The contribution of Tomas Maldonado to the scientific approach to design at the beginning of computational era

THE CASE OF THE HFG OF ULM

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ABSTRACT:
Nowadays the use of computational design processes in architecture is a common practice which is currently recovering a set of theories connected to computer science developed in the 60`s and 70`s. Back then, such pioneering experiences were carried out by an interest in employing scientific principles and methodologies in architectural design, which, with the help of computers, were developed in Research Centres mainly located in the USA and the UK. Looking into this period, this paper investigates the relevance of the German design school of the Hochschule für Gestaltung of Ulm to the birth of computation in architecture.

Even though there were no computers in the school, this paper argues that the innovative pedagogies introduced by a group of distinct professors built clear foundations that can be understood as being at the basis of further computational approaches in architecture.

This paper focuses on the remarkable work done by Tomas Maldonado. His contribution was paramount in the emergence of analogical ways of computer design thinking. This analysis ultimately wants to emphasize how the HfG Ulm's role and its scientific approach have paved the way for the onset of the computational era in architecture.

KEYWORDS:
HfG - Hochschule für Gestaltung Ulm; Educational Project; Semiotics; Operational Research; Computational Design; Architecture

1. The Scientific Approach to Design _The Case of the HfG of Ulm

Albert Einstein was born on March 14, 1879 in Ulm and decades later the city would remember this by associate the motto Ulmenses sun mathematici (people of Ulm are mathematical) to his famous countryman. Is it just a coincidence that one of the most fundamental schools of the XX century, the Hochschule für Gestaltung (HfG Ulm), was founded in Ulm and during its existence (1953-1968) it had three directors, the Swiss architect Max Bill, who had been on of Hannes Meyer´s students at the Bauhaus, the Argentinean painter Tomas Maldonado and the German philosopher Max Bense.

During the early sixties, the computer was only accessible to a few mathematicians and programmers, however it became object of a much wider theorization and influence. The calculus and mathematical logic inherent to the computer supported the emergence of areas including, Information Theory, Operational Research, as well as of Social Sciences and the Arts.

Later in some Research Centers pursuing investigation upon the advances of computing technology when applied to architecture and planning, such as the Land Use and Built Form Studies Center (LUBFS) at the University of Cambridge, UK, the Design Methods Movement at the Royal College of Art in London or the Architecture Machine Group at the MIT, USA, begins to be developed and applied some analytical and mathematical models to the process of design (Rocha. J, 2004). However, earlier, this motivation was also predominant at the Hochschule für Gestaltung in Germany.

Despite its short existence, it was considered one of the most important schools in the twentieth century. The HfG had no access to computer systems and was nevertheless of extreme importance in the history of the beginning of the computer era in architecture due to the work carried out by some of its faculty members. Their research led the foundations for a new theoretical approach in architecture and design: One that uses computer science not as a tool for geometric design but as a tool for computer design. On this realm Kenneth Frampton mentioned that computational thinking initially characterized by an analytic approach to methods design research, or data processing that characterizes the HfG and made it famous, opened the way in mid 60`s to heuristic proceedings related to the power of new computational methods.

This kind of pedagogy, informed by the information theory and by the scientific method emerged from Ulm, constituting a legacy of computational thought, carried out by the vanguard architecture in the 60s and 70s, with other type of means. In short, this paper traces the contribution of the HfG Ulm in the introduction of computation in architectural design that not much studied and not very known nowadays, describing one of the most visible conditions that gain relevance in HfG of Ulm: the Education Project coordinated by Tomas Maldonado which consisted on the confluence of Teaching of Fundamentals, Semiotics and Scientific Operationalism.

2. The HfG Ulm – Educational Project

The Hochschule für Gestaltung Ulm, in Germany was founded in 1953 and operated until 1968, lasting the transition from industrial society to post-industrial society. Despite its short existence during the Post-World War II period, the HfG Ulm project also rethought the role of social sciences based on a strong belief in reason. Belonging to an era of Nazi resistance, the founder promoted the idea that in a democratic society, "good design" should be accessible to all. In one of the few critical texts regarding the contribution of the HFG, Kenneth Frampton says: "There is little doubt that HfG has been the most significant school of design to come into existence since the end of WWII, not so much for what it achieved in terms of actual production, nor for the large number of designers it effectively educated, but finally for the extraordinary high level of critical consciousness that it managed to sustain in its daily work (...) The questions that the Hoschushule began to ask a decade ago are now being asked, consciously or unconsciously, by every design and architecture school, and the crisis of identity that befell the Hoschushule has now become a universal malaise." (Frampton 1974)

Recognizing the ideals of standardization and mass production, the teaching at the HfG of Ulm investigated a scientific approach integrating systemic and objective methods of collecting and processing data in order to inform of the design solution. It would synthesize science and design in a new scientific humanism that recognized the pluralism of methods and methodological perspectives needed by the designer in addressing the new problems of industrial culture. What did emerge however were the beginnings of an operational view of design science – what Maldonado sometimes called a "scientific operacionalism"- drawing on particular methods form many disciplines, gathered in an eclectic array. Nowhere was this question more focused among designers of "Utter devastation" yet with "unlimited curiosity" about all of the new disciplines of science and new ideas in the philosophy of science and mathematics. (Buchanan, 2009, p. 427) As Maldonado states, "The mainspring of all of our curiosity, our reading, and our theoretical work was our determination to find a solid methodological basis for the work of design". (Maldonado 1991: 222). In this way scientific knowledge and new methods could be applied in the search of design problems solution within a industrialized environment.

3. The contribution of Tomas Maldonado: Intentions and Influences

The ideology that emphasized the artistic dimension of the project, a legacy of Bauhaus carried out by Max Bill, the first director of HfG of Ulm, was opposed by a multidisciplinary scientific approach, and supported by the next director Tomás Maldonado. Maldonado was born in Buenos Aires and studied at the Academy of Fine Arts. Between 1943 and 1954, he actively participated in the Concrete Art movement in Argentina. He taught at the university of Hochschule für Gestaltung Ulm from 1955 to 1967 and was its Dean between 1964 and 1966. During this period he devoted himself to teaching industrial design and visual communication (semiotics). In this context his theoretical interests focused on the philosophy of science and technology. In 1957, succeeding Max Bill, Tomas Maldonado became the director of the University, and the orientation of design for science was consolidated. Bauhaus's perspectives seemed to have become obsolete as their assumptions were artistic and not scientific. A closer relationship with science and technology was valued, a productivity-functionality orientation was valued more than a more stylistic and formalist one.

In an interview for this investigation, Tomas Maldonado refered that "we were living in another time. There was the onset of a conflict in which young professors understood that it was no longer possible to continue with Bauhaus traditions, because Max Bill proposed the same exercises they did at Bauhaus, that is it was a near repetition of the same ideas. It was a difficult conflict to manage because there were Bill's ideological characteristics and ours, and the conflict grew worse with time, I am talking about 1955. For example, Bauhaus was known for not having a library, there was distrust for all that could be considered philosophical and scientific literary culture. This was of the first problems that young people would encounter in this library. Ulm began to be more oriented towards the theoretical part, but also with a strong tendency for the technological part, for design, but a very technological design. Let me remind you of Braun, technical elements, medicine, and appliances for pharmacists" (Maldonado, 2012)

In this second phase of this school, different subjects such as economics, sociology or mathematics, operational research, statistics, set theory, linear programming techniques, cybernetics and this subjects that deal with the history of science and the theory of machines, built a dynamic of analytical and evolutionary knowledge that determined emergence of the project. With a catalog of new subjects, and with the election of guest teachers, Maldonado made it possible for the students of Ulm to engage and participate in the scientific and theoretical philosophy of the time. The integration of the subject of Semiotics in the university's curriculum was an innovation in Europe, and is due to his initiative.

After a short stay in London, Laszlo Moholy Nagy a Hungarian painter and photographer goes to the USA and become the director of the New Bauhaus founded in Chicago He invited the scientists to give lessons and William Morris introduced in the course the principle of "Intellectual Integration", which was understood as the unification of the theories of arts, sciences, and technology under his theory of signs, based on assumptions that all human activities can be analyzed as "a certain type of sign structure." Although Morris taught this course in the early 1940's, his effort was recognized a decade later by HfG of Ulm. Influenced by the Unified Movement Science, the movement to which Charles W. Morris belonged, Tomas Maldonado chooses certain fundamental principles for a change in direction of HfG. His disciple, William Huff, described "It was a feverish, avid curiosity, which favored above all certain fields, which were emerging at that time: cybernetics, information theory, system theory, semiotics and ergonomics. But one must also mention other more established and not less important fields such as philosophy of science and mathematical logic." (Huff, 2009, p.110)

3.1 Teaching of Fundamentals

Anticipating the role of industrialized production methods, information theory, cybernetics, and computer theory, the HfG's essential didactic impulses came from the teaching of fundamentals: Visual Methodology, Means of Representation, Methodology, and finally Perceptual Understanding,(1) which introduced the main problems of perception. The newly established objective of the foundational course was the introduction of rigorous methods, showed mathematical equations and their translation became the focus of interest as the exercises given Tomas Maldonado. He wrote in 1963, "Albers took upon himself perhaps the most difficult task in the development of the Bauhaus preliminary course, which he solved brilliantly, that is he transformed the different and partly contradictory components (pedagogical activism, mystical expressionism, and exaggerated constructivism) into a systematic, coherent and operable subject of teaching". (Maldonado, Ulm no8/9, 1963). Maldonado reaffirmed Albers`s basic design model, as it has eventually been articulated – avoiding stresses on semantic issues, the materialization that takes place in the applied design process, as well as stresses on pragmatic issues, the appraisal of the usefulness of the product of design , while effectively dealing mainly with syntactic issues of design- shape, colour, and texture. However, he made a significant contribution to that model by supplementing the visual training component of the Basic Course with interdisciplinary content: that is with abstract fields of knowledge that can augment the granted formal issues of design. Maldonado stated that the Bauhaus didactics, particularly its preliminary course, "was a question of exaltation of expression, intuition, and action, above all of "learning by doing". As he said: "but this educational philosophy is in crisis. It is incapable of assimilating the new types of relations between theory and practice, engendered by the most recent scientific developments. We know now that theory must be impregnated with practice, practice with theory. It is impossible today to act without knowledge, or to know without doing."

Maldonado expanded that base with his lectures on symmetry and topology, and the studio assignments addressing those topics. The other interdisciplinary field of knowledge that Maldonado brought into play was perception, particularly Gestalt Psychology. He picked up on Gestalt and depth perception, as well, and presented both in a comprehensive manner, far more thoroughly than Albers did; and his directives for exercises that involved perception were more elaborate than his directives that addressed symmetry and topology. Maldonado pondered the problem of background, otherwise ground, as a problem of art concret was introduced to Gestalt Theory in 1946. His subsequent straight forward coverage of Gestalt at the HfG corresponded to his own remonstrance to "impregnate" Knowledge. In his HfG Basic Course, in lecture-form, Maldonado introduced non-visual fields of Knowledge, among which were ergonomics and semiotics. (Huff, 2009, p.110)

Maldonado affirmed in 1955: "The point of the basic course is to overcome the opposition between pure knowledge and habitual action. On basis of practical experiences and allied systematic investigations, the theoretical bases of new methods of design will be laid."(2) The changes became already apparent in the foundation course in 1955/56, as the new principles formulated by Maldonado were put into practice (figure1). In particular, Maldonado's course attempted to integrate mathematical knowledge into design, elaborating on early versions of fractals like the Sierpinski Triangle (figure 2), the Peano or Hilbert Curve, which articulated the tension between finite and infinite.

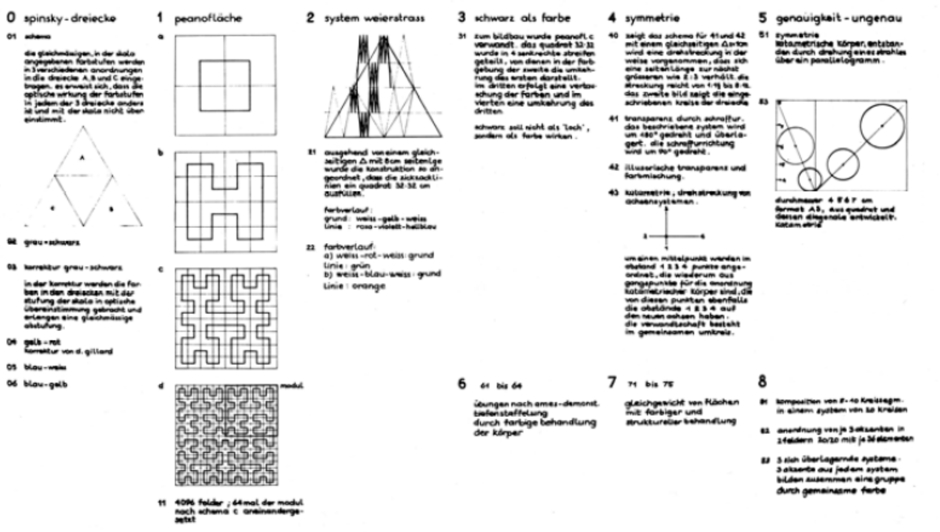


Figure1: Course assignment, Student: Klaus Franck, Professor: Tomás Maldonado, 1955–1956. source: Herbert Lindinger, ed., Hochschule für Gestaltung Ulm, Ulm Design: The Morality of Objects, transl. David Britt (Cambridge: MIT Press, 1990), 44.

Figure 2: Sequence of Sierpiński Triangle source

Maldonado's research at first explored the relations of parts to the whole and the whole to the parts, a discourse informed by Gestalt theory. Later, he reflected on the arrival of the digital and the digitalization of images. Many of the works produced at the HfG, and in particular, in the foundation course taught by Maldonado, were produced by systematizing the principle of points in a grid. (Figure 3) As he said for an interview specifically for this investigation: "My contribution was important due the formative disciplines such as cybernetics, information theory. The computer is emerging. There was no computer at that time. We did not know the computer right now. (…) In the first year, students were linked to fundamental course in elementary school, where I think the important question and contribution was how to fix and change the fundamental course at the Bauhaus to one that assimilated these new concerns (…) In the elementary course something very interesting happened. All exercises that were made had a very special character. Apparently they had some things still related with the Bauhaus, but they included one more thing. That was the idea of how through the behavior of elements could one create an image. The model was a grid of little dots with different diameters to produce an image. This very elementary idea allowed us to manually simulate what you would be able to do later with computers. The students were asked to make such images with incredible detail which was an immense difficulty. Here one can see clearly the intuition of what would become a computer use, but in our case it was a manual production... that was crazy". (Maldonado, 2012)

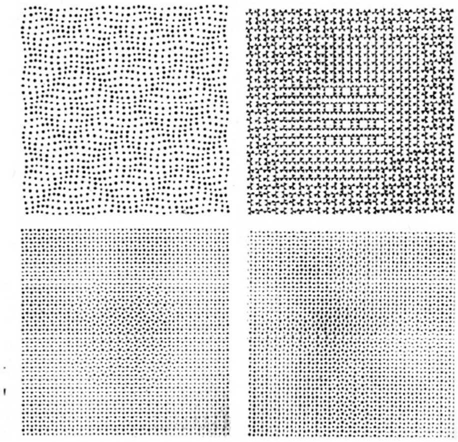


Figure3: Exercise "Raster, Square Lattice", Student: Gerald Weismann (1964)Charles First (1963) and Fred Watts (1963) Professor: Tomás Maldonado, 1955–1956. source: pag 31 Ulm no12/13, March 1965, p.12.

A powerful intuition, which is what the development of the computer and automation technologies subsequently confirmed, above all, after 1963. For Maldonado, there is no doubt, for example, that the idea of arriving at a sort of symbiosis between calculus and graphic representation in the resolution of problems, of which were many of us closely attached to during the 1950's, is at the basis of the currently expanding utilization of computer (Maldonado, 1991: 222). In fact Maldonado was not only developing his *Visuell Einffuhrung* (introductory visual training) but he was exploring diverse ideas that later shaped the curriculum of the school as a whole. By 1959, he had revived the HfG Journal Ulm, in which HfG ideas could be disseminated to a larger design community of academics and professionals, with the upshot that many of the HfG `s innovative curricular topics began to crop up all over.

3.2 Semiotics

One year after Maldonado coordinates HfG Ulm, he introduced semiotics in the curriculum. As he said: "Our interest, especially mine, was to understand what was happening in the world of information and communication. The first thing that caught our attention and struck me over the years was cybernetics. We were concerned not only with the semantic function. Today no longer speak in cybernetics. I was the first professor of semiotics in the world, the program HfG of Ulm, in which first appears a discipline called semiotics in design. Now everyone is talking about the semiotics of semiology etc. Then the concern was to link the process of computerization of communication with the program, not only as management signs, but signs and symbols" (Maldonado, 2012)

With his contribution to Semiotics in 1961, Maldonado published the definitions of 94 terms "Terminology Semiotics". These definitions were intended to be a series of analytical tools, enhancing the semiotic discourse for design. Subsequently Maldonado`s students added rhetorical concepts and applied them to the descriptively and widely to the visual phenomenon, materializing so that idealized Educational Project for HfG of Ulm. He explained that "The glossary was a result of the seminars on semiotics I coordinated from 1957 to 1960 in HfG-Ulm. The starting point for these interdisciplinary studies is the writings of Charles W. Morris. This outstanding representative of the U.S. scientific philosophy can be regarded as a founder of modern semiotics. He was one of the first to attempt to systematize semiotic philosophy. (Maldonado, 59/60) At the International Congress of Scientific Philosophy (Paris, 1935), C.W. Morris showed the need to establish a link between all disciplines interested in the problem of meaning. This work was carried out by semiotics, i.e. the theory of signs.

Maldonado and Gui Bonsiepe wrote articles for the Ulm Magazine and developed practical works, like the symbol system for electronic data processing machines, called Computer System ELEA 9003 (figure

4). This work consisted in the design for the alphabet of a new system of signs: approaches for the combination of theory and practice can be seen in the contract given out by Olivetti, the manufacturer of typewriters and computers, to develop a semiotic system. The task consisted of analysis of existing systems of signs, and the development of a new sign system for electronic data processing machines. The work included, the development of a non-grammatical sign system and it involved the development of a building block system of lamp holders, buttons, symbol carriers, and the structures that supported these components. “The design of the sign system: At first an inventory of signs, an alphabet was created. This contained the elements that could be combined to represent the various references. The alphabet consisted of two classes of signs: basic signs, comparable to the nouns in a language, and determinatives, like adjectives and verbs. The referents of the basic signs are the functional units of a system — that is, magnet strip, punch hole writer, disk memory. The referents of the determinatives are mostly states and processes carried out by the machines; that is, “ready,” “compare,” “functioning.” The square was used as the fundamental geometric form for the basic signs. They mostly have a planar character, while the determinatives are linear — between both sign classes there are syntactic and semantic relationships. The sign for “writing” is integrated into the sign for “punch tape writer.” The sign for “reading” is the reverse of “writing;” in order not to detract from recognizability”. (Ulm no8/9 1963 p. 20)

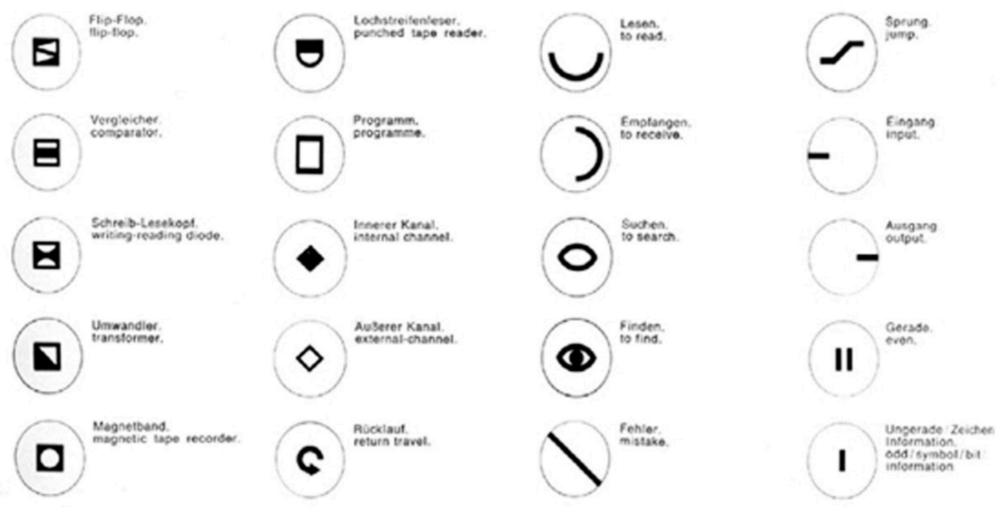


Figure 4: Computer System ELEA 9003, Design for the alphabet of a new system of signs: Design: Tomás Maldonado, Gui Bonsiepe for Olivetti S. p. A., Milan. Source: Ulm 8/9 (September 1963): 20–24, 22.

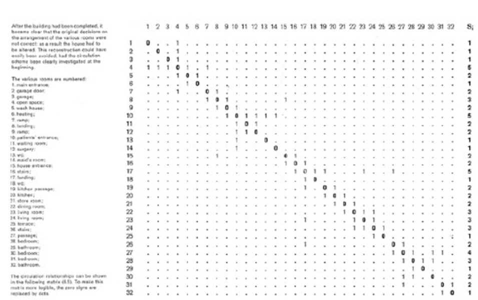
3.3 Operationalism Scientific

Maldonado was one of the first to recognize that the progressive aspects of the Bauhaus-oriented practical experience were opposite to the verbal emphasis of the humanist tradition. He clearly recognized that the rapid technical and economic developments presented new demands in teaching industrial design. The educational style of the Bauhaus became obsolete from this point of view, since the assumptions had been formulated around art and not science.

As stated in the text “Science and Design” in Ulm magazine, number 10 and 11, the method is a “method is the strategic dissemination of prudence”. Imagination is the dialectic counterpart of method – the rational application of define techniques within the inventive process”. In an interview above mentioned, Maldonado refers that in the late 50s and early 60s, the concern was the methods of drawing, because the methods of the Bauhaus were different and were much more intuitive, more artistic. He refers “We were interested in all the serious and rigorous methodology. Our methodology later became a sort of “methodolatry”, and it originated a series of problems. I realized that because I was on the board. There was a controversy between professors and students increasingly motivated by this matter of methodology. I observed this whole progression of the methodology, and I supported it. I had to react against this obsession towards the method. I realized that the process was becoming increasingly more abstract, because things were exaggerated, since one could not speak of things normally. However, evidently the more rational, and not exaggerated methodological contribution in its early stages, was influential because it made issues of method throughout the project more objective. It allowed for a confrontation between relationship and industry, providing a more objective mindset to face things, not simply design as a matter of taste." (Maldonado , 2012).

The distance from Bill's interpretation of Bauhaus pedagogy was most obvious in the teaching of the theoretical courses that were required to teach the new methodologies. These were based, on the one hand, on mathematical "operation analysis" and on the other hand, on the history of science. Originating in military efforts before and during World War II, operational analysis was defined as "a scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control." (Maldonado, 1964, p.11) Since then, the techniques of operational analysis were used to solve problems in a variety of industries. Being interdisciplinary, its problem-solving techniques and methods use tools such as statistics, optimization, probability theory, graph theory, decision analysis, mathematical modeling, and simulation.

Nevertheless, it was clear that there had to be another approach, a new philosophy of praxis. To this end, Maldonado proposed a scientific operationalism: "A new educational philosophy is already in preparation, its foundation is scientific operationalism. It is no longer a question of the names of things, nor of things alone: it is a question of knowledge, real knowledge". (Maldonado, 1958b, p.40). Maldonado refers to the philosophical system developed in the early '50s by Anatol Rapoport and published in 1953 under the title Operational Philosophy. Rapoport attempted to provide an accurate system for the evolution of alternative actions. In 1953, he wrote that "operational philosophy is focused on the objectives". Maldonado saw a solution in the introduction of a "scientific thinking operation" that propagated an objectivist-experimental methodology. He refers to the North American philosopher, Charles Sanders Peirce, one of the protagonists of the so-called pragmatism formulated in 1882, in the following: "This is the time and the methods that a university should be the exponent of the living conditions of the human." It was an opportunities of a new philosophy of education based on a scientific operationalism action, oriented towards overcoming the Dichotomy dividing theory and practice. In 1958, Maldonado referred: "The methodical aspect, which we are here speaking of, and which in our opinion is of special importance, has in the past not only been neglected, but even discredited. Today, this attitude is, it seems to us, no longer appropriate. The technologized world and industrial society are so difficult to comprehend that we cannot do without new methods of working. It is no longer possible to gather information without knowing and drawing near to such disciplines that make it possible for us to accumulate the maximum possible amount of information (…) Because of these facts we have become convinced of the necessity of building a new dimension into our teaching plan, which we can call the methodological dimension. Even now, the students are already introduced to the fundamental teachings of mathematical logic."(Maldonado, 1958, 218-19)



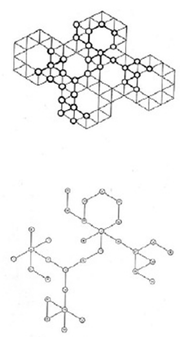


Figure 5 and 6: Anthony Fröshaug "Foundations of Visual Methodology." Source: Anthony Fröshaug, "Visuelle Methodik," ulm 4 (April 1959): 61–68.

In his foundational course, Fröschaug (4) used graphs for the representation and analysis of existing situations, highlighting their "operative character in their constructive use in solving problems." (figure 5 and 6) Graphs seemed to Fröshaug the suitable tool to present relationships, thus to realize the topological relations between spaces. Fröshaug hoped by "cataloging with graphs different design options to arrive at a complete overall view of the design possibilities and even a rough design." (Fröshaug 1959, p.61)
Fröshaug's design methods were rigorous and contribute in some way to a scientific methodology. To further enhance the scientific foundation, a number of specialists were invited by Maldonado to teach at the HfG.

An important example of this is Horst Rittel, the mathematician, physicist, and sociologist, who teach design methods, information theory, mathematical operation analysis, developing different ways of "scientification" of design or "design methods". Horst Rittel is main mentor of a notable point in HfG of Ulm that is the scientific methodology. In this school, all procedures of project and forms product were interrogated and had to be justified or, failing that, could be tried as arbitrary and less. Rittel served as a kind of funnel transferring knowledge (developed during and after World War II) of science and engineering to the design professions. In HfG of Ulm, Rittel taught courses in operations research and cybernetics. With a background in mathematics, physics, and sociology, Rittel introduces students and colleagues to a somewhat different perspective through teaching in methodology, theory of science, and operations research (figure 7 and 8). Indeed, Rittel explains that the genesis of his own approach to design methodology came when he tried, around 1960, to apply the new methods of design in the area of planning and found that they did yield satisfactory results. This led him to reconsider the foundations of design methodology. (Richard Buchanan, 2009, p. 428)

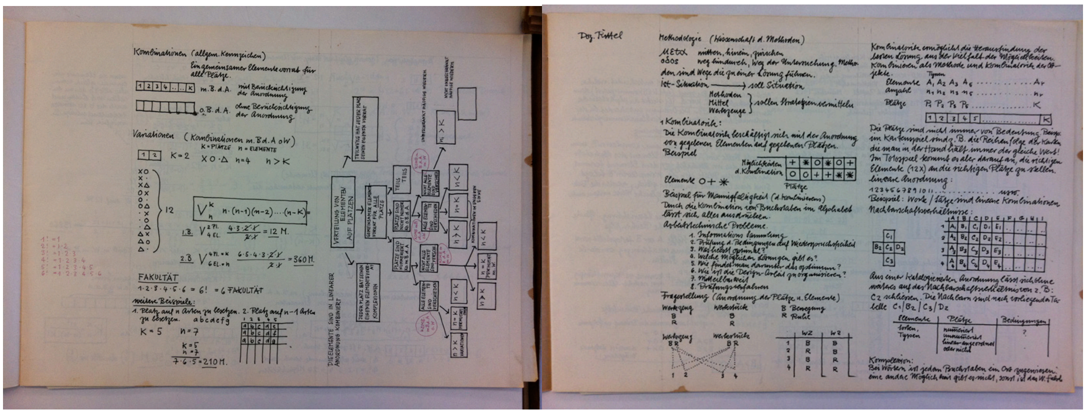


Figure 7 and 8: Discipline "Methodology" 1959, Professor Horst Rittel Source: Archive HfG, Ulm Personal photography, March 2012

4. Computing without Computers

In "Looking Back at Ulm," Tomás Maldonado also stated that Ulm had a pioneering vision on the design process, but they lacked a machine - the computer. He says, "But in the midst of our limitless faith in method (...) there lay some powerful intuitions that the evolution of information technology, especially since 1963, has to a large extent confirmed." (Maldonado, 1991 p. 222) Prior to the use of computers in HfG, a kind of "computing without computers" was already taking place, and this factor constitutes a theoretical and practical contribution carried out by some of the main figures of the HfG of Ulm, such as Tomás Maldonado. The few who had access to computer systems at universities and companies in the 1960s shared their knowledge in writing or in lectures organized by Tomas Maldonado. So through these exhibitions and interferences, computer technology also found its way in the HfG. While HfG felt the implicit impact of new computer technology through the diffusion of general concepts connected to hardware, those were not fully recognized and studied in depth by critics and theorists.

"Computing without computers" as much as "computing with computers" led to an increased use of models and simulations in architecture. At first, this process implied a transfer from the sciences and other engineering disciplines into architecture. Architecture's tendency towards model was the reason why operation research and semiotic models were so well accepted in places like the Hochschule für Gestaltung in Ulm, despite their abstract character. Paraphrasing Ingrid Rocker, "Computing without computers allowed for the conceptualization of the computer, while computing with computers transposed the traditional modes of operation and thinking into a new medium. It was computing without computers, analyzed in this paper through the School of Ulm, that had led to a radical shift in the understanding of subject and object that had led to a radical rethinking of the production of form". (Rocker, 2010: p. xxvii)

Maldonado teaching promoted a different approach to the design process. Instead of focusing on the design and development of specific and finite forms, students sought to exploit the definition of geometric design rules to control the generation of form(s). Thus, by reflecting a scientific methodology, the design practice starts to embrace the concept of systems, where sets of interdependent information are structured to control the generation of design solutions. The exercises about geometric patterns are some clear examples where this system-based approach is evident. In them, one can see how students think about a set of variation rules for a given geometric module and, from then, conceive geometric patterns where the module is no more a fixed and repetitive entity but, instead, is an element that varies geometrically in each instance. Although these constructions are hand drawn, they already reflect a mode of computational design thinking, similar to the parametric design approaches of contemporary architecture. Expanding the manual possibilities, the computer can extend the idea of design systems to a greater level of flexibility and complexity. On the one hand, by digitally programming the rule-based design system, the designer can generate, view, evaluate and change his ideas in real time and thus refine the quality the solutions. On the other hand, the calculation power of the computer allows handling more complex design algorithms, which would be very difficult to be conceived and implemented only by mental and manual design processes.

5. Conclusion

It may be concluded that the HfG Ulm was also somehow paradoxical, seeing that at first it reinforced functionalism, and in a second phase it contributed, even if unconsciously, to the collapse of functionalism. The School asserted itself in the development of a new approach to architectural design, which was based on the sequential use of the operations of transformation, such as duplication, rotation, scale and skew. It is therefore thought that a new understanding of design which we call "informational systems" was developed from the HfG Ulm and subsequently had a high influence on the movement of the 1960s, the so-called "computational architecture". The "informational systems" were a scientific approach based on methods of research design of information processing, powered by an aesthetic interest. It was not a mere interest in the appearance/look of the object, but a new, syntactic, anti-semantic aesthetic where there are only relations and forms, not meaning. There was an interest in an underlying structure that math tried to capture, thus we defend that it was in Ulm where the theoretical basis by which computing models operate were formed.

We review these most radical educational experiences of the '60s and '70s, of which the example of HfG Ulm is relevant, remembering what can happen when pedagogy takes risks. The HfG Ulm took real risks in relation to pedagogy in force at the time, most of them forwarded by Tomas Maldonado. The school used philosophy, sociology and mathematics to advance the ideology of functionalist design inherited from the Bauhaus, as an attempt to negotiate technological innovation with a desire for democratization of postwar Germany. It was a rich period in the foundation of beauty and aesthetic concerns issues supported by information processing. In short, this type of pedagogy, informed by information theory and by Ulm scientific method, constitutes a legacy of computational thinking, conducted by the avant-garde architecture during the 60s and 70s, with other means, generalized and extended by modern architecture.

Endnotes

(1) Visual Methodology taught perception, symmetry, and topology in two- and three-dimensional experiments; Means of Representation taught drafting and sketching as well as exercises in writing and language; Methodology gave an introduction to mathematical logic, combinatorics, and topology; as well as the sociology and cultural history of the 20th century, which analyzed the influence of the Industrial Revolution on society as well as its means of production;Perceptual Understanding introduced the main problems of perception.
(2) Tomás Maldonado, "Principles of the Basic Course 1955," HfG Archive, Ulm.
(3) In 1938, C.W. Morris published the article "Foundations of the theory of signs" and, in 1946, the book "Signs, Language and Behavior". Morris was very criticized because of his work, and he answered critics by stating "terminology is not a science." Terminology is just a tool that can be used scientifically. Semiotics, and not his terminology, tends to become a science. However, as Morris says, it can only become a science by the contribution of "many experts in many different fields for many generations" (Maldonado, Uppercase 5)
(4) Anthony Froshaug (1920–84) was an English typographer and teacher. He taught typography, first at the Central School, then at the HfG Ulm, the Royal College of Art in London, Watford School of Art.

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