Cybernetic Architecture Peculiarities

The lesser-known side of early digital Architecture Augmentation and a story of its failure.

Author: Jan Zawadzki

Main tutor: John Hanna

Many thanks to: Prof. dr. Georg Vrachliotis

Delft University of Technology

AR2A011 Architectural History

April 2024

Table of Contents

Abstract

This article explores stories of the first digital tools in architectural design, with a focus on the Cybernetics movement of the 1950s and 1960s. Through an examination of pioneering technologies, their initial promises, and the subsequent reasons for their failure or abandonment, the text aims to shed light on the historical development of digital tools in architecture and design. By questioning prevailing definitions of success and failure within the context of architecture technology history, the study encourages critical reflections on alternative paths that may have shaped current digital toolsets. Additionally, the analysis includes an exploration of the sentiments of professionals, users, and the broader public during this transformative period, revealing the significant influence of community voices on the trajectory of digital architectural toolkits. Drawing upon extensive literature reviews, archival document analysis, and case studies including the “Lightpen”, “Sketchpad”, or the “Lincoln Wand”, this article contributes to filling the gaps in existing knowledge regarding the lesser known, often peculiar from modern perspective, cybernetic tools in the context of architectural design.

Keywords

Architecture, Design, Digital Design Tools, Computer Aided Design, Augmentation, Cybernetics, Virtual Reality, Lightpen, Head Mounted Display, AI Winter

Introduction

Alan Turing's visionary concept of universal computing machines (nicknamed Turing machines) laid the foundation for what we now know as, simply, computers, which have become indispensable in modern civilization.[1] These machines have revolutionized various industries, including architecture and design, where they facilitate tasks ranging from Computer-Aided Design (CAD) to rendering, simulations, optimization, and project management tools like Building Information Modelling (BIM). However, the journey from Turing's and other’s groundbreaking ideas to widespread computer usage was not immediate. There was a gap characterized by a fascinating era, today known as Cybernetics, which lasted until the onset of the first AI winter in the early 1970s. During this time, there emerged a plethora of novel concepts, theories, and experimental projects that left a rich legacy worthy of exploration.

The text investigates how the digital transition in architectural design started. It focuses on what were the first ideas in the field, the hopes of the first developers, users, and designers on how the first digital tools would look like and what promises they offered in the future. Special attention is put on the peculiarities of that time, experiments and projects that were characterized by bold thinking reaching far into the future.

In the wake of World War II, the computational revolution gained momentum, ushering in a hopeful and dynamic period of digital development known as "Cybernetics." During the 1950s and 1960s, new theories, ideas, and algorithms, including Artificial Intelligence, emerged, shaping our world, and enabling previously inconceivable changes across society and industries. The zeitgeist of that era

[1] Alan Mathison Turing, “On Computable Numbers, with an Application to the Entscheidungsproblem” (Princeton University, 1936).

did not omit architecture and design fields, and the first experiments on integrating computers into workflows surfaced shortly after the hardware foundations became available.[2] Architects and designers eagerly embraced the potential of digital tools, envisioning a future slightly different from the standard keyboard and mouse interface we are so used to nowadays. From novel machines to peculiar experiments, they explored diverse avenues, yet most of these early endeavours were abandoned just before the universal computer emerged as the dominant tool. They were forgotten, along with their stories and reasons for their failure. Whether they in fact "failed", and what it means in the context of technological tools, is the question to be lingered on while exploring their tales. The legacy of the Cybernetics movement suggests that architects and designers, perhaps discouraged or romantically conservative about their profession, may have overlooked opportunities for tools that are now sought after.

This text examines the origins of digital tools in architectural design, focusing on the pre-1970s Cybernetics movement and its impact on present-day instruments or software. By exploring the visions of early developers, users, and designers, we uncover unique insights into the first ideas and promises held for digital tools tailored for architecture and design. The text places particular emphasis on experiments and projects unusual from our common modern perspective, i.e. "the peculiars", reflecting ambitious aspirations stretching towards a technologically advanced future.

Moreover, the text delves into the stories and reasons behind the failure, abandonment, or lack of progression in those certain inventions. Questions surrounding definitions of success and failure within architecture technology history arise, prompting reflection on whether alternative paths may have emerged given varied outcomes. Would it be different from a standard setup of a screen, keyboard, and mouse? The methodological basis in that context is explored in the next section of this text. Furthermore, analysing the sentiments of professionals, users, and the broader public provides valuable perspectives on the influence exerted by community voices over the trajectory of digital architectural toolkits. Ultimately, the narrative seeks to illuminate the tales of these tools, encourage thoughtful consideration of what constitutes success or failure in their historical context, and prompt reflection on the architecture and design field's will for customised digital augmentation toolset.

Two areas of research and writing relate to the cybernetic era's failed tools. One is considering said tools and period, however touching only briefly on their story and possible reasons of failure, while focusing on some other main research topic. Jacek Markusiewicz, a Polish architect and academic, in his PhD thesis[3] collects a substantial number of cybernetic era tools, however, the goal of his research was to qualitatively categorize all possible tools and interfaces focusing on future development of the toolset in the field. Similarly, Molly Steenson, an American professor of design and a historian of architecture and technology, explores the history of architecture toolset and computational thought but focuses on the notion of intelligence and does not delve deeply into peculiar cybernetic tools and reasons for their demise.[4] The writing of Ludger Hovestadt, Urs Hirschberg, and Oliver Fritz covers extensively the topic of digital tools used or sporting potential in architectural design,

[2] Mollie Claypool, "The Digital in Architecture: Then, Now and In the Future," SPACE10: Copenhagen, Denmark. , November 18, 2019, https://space10.com/project/digital-in-architecture/.

[3] Jacek Markusiewicz, "The Importance of Interactivity for Contemporary CAAD Tools," 2023.
[4] Molly Wright Steenson, "ARCHITECTURAL INTELLIGENCE: How Designers and Architects Created the Digital Landscape.," 2022.

serving as a great source for this research touching a little bit on economic reasons on why some developments might have been startled. [5] However, it does not cover much about the sentiment of people and practitioners of those times about said tools. Almost identical work was done by Yehuda E. Kalay, a Professor of Architecture at the University of California, Berkeley. He additionally explores deeply how computer evolution enabled needed developments for designers and architects.[6]

The other way of conveying history related to this research topic is writing about the cybernetic period, or soon after, however, focusing on the general ideas and methodology or specific concepts within architectural computational thought. Georg Vrachliotis, currently a Professor Theory of Architecture and Digital Culture at the Department of Architecture at TU Delft, in his book mentions a couple of the most famous examples of early cybernetic tools, however, his book focuses on cybernetic movement in general and does not go in-depth into any tool history. [7] John Frazer, a renowned British architectural academic, writes similarly, focusing on the main topic of his research which is how architecture and design itself can evolve, however, he touches only just briefly on the cybernetic movement tool developments. [8]

There is scarce information in a collated form on the topic of cybernetic tools in the context of architectural design in general, especially the ones that did not succeed in being widely used or developed. Despite having some potential in the field of design and architecture, many examples of those tools were developed further in other disciplines, fostering their use there. This results in a situation where some literature about them can be found in different fields, but a connection between them and architecture or design is rare. Even if there is literature about said cybernetic inventions in general, it is difficult to find information on why they were not developed further. They are being reported as interesting examples that had their time of shine for a brief moment, without much more deep investigation into their slow demise, why and what new technology they yielded to.

There is no example of writing that would collect those peculiar cybernetic tools and interfaces, tell their story concerning their potential for architectural design, why they failed, and what happened that architects went for personal computers forgetting about those more tailored, more physical tools for their discipline.

This text tries to close the beforementioned gap. It is a piece of history writing, more specifically a so-called “archaeology” of cases and socio-economic phenomena within architecture and design fields. It delves into stories of success or failure of tools or experiments and their authors, in relation to the broader discipline’s practitioner’s sentiment about them. The research is carried out by reviewing existing contemporary literature on the topic, and most importantly by gathering information from archival sources of various kinds, from patent filings, governmental agency reports, and conference proceedings, to popular science and technology magazines or newspapers.

---

[5] Ludger Hovestadt, Urs Hirschberg, and Oliver Fritz, “Atlas of Digital Architecture : Terminology, Concepts, Methods, Tools, Examples, Phenomena,” 2020, https://doi.org/10.1515/9783035620115.

[6] Yehuda E. Kalay, *Architecture’s New Media: Principles, Theories, and Methods of Computer-Aided Design*, Mit Press (MIT Press, 2004), https://books.google.pl/books?id=BDboJQJvUq8C.

[7] Georg Vrachliotis, *The New Technological Condition, Architecture and Design in the Age of Cybernetics* (Birkhäuser, 2022), https://doi.org/doi:10.1515/9783035624816.

[8] John Frazer, “An Evolutionary Architecture,” 1995.

Defining Failure – Theoretical Framework

Quantifying the criteria if a digital tool was a failure or success in the historical context could very well be a separate field of research going beyond the scope of this text. Can it be defined anyway? It can be seen as a performance or outcome that falls short of expectations or objectives set for a particular activity, project, etc. It can also be understood as the absence of success or the inability to achieve desired goals or outcomes in research or innovation endeavours.[9] However, failure can also be framed as an opportunity for learning and strategic renewal at the individual, or organizational level. Failure is a fact of life. It is strictly tied to the process of innovation.[10] Every groundbreaking idea sprouted from soil fertilised by countless mishaps and dead-end experiments.

It is difficult to define failure in terms of digital tools. There might have been an example of a tool or idea, that did not work out at the very beginning, being dismissed or forgotten for some reason, only to re-emerge later, and be used in some different way. Take for example using a pen to navigate a digital device, especially in the context of Apple products like tablets. Steve Jobs was a strong opponent of using any physical peripherals for his devices, reasoning that it is the human palm with its fingers that is the ultimate best and most immersive tool for navigation.[11] He did not foresee that later tablets would be widely used by artists and all people alike, with a far greater preference for the digital pen, with its accuracy superiority over a finger. It is not obvious to say a digital pen was a failed project then. Only because it did not receive widespread recognition at first and needed to wait a decade, might not render the idea or even its implementation a failure.

Setting criteria for the success or failure of digital tools, and drawing a line, can be a tough exercise. Is there a point in doing so anyway? One criterion of evaluation, especially in terms of architectural design, would be to determine if a tool was used in actual design in any way, even better a design that later led to a built project. That would show some kind of validity in the industry, not only within speculative academic research endeavours.

However, if that did not happen, and a certain tool did not leave university lab walls, then still it could be evaluated by its impact on further research. Often it happened that some prototype idea was not used at scale commercially, or happened to be a financial flop, but paved the way for the next generation of similar tools that did in fact find their way to designers' everyday lives. Did they fail then? In itself, one might say, yes, in the general context of history, not so much, it still could be considered a success.

Those thoughts later led to reasons for choosing specific tools for this research. The list could go on three times longer, was it for every cybernetic era tool with potential for architecture to be explored and analysed. The choice came for the ones that were either too influential to omit so that general understanding about the whole field was not lost, the ones that were in some sense peculiar to modern audiences, or the ones that were discontinued despite their legacy being greatly influential.

[9] Bruno Turnheim and Benjamin K. Sovacool, "Exploring the Role of Failure in Socio-Technical Transitions Research," *Environmental Innovation and Societal Transitions* 37 (December 1, 2020): 267–89, https://doi.org/10.1016/J.EIST.2020.09.005.

[10] Chris Coldwell, "Why Failure Is A Necessary Part Of The Innovation Process," November 4, 2022, https://www.forbes.com/sites/forbesbusinesscouncil/2022/11/04/why-failure-is-a-necessary-part-of-the-innovation-process/?sh=69254d1a3ff7.

[11] Walter Isaacson, *Steve Jobs* (Simon&Schuster, 2011).

Structure

The text begins with a brief introduction to the Cybernetics movement to provide essential context for the reader. It then continues by following a chronological approach to introduce and analyse chosen tools, mainly the "Lightpen", "Sensorama, "Sketchpad", "Lincoln Wand", "Ultimate Display", and "URBAN5". And later the sentiment of industry and contributors is explored, with concluding thoughts at the end.

Cybernetic Craze Begins

It is difficult to mark a specific event from which the broader digital culture epistemological and cultural paradigm shift emerged. its wider history stretches to early XX century bureaucratic modern capitalism processes, while it is mostly agreed, however, that a clear definition is tied to the postwar sociopolitical and economic environment.[12]

Pioneering theoretical and practical work was done by Alan Turing, famed English mathematician and computer scientist, who in his 1936 seminal paper "On Computable Numbers, with an Application to the Entscheidungsproblem" conceptualized "universal computing machines" (later nicknamed "Turing Machines"), which served as a basis for future computers.[13] He also proposed a "Turing Test" which is supposed to determine whether a machine is capable of human-level artificial intelligence, and formed the basis in the field of artificial neural networks.[14] Along with Turing, it is worth noting John von Neumann and his work on cellular automata, discrete computational systems based on very simple rules, that at scale and through iteration evolve into great complexity.[15]

Another contribution to the emerging paradigm shift, that is important for its understanding, was a conceptual school of thought called "bionics", also referred to as "biotechnics". It was present since around the late XIX century and was later explored by biologists and science fiction writers. It developed the idea of "organic mechanism", studying nature's techniques, principles, and processes as possible models for human technologies and nature–human interaction.[16]

All those innovations and concepts - computation, neural networks, cellular automata, biotechnics – and most importantly human–nature and human-machine interaction, fuelled by technological advancement during the two world wars, led to the emergence of a new very influential school of thought.[17] It was broadly collated as a research field referred to as "Cybernetics" – a term defined in 1948 by German philosopher and mathematician Norbert Wiener.[18] The field gained attention, and later in 1960, after further progress was being made in computer science, psychologist J.C.R. Licklider published his "Man-Computer Symbiosis", which was considered a milestone in the cybernetic notion of human-machine interaction.[19] Licklider saw symbiosis as a natural next step for interaction between humans and machines, specifically

[12] Socrates Yiannoudes, "Architecture in Digital Culture : Machines, Networks and Computation," *Architecture in Digital Culture*, December 14, 2022, https://doi.org/10.4324/9781003241287.
[13] Turing, "On Computable Numbers, with an Application to the Entscheidungsproblem."
[14] Frank Honywill George, *Philosophical Foundations of Cybernetics* (Abacus Press, 1979).
[15] John Von Neumann, *The Computer & the Brain* (Yale University Press, 1958), https://yalebooks.yale.edu/9780300181111/the-computer-and-the-brain.
[16] Yiannoudes, "Architecture in Digital Culture : Machines, Networks and Computation."
[17] Claypool, "The Digital in Architecture: Then, Now and In the Future."
[18] Norbert Wiener, *Cybernetics or Control and Communication in the Animal and the Machine. Reissue of the 1961 Second Edition, Cybernetics or Control and Communication in the Animal and the Machine* (The MIT Press, 2019), https://doi.org/10.7551/MITPRESS/11810.001.0001.
[19] Markusiewicz, "The Importance of Interactivity for Contemporary CAAD Tools."

computers. A human would give instructions, formulate hypotheses and criteria, and computers would be the extension doing the rest of the work.[20]

Theoretical foundation goes together with technological progress, numerical-based machine codes used in the late 1940s evolved into primitive programming languages in the 1950s, which were succeeded by high-level coding in the 1960s.[21] Then, in the 1960s rapid progress in the accessibility of computer technologies took place, mainly due to the shrinking of the size and cost of computer machinery, but also thanks to the beforementioned progress in programming languages. All of this set up an extremely fertile ground for the cybernetics movement to flourish and for researchers to work on fulfilling their ambitions.[22]

Augmenting the Architect - Fate of the Peculiar

Work on the cybernetic toolset begins.

The theoretical stage was set, and the technical capabilities of computer researchers were growing at a significant pace. It was only a matter of time before some bright minds started tinkering with those new whimsical machines to see what could be done to benefit different professions of humankind at large. As often happens, the first technological advancements, before they are scaled for the greater consumer market, are developed as part of a military research agenda.

Lightpen, 1951-1958

One of the earliest tools that showed its use case for the design and architecture industries was the "lightpen". It was created as a complementary part of the "Whirlwind I" project at MIT, between the years 1951-1955, and later developed at the SAGE project, which both were early detection radar systems in development.[23] At that time, while still being called a "lightgun", it served to point directly on the CRT display screen and select different symbols to operate the machine, in that case, tactical real-time control of radar-networked airspace. It enabled for quicker and easier use of the system, as until then everything had to be done by pushing specific buttons on the large desktop. "By pointing to critical elements on the display, the user has a relatively simple and reliable mechanism for communication and interaction with the processor. If the user of the lightgun wants the computer to perform some action, he merely points this pointer at the appropriate command displayed to him on the display, and the computer will operate accordingly."[24]

---

[20] Joseph Carl Robnett Licklider, "Man-Computer Symbiosis," *IRE Transactions on Human Factors in Electronics* HFE-1, no. 1 (1960): 4–11, https://doi.org/10.1109/THFE2.1960.4503259.
[21] Krystian Kwiecinski, *Cyfryzacja Partycypacji. Studium Komputerowego Wsparcia Uczestnictwa w Projektowaniu Domów*, 2023.
[22] Nigel Cross, *The Automated Architect* (London: Viking Penguin, 1977).
[23] Nicholas Metropolis, Jack Howlett, and Gian-Carlo Rota, *A History of Computing in the Twentieth Century, A History of Computing in the Twentieth Century*, 1980, https://doi.org/10.1016/C2009-0-22029-0.
[24] Joseph Spiegel, John K. Summers, and Edward M. Bennett, "AESOP: A GENERAL PURPOSE APPROACH TO REAL-TIME, DIRECT ACCESS MANAGEMENT INFORMATION SYSTEMS" (Massachusetts, June 1966).

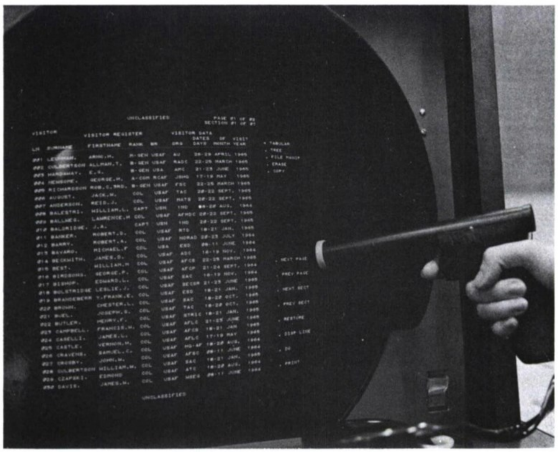

Fig. 1 Lightgun firing on Marginal Command. (AESOP, Massachusetts, 1966)

Fig. 2 The operator uses a lightgun and operates the console controls. (MIT Lincoln Laboratory. 1958)

On the SAGE terminal, for example, the user (operator) could select targets to gather more information, choose an appropriate defence strategy or give order to attack. The user-computer communication took place in real time, demonstrating the interactivity of the interface and its effectiveness.[25]

Soon after the success story of the lightgun usability was clear, it was being developed further by researchers in many different fields to evolve into a lightpen. Notable examples include the Digigraphics Display Program, Design Augmented by Computers (DAC-1) at General Motors, or most importantly for the architecture domain – Sketchpad (on which this paper expands later), all developed at the same time around 1963.[26] At Digigraphics Display Program the capabilities of lightpen – lightgun technology modified to resemble a stylus – were being explored in the field of computer graphics. The question was, can it be used efficiently to draw on the screen? The first results were promising.

Fig. 3 Lightpen usage at Digigraphics. (Charles Babbage Institute Archives, University of Minnesota Libraries. C. 1963)

Instead of reducing design problems to equations, as it was done up to this point, the Digigraphics Display Program system directly processes graphic data "input" by a user using a lightpen.[27] "It allows drawing on a screen because by pressing the button on the stylus, the operator signals the computer to start and stop drawing a line. Data can be recalled at any

[25] "Un Terminal Du Semi Automatic Ground Environment (SAGE), c. 1958. @ Problemata," accessed March 5, 2024, http://problemata.org/en/resources/678.

[26] Jordan Kauffman, "Dessiner Avec l'ordinateur Dans Les Années Soixante: Le Design et Ses Pratiques à l'aube de l'ère Numérique," *Livraisons de l'histoire de l'architecture* 32 (2016): 105–23, https://research.monash.edu/en/publications/dessiner-avec-lordinateur-dans-les-ann%C3%A9es-soixante-le-design-et-s.

[27] "Le Système Digigraphics Opéré Par La Control Data Corporation, c. 1963. @ Problemata," accessed March 5, 2024, http://problemata.org/en/resources/680.

time, and the "drawings" – light lines on a monitor – can be changed to different scales."[28] Around the same time, the lightpen found its use as the main tool for interaction with a hardware-software cybernetic system developed by Ivan Sutherland – Sketchpad.[29] We discuss Sketchpad later in this paper, thus it's not going to be covered in detail here. A tiny bit later, at General Motors company, with the collaboration of IBM as a partner, the Design Augmented by Computer (DAC-1) system was brought to use. It was developed in the early 1960s and unveiled at the Fall Joint Computer Conference in 1964.[30]

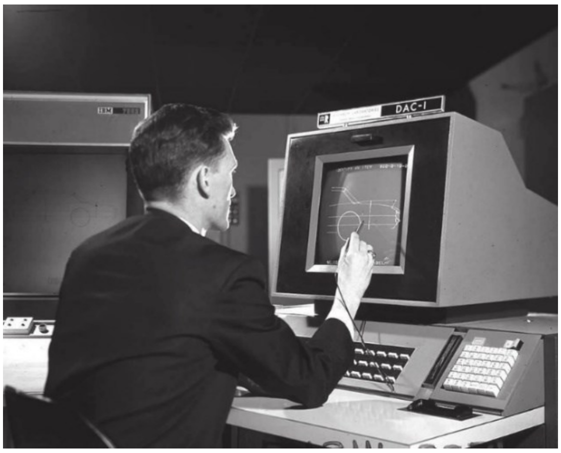

Fig. 4 DAC-1 in use at General Motors. (General Motors Archive, c. 1964)

At General Motors lightpen found its use in the digital design of new automobiles, making the whole process faster by enabling repeatability, drawing data storage and non-destructive drawing manipulation.[31] The system traces lines drawn on a computer screen, similar to "drawing lines with a pencil on the CRT [television] screen". The difference is that the lightpen is not used directly on the screen, but on the conductive surface, making it feel like a person is drawing with a pen or pencil, instead of an optical pen in the air.[32]

Lightpen continued to be used widely throughout the 1960s and early 1970s as a main manipulation tool in various computer interfaces, be it military defence, design, architecture, or mathematics etc., and was widely advertised in computer magazines alongside the IBM 360[33] for example. Various architectural and engineering projects of great complexity required using computer calculations and digital graphics manipulations with lightpen to enable their feasibility. One example of that is the Olympic Stadium in Munich by Frei Otto, where "with the aid of a monitor screen and a lightpen it was possible to transform the [structural cable] network output in different directions and to correct mistakes in a direct interaction." One of the architects pointed out during the design that "at last one could make a design on the screen, as some of us are dreaming of", showing that the custom interaction of the designer or engineer with the computer was very much sought after.[34]

The apparent success of the lightpen is visible in its occurrence not only in professional fields but also in popular culture. In the late 1960s, it was seen as the tool that would stay, even being immortalised in mainstream pop culture and science fiction novels.[35] Alas, nothing lasts forever and the lightpen reign gave way to a

[28] Kauffman, "Dessiner Avec l'ordinateur Dans Les Années Soixante: Le Design et Ses Pratiques à l'aube de l'ère Numérique."
[29] Ivan Edward Sutherland, "Sketchpad, a Man-Machine Graphical Communication System" (Massachusetts Institute of Technology, 1963), https://dspace.mit.edu/handle/1721.1/14979.
[30] "The '64 Fall Joint Computer Conference," *Datamation* (Los Angeles, December 1964).
[31] "Le Système Design Augmented by Computers (DAC-1) Élaboré Par General Motors, c. 1964. @ Problemata," accessed March 5, 2024, http://problemata.org/en/resources/684.
[32] Kauffman, "Dessiner Avec l'ordinateur Dans Les Années Soixante: Le Design et Ses Pratiques à l'aube de l'ère Numérique."
[33] "The '64 Fall Joint Computer Conference."
[34] Mick Eekhout, "Frei Otto and the Munich Olympic Games. From the Measuring Experimental Models to the Computer Determination of the Pattern," *Zodiac 21* (Milan, September 1972).
[35] John R. Pierce, "A Different Girl Every Night," *Penthouse* (New York, July 1971).

new, cheaper, and more comfortable tool for most daily computer use cases – the mouse. In 1969 David Evans argued for the first prototype of a computer mouse, which subsequently quickly replaced the lightpen in most use cases.[36] The cost was one of the drivers of that transition, but also user comfort, which was especially apparent in design fields. It was too early in hardware terms to cheaply simulate a desk and paper setup, like a modern lightweight tablet, and holding one's hand up to the screen was very irritating for prolonged time durations.[37] Thus, the domination of the lightpen ended, and it gave way to the mouse and keyboard. The idea however stayed alive and evolved further in different forms to be used as a stylus for various digital devices.

Sensorama, 1962

While lightguns were evolving into lightpens, a visionary genius was working on his way to experience and ultimately communicate with non-physical worlds through computers. Morton Heilig was working in the cinema and entertainment industry in the early 1960s, envisioning the cinema of the future, where the audience experiences the show with all senses and 360-degree vision.

He started as early as 1957, by filing a patent for 3-D Stereoscopic vision device and filming technology, that was granted on October 4th, 1960.[38] In the meantime, he was already working on his prototype vision for a device that would make use of his 3-D vision technology, and recently developed by Mike Todd Jr "Smell-o-Vision" that simulated, as expected from the name, different scents.[39] He filed a patent for "Sensorama" in 1961, granted in 1962, a simulator machine that creates a whole new environment for the user.[40] The invention gathered interest and Heilig quickly started his own research and development film company, "Sensorama Inc.". The product created for its user the illusion of being "physically present in a different environment.", achieving this through a technique that combines peripheral vision, colour, binaural sound, breezes, odours and tactile sensations with three-dimensional imagery without the need for special glasses to achieve this effect.

Fig. 5 Sensorama advertisement in a popular business and technology magazine (Business Screen c. 1964)

[36] David Evans, "Augmenting the Human Intellect," in *Computer Graphics in Architecture and Design*, ed. Murray Milne (Connecticut: Yale School of Art and Architecture, 1969), 61–66, https://archive.org/details/computergraphics0000murr/page/61/mode/2up?view=theater.
[37] Kauffman, "Dessiner Avec l'ordinateur Dans Les Années Soixante: Le Design et Ses Pratiques à l'aube de l'ère Numérique."
[38] Leonard Morton Heilig, STEREOSCOPIC-TELEVISION APPARATUS FOR INDIVIDUAL USE, 2995156, *ACM SIGGRAPH Computer Graphics* (United States of America: United States Patent Office, issued October 4, 1960), https://doi.org/10.1145/178951.178972.
[39] Cleveland Amory, *Celebrity Register* (New York: Harper&Row, 1963).
[40] Leonard Morton Heilig, SENSORAMA SIMULATOR, 3050870 (United States of America: United States Patent Office, issued August 28, 1962).

Sensorama was being showcased at various conferences, and entertainment fairs and was being featured often in newspapers as a fascinating novel contraption, mostly for the entertainment industry. The initial machine had 4 movies, or "experiences", in its storage, including for example a buggy ride on the desert or belly dancer private show, and early spectators recalled that featured movies were "the closest thing to reality [they] had ever seen on a film system".[41] Although being intended to be commercially employed as "a coin-operated entertainment device and as an audio-visual advertising and selling aid for industry", Heilig already saw its potential in education or design.[42] Sensorama had its run throughout the 1960s, still being present at shows in the early 1970s next to SEGA or other big players in the market.[43]

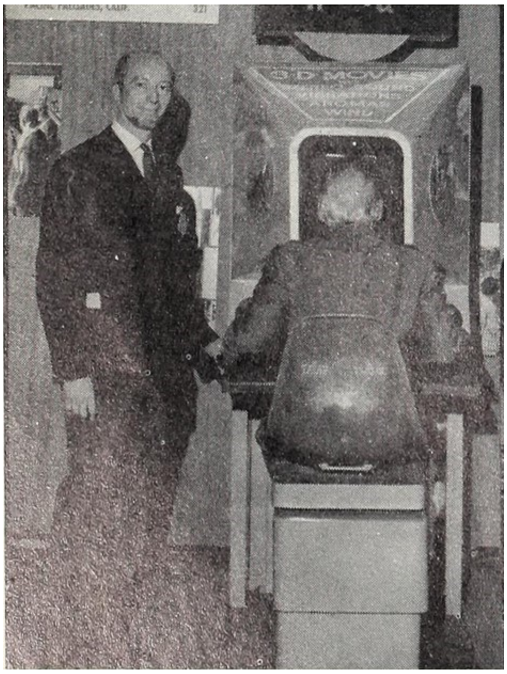

Fig. 6 Mort, Heilig, a pioneer in the audio-visual games field, displays his "Sensorama" machine at the Parks Show. (Cash Box, c. 1970)

Sensorama did not see much success during its times in general since the business community had problems advertising and selling it. Filming the films in 3-D stereoscopic vision dedicated for Sensorama was just too expensive. It seems that Heilig mismatched the target audience, focusing on cinema and entertainment rather than education or something else. The project was sadly abandoned, and its possible potentials did not see further development.[44]

Only now in recent interest about Sensorama in various media, like online articles or video interviews[45], it is visible how valued Heilig's idea was in the wider historical context of the field. What is a shame in retrospect is that there was little to no interest in Sensorama in the wider design or academic community, looking at its potential in those fields. A similar idea in a more academic environment was being carried on later by Ivan Sutherland and David Evans with their Head Mounted Display, (expanded on later in this paper), one could see how well those visionaries could work together. The longer-lasting impact of Sensorama, however, was in the idea itself, which had implications in decades to come.

Sketchpad, 1963

As mentioned earlier while introducing the lightpen and the systems using it, one of them was Sketchpad. Developed since 1961 and presented in 1963 "Sketchpad" by Ivan Sutherland is probably the most widely known and written about cybernetic era tool for architects and designers, and rightly so.[46] It was recognized as "one of the most influential computer programs ever written by an individual" while obtaining the Turing Award in

[41] "3-D Multi-Sense Film Machine Introduced," *Cash Box*, April 25, 1964.
[42] "Sensorama Simulator Creates Environment for the Viewer," *Business Screen*, 1964.
[43] "Amusement Coin-Op Novelty Units Spark Park Ops' Interest at Show," *Cash Box*, December 12, 1970.
[44] Scott Tate, "VIRTUAL REALITY: A Historical Perspective," 1996, https://ei.cs.vt.edu/~history/Tate.VR.html#2.
[45] Itsuo Sakane, *Morton Heilig's Sensorama (Interview).Mov - YouTube* (Japan, 2010), https://www.youtube.com/watch?v=vSINEBZNCks.
[46] Vrachliotis, *The New Technological Condition*.

1988.[47] Its popularity however is the reason Sketchpad will not be covered here in as much detail as it could be, since much can be found in other sources.

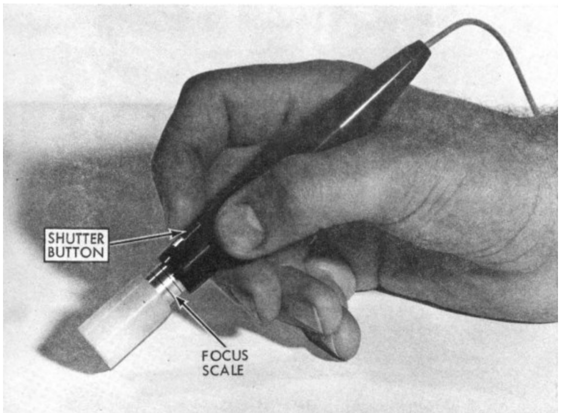

Fig. 7 Custom lightpen made for Sketchpad. (Sketchpad, c. 1963)

Ivan Sutherland takes a similar approach to other researchers in the field of computer graphics and computer interface in general at the time and explores the possibility of using the lightpen for human-computer interaction. In his specific case, for an architecture and engineering-focused drafting computer program. Sketchpad is made specifically for the TX-2 computer at MIT, a custom machine made at the Lincoln Laboratory.

Fig. 8 Ivan Sutherland using Sketchpad on TX-2 operating area. (MIT Museum, c. 1963)

Sketchpad was being operated by a lightpen and many toggle switch buttons and knobs on the TX-2. In Fig. 8 the push buttons used to control specific drawing functions are on the box in front of the Author. Some of the toggle switches can be seen behind the Author. The size and position of the main drawing fragment is obtained through the four black knobs just above the table. The biggest strength of Sketchpad was its versatile functionality, despite being tailored specifically for architecture and engineering purposes. It enabled vector drawings, using previously drawn and stored objects in a similar way as blocks or instances known in modern software, creating custom lines, and it also had snapping capabilities built in, so that drawings could be mathematically perfect in vector space. It also boasted nowadays obvious functions like scaling and morphing objects. "It has been used to draw electrical, mechanical, scientific, mathematical, and animated drawings; it is a general-purpose system. Sketchpad has shown the most usefulness as an aid to the understanding of processes, such as the notion of linkages, which can be described with pictures. Sketchpad also makes it easy to draw highly repetitive or highly accurate drawings and to change drawings previously drawn with it."[48] It was also used to calculate the distribution of forces in models of truss bridges.

[47] Ivan Edward Sutherland, Alan Blackwell, and Kerry Rodden, "Sketchpad: A Man-Machine Graphical Communication System" (University of Cambridge, 2003), http://www.cl.cam.ac.uk/.

[48] Sutherland, "Sketchpad, a Man-Machine Graphical Communication System."

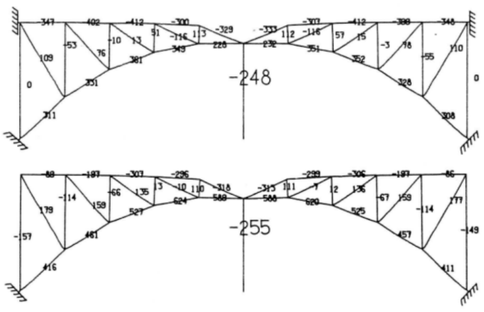

Fig. 9 Cantilever and arch bridges drawn in Sketchpad. (Sketchpad, 1963)

Sutherland already saw other use cases for Sketchpad in the future. "If the almost identical but slightly different frames that are required for making a motion picture cartoon could be produced semi-automatically, the entire Sketchpad system could justify itself economically in another way."[49] Though those might not have come true, it proved to be the precursor of later AutoCAD and other similar drafting computer software.

Sketchpad in itself did not see much further development and success, even though already in his original paper Sutherland mentioned that the next generation is being developed by his students. It was mostly due to being limited to the customized TX-2 machine at MIT Lincoln Laboratory. Sketchpad's influence has been in the ideas it introduced and how it set a precedent in how a computer graphics program can be developed, rather than a direct scalable usage.[50] It directly influenced developers of the later Xerox Star computer workstation development (the first computer setup resembling what is a standard now), especially if it comes to the graphical user interface (GUI) and its graphics applications.[51] From Xerox, through Steve Jobs and the early Apple team, it led to a direct link in the commercialization of the Macintosh, and later Windows interfaces.[52]

The Lincoln Wand, 1966

The exciting race to develop the best new tool for architects' and designers' augmentation continued. The idea of Sketchpad and lightpen tandem inspired later researchers to explore it in different ways and build upon it. One of them was Lawrence Roberts, who in 1966 presented his invention – The Lincoln Wand. The name came straight from the already familiar Lincoln Laboratory at MIT at which most of the new endeavours in this field were pursued.

The Lincoln Wand allowed for 3D object manipulation both in computer memory and physically with hand gestures. "An ultrasonic position-sensing device has been designed" with four sensors or transmitters attached to the corner of a screen. Those would "allow a computer to determine periodically the x, y, and z coordinates of the tip of a pen-sized wand."[53] The ability to conveniently provide 3D position information also made it practical to draw objects like curves or lines in 3 dimensions.

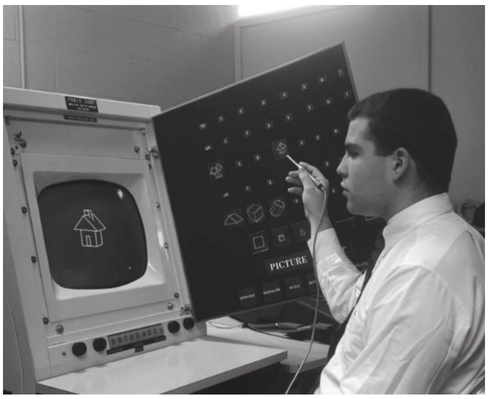

Fig. 10 Lawrence Roberts operating the next-gen Sketchpad-like software with The Lincoln Wand. (MIT Lincoln Laboratory, c. 1966)

[49] Sutherland.
[50] Sutherland, Blackwell, and Rodden, "Sketchpad: A Man-Machine Graphical Communication System."
[51] Jeff Johnson et al., "Xerox Star: A Retrospective," *IEEE Computer* 22, no. 9 (1989), https://doi.org/10.1109/2.35211.
[52] Isaacson, *Steve Jobs*.
[53] Lawrence Gilman Roberts, "The Lincoln Wand," in *AFIPS Fall Joint Computer Conference* (Washington D.C.: Spartan Books, 1966), 223–28.

The invention was supposed to replace the current state-of-the-art tools for human-machine interaction like the lightpen or RAND Tablet. However, that did not happen for reasons not so clear to determine. One reason could be the initial cost of the whole Wand setup, with $1,500 for just the ultrasonic equipment (around $14,000 at the time of writing). The other might be that, similarly to Sketchpad, it was created specifically for the MIT Lincoln Laboratory internal custom computer, making it difficult to translate and scale to other systems. Additionally, not much later, the computer mouse was introduced by D. Evans[54], which not only was a cheaper solution but also sported the same advantage it had over the lightpen, being that the user did not have to hold one's hand up in the air all the time.

Only in retrospect, we can see how brilliant and prescient Robert's idea was. The same type of interface interaction is being explored and pushed more into mainstream design practices now, 50 years later, with Virtual Reality applications for free-form 3D modelling or Architectural model viewing and manipulation. From my personal experience, I can tell it is an incredible feeling to be able to draw three-dimensional forms with just my palm and arm gestures in the air.

The Ultimate Display, 1968

Ivan Sutherland continued his interests in human-machine interaction and pursued them further with research towards the right interface to do that. The success of his Sketchpad gathered attention in the fields of computer graphics, architecture, design, and engineering, but also outside, in the USA military-industrial complex. Sutherland continued his work partly at MIT Lincoln Laboratory, but mainly his efforts were focused at the Advanced Research Projects Agency (ARPA, later DARPA) on exploring the possibilities of expanding the human intellect through interaction with machines. There was a long-running program gathering numerous great minds, "The BRAIN" (The Harvard Experimental Basic Reckoning And Instructional Network). "The project objective has been to determine what creative thought processes can best take advantage of new technology in computer hardware and software. The plan has been to acquire or develop online computer systems of significant mathematical power, and to explore their use in vivo in teaching and research situations".[55] His research output during that time, not surprisingly, is shrouded with a little bit of mystery. What is known, however, is that "at ARPA, Sutherland had helped implement J.C.R. Licklider's vision of human-computer interaction, and he [later] returned to academia to pursue his own efforts to extend human capabilities."[56]

Fig. 11 Dr Ivan Sutherland, a pioneering creator of computer graphics software, had a leadership role with ARPA, the umbrella overseeing early interactive computing. (Tribune file photo. C. 1972)

While still at ARPA, Sutherland saw the potential of a computer display and its far-reaching

[54] Evans, "Augmenting the Human Intellect."
[55] "FINAL REPORT SD-265 - The BRAIN" (Massachusetts, October 1, 1968).

[56] Wayne Earl Carlson, "Computer Graphics and Computer Animation: A Retrospective Overview" (The Ohio State University, June 20, 2017).

extrapolations. "A display connected to a digital computer gives us a chance to gain familiarity with concepts not realizable in the physical world. It is a looking glass into a mathematical wonderland"[57]. He envisioned "The Ultimate Display" and presented his ideas at the Internation Federation of Information Processing Congress in 1965. He foresaw that "machines to sense and interpret eye motion data can and will be built", and he wanted to be the one to try and see if we can control a computer with a language of glances.

"The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the wonderland into which Alice walked"[58]. One can wonder if Sutherland, also given his collaboration at NSA[59], was familiar with Aldous Huxley's' writing[60]. One can also see in retrospect, almost 50 years later, how prescient those ideas were, considering the famed popularization and expansion of them in 1999s "Matrix" by Wachowski's[61] for example, or recent efforts in achieving "The Metaverse."

As a good start for all those bold visions, first "an interesting experiment will be to make the display presentation depend on where we look"[62]. As he said, he later did.

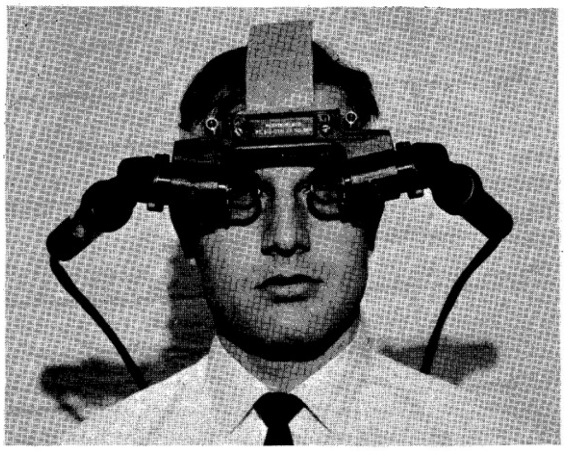

Fig. 12 The Head-Mounted Display optics with miniature CRTs. (Fall Joint Computer Conference Proceedings, c. 1968)

In 1966, Ivan Sutherland moved from ARPA to Harvard University as an associate professor in applied mathematics, where he continued his work envisioned earlier in 1965.[63] After 3 years of research, experiments, and development built on the network of personal and professional contacts he had developed at MIT and ARPA, Sutherland presented "The Ultimate Display" prototype, a precursor of later VR technologies, at the AFIPS Conference in 1968. He had done preliminary three-dimensional display experiments at the MIT Lincoln Laboratory in early 1967, just for one eye, and was finally able to "present the user with a perspective image which changes as he moves" for both eyes.[64] The project was nicknamed "The Sword of Damocles" as it was a piece of very heavy equipment hanging from the ceiling so that the user had to "enter" the headset from below, in place.[65]

[57] Ivan Edward Sutherland, "The Ultimate Display," in *IFIP Congress Proceedings*, 1965, 506–8.
[58] Sutherland.
[59] "Ivan Sutherland | Lemelson," accessed March 16, 2024, https://lemelson.mit.edu/resources/ivan-sutherland.
[60] Aldous Huxley, *The Doors of Perception : And Heaven and Hell* (New York : Harper & Row, 1963. ©1956, 1963), https://search.library.wisc.edu/catalog/999606461202121.
[61] Lana Wachowski and Lilly Wachowski, *The Matrix* (USA: Warner Bros., 1999).
[62] Sutherland, "The Ultimate Display."
[63] Carlson, "Computer Graphics and Computer Animation: A Retrospective Overview."
[64] Ivan Edward Sutherland, "A Head-Mounted Three Dimensional Display," in *Fall Joint Computer Conference* (San Francisco, 1968), 757–64.
[65] Sean M Grady, *Virtual Reality: Simulating and Enhancing the World with Computers*, 2003.

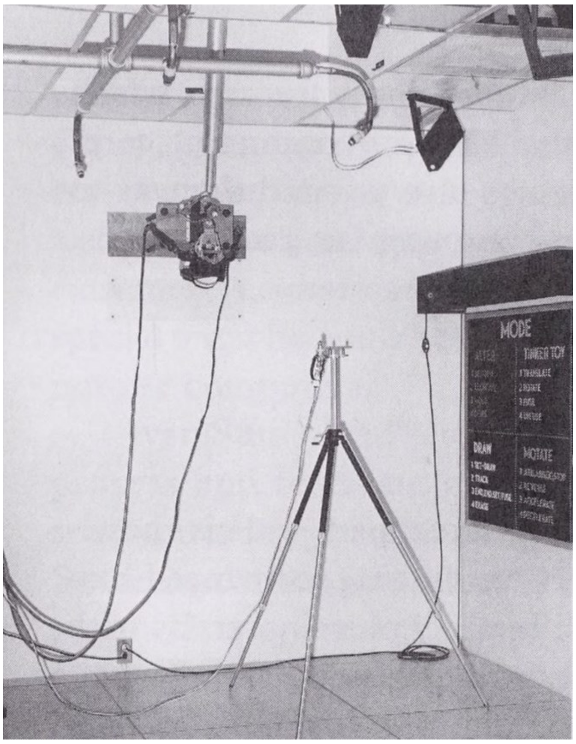

Fig. 13 The Sword of Damocles. (University of Utah, c. 1968)

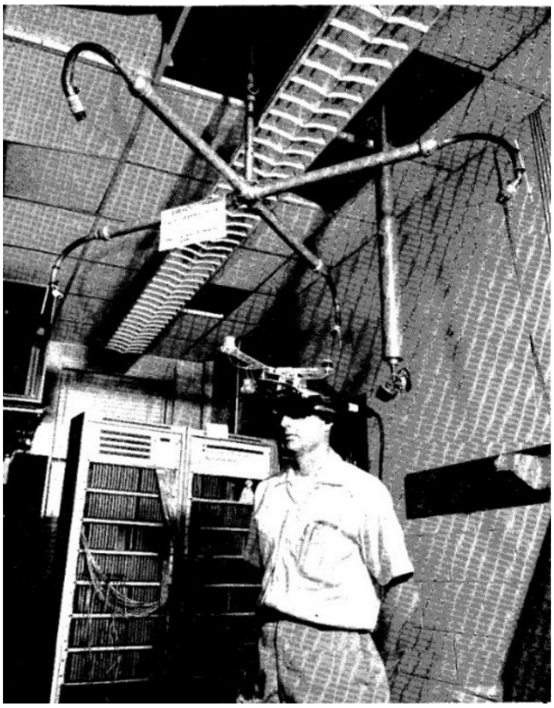

Fig. 14 The Sword of Damocles was very cumbersome: its users had to strap themselves into it for the display's 3-D effect to work. (Fall Joint Computer Conference Proceedings, c. 1968)

It worked by tracking the head movements in three dimensions, and displayed wire-frame geometries on miniature transparent CRTs, so that the user saw his environment and the displayed content on top of it, like in modern Augmented reality headsets. There were some peculiar and as yet unexplained phenomena occurring during experiments. For example, because of the transparent wire-frame images being displayed, ambiguous interpretations of reality were possible.[66] Those gave rise to the whole research on human orientation in digital 3-D environments later.

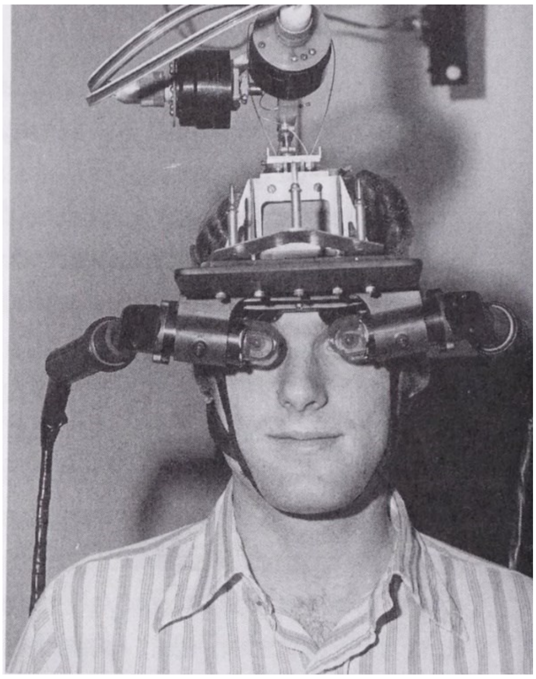

Fig. 15 One of Ivan Sutherland's students tests out the Sword of Damocles. (Evans & Sutherland Computer Corp. c. 1968)

[66] Sutherland, "A Head-Mounted Three Dimensional Display."

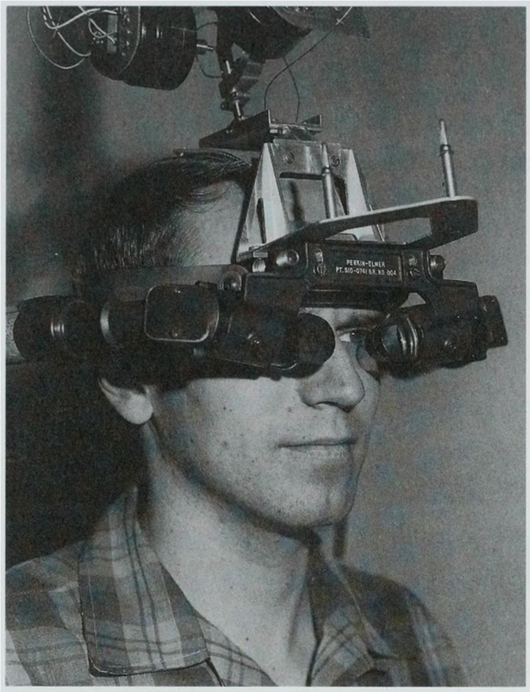

Fig. 16 The two prisms in front of the student's eyes reflected computer images from the cylindrical Cathode-Ray Tubes (CRT). (Evans & Sutherland Computer Corp. c. 1968)

The project was tough from the beginning, and "would have died many times but for the spirit of the many people who have become involved".[67] The apparent potential of the technology and ambition of the team kept it going and continued for many decades.

According to Sutherland "there was [...] no chance of immediately realizing [the] vision for the head-mounted display" at the time, mostly due to hardware limitations, despite incredible funding and help in the form of hardware from various institutions like MIT, ARPA, Central Intelligence Agency (CIA), Bell Laboratories, Bell Helicopter, and US Air Force. Still, the project was viewed as an important "attention focuser", and provided a reason to go forward and push the technology as hard as one could. "Spin-offs from that kind of pursuit are its greatest value".[68]

Specifically in architecture and design context, unfortunately, the idea of The Ultimate Display was not developed further. The technology was snatched away for "more important" purposes at the time.[69] It was mostly due to interest from defence and military industries, where the potential for head-mounted displays was far more valuable, for simulation, teaching, and research into various experiments in human intellect augmentation.[70]

URBAN5, 1968

Around the same time Ivan Sutherland with his team were finishing the work on The Ultimate Display, at MIT Nicholas Negroponte was working on another kind of human-computer interaction, exclusively for architecture. Negroponte together with Leon Groisser envisioned a design partner, a thinking machine that one communicates with in plain English, like a dialogue. "It was developed to study the desirability and feasibility of conversing with a machine about environmental design projects."[71]

Negroponte and his team were very optimistic about machines evolving in the future, like true Artificial Intelligence, not surprising as they were closely related in research and in private with one of the pioneers in the field – Marvin Minsky.[72] They envisioned three possible ways of having machines assist the design process:

"1. current procedures can be automated, thus speeding up and reducing the cost of existing practices.

[67] Sutherland.
[68] Carlson, "Computer Graphics and Computer Animation: A Retrospective Overview."
[69] Grady, *Virtual Reality: Simulating and Enhancing the World with Computers*.
[70] Evans, "Augmenting the Human Intellect."
[71] Gary T. Moore and Design Methods Group., "Emerging Methods in Environmental Design and Planning" (MIT Press, 1968), https://search.worldcat.org/title/116699.
[72] "Marvin Minsky - Nicholas Negroponte's Lab: The Architecture Machine (140/151) - YouTube," accessed March 16, 2024, https://www.youtube.com/watch?v=mk-ouQBkBeQ.

2. existing methods can be altered to fit within the specifications and constitution of a machine, where only those issues are considered that are supposedly machine compatible.

3. the process, considered as being evolutionary, can be introduced to a mechanism (also considered as evolutionary), and a mutual training, resilience, and growth can be developed."

"Imagine a machine that could follow your design methodology and at the same time discern and assimilate your conversational idiosyncrasies. This same machine, after observing your behavior, could build a predictive model of your conversational performance. Such a machine could then reinforce the dialogue by using the predictive model to respond to you in a manner that is in rhythm with your personal behavior."[73]

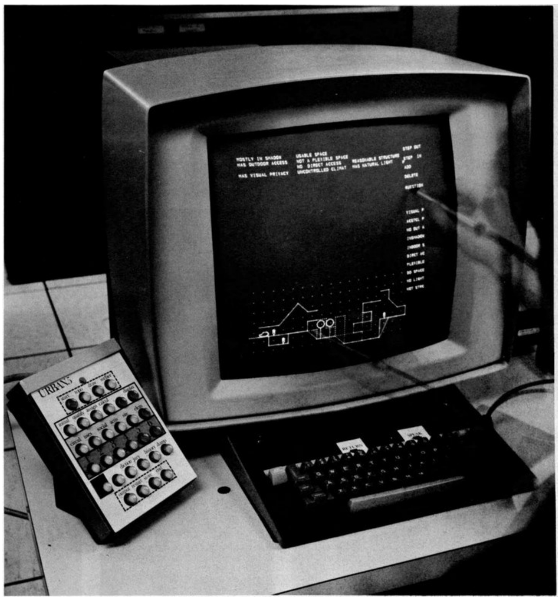

Fig. 17 URBAN5 workstation setup, pointing on the screen with a lightpen. (MIT Technology Review, c. 1969)

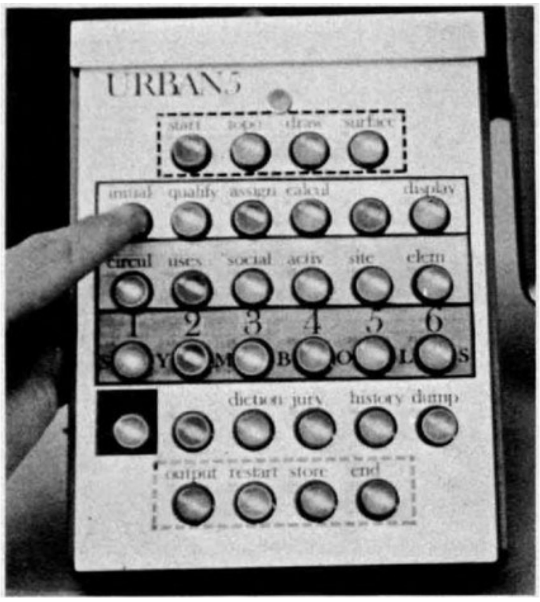

Fig. 18 URBAN5 custom additional keyboard. (MIT Technology Review, c. 1969)

It was continuing the trend of cybernetic tools to rely more and more on the software side rather than hardware. The software enabled drawing one's own urban design as symbols on a grid, choosing variables such as height, building, tree etc. It was also mainly based on typing commands to converse with the system. The design was then displayed in three dimensions, it was possible to move around and make adjustments while having a dialogue with one's own machine assistant.[74]

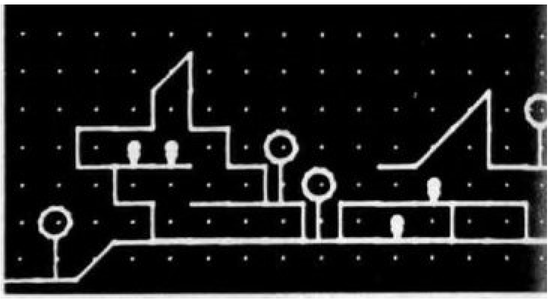

Fig. 19 2-D section of a drawn design on URBAN5. (MIT Technology Review, c. 1969)

[73] Nicholas Negroponte, "Towards a Humanism Through Machines," *MIT Technology Review*, April 1969, 44–53.

[74] Moore and Design Methods Group., "Emerging Methods in Environmental Design and Planning."

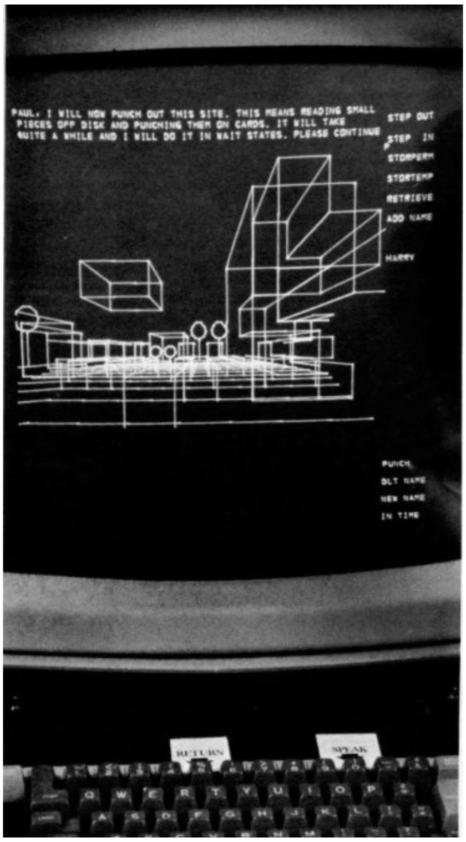

Fig. 20 3-D view of the design. (MIT Technology Review, c. 1969)

The hardware part of URBAN5 consisted of custom buttons on an additional keyboard-like panel for faster and more convenient use. As screens were still too small and object-oriented Graphical User Interfaces did not yet exist at the time. On the panel, action buttons like "topo", "draw", "surface", "social", and "active" could be seen (Fig. 18). The program was also operated on the screen with a lightpen.

The grand idea was that it worked like a conversation, meeting for the first time, and introducing oneself with a name. The machine evolved by learning its users' thinking, at some point being a customized program to the user.

' " Designer:

"All studios must have outdoor access."

URBAN5:

"I am sorry I do not understand."

Designer:

"All studios must have access to the outdoors."

URBAN5:

"I am sorry I do not understand."

Designer:

"A one-room residential unit must have outdoor access."

URBAN5:

"Now I understand. Furthermore, from now on, whenever you say studios, I will assume you mean one-room residential units."

"In theory, after some time the designer's system would bear little resemblance to the original URBAN5. The authors of URBAN5 might not recognize the transformed version. URBAN5 will have nursed the user deeper and deeper into the system, first teaching him, then learning from him, and eventually carrying on a dialogue with him."'[75]

The machine, and more specifically the idea, gathered a lot of attention in the field, Negroponte was invited to numerous conferences and schools to give talks about his research and his views for the future.[76] Excitement grew as it demonstrated the earliest visions of AI in Architecture. The talk about the "replacement" of architects started, to which Negroponte consoled. "Let us not be misled. We are not interested in a machine that will simply parrot a human designer, nor are we interested in a machine that will have an autonomous existence by which to mimic and replace an architect. An Architecture Machine will feature a dependence. An artificial intelligence is in fact an interdependence."[77] With that in mind,

[75] Moore and Design Methods Group.
[76] "A.T.I.," *The Mass Art Paper*, October 30, 1969.
[77] Negroponte, "Towards a Humanism Through Machines."

Negroponte started the Architecture Machine Group at MIT.[78]

URBAN5 was ultimately abandoned. Despite being an interesting experiment, it generated meaningless things mostly, especially after some more time of use, and it struggled to understand the user and to do this, it would need a true AI inside, of potential we only start seeing now.

URBAN5 was ultimately abandoned. Despite being an interesting experiment, it generated mostly meaningless things, especially after some considerable time of use. "Playing is learning, but URBAN5 has not been sufficiently sophisticated actually to frolic; instead, it has inexhaustibly printed garbage".[79] The main reason for abandonment was the problem of "giving the user the generality he needs through a brute force system".[80] It lacked the general plasticity of generalist Artificial Intelligence that we can only start enjoying now, half a century later.

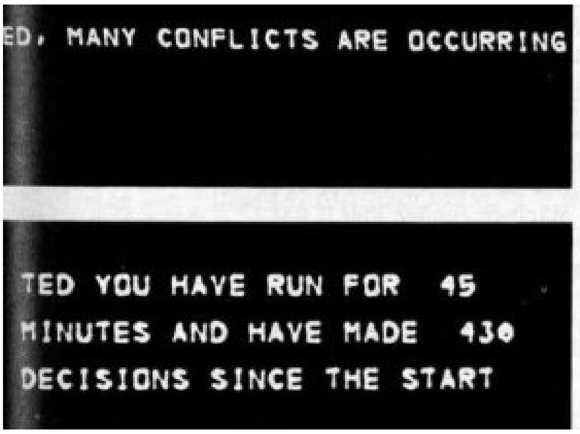

Fig. 21 Ted, many conflicts are occurring... (MIT Technology Review, c. 1969)

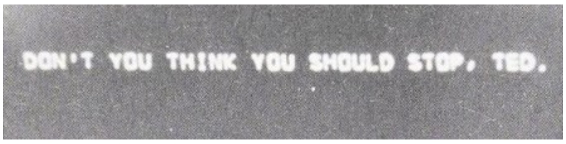

Fig. 22 Don't you think you should stop, Ted? (Computer Graphics in Architecture and Design, c. 1969)

There were incorrect assumptions made about the system, including underestimating the hardware capabilities and the complexity of the premise of Artificial Intelligence. The problems were solvable, but "it would be like constructing a building with the cornerstone in the wrong place. It is very difficult to replace [...] original assumptions, especially [...] programming assumptions."[81] The idea simply preceded greatly the hardware capabilities.

Another problem was that the machine saw the world only through the user, and Negroponte understood that was not enough. In the ideal case (as it is possible only now, and still not completely) would be that the system had live real-world knowledge through many sensory inputs, gathering a lot of data. "Eventually this may mean robots running around looking at things. It may be little thermostats inside rooms, figuring out the temperature, [etc.]".[82]

The project was nonetheless a success, though not in the sense of a readily scalable product, but as a research endeavour guiding future developments in different directions that would enable such a system. Ideas of URBAN5 and Sketchpad permeated the industry later leading to the development of AutoCAD or BIM software on commercialised and cheaper machines like Xerox, Macintosh, or IBM.

The legacy of URBAN5 is still being recognized, for example by modern attempts to reconstruct

[78] Nicholas Negroponte, "The Architecture Machine: Toward a More Human Environment," 1973, https://api.semanticscholar.org/CorpusID:109283490.
[79] Negroponte.
[80] Nicholas Negroponte, "URBAN5: An Experimental Urban Design Partner," in *Computer Graphics in Architecture and Design*, ed. Murray Milne (Connecticut: Yale School of Art and Architecture, 1969), 77–88, https://archive.org/details/computergraphics0000murr/page/77/mode/2up?view=theater.
[81] Negroponte.
[82] Negroponte.

the software as it was originally, as an experiment[83], or numerous attempts to use modern Artificial Intelligence for making similar assistant-type programs for urban developments, as Negroponte envisioned himself.[84]

The AI winter comes.

In the early 70s, it became apparent that hardware struggles to meet theoretical expectations when it comes to architecture and design, but generally the whole computer science industry, especially in the Artificial Intelligence field. The developments in machinery, computer memory capacity, and processing speed just could not keep up the pace with futuristic visions of the time. Industry became disillusioned. Funding was slowly drying out, and there were not enough breakthroughs to keep the fire going.

In terms of cybernetic tools, some projects were abandoned, mostly because of frustration with complexity and hardware limitations or lack of funding. The industry was also simply moving towards more standardized keyboard and mouse setup and graphical interface software, that waited to be distributed at scale in the early 1980s with MS-DOS on IBM machines or the first Macintosh.[85] Some projects went on being developed in other industries on different terms, like military, aeronautics, or automobile, where their usage saw more immediate benefits, ex. "The Ultimate Display".

But what was the feeling of practitioners before that happened?

Industry Sentiment and Visions for the Future

The end of the 1960s marks the peak of general cybernetic hype, also in the architecture and design industries. The theoretical stage for machines and human coexistence was set in full glory, and prototypes of tools fuelled almost utopian imagination on how they could evolve in the future. A great insight into the sentiment of architects and theorists at the time can be found in a panel discussion closing the 1969 conference "Computer Graphics an Architecture and Design". It was an exchange of opinions and visions between, Louis Kahn, Charles Moore, Steven Coons, and Warren McCulloch.[86]

Fig. 23 Dr. Charles Moore - Chairman of the Department of Architecture at Yale, renowned educator and architect. (Computer Graphics in Architecture and Design, c. 1969)

[83] Erik Ulberg, "Software Reconstruction of URBAN5," 2019, https://github.com/c0deLab/URBAN5.
[84] "Kolega," accessed April 11, 2024, http://www.kolega.space/.
[85] Mario Carpo, "Chronograms of Architecture - Mario Carpo - A Short but Believable History of the Digital Turn in Architecture," March 2023, https://www.e-flux.com/architecture/chronograms/528659/a-short-but-believable-history-of-the-digital-turn-in-architecture/.
[86] Murray Milne, ed., "The Past and Future of Design by Computer," in *Computer Graphics in Architecture and Design* (Connecticut: Yale School of Art and Architecture, 1969), 97–103, https://archive.org/details/computergraphics0000murr/page/97/mode/2up?view=theater.

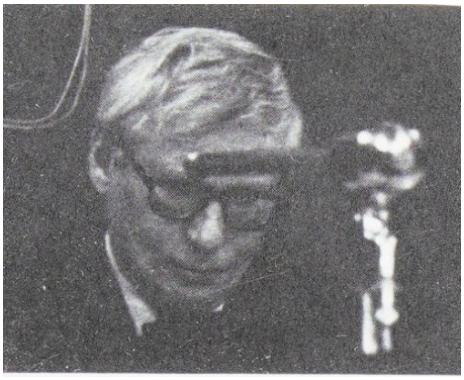

Fig. 24 Louis Kahn - Architect and Professor of Architecture at the University of Pennsylvania. (Computer Graphics in Architecture and Design, c. 1969)

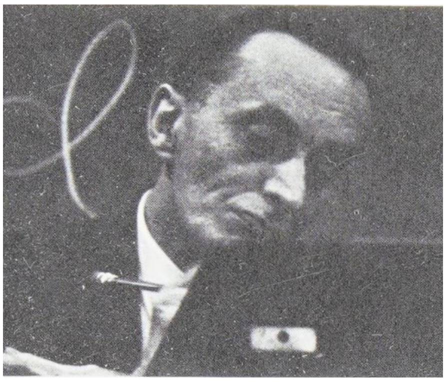

Fig. 25 Prof. Steven Coons - one of the pioneers of Computer Graphics, Mechanical Engineering at MIT. (Computer Graphics in Architecture and Design, c. 1969)

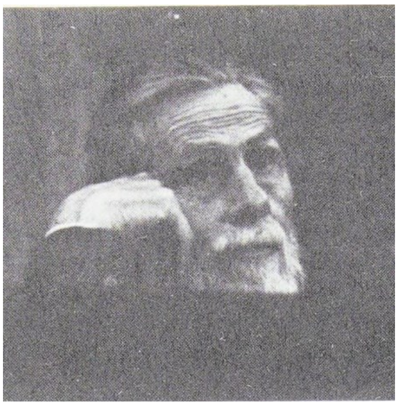

Fig. 26 Dr. Warren McCulloch - President of the American Society for Cybernetics, researcher in neurophysiology and electronics at MIT. (Computer Graphics in Architecture and Design, c. 1969)

"Architects now are looking carefully at the computer to assay whether it is enemy, friend, or simply replacement." Charles Moore focuses on the language architects speak and how it limits us in our creative work. To fulfil significant developments architects ought to describe a new language to communicate in. "If we develop this language, we may find computers saving rather than superseding us." Louis Kahn saw a great distinction between the mind and brain, stating that a mind is a brain fused with spirit. In that sense, he saw that computers are just soulless brains, that cannot conceive or invent, but are capable of releasing designers from the burden of organising massive amounts of data and spending more effort on "sensing the wonders of the spirit". He concluded that "the machine can clarify relationships which [...] only present the physical and cannot reach out to the power of anticipation." Steven Coons criticised the ongoing euphoria in some people about a new era of the computer being in full swing. He saw an ongoing misconception with computers as closed rigid systems, like automobiles, however, computers in his view are "perhaps, the most congenial mechanical device ever envisioned by human beings." Coons sensed that computers are here to stay, but it will take more time to fully incorporate them than previously thought, and they will be different. "Things as they are today, this instant, are not the way things will be tomorrow. Computers will be different [...], more capable, they will be cheaper, and they will be far more congenial to human beings than they are today." On the slightly more pessimistic side of the spectrum was Warren McCulloch. He voiced his concerns about architects working less and less on the open field with materials, while that was in his view the best way to learn. He feared the future in which "the kid sits there and pushes buttons". "If you want kids to learn, get them mobile. [...] An animal that is immobilized or moved passively just doesn't learn to see."[87]

But how they and the inventors imagined future development, what were their visions? Steven Coons, probably thinking about The Ultimate Display and the like, dreamed that "in a few

[87] Milne.

years it will be possible [...] to sketch in the air and have the thing [...] come to your eye, solid and real, so that you can walk around it, so that you can scrutinize it from any direction and any viewpoint". After more than 50 years later, we are slowly getting there. David Evans saw the development of the computer and computer graphics in general as an extension of our already existing abilities of sketching with pen and paper. He envisioned that they would release constraints on creativity imposed by current technology, and influence the style, hopefully in a more sensible way of perception. Evans thought that "once systems such as this start to become really usable, they won't be a damper on sensitivity. They could very well be an amplifier of it."[88]

As already discussed earlier in the text, people working on their inventions were naturally incredibly optimistic about what future developments might bring. Ivan Sutherland was excited about the next implementations of Sketchpad, or quick progress in computer vision capabilities[89] that we can enjoy at scale only since the early 2010s[90]. He and Evans hoped for a virtual "mathematical wonderland" in which we could work and interact. A slight exception in that excitement was of Nicholas Negroponte, who noticed early the hardware limitations and other difficulties possibly preventing the exponential growth just yet.[91] He later voiced his concerns more clearly reflecting on those misconceptions in his book "The Architecture Machine: Toward a More Human Environment"[92] and took a more pessimistic tone while "the winter of artificial intelligence" progressed.[93]

Redefining Failure

As mentioned in the text while exploring individual stories of those tools, it is not immediately possible to label one example as a failed one. Even though some of them did not leave university lab walls, they still catalysed future developments, providing researchers with valuable ideas, data, and paths for improvement. In many cases the idea remained, dormant or slowed down, until technological maturity could advance their development decades later, creating a successful scalable device with the real potential of influencing the paradigm of architecture and design practice.

It is also possible to notice that if it wasn't for architects' apparent romanticism about the profession and reluctance for progress, as technological conferences were not that common, a lot of potential effort and interest could have been devoted to the new toolset development. As exemplified in the text, some tools or ideas were simply snatched from design disciplines to serve in others, like aeronautics or military, where they proved to be of much help, only to re-emerge decades later back in their original research field.

One's failure might very well become the others' success.

[88] Evans, "Augmenting the Human Intellect."
[89] Sutherland, "Sketchpad, a Man-Machine Graphical Communication System."
[90] Alex Krizhevsky, Ilya Sutskever, and Geoffrey E Hinton, "ImageNet Classification with Deep Convolutional Neural Networks," *Advances in Neural Information Processing Systems* 25 (January 2012), https://doi.org/10.1145/3065386.
[91] Negroponte, "URBAN5: An Experimental Urban Design Partner."
[92] Negroponte, "The Architecture Machine: Toward a More Human Environment."
[93] Nicholas Negroponte, "Soft Architecture Machines," *Soft Architecture Machines*, February 15, 1976, https://doi.org/10.7551/MITPRESS/6317.001.0001.

Epilogue

In decades following the peak of the Cybernetics movement up until now, technology saw exponential growth, with some bumps on the road, of course. In the same fashion, the architecture and design industry got new tools to create with, and some ideas born long ago are only now seeing meaningful developments. In general, it seems that not much has changed on theoretical grounds since the Cybernetics era, Not only in the architecture field, in terms of software used nowadays, but more broadly in computer science as well. Those people set the theoretical framework and mostly what changed, was their ideas being evolved further through ever more powerful computing capabilities. What it can teach us is that having bold, almost science-fiction-like visions about the future can help open our minds for novel pursuits, even if their path to success would take decades.

Whether current tools are helping the industry more than limiting it in current technological condition, is a topic to explore in another research endeavour, possibly with no concrete answer. However, from personal experience and conversations with professionals of varying tenure, one could feel that there still is a lack of some digital design toolset tailored to modern times.

It was surely not possible to cover all the researched tools and their stories within the scope of this text. The main reason is that the list is simply too long, and it would take a whole book or two to achieve it, and then again for the sake of this text with its research focus it was not reasonable to include all known examples. The other reason is that the tools researched were the ones for which at least some information could be found through the available means and knowledge. One might hope there were many more ideas and experiments that did not start development at all or were born in different countries and institutions to which access is close to impossible, due to confidentiality, lack of archive entries, or simply language barriers. There is also no way of saying how many world-changing projects ended up as shelved master graduation theses whose potential was not considered at the time. That said, there is definitely room for further research on the topic, with more time and resources, those exciting stories can be uncovered, and there is much to learn about the history of augmenting architecture and design practice, with possible applications nowadays using modern technologies.

List of Figures

Bibliography

Amory, Cleveland. *Celebrity Register*. New York: Harper&Row, 1963.

Business Screen. "Sensorama Simulator Creates Environment for the Viewer." 1964.

Carlson, Wayne Earl. "Computer Graphics and Computer Animation: A Retrospective Overview." The Ohio State University, June 20, 2017.

Carpo, Mario. "Chronograms of Architecture - Mario Carpo - A Short but Believable History of the Digital Turn in Architecture," March 2023. https://www.e-flux.com/architecture/chronograms/528659/a-short-but-believable-history-of-the-digital-turn-in-architecture/.

Cash Box. "3-D Multi-Sense Film Machine Introduced." April 25, 1964.

Cash Box. "Amusement Coin-Op Novelty Units Spark Park Ops' Interest at Show." December 12, 1970.

Claypool, Mollie. "The Digital in Architecture: Then, Now and In the Future." *SPACE10: Copenhagen, Denmark.* , November 18, 2019. https://space10.com/project/digital-in-architecture/.

Coldwell, Chris. "Why Failure Is A Necessary Part Of The Innovation Process," November 4, 2022. https://www.forbes.com/sites/forbesbusinesscouncil/2022/11/04/why-failure-is-a-necessary-part-of-the-innovation-process/?sh=69254d1a3ff7.

Cross, Nigel. *The Automated Architect*. London: Viking Penguin, 1977.

Datamation. "The '64 Fall Joint Computer Conference." Los Angeles, December 1964.

Eekhout, Mick. "Frei Otto and the Munich Olympic Games. From the Measuring Experimental Models to the Computer Determination of the Pattern." *Zodiac 21*, Milan, September 1972.

Evans, David. "Augmenting the Human Intellect." In *Computer Graphics in Architecture and Design*, edited by Murray Milne, 61–66. Connecticut: Yale School of Art and Architecture, 1969. https://archive.org/details/computergraphics0000murr/page/61/mode/2up?view=theater.

"FINAL REPORT SD-265 - The BRAIN." Massachusetts, October 1, 1968.

Frazer, John. "An Evolutionary Architecture," 1995.

George, Frank Honywill. *Philosophical Foundations of Cybernetics*. Abacus Press, 1979.

Grady, Sean M. *Virtual Reality: Simulating and Enhancing the World with Computers*, 2003.

Heilig, Leonard Morton. SENSORAMA SIMULATOR. 3050870. United States of America: United States Patent Office, issued August 28, 1962.

———. STEREOSCOPIC-TELEVISION APPARATUS FOR INDIVIDUAL USE. 2995156. *ACM SIGGRAPH Computer Graphics*. United States of America: United States Patent Office, issued October 4, 1960. https://doi.org/10.1145/178951.178972.

Hovestadt, Ludger, Urs Hirschberg, and Oliver Fritz. "Atlas of Digital Architecture : Terminology, Concepts, Methods, Tools, Examples, Phenomena," 2020. https://doi.org/10.1515/9783035620115.

Huxley, Aldous. *The Doors of Perception : And Heaven and Hell*. New York : Harper & Row, 1963. ©1956, 1963. https://search.library.wisc.edu/catalog/999606461202121.

Isaacson, Walter. *Steve Jobs*. Simon&Schuster, 2011.

"Ivan Sutherland | Lemelson." Accessed March 16, 2024. https://lemelson.mit.edu/resources/ivan-sutherland.

Johnson, Jeff, Teresa L. Roberts, William Verplank, David C. Smith, Charles H. Irby, Marian Beard, and Kevin Mackey. "Xerox Star: A Retrospective." *IEEE Computer* 22, no. 9 (1989). https://doi.org/10.1109/2.35211.

Kalay, Yehuda E. *Architecture's New Media: Principles, Theories, and Methods of Computer-Aided Design*. Mit Press. MIT Press, 2004. https://books.google.pl/books?id=BDboJQJvUq8C.

Kauffman, Jordan. "Dessiner Avec l'ordinateur Dans Les Années Soixante: Le Design et Ses Pratiques à l'aube de l'ère Numérique." *Livraisons de l'histoire de l'architecture* 32 (2016): 105–23. https://research.monash.edu/en/publications/dessiner-avec-lordinateur-dans-les-ann%C3%A9es-soixante-le-design-et-s.

"Kolega." Accessed April 11, 2024. http://www.kolega.space/.

Krizhevsky, Alex, Ilya Sutskever, and Geoffrey E Hinton. "ImageNet Classification with Deep Convolutional Neural Networks." *Advances in Neural Information Processing Systems* 25 (January 2012). https://doi.org/10.1145/3065386.

Kwiecinski, Krystian. *Cyfryzacja Partycypacji. Studium Komputerowego Wsparcia Uczestnictwa w Projektowaniu Domów*, 2023.

"Le Système Design Augmented by Computers (DAC-1) Élaboré Par General Motors, c. 1964. @ Problemata." Accessed March 5, 2024. http://problemata.org/en/resources/684.

"Le Système Digigraphics Opéré Par La Control Data Corporation, c. 1963. @ Problemata." Accessed March 5, 2024. http://problemata.org/en/resources/680.

Licklider, Joseph Carl Robnett. "Man-Computer Symbiosis." *IRE Transactions on Human Factors in Electronics* HFE-1, no. 1 (1960): 4–11. https://doi.org/10.1109/THFE2.1960.4503259.

Markusiewicz, Jacek. "The Importance of Interactivity for Contemporary CAAD Tools," 2023.

"Marvin Minsky - Nicholas Negroponte's Lab: The Architecture Machine (140/151) - YouTube." Accessed March 16, 2024. https://www.youtube.com/watch?v=mk-ouQBkBeQ.

Metropolis, Nicholas, Jack Howlett, and Gian-Carlo Rota. *A History of Computing in the Twentieth Century. A History of Computing in the Twentieth Century*, 1980. https://doi.org/10.1016/C2009-0-22029-0.

Milne, Murray, ed. "The Past and Future of Design by Computer." In *Computer Graphics in Architecture and Design*, 97–103. Connecticut: Yale School of Art and Architecture, 1969. https://archive.org/details/computergraphics0000murr/page/97/mode/2up?view=theater.

Moore, Gary T., and Design Methods Group. "Emerging Methods in Environmental Design and Planning." MIT Press, 1968. https://search.worldcat.org/title/116699.

Negroponte, Nicholas. "Soft Architecture Machines." *Soft Architecture Machines*, February 15, 1976. https://doi.org/10.7551/MITPRESS/6317.001.0001.

———. "The Architecture Machine: Toward a More Human Environment," 1973. https://api.semanticscholar.org/CorpusID:109283490.

———. "Towards a Humanism Through Machines." *MIT Technology Review*, April 1969, 44–53.

———. "URBAN5: An Experimental Urban Design Partner." In *Computer Graphics in Architecture and Design*, edited by Murray Milne, 77–88. Connecticut: Yale School of Art and Architecture, 1969. https://archive.org/details/computergraphics0000murr/page/77/mode/2up?view=theater.

Neumann, John Von. *The Computer & the Brain*. Yale University Press, 1958. https://yalebooks.yale.edu/9780300181111/the-computer-and-the-brain.

Pierce, John R. "A Different Girl Every Night." *Penthouse*, New York, July 1971.

Roberts, Lawrence Gilman. "The Lincoln Wand." In *AFIPS Fall Joint Computer Conference*, 223–28. Washington D. C.: Spartan Books, 1966.

Sakane, Itsuo. *Morton Heilig's Sensorama (Interview).Mov - YouTube*. Japan, 2010. https://www.youtube.com/watch?v=vSINEBZNCks.

Spiegel, Joseph, John K. Summers, and Edward M. Bennett. "AESOP: A GENERAL PURPOSE APPROACH TO REAL-TIME, DIRECT ACCESS MANAGEMENT INFORMATION SYSTEMS." Massachusetts, June 1966.

Steenson, Molly Wright. "ARCHITECTURAL INTELLIGENCE : How Designers and Architects Created the Digital Landscape.," 2022.

Sutherland, Ivan Edward. "A Head-Mounted Three Dimensional Display." In *Fall Joint Computer Conference*, 757–64. San Francisco, 1968.

———. "Sketchpad, a Man-Machine Graphical Communication System." Massachusetts Institute of Technology, 1963. https://dspace.mit.edu/handle/1721.1/14979.

———. "The Ultimate Display." In *IFIP Congress Proceedings*, 506–8, 1965.

Sutherland, Ivan Edward, Alan Blackwell, and Kerry Rodden. "Sketchpad: A Man-Machine Graphical Communication System." University of Cambridge, 2003. http://www.cl.cam.ac.uk/.

Tate, Scott. "VIRTUAL REALITY: A Historical Perspective," 1996. https://ei.cs.vt.edu/~history/Tate.VR.html#2.

The Mass Art Paper. "A.T.I." October 30, 1969.

Turing, Alan Mathison. "On Computable Numbers, with an Application to the Entscheidungsproblem." Princeton University, 1936.

Turnheim, Bruno, and Benjamin K. Sovacool. "Exploring the Role of Failure in Socio-Technical Transitions Research." *Environmental Innovation and Societal Transitions* 37 (December 1, 2020): 267–89. https://doi.org/10.1016/J.EIST.2020.09.005.

Ulberg, Erik. "Software Reconstruction of URBAN5," 2019. https://github.com/c0deLab/URBAN5.

"Un Terminal Du Semi Automatic Ground Environment (SAGE), c. 1958. @ Problemata." Accessed March 5, 2024. http://problemata.org/en/resources/678.

Vrachliotis, Georg. *The New Technological Condition. Architecture and Design in the Age of Cybernetics*. Birkhäuser, 2022. https://doi.org/doi:10.1515/9783035624816.

Wachowski, Lana, and Lilly Wachowski. *The Matrix*. USA: Warner Bros., 1999.

Wiener, Norbert. *Cybernetics or Control and Communication in the Animal and the Machine. Reissue of the 1961 Second Edition. Cybernetics or Control and Communication in the Animal and the Machine*. The MIT Press, 2019. https://doi.org/10.7551/MITPRESS/11810.001.0001.

Yiannoudes, Socrates. "Architecture in Digital Culture: Machines, Networks and Computation." *Architecture in Digital Culture*, December 14, 2022. https://doi.org/10.4324/9781003241287.