Transdisciplinarity in Architecture as a Digital Change: Back to the Future

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This paper outlines a historic perspective of transdisciplinarity in digital architecture through the work of several key figures (architects, computer scientists, mathematicians, engineers and artists) from the 20th century. Transdisciplinary Digital Architecture deals with digital means and science. The research methodology adopted in this study allows analyzing historic documentation available on the Internet (text, audio, picture, video) to establish the links between them and their relevance to present time digital architecture. This paper aims to describe the first preliminary results of the research to establish a new theory of the digital in architecture based on a body of theoretical foundations that link "first age" transdisciplinarity to Bauhaus teaching methods, and to the early use of computers in architecture.

Introduction

> The objective of the Computer-Aided Design Project is to evolve a man-machine system which will permit the human designer and the computer to work together on creative design problems (Coons and Mann, 1960: iii).

The emerging field of digital design theory takes digital architectural design research to different meanings in the context of different design practices, theories and methods. Digital in architecture has become a more dominant subject in architectural theoretical writings. Digital architectural design emerges as a holistic integrated process from conceptualization to materialization to fabrication. Digital in architecture has begun to foster a new set of methods to promote new theories and practices.

Transdisciplinary architecture can be considered a new approach in architecture but transdisciplinarity itself is a relatively new concept, less than fifty years old (Nicolescu, 2006). It was used for the first time in an Organization for Economic Co-operation and Development (oecd) congress by Jean Piaget (1972) and two other speakers. It is also possible to consider transdisciplinary architecture as a new way of teaching, researching and practicing. Architectural researchers like Mark Burry, Carole Després, Roderick Lawrence Isabelle Doucet and Nel Janssens have given important contributions to the concept of transdisciplinary architecture. That transdisciplinary architecture can be briefly described as an architecture of a hybrid nature redefined by other disciplines to target complex problems (Burry, 2012; Lawrence & Després, 2004).

However, what was the path to what architecture is today? To answer this question, it is necessary to explore outside the fields of design and architecture, focusing on the important developments in electronics and computation that made it possible for architects to deal with digital means and science. Over the last two decades, there were important works of authors from academia that started writing about digital architecture history with different perspectives on the way that digital technologies changed architectural theory (Rocha, 2004; Picon, 2010; Llach, 2015). Nevertheless, these PhD dissertations and books were not focused on producing a historical perspective of transdisciplinarity in digital architecture.

Therefore, this paper introduces a new perspective by focusing on the question of the beginning of transdisciplinarity in digital architecture relating key figures of the process. It pays particular attention to the role of transdisciplinarity as a way of thinking, of teaching and as a research methodology with a great influence on current architectural practice and namely on architectural design.

Additionally, it suggests that it is possible to trace the evolution of transdisciplinary architecture from Bauhaus to Sketchpad and from there to the pioneering work of digital architecture's beginnings, focusing on relationships and interactions between people, places, and institutions in a five-decade period, using mainly historiography, aided by computational methods.

This paper considers it essential to outline a transdisciplinary vision of digital architecture by linking key people in five groups: (1) Bauhaus teachers—Walter Gropius and László Moholy-Nagy; (2) Second generation Bauhaus—friends and colleagues of Bauhaus teachers—Serge Chermayeff, György Kepes and Leslie Martin; (3) Design theorists and contributors to architectural design research—Steven Coons and Herbert Simon; (4) Interactive CAD inventor—Ivan Sutherland; and (5) Pioneers of digital architecture—Lionel March, Christopher Alexander, Nicholas Negroponte, William Mitchell and Charles Eastman.

Besides their importance to transdisciplinary digital architecture, all the personalities have in common the fact that they were teachers and researchers, not all architects but almost all educators and advisors to next generations of architects (Fig. 1).

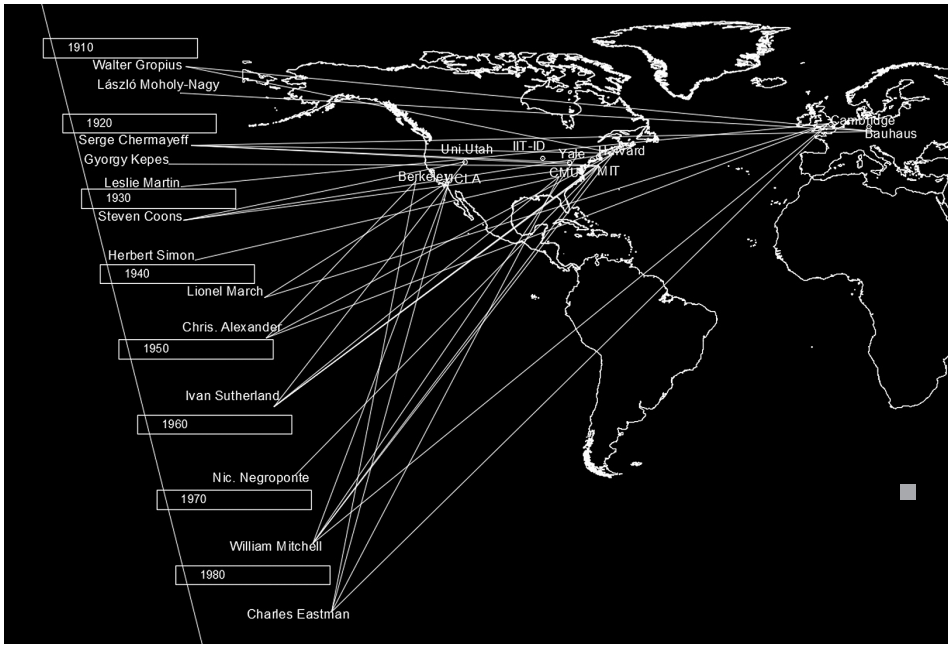

Fig. 1 *Transdisciplinary digital architecture.* From the author.

The adopted methodology is grounded on archival and oral historical research. The criteria for selecting data is its relevance to transdisciplinary digital architecture history and the connections between personalities involved, aiming to help the understanding of the historical process. The aim is to establish a theory of the digital in architecture and to identify how these theoretical foundations could be related to the issue of whether there are emerging distinctive architectural characteristics that might constitute a transdisciplinary digital architecture.

Transdisciplinary Digital Architecture in a historical perspective: from science in architecture to computer science in architecture. This paper considers the idea that to describe the digital technology background in architectural design it is necessary to study the association of science and architecture. Throughout history, the association of architecture with science and technology has helped to develop new tools that originated new representation methods.

Going further back in time, in the Renaissance, this relationship between science and architecture became very clear (Picon, 2010). Nowadays, several authors consider the possibility that digital design had its origins in Leon Battista Alberti's treatises and on the geometrical demonstrations about perspectives made a few decades before by the architect of Florence's Duomo, Filippo Brunelleschi. Mitchell (2008) goes even further on this idea, considering that Alberti was doing computerized design more than five hundred years before the computer was invented.

The historical perspective of this research also gives prominence to the antecedents of the digital change, made by the representation of an architectural idea with a growing relation between science and architecture, with beginnings in academic circles. It explores the connection between a first generation of architecture teachers, who used science as a learning method, and a second generation of followers, the first practitioners of digital architectural design, protagonists of an era in architectural research that Keller (2005) called "The Scientific Sixties".

Focusing on the early sixties and on the key figures it is possible to relate both the first interactive CAD and the contemporaneous use of non-interactive computation in architectural research, as well as the extension of interactive CAD to architecture, a few years after, in the late sixties.

In a historical perspective of transdisciplinary architecture, the importance of the first interactive CAD to architecture is vast. However, it is possible to draw a timeline that begins on January 7th, 1963 when the interactive CAD inventor Ivan Sutherland submits his PhD dissertation *Sketchpad: a man-machine graphical communication system* at MIT, even considering that there was a movie to promote a first version of the *Sketchpad* software, almost a year earlier (Sutherland, 1963). *Sketchpad* was developed in a bit more than two years by a researcher, in his early twenties at MIT, creating a tool that gave a man the possibility of interacting with a computer through a light-pen. A software that used a computer screen to design. Although an almost uncontested inception point, it is not completely solid because *Sketchpad* was associated with people and knowhow from MIT's Project CAD, research which had started around a year before Sutherland's PhD. From this moment on, architecture interacts with other scientific areas more oriented to technological research. Then, the first signs of that interaction emerge with the search for a link between the human creative capacity and the automation of processes. It is important to describe the backgrounds of interactive digital design

through academic circles, the linking of science with architectural design. *Design Methods Movement*, usually described as the outcome of work of Bruce Archer, John Chris Jones, Christopher Alexander and Horst Rittel, introduced scientific thinking of cybernetic, biological and linguistic natures into architectural design. The conceptual process becomes scientific and the construction of knowledge in the field of architecture arises from the articulation between science and computing (Krüger, 1986).

Nevertheless, it is possible to establish an inception point in transdisciplinary architecture if we go back to the beginning of the association of technology, science and architecture at Bauhaus. If we have a look at Gropius and Moholy-Nagy's teaching we can consider that architectural design stepped out of the pure fine arts field. The school is associated with a machine based learning. Bauhaus school's curriculum, mainly after Moholy-Nagy's arrival in 1923, contemplated not only technology but also science (Findeli, 2001). This association of technology and science can be related to the transdisciplinary architecture idea, even considering that is a long shot trying to relate Bauhaus and digital computers, because we are talking about times when an electronic artistic interaction could only be made through phone, like Moholy-Nagy did with EM1, EM2, and EM3, better known as Telephone Pictures (Moholy-Nagy, 1929). Nevertheless, it is possible to relate Bauhaus architecture teaching and science. The architecture of Bauhaus marked a change of attitude towards science, to the point that the architects of the Bauhaus were treated by their contemporaries as scientific architects. Another important idea is related to the fact that the designers of Bauhaus observed science as a vehicle for the development of drawing (Anker, 2005).

In the late thirties Moholy-Nagy founded the *New Bauhaus* in Chicago. This school's curriculum had even more science than the original Bauhaus, also including social sciences. He later directed two other design schools in Chicago, the *School of Design* and the *Institute of Design*, where he developed a pedagogical method in which students designed, in collaboration with art, science and technology (Findeli, 2001).

But before Moholy-Nagy went to Chicago and Gropius to Harvard, there was a period of a couple of years when some of the Bauhaus faculty lived and worked in the UK. In that period in Great Britain, they took part in a British avant-garde movement that promoted a culture of scientific research that was extended to architecture. The Second World War planning effort also made it possible for architects to work together with other scientists. And those emigrated architects would carry those ideas when they emigrated again, this time to the US, right before the start of World War II. This allowed those transdisciplinary ideas to flourish on both sides of the Atlantic (Rocha, 2004).

Serge Chermayeff, Gyorgy Kepes, Josef Albers and Marcel Breuer and Herbert Bayer were also exploring these transdisciplinary ideas. With the concepts brought by the Bauhaus faculty and their disciples and friends, it was easier to use science and specially mathematics in architecture. This "Second generation Bauhaus", Serge Chermayeff and Gyorgy Kepes in the US, and also Leslie Martin, in the UK, justify particular attention, especially for the role they would play as teachers and advisors of the digital architectural design pioneers of the sixties (Rocha, 2004; Steenson 2017).

After the death of Moholy-Nagy in 1946, Gropius suggested Chermayeff to replace the Hungarian artist and educator as the Director of the Chicago Institute of Design, a place he occupied until 1951. He then went to Massachusetts, one year at the MIT and then to Harvard where he helped to establish the teaching of the Environmental Design Seminar (Chermayeff, 1985). But more important for transdisciplinary digital architecture was the fact that less than 10 years after Chermayeff left the Institute of Design, he was doing research with Christopher Alexander at the "The Urban Family House Project", developed at the Joint Center for Urban Studies of MIT and Harvard. Chermayeff was also Alexander's advisor in his PhD dissertation. The project conclusions were edited, after the PhD conclusion, in an important book of architectural design, jointly authored by Alexander and Chermayeff (1963), called *Community and Privacy*.

Christopher Alexander's PhD dissertation, *The Synthesis of Form: Some Notes on a Theory*, was a groundbreaking work because it was, in the early sixties, one of the first architectural researches that applied mathematics to urban modeling. The dissertation would be known for posterity by the name of its literary edition, *Notes on the Synthesis of Form*. He was using computers but not yet on an interactive drawing basis. Alexander, besides being an architect, was a University of Cambridge trained mathematician and developed a systematic approach jointly using mathematics, design and computation. That gave Alexander the ability of being one of the few architects in the early sixties capable of using and programming a computer (Alexander, 1971; Keller, 2005). It also is important to mention that Alexander's period at University of Cambridge, after studying mathematics, coincided with a time when the Department of Architecture was led by the British friend of the Bauhaus teachers Leslie Martin (Steenson, 2017).

In the early sixties, Alexander was modeling urban problems through computation at Harvard, a few kilometers away from the place where Sutherland was improving his *Sketchpad*. But it is important to distinguish that Alexander in his research, such as *Notes on the Synthesis of Form*, "HIDECS (Hierarchical Decomposition of Systems)" or "A city is not a tree", was using computers on a non-interactive basis, programming a com-

puter to design through punched cards and tapes while Sutherland was contributing to architectural design through a new representation method that went through designing directly on a screen in an interactive manner (Steenson, 2017).

Alexander made very important contributions to architectural design through systematization of design processes through a non-interactive computer while Sutherland literally invented a new tool. But Sutherland was an engineer and invented a computer-aided design to be used by mechanical and electrical designers and engineers. Yet, although *Sketchpad* had independent funding it used the ideas of the MIT's military backed research Project CAD of using the new design machine for other kinds of design (Coons and Mann, 1960; Llach, 2015).

The MIT mechanical engineering design teacher Steven Coons was the important design theorist and contributor to architectural design research—Project CAD. Sutherland did not conceive *Sketchpad* for architects but soon after he left MIT for a short military career. Coons became *Sketchpad*'s main advocate and promoted it to creative designers. He even starred in a National Educational Television documentary (NET – PBS ancestor), in 1964, to spread the word of *Sketchpad*. Coons talked about the level of interactivity reached by *Sketchpad* in a very eloquent way, claiming that with *Sketchpad* a man could talk to a computer, taking a few moments to explain that was a graphical dialogue made through design (Llach, 2015; Morash, 1964).

By the end of that year, Coons made a presentation of *Sketchpad* at a congress of architecture called "Architecture and the Computer", one of the first to debate computation in architecture. He was the *Sketchpad* presenter on a day, December 5th, 1964, when two key figures of 20th century architecture, Christopher Alexander and Walter Gropius were also speakers. Coons' presentation was named after the ideas of the project he helped to develop, "Computer-Aided Design", and one more time he accentuated the importance of the architect / computer symbiosis through design interactivity. Alexander, who was a non-interactive computer user, saw CAD as a substitute for clerk work but his advisor Chermayeff, who was the keynote speaker, argued that computers could save time that might be used in creative work and could also give the architectural designer more drawing alternatives (Rocha, 2004).

In 1967, Coons chose as a substitute, to teach CAD design to mechanical engineers, the young architect he taught in a master's thesis. Nicholas Negroponte took the idea of mixing architecture and science a step further by establishing the *Architecture Machine Group* (AMG) the following year, one of the first research centers to be dedicated to architectural computer research. At the AMG, Negroponte associated science to architectural research and namely interactive CAD to architecture with projects like URBAN 2, URBAN 5, SEEK and HUNCH. All of them with military funding to study interactivity in architecture. That research would originate two important books in digital architectural design research in the seventies: *The Architecture Machine* (1970) and *Soft Architecture Machines* (1975). The last one with a chapter called *Computer Graphics* with an introduction by Coons (Rocha, 2004; Steenson, 2017).

Also important were the contributions from other key figures in the second half of the sixties. Lionel March was Alexander's colleague from Cambridge, also a mathematician and a pioneer of digital architecture, who went with him to the United States but returned to the UK to work with his former teacher Leslie Martin on the Whitehall Plan research (March, 2000; Sharr and Thornton, 2013). Together, they used quantitative ideas in land use planning and computers to study urban shapes, in a research center they established called Land Use and Built Form Studies at Cambridge (Rocha, 2004; Keller, 2005). Herbert Simon (1969) was not an architect but his book *The Sciences Of The Artificial* contained a chapter concerning research in design, "The Science of Design", that was very important to design research in architecture. Charles Eastman, who was both Simon and Alexander's disciple, himself a pioneer of digital architecture, made important progress in architectural design research using protocol analysis, a method from cognitive psychology (Eastman, 1969).

This paper goes through transdisciplinary digital architecture's origins aiming to make the link between the Bauhaus ideas to both non-interactive and interactive use of computation in architecture in the sixties.

Both Alexander and Sutherland are very important to establish an historical perspective of transdisciplinary digital architecture but are also great influences on the generations of IT programmers that follow. The influence of Alexander on digital architecture was direct when he started using digital non-interactive computers in design, while Sutherland exercised an indirect influence by developing the tool. It was Coons who had the vision of interactive parametric CAD being used by architects and had an advisee architect who could use it in architectural research (Steenson, 2017).

Negroponte, like Alexander, had an advisor that came from the Bauhaus lineage, Gyorgy Kepes, a visual artist that taught at Chicago's New Bauhaus and that can explain his use of science and art in transdisciplinary digital architectural research. Negroponte and Alexander, like March, Eastman and

Mitchell, are amongst a first generation of digital architects that had teachers and advisors that can be connected to the Bauhaus and to the tradition of architecture and science.

Preliminary results and discussion

This paper is part of ongoing research whose purpose is to gather relevant information in the matter of the connections between people, places, and institutions comprising a fifty-year period to make an historical perspective of the transdisciplinary change in architecture as an important step to a digital change. A change that started with a first generation of transdisciplinarity teachers with the Bauhaus research and learning methods to the teachers of the pioneers of digital architecture in the sixties.

This paper presents some preliminary results suggesting that is possible to link the use of science and technology in architectural design teaching in schools like Bauhaus and New Bauhaus / School of Design / Institute of Design to the groundbreaking use of computation in architecture, in schools like MIT and Harvard that led to changes in architectural research, teaching and practice methods.

This paper suggests a new theory for digital architecture based on the relations between the Bauhaus lineage of teachers and some of the pioneers of digital architecture, as well as how it is possible to relate those pioneers with the main figures responsible for the creation of interactive CAD. The use of science in architectural research before digital computation can thus be linked to the use of computer science in architecture. It is possible to link Bauhaus ideas of art, architecture, technology and science to both non-interactive and interactive use of computation in architectural research in the sixties through the pioneering work of personalities that have links between them.

In a certain way we are going back to the future because nowadays digital architectural design can possibly be more easily related to Project CAD ideas of a human designer working together with the computer on creative design problems than with an eighties or nineties CAD where the screen almost mimicked the paper sheet.

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