabs. We know that sculp-

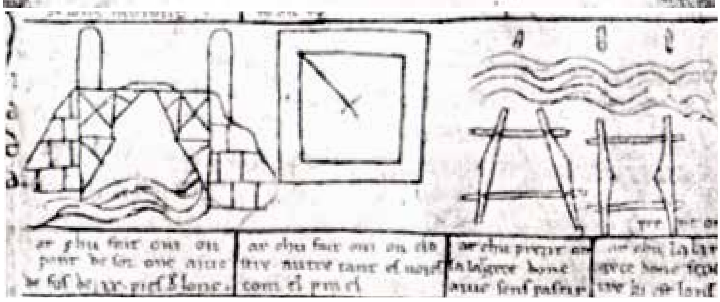
tures were drawn on the walls of spacious lounges and remained on display for the evaluation of commissioners. On the construction site, floors or walls just erected could be used as suitable supports to draw solutions and how to proceed with the construction. But even in the scarcity of proofs, we have to agree that drawing was also already a practice of epistemological value.
An example is the famous notebook or *Livre de Portraiture* by Villard de Honnecourt designed by the Picard architect-engineer in the decade from 1225 to 1235. Inside we can appreciate figures of various topic: pseudo-perspective, examples of architectural buildings traced using approximate orthogonal projections, descriptions of measurement methods and instruments.
During those years, the measurement became, a major concern in the practice of builders and, more generally, for drawing craftsman. According to scholars, this can be connected to travels that in the first centuries of the Millennium started again especially towards the East. Consequently, the production of nautical and territorial charts flourished based on techniques and tools from the Arab world and as a refinement of instruments used in antiquity.

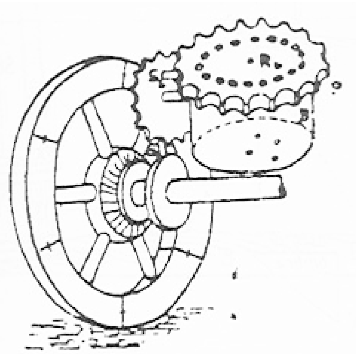
Vitruvius told us of different measuring instruments. Ancient Romans used sundials, developed by the Greeks, to measure angles, topography techniques inherited from the ancient Egyptians where there were highly developed because their need to conduct continuous perimeters of land overflowed by the Nile. With such techniques, and in combination with the Babylonians, Egyptians made the first maps already in the third Millenno BC. Always from the Egyptians, Romans had inherited the plumb line, perfect in the *Crocera* or *Groma*: a metal cross from the ends of which descended four-wire lead to check orthogonal alignments. For their impressive hydraulic works, Romans invented several instruments such as the *archipendolo*; the *calibro*; the *libella*; the *lychnia*, an altimeter that exploited the properties of similarity of triangles to measure heights of unreachable objects; the *chorobates*, an instrument consisting of a wooden pole about six meters long with a channel filled with water to level and plumb lines to guide the measurement of height differences; in late imperial age, the *odometro* to measure the distance travelled.
These instruments were then studied and continually improved refining techniques to realize other devices such as the *Quadrante*: a simplification for builders of the *Abstrolabium* the most widely measurement tool from the Arabic word *Asturlâh*, whose origin is traced back to several centuries before Christ for astronomical applications.
It wasn't a world without science and instruments. It was simply a world that reasoned and worked differently. It worked through the "analogical syllogism" of descriptive geometry and tools resulting from the observation of phenomena and error correction. The ineffable knowledge of quality based on evidence.

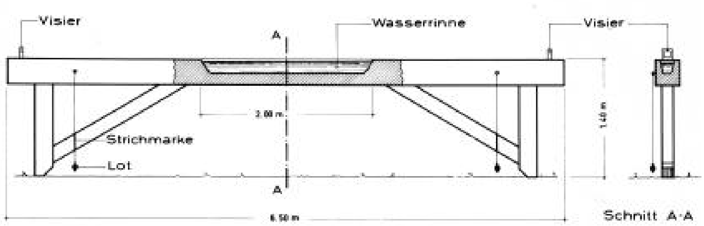










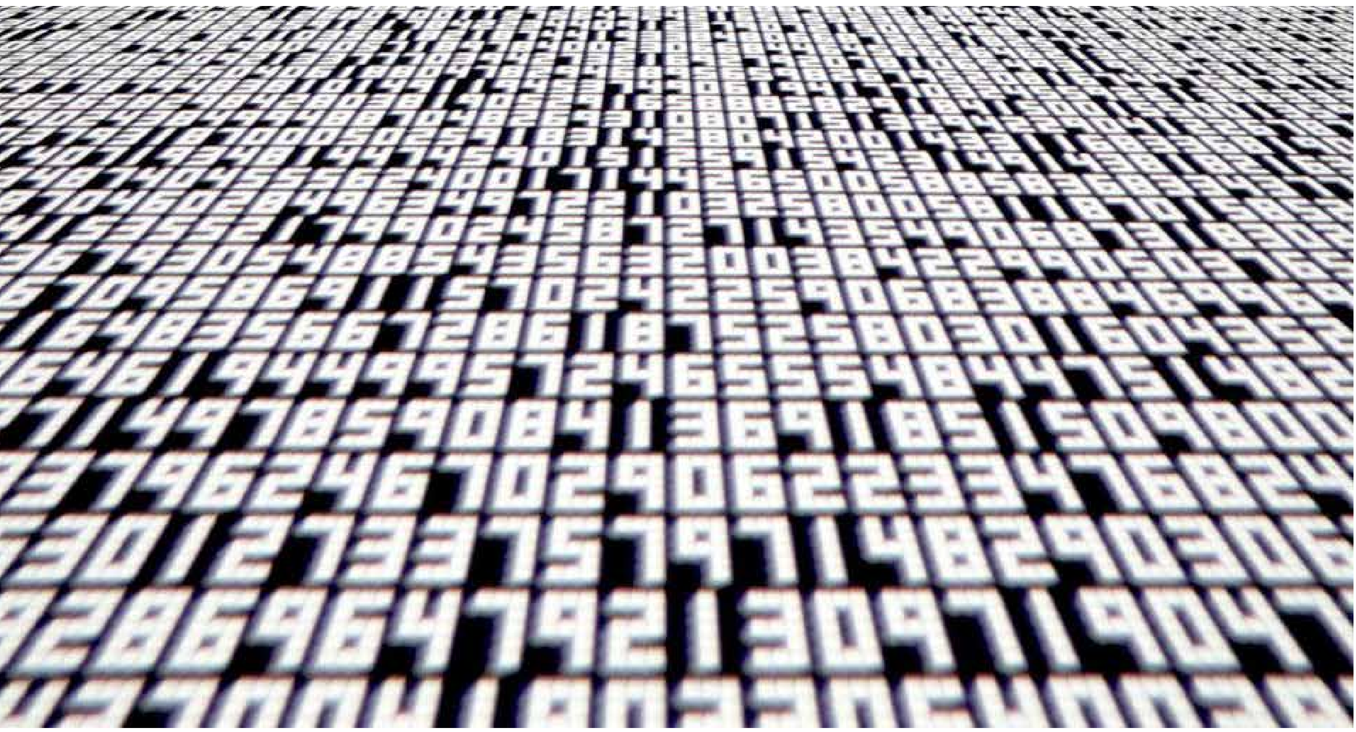


• Villard de Honnecourt, Livre de Portraiture, 1225 -35

• Chorobates, Archipendolo, Groma, Lichnya , Odometro (di Vitruvio).

Numbers, measurements and design objectivation.

We have to wait until the end of the XV century to see numbers as drawing specifications. Among the most ancient testimonies are some drawings of Francesco di Giorgio Martini. Between 1494/95, during his military engineering services for the courts of Naples and Calabria, he went to the Roman city of Casinum handing down sketches of ornaments and decorations and other drawings of a building, perhaps identifiable in the school of Marco Varrone, with some measurement specification. The San Gallo family was the architectural firm that more than any other architects used numbers and measurements. They used to start with some sort of study of the status quo, carried out with all the measuring instruments available and providing detailed and accurate descriptions and related measures from which to proceed to the subsequent realization of the project.

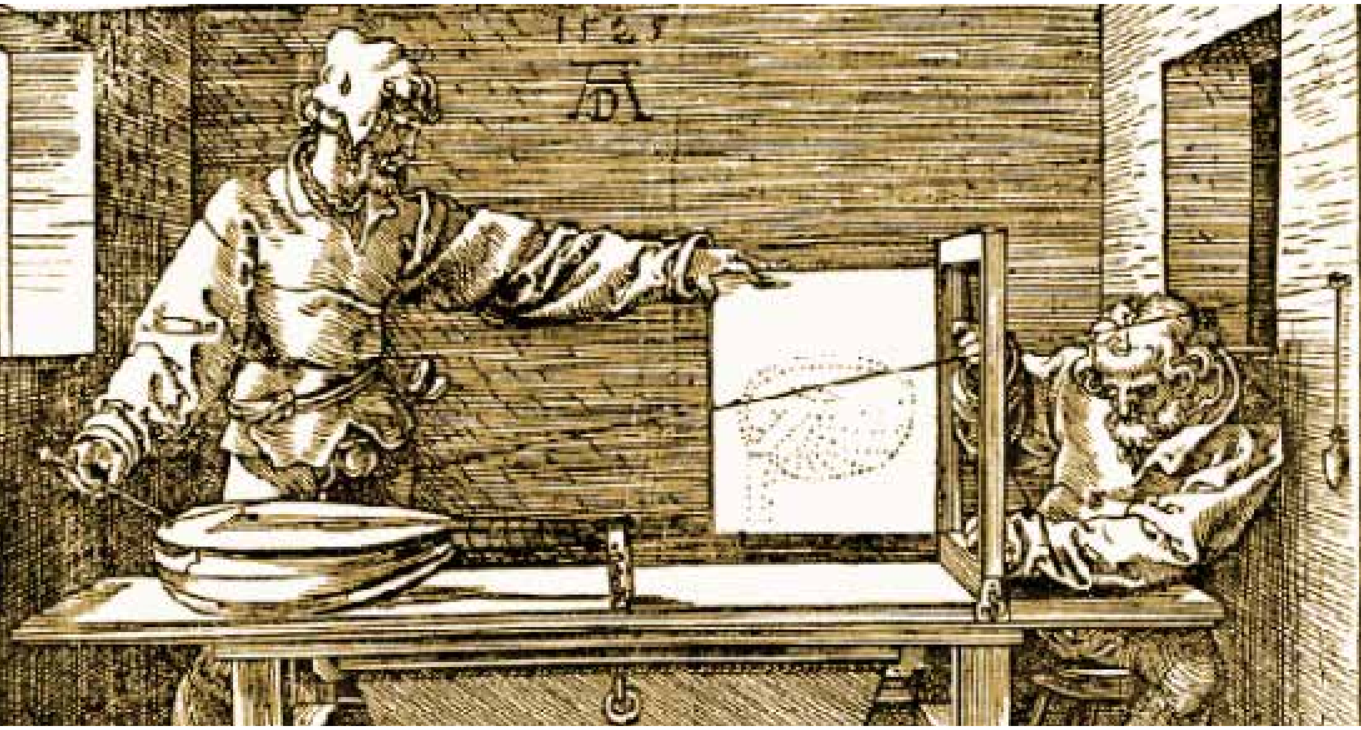


• R. Ikeda - data.tron / data.scan

Despite these historical antecedents, however, it was not until the Sixteenth century that the number would start to accompany drawings in a more stable manner offering an instrument to assure control and precision in design. For example, the precision of the Palladio's drawing and architectures was due to a very refined use of the modularity rather then a precise measurements. In fact, Rudolph Wittkower asserts Reinassance architecture as a science was due

to the mathematical ratio used by the architect and especially for Palladio due to the harmonic proportions derived from musical scales.
However, it's fairly clear that, also in drawing and design the world of «more or less» was slowly turning into precision.

The instrument that, during the Renaissance, pushed towards the direction of precision is the *Prospettiva.*
Although perspective is an innovation that is still deeply linked to knowledge and ways of working of the craftsman, the introduction of perspective (1420) represented a significant opportunity for such a society that, at the turn of the Middle Ages into Modernity, was searching for «pondere et mensura», for a system of measurement based on quantity rather than qualitative comparison. As a result, in the later centuries quality will be relegated to the inaccurate work of the craftsman and to the arbitrary practices of the creative genius of artists.



• A. Dürer, perspectograph

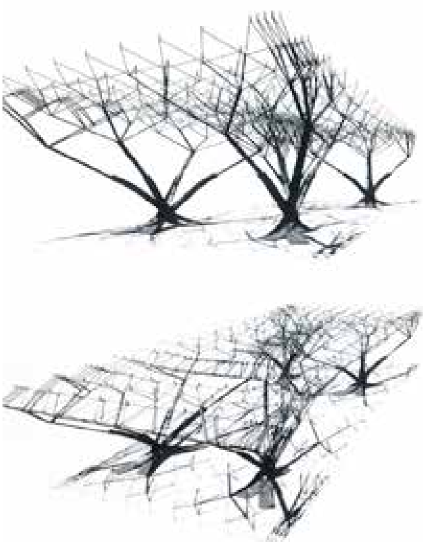
In addition to the perspective frame there followed many tools for surveying and drawing: compasses of various shapes and with different functions by Leonardo, Antonio da San Gallo the young, Albrecht Dürer; *circini* for the correct design of a variety of geometries that are represented in the *Theatrum instrumentorum et machinarum*, published in Lyon in 1578 by Jacques Besson.

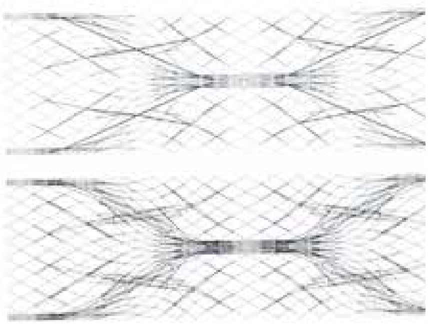
Quality vs Quantity. From analogical to analytical.

With the introduction of perspective as operational practice of design there is the deep epistemological change that – by convention – started in 1630, when Galileo Galilei published his *Discorsi* and culminated with sir Isaac Newton's work.
It was a profound change that will affect the methods of production, living, thinking and designing.
This will mark the passage, as stated by Fulvio Carmagnola, «from a qualitative quality to a quantitative quality»; from a description of the world in qualitative to a quantitative way. A new world where the way of describing in terms of measurable quantities and quality was seen as an ontological diseases.

This transition is well explained by Fulvio Carmagnola:

> Nel modello aristotelico, influente fino agli albori dell'epoca moderna, la scienza è una definizione





• Ciro Najle, Force field

• Ciro Naile, Branching

• Frei Otto, numbered diagram for cutting pattern of the membrane for the tensile *Montreal Universal Expo German Pavilion* , 1968

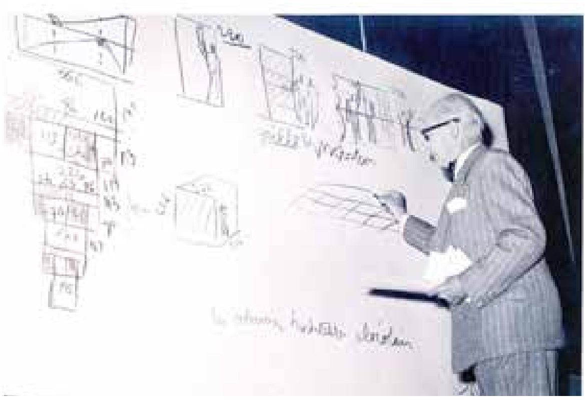
• Le Corbousier, Making diagram at the Triennale in Milan, 1951

NEXT PAGE

• Asymptote, *New York Stock Exchange virtual inhabitable diagram*, 2001

•MVRDV, Metacity/Datatown, Sector Waste, 1991

•MVRD/Berlage Institute, Global Trends, Gap Diagram, KM3: Growing population vs Resources decreasing.



qualitativa (non metrica) delle essenze individuali, basata su un'ontologia pluralistica Nei secoli a venire la comprensione del mondo si distaccherà sempre più da modelli di conoscenza aristotelici fondati sull'intuizione e sul riconoscimento delle differenze qualitative, ma attraverso la specificazione quantitativa di attributi. Di conseguenza lo spazio e la sua rappresentazione non sarà più una varietà fenomenologica gerarchicamente organizzata, ma un'entità astratta e indistinta la cui unica descrizione possibile e la sua identità possono darsi solo attraverso la misura. (1991 – F. Carmagnola, *I luoghi della Qualità*)

[In the Aristotelian model, influential until the dawn of the modern era, science is a qualitative definition (non-metric) of the individual essences, based on an pluralistic ontology. Centuries later, the understanding of the world will detach himself more and more from the Aristotelian knowledge models based on intuition and on the recognition of qualitative differences, but through the quantitative specification of attributes. As a result the space and its representation will no longer be a phenomenological variety hierarchically organized, but an abstract and indistinct entity where the only possible description and identity can be achieved only through the measurement].

From the point of view of design, this transition will involve a process of abstraction increasingly pushed ahead until the final outcome that is the digital computation.

While Perspective in architecture was playing its baroque exaggerations, mathematics started that revolutions that influenced design and architecture: the new instruments is Cartesian space and functions. The Cartesian doubt makes a clean sweep of perspectival space and in its place substitutes a plane defined by the values of X, Y: a new space describable with the elegance of numbers and mathematical formulas of functions.
From this moment onwards the Aristotelian geometry was threatened by a new approach that it is no longer the syllogism but numerical modeling.
With numerical modeling the behaviour of materials and the structures resistance were studied and more recently, morphological generation.

The first examples of architectural form generation directly affected by mathematical modeling and in particular by applied geometry were fortifications and bastions of urban development that occurred from the sixteenth to the nineteenth century. Walls and urban shape of medieval towns related to the morphology of the site were replaced by an «abstract» design fruit of ballistic calculations, crossfire, or lines that organize gaps and the arrangements of the ramparts. Modeling reality will no longer be entrusted to wax, gypsum or wood, but to mathematics: an abstraction process even more stringent and less and less comprehensible to the majority of people that, at a distance of about half a century since the perspective frame, can now make use of a new and powerful tool. This new tool is the computer, or more precisely the «personal computer», capable of carrying the design in the universe of precision and its fashion modes in those of the industrial manufacturing.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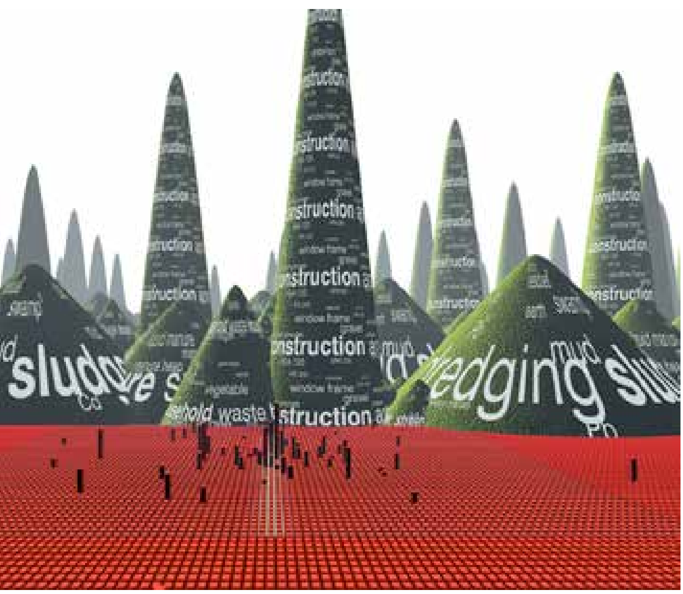
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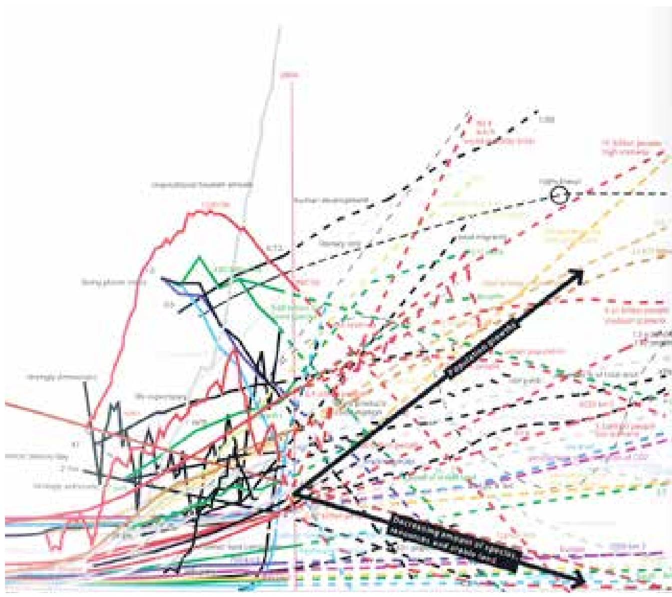


From digital drafting to construction automation.

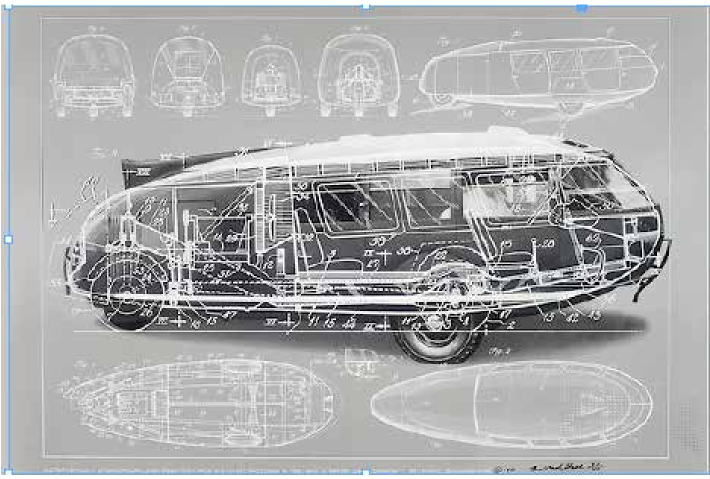
A new jump occurred in the ‘80s when the «personal computer» (the tool) and digital information (the medium) of the 2D CAD started to enter architecture and building construction in general.
In 1977 Apple II, Commodore PET 2001, and TRS-80 were sold and advertised as «personal computers». 1982 was the year when the first release of AutoCAD was launched and CATIA (Version 1) was announced as an add-on product for 3D design, surface modeling and NC programming. Two years later Apple put on the market The Macintosh, the first successful mass-market personal computer based on the Motorola 6800 microprocessor, but above all, the first mouse-driven computer with the WIMP (Windows, Icons, Menus, and Pointers). graphical user interface.
The new machines offered designers an instrument to work in the industrial manner, reducing tolerance and making drafts easy to edit and to reply in multiple and identical copies.

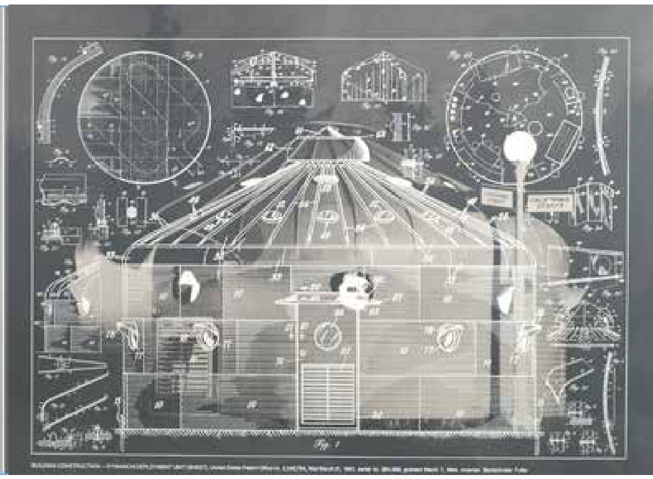
During the ‘90s, thanks to this instrument and in addition to the software evolution architects discovered that new forms could be possible to conceived, but very difficult to realize in the physical world. 3D modeling was opening a new frontier in drafting, but very controversial in design application. In fact, assembling materials in the complex shapes generated by 3D software was able to offer was a very complicated task. Other software came out to help designers, civil engineering, and project managers but these new tools weren’t able to affect the construction phase where activities remained largely handmade and the lager amount of work continued to be carried on site.

A new scenario in construction started in the last 20/15 years in constructions after the Computer Aided Manufacturing (CAM), supported by the Computer Numerically Controlled (CNC) production, was introduced in some industries like aerospace, automotive and shipbuilding, in fields where reliability is very important. All fields historically very close to the buildings construction that prepared the technology transfer and allowed to turn construction from crafting to industrial manufacturing.

The tradition of this bond is – for example – evidenced by Palladio in Piazza dei Signori in Venice that used shipbuilder masters to realize the roof of the basilica; by the concrete formwork workers mainly from the shipyards; by the Buckminster Fuller’s Dymaxyon House or by Renzo Piano that has always remembered how he looked at the shipbuilding technology as a source for his experimentations. In principle, the use of CAD in conjunction with the CAM was used by architects at small scale working in product design, especially for building components, where digitally driven machineries operated design and fabrication. Today, advanced Robotic Technology is able to manage the construction of the whole building even if, as Leslie Cousineau and Nobuyasu Miura, on «Construction Robots: The Search for new Building Technology in Japan» quoting Shigeru Sakamoto wrote:

> Building is stationary and robots must change their location [...] in construction, the product is custom-made and robots must be reprogrammed to operate given new conditions. [...] Each building is a custom-designed product. The same form is seldom repeated. Its shear size prohibits assembly line movement. Its shear size prohibits line movements. Building materials and componente are much larger and heavier than most industrial materials. Buildings are also made of many kinds of materials, and each material may be a different shape. Building materials also are not as precisely fabricated as required for most industrial materials.
>
> [1998 – Leslie Cousineau and Nobuyasu Miura,]





• Richard Buckminster Fuller, *Dymaxyon Car*, 1933 and *Dymaxion House* 1944-46

Digital information as a new standard.

As a result, also the Architecture Engineering and Construction (AEC) industry started to experiment the *zero tolerance* production. Materials could be shaped and crafted to achieve particular design goals and purpose fitting exactly the visualization that architects are able to produce with their computer software. Standardization of elements was anymore a technique to build in an industrial way and –at the same time– a limit to make architecture. Nowadays standardization is only in the medium. The digital information is the standard that designers, industry and craftsmen are sharing as language to perform

their works and professions unifying and streamlining the process.
This process is called *File to factory*. A process in which data flow from the architect's computer straight to numerically controlled (CNC) machines and fabrication technologies. Prepared drawing files are used to cut, to bend or to realize molds useful to fabricate elements and components to be assembled.

The first example, historically recognized where CAD/CAM was used to realize a large-scale object related to building construction, was driven by the Ghery Partners firm. His first work using CAD/CAM was the Fish Sculpture or Barcelona Fish (1992), a huge sculpture forming a landmark for the Olimpic village and anchoring a retail complex designed by Gehry Partners within a larger hotel development by Skidmore, Owing & Merill.

This fish sculpture, a landmark in the history of Frank O. Gehry & Associates, inaugurated the use of computer-aided design and manufacturing putting the firm in a pivotal role in the advent of digital technology in construction.
The project's financial and scheduling constraints prompted James M. Glymph, a partner in the firm, to search for a computer program that would facilitate the design and the construction process, leading to the adoption of CATIA (Computer Aided Three-dimensional Interactive Application) an aerospace industry software by the French company Dassault Systems.
In this work the sculpture was modeled entirely in 3D and delivered directly to the fabricators as a 3D model, but with an approach that was very different from the ortodox digital work-flowing. In fact, the approach, also used in subsequent's projects, was based on the «reverse engineering». According to this technique, initially, Ghery hand-made the physical model, then he coded the model in digital using digitizer and imported it in 3D software to drive tests and changes until the final phase, where the files were exported for fabrication.
The project's success convinced Ghery to develop the use of this technology and bring him to start the Ghery Technologies in association with his design firm in order to support and expand the digital approach.

A few years later, this experience was transferred to the Disney Concert Hall project started in 1989. The Walt Disney Concert Hall in Los Angeles was the first work with a comprehensive use of CAD/CAM that Ghery used due to the complexity of the form.
In this project the firm used CATIA to produce stonework. The stones for the 1:1 scale model was automatically sculpted in Italy using the information provided by the software and shipped in the USA to be reassembled. Because of the excessive costs, stones were replaced by a metallic cladding, but the different choice demonstrated the great potentiality of the technology that was reused also for the realization of the Guggenheim Museum in Bilbao (opened in

• Ghery Partners, *Fish Sculpture* aka *Barcelona Fish*, 1992

• Ghery Partners, *Walt Disney Concert Hall*, 2003

• Ghery Partners, *Walt Disney Concert Hall*, Construction phase on May 20, 2001

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Examples of «flexible» production using tessellating technique from different ages.

• PTW Architects, CSCEC, CCDI, Arup, *The National Acquatic Center* aka *Water Cube*, 2004-2007

• Twelve angle stone, Hatun Rumiyoc, Cuzco,

1997) where each pieces was bar coded and assembled using laser surveying.

It was immediately clear that, despite the fascination of the free-form that digital technologies are bringing in designing, other aspects could play a very important role in the production process of architecture. This importance is the opportunity to control at the maximum level (with *zero tolerance*) the whole process of building architecture to the point that it's finally possible to consider construction as an industrial process: a manufacturing process in which a key role is played not any more by the contractor but by the industry and by the designer.

Flexibility and integration: Converging Design

Another aspect emerging from these pioneering experiences was the flexible production.
Complexity and uniqueness of geometry didn't affect the production cost. Producing many different pieces was almost the same to repeat the same object many times. It was the effect of the so called «flexible production» driven by digital technology and CAD/CAM in particular.

But the most important aspect of the digital era affecting Design and more in particular the Industrial Design is that new technologies are now able to support a dynamic interplay between conception and realization. On this new and important aspect Branko Kolarevic wrote:

> What unites digital architects, designers, and thinkers is not to "blobify" all and everything, but the use of technology as an enabling apparatus that directly integrates conception and production in ways that are unprecedented since the medieval times of master builders. [2003 – B. Kolarevic, *Architecture in the Digital Age*]

As a flow of binary numbers, information began to connect directly the designer and the constructor preventing any misunderstanding.
But this interplay is covering many aspects of the construction

sector. As new standard, digital information is giving an unprecedented opportunity for all the building professionals involved in design, construction and management: from project programming to building demolition. It is a new language to share information and choices turning the project into an open process able of real-time generations and interactions between the endless options coming out from different disciplines and, therefore, able to produce a multi-goal optimized solution.

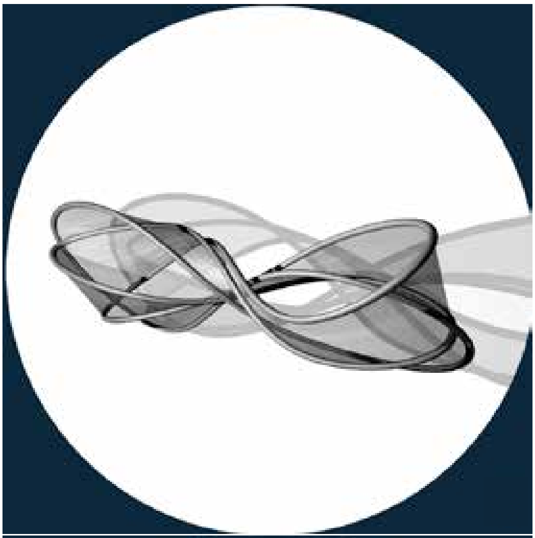
It is a new field of digital design that since the first definition in 1974 given by Charles Eastman (*Building Description System*) is now internationally recognized with the name of Building Information Modeling (Revit/Autodesk, 2003). Therefore, when we appreciate the continuity of the curve surfaces in the *Möebius House* (Un Studio, Ben Van Berkel and Caroline Bos, 1995) we have think that this continuity is only an exterior manifestation of the deeper continuity of the process that digital brings into architecture. Architectural digitally-based design represents a converging ontology able to reassign to the Greek word *αρχιτέκτων (architekton)*, its original meaning and capabilities: the leader of the construction.

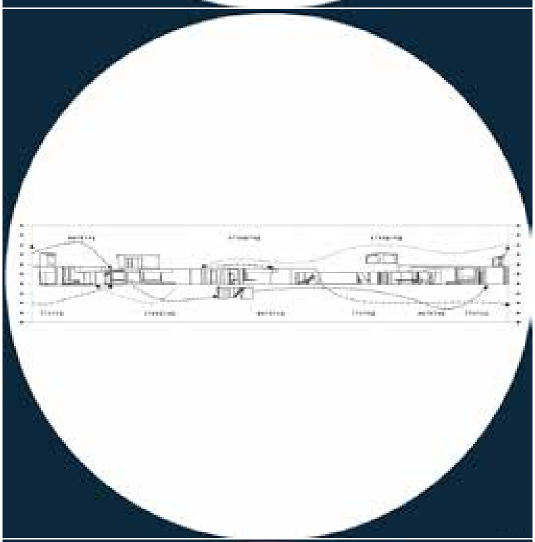
New language for new designers.

To conclude this brief analysis around the transformations around the transformations that have occurred in construction and design as a result of the advent of industrialization and more recently of CAD/CAM systems we can say that contemporary architects, acting as Industrial Designers, can no longer operate without considering new tools and technologies, or ignoring new languages and words such as : Computer Aided Design, Computer Aided Manufacturing, Computer Numerically Controlled, Building Information Modeling, associative design, parametric design, genetic algorithms, isomorphic surfaces, scripting and programming, rapid prototyping, topological transformations, non-Euclidean geometric space, kinetic and dynamic systems and so on.

Tools that, as with Prospettiva, do not just transform the practical and operational activities, but are intended to introduce, as already noted by Mc Lhuan, new meanings and transformations on the architectural forms that convey them; to irreversibly modification of all the all previous relationships between design and construction and – if possible – a new concept of the industrial designer in the shape of an unusual new craftsman. A new craftsman, that reusing Gropius's words.

> will result in a new unit of work, which will make him the exponent of experimentation to be applied in the industrial production. [1925 – W. Gropius, *der Grundsätze Bauhausproduktion*]





In 1993, a young couple commissioned the Dutch architect Ben van Berkel to design "a house that would be acknowledged as a reference for the renovation of the architectural language". It took the architect six years to fulfil his clients' wishes, creating a house based on the studies of a 19th-century German mathematician.
The scheme to convey these features was found in the Möbius band, a diagram studied by the astrologist and mathematician, August Ferdinand Möbius (1790-1868). By taking a rectangular strip of paper and marking its corners, A -superior- and B -inferior- in one side, and C -superior- and D -inferior- on the other, the Möbius band is constructed by twisting and joining corners A with D, and B with C. The result is a strip of twisted paper, joined to form a loop which produces a one-sided surface in a continuous curve. It is a figure-of-eight without left or right, beginning or end. By giving the Möbius band a spatial quality, the architect has designed a house that integrates the programme seamlessly, both in terms of circulation and structure. Movement through this concrete loop traces the pattern of one's day activities. Arranged over in three levels, the loop includes two studies (one on either side of the house for the respective professions), three bedrooms, a meeting room and kitchen, storage and living room and a greenhouse on the top, all intertwined during a complex voyage in time.
With its low and elongated outlines, the house provides a link between the different features of its surroundings. By stretching the building's form in an extreme way and through an extensive use of glass walls, the house is able to incorporate aspects of the landscape. From inside the house, it is as if the inhabitant is taking a walk in the countryside.
The perception of movement is reinforced by the changing positions of the two main materials used for the house, glass and concrete, which overlap each other and switch places. As the loop turns inside out, the exterior concrete shell becomes interior furniture - such as tables and stairs - and the glass facades turn into inside partition walls.
The contortions and twists in the house go beyond the mathematical diagram. They refer to a movement that has moulded a new way of life as a consequence of using electronic devices at work. Ben van Berkel has managed to give an additional meaning to the diagram of the Möbius band, where its new symbolic value - characterised by the blurred limits between working and living - corresponds to the clients' way of life.

http://storiesofhouses.blogspot.it/2006/09/mbius-house-in-amster-dam-by-ben-van.html

image references

cover: http://redfrontdoor.org/blog/wp-content/uploads/2014/07/synthetic-64QAM-constellation.png
pg: 4 author's illustration
pg: 6 http://4.bp.blogspot.com/_O2CKyGaaE3A/S6lrq3UJ8lI/AAAAAAAAABA/VRYOfS1rx9U/s400/Werkbund-Gropius-Bauhaus-32.jpg
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pg: 31 https://chefotografia.files.wordpress.com/2013/01/durer2.png?w=545&h=391
pg: 32 Mark Garcia, The Diagrams of architecture, Wiley & Sons, London,2010: pg 174
pg: 32 Ibidem: pg 51
pg: 32 Ibidem: pg 15
pg: 34 http://www.fa.vutbr.cz/home/uz/ateliery/0708/nyse.jpg
pg: 34 http://1.bp.blogspot.com/-0JVqk0_Cmi0/UHQ52hze--I/AAAAAAAAtzo/8bDNDU0kU4E/s1600/MVRDV_VIEW_MVRDV_MetaCityDataTown_01.jpg,
pg: 34 Mark Garcia, The Diagrams of architecture, Wiley & Sons, London,2010: pg 244
pg: 36 http://www.dexigner.com/news/image/22008/sfmoma_Fuller_Dymaxion_Car
pg: 36 http://www.barbarakrakowgallery.com/stuff/contentmgr/files/1/7e2359d731ab7a06e89b1275813e37f9/img_two/fuller_building_construction_dymaxion_deployment_unit_23304.jpg
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