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Architecture Goes Digital: The Discrete

Mollie Claypool

This is an account of a broad narrative substantiating a contemporary architectural moment: that of the Discrete. The Discrete emphasizes part-to-part and part-to-whole relationships in the deployment and contextualization of architectural "wholes." As Daniel Köhler has written, the Discrete is derived from *mereology*[1] in philosophy, the theory of parthood, as well as discrete mathematical logics such as the use of numbers with distinct and separate values, which differs from the "smooth" mathematics of continuity such as calculus. The Discrete also utilizes a critique of matter, developed at the Massachusetts Institute of Technology by Professor Neil Gershenfeld, as having not yet been digital, as material is analogue.[2]

The Discrete is inextricable to digital thinking, embedded in a discourse around the tools architects use, such as computer software and automated manufacturing technologies. Despite this connectedness to digital innovations, it has been argued by architect Gilles Retsin that it is via the Discrete that architecture is only now becoming digital[3]—almost eighty years after the invention of the first electronic computer. As this essay will show, core aspects of the Discrete that draw from computational developments such as notions of scalability, versatility, open-endedness, and distribution have existed within architectural production for decades. They are embedded within a history of architectural projects—both long past and very recent—that are disruptive of, but also contingent to, the changing relationships between people and capital, politics and space, domesticity and social practices fueled by ideology as well as innovation in computing and automated technologies.[4] To demonstrate how these relationships and concepts intertwined and contributed to the Dis-

[1] Daniel Köhler, *The Mereological City* (Bielefeld, Germany: transcript Verlag, 2016).

[2] Neil Gershenfeld, "How to Make Almost Anything," *Foreign Affairs* 91, no. 6 (2012): 52.

[3] Gilles Retsin, "Discrete and Digital," *TxA*, 2016.

[4] Mollie Claypool, "Discrete Automation," *e-flux architecture*, 2019, accessed January 9, 2020, www.e-flux.com/architecture/becoming-digital/248060/discrete-automation/; Mollie Claypool, "From the Digital to the Discrete," *Proceedings of the 107th Annual Meeting of ACSA*, 2019.

crete, I will situate the developments that have contributed to its emergence today between two distinct periods of time—the twentieth-century postwar period and the years after the 2008 financial crash—connected through dialogue around the role of computing technology with an economic and social project in architecture. I will articulate a history of Discrete part-to-whole relationships through the dissolving of architectural "wholes" into "frames," then "modules" and "surfaces," before reaching "parts." It is in "parts" that architecture goes digital.

A New Regime of Accumulation

The 1930s to 1950s was a period marked by social, economic, and political progress in relationship to the development of computing, associated mathematical and philosophical developments, and new manufacturing technologies. This moment cannot be extracted from the simultaneous invention and proliferation of new archetypical models for architectural production. These models were reliant on the articulation and provision of the "universal whole" as a mechanism for the provisioning of the welfare state within mid-twentieth-century capitalism. The Discrete has learned from this period of time, understanding that architecture can provide a platform for the expansion of a comprehensive social project.

The Discrete is also a response to, and critique of, the last two decades: a time of expanding computational power. Today, mere seconds of data processing equate to the labor of billions of human beings. This "end of modern science" outlined by architecture historian Mario Carpo, of understanding or truth enabled by observations of precedent and utilizing predictive modeling,[5] capitulates architectural production into an opportunity to completely rearticulate our current understandings of the relationship between labor and production in architecture and the built environment suitable for an age of automation.[6] This is, as one might imagine, a timely necessity. The asymmetrical hegemony of neoliberalism signified by the financial crash of 2008, and underpinned by the free market, deregulation, globalization, and corporatization since the 1970s and 1980s, is no longer sufficient. Accumulation for the sake of unlimited growth and productivity is inextricably bound to a continuation of capitalism, increasingly seen as creating financial instruments for the wealthy[7] and rapid-

[5] Mario Carpo, *The Second Digital Turn: Design beyond Intelligence* (Cambridge, MA: MIT Press, 2017), 33–40.

[6] Mollie Claypool et. al., eds., *Robotic Building: Architecture in the Age of Automation* (Munich: Detail Edition, 2019).

[7] Saskia Sassen, "Expanding the Terrain for Global Capital When Local Housing Becomes an Electronic Instrument," in *Subprime Cities: The Political Economy of Mortgage Markets*, ed. Manuel B. Aalbers (Oxford: Blackwell Publishing, 2012).

ly driving inequity through “top-down,” “trickle-down” economics. This crisis of scarcity and abundance is ever more amplified by the ongoing climate emergency and our limitations in computing the consequences of this crisis in relationship to issues of social justice.[8] Architecture as a material hegemony has the opportunity—through catalyzing within its approach to design a social project that was lost in architecture utilizing mathematics and computational thinking in the late twentieth century and early twenty-first century—to be understood through positioning “emerging technologies as inaugurating a new regime of accumulation” rather than “continuing earlier regimes.”[9]

Wholes

To contextualize this, a useful moment to go back to is over a hundred years ago. Oft presented as a disruptor of ideology, of history, and of precedent, the latency of Maison Dom-Ino (Le Corbusier, 1914) is contingent to technological innovation and discourse on the modernist ideological nature of a disciplinary social project. As a mechanism for the ordering and organizing of space and production, Maison Dom-Ino (Fig. 1) as a prototype was an embodiment of the rapid acceleration of technological progress due to twentieth-century militarization and symbolic of power relations within the production of the built environment. The continued and undeniable presence of this archetype was enabled by changes in French governance that allowed its implementation at a large scale. Utilized across Europe and America, and later worldwide as a response to housing crises, it has formed much of the underlying rule set for the rationalization of relationships between architectural “parts” for mass-standardized production of architectural “wholes”—just six columns, three slabs, a staircase to make a “whole,” which, combined, make larger wholes. Furthermore, the abstraction of architecture to the serialization of three different architectural parts that together constructed a prototypical, modular “whole” was made possible, as Pier Vittorio Aureli has written, “by a specific historical condition: the gradual transformation of life into economy and production.”[10] As such, Maison Dom-Ino—a name derived either from the repeatable pattern-making game Domino or from a combination of *domus* (home) and *innova-*

[8] “Global Warming of 1.5°C,” *IPCC Special Report*, 2019, accessed September 1, 2019, www.ipcc.ch/2019/.

[9] Nick Srnicek, *Platform Capitalism* (Cambridge, UK: Polity Press, 2017), 7.

[10] Pier Vittorio Aureli, “The Dom-ino Problem: Questioning the Architecture of Domestic Space,” *Log*, no. 30 (Winter 2014): 155.

tion—embodied the techno-utopianism of industrial modernism in a time of postwar scarcity: efficient, universal, and abstract.

Frames

The inherent contradictions of this "whole" are apparent. Exposed in the section drawings are hollow tiles to be poured over with concrete on-site. The patent image, however, suggests an entirely prefabricated, mass-produced monolith.[11] In these images the new assembly line of the Taylorist factory had not yet entirely permeated architectural production. In fact, what Le Corbusier promised is no more than a "frame" through which architectural order of the postwar environment could be achieved on a mass scale. Nonetheless it is the visual description that has perpetuated a long-lasting image of an architectural archetype that is capable of becoming a tool of large-scale industrialization,[12] and thus automation—a totality, a "machine for living."[13] The mass standardization of building elements, and the possibility of prefabricating these elements in factories, recalibrated the production of architecture from the scale of the local or contextual to the precise, optimized architectural coordination of a system for building able to be replicated across global contexts as a series of frames through which the world could be comprehended.

Le Corbusier was not alone in this search for an architecture that could bring together both the singularity of technological progress and the necessity of social unification at a time when the image of architecture that had existed previously was deemed wholly insufficient in the face of widespread postwar devastation. Hyperrationalized architectural systems such as Walter Gropius and Adolf Meyer's "Big Construction Kit" (1923), Buckminster Fuller's notion of "doing more with less" most exemplified in *Nine Chains to the Moon* (1938) and the Dymaxion Deployment Unit exhibited at the Museum of Modern Art in 1941, the system of standardized steel component–based assembly of the Eames House (1949) by Charles and Ray Eames, or Jean Prouvé's three prototypes developed under the umbrella of Maison Tropicale (1949–51) were also created in the same period (Fig. 2), with similar intentions of scalability and wide distribution across contexts. In these moments the architect became the facilitator of the beginning of a process of reproduction, concerned with architecture's function as pure structure. Domestic space became a scaffold for projection,

[11] Le Corbusier, *Towards an Architecture*, 1923, 24.

[12] Ibid., 236, 263.

[13] Ibid., 4.

where the space for design was relegated to the "frame," to everything beyond the coordination of predetermined modular, structural "wholes." The total machine for living was a space of abstracted, ambiguous potential. This enabled the customization of the hung facade within the universal structural frame according to stylistic, aesthetic, or contextual concerns.[14] It was now the space for the reproduction of life itself—according to technological progress[15]—to be instantiated and imagined further into the domestic sphere, framed, or even gridded.

Modules

It is not by chance that the wide deployment of mass-produced and mass-standardized "modular" systems in the latter half of the twentieth century coincided with the development of early computing systems and automation technologies in the 1940s and 1950s. Modular architectural syntax learned from the possibilities afforded by systematizing the organization of data and information during this period of expansion in early computing and cybernetic theory. This is found in the work of Claude Shannon ("A Mathematical Theory of Communication," 1948), John von Neumann ("The General and Logical Theory of Automata," 1948), William Grey Walter ("An Imitation of Life," 1950), and Norbert Wiener ("Cybernetics: Or Control and Communication in the Animal and the Machine," 1948) as well as in earlier developments in manufacturing technologies in the 1900s, such as the linearity proposed by the assembly line.

Promising an optimized system of coordination of modules embedded in principles from early computing such as the notion of the "black-box" module masking internal processes, connectivity interfaces for the transposition of information, and "plug and play" systems, modularity proposed a solution to a modern scenario: the postwar crisis of architecture in an age of mass production. Each module is a complete whole, and is reliant on the supposition of a larger, more unifying whole, as a means for "confronting and managing complexity in a […] systemic context."[16] Perhaps the most important example relating to the Discrete is the four-inch cubic standardized module outlined in *The Evolving House* (1936) by Alfred Bemis (Fig. 3), which proposed a system of ideological management and coordination of parts at every scale of building. Yet Be-

[14] Antoine Picon, "Dom-ino: Archetype and Fiction," *Log,* no. 30 (Winter 2014): 169–75.

[15] Beatriz Colomina, *Domesticity at War* (Cambridge, MA: MIT Press, 2006).

[16] Andrew Russell, "Modularity: An Interdisciplinary History of an Ordering Concept," *Information & Culture* 47, no. 3 (Austin: University of Texas Press, 2012), 258.

mis's argument existed in a period when methods of organizing architectural production were not as intelligent as the module itself. When scaled up, the module, like the frame, continues the redistribution of the function of structure to points rather than along a line. In this, modular architecture can become open-ended in terms of context, needing merely to "touch down" to be located. Its most important relationship is to the next module that it meets within the larger, economizing whole. The module must always have the same orientation in its repetition, and thus tends to have a relatively homogeneous distribution, as demonstrated in many projects throughout the twentieth century, including Yona Friedman's Spatial City (1959–60), Moshe Safdie's Habitat 67 (1967), or Kisho Kurokawa's Nagakin Capsule Tower (1972).

Aureli has written that "architecture became form devoid of any references outside itself at the moment it was fully conquered by the forces of industrialisation."[17] The utmost efficiency of the module set the seed for what came next: a well-publicized story of the questioning and downfall of modernist, standardized modular systems—of ideal and exact geometries—and indeed the eventual "death" of modern architecture delivered by the demolition of Pruitt–Igoe in St. Louis, Missouri, in 1972.[18] Parallel to the demise of the welfare state and rise of neoliberalism, its failure resulted in the projection of a transhistorical collective approach via analytical formalism[19] fading quickly from view. This happened just as the apolitical diversity inherent to the predominance of the "collage approach"[20] began to meet the potentialities presented by nonstandard digital mass customization. In its reduction of context, style, or aesthetics to the surface between points held in the frame of a larger whole, modularity must be seen as an actor in the rise of the contemporary surface of capital-driven "parametric design," where the exuberance of form relates to the maximum efficiency of available resources.

Surfaces

An antidote to modernism's failure, the "animation" of architectural form was made possible in the late 1980s and 1990s through engagement with new kinds of digital modeling and digital manufacturing technologies from aeronautical, naval, and automobile industries. The smoothing of the composite curve—com-

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[17] Aureli, "The Dom-ino Problem," 154.

[18] Charles Jencks, *The Language of Post-modern Architecture* (New York: Rizzoli, 1977), 7.

[19] Colin Rowe, "The Mathematics of the Ideal Villa," *Architectural Review*, March 1947, 101–4.

[20] Colin Rowe and Fred Koetter, *Collage City* (Cambridge, MA: MIT Press, 1978).

posed of an array of circular segments—of industrial modernism was transformed into the Bézier, or spline, curve of calculus.[21] This was adopted by the architects of, as Mario Carpo designated, the "first digital turn," such as Greg Lynn, Frank Gehry, Reiser & Umemoto, Foreign Office Architects, and Bernard Cache.[22] The functionalism and structuralism of the previous "mathematics" of architecture found in the grids of Le Corbusier or Mies van der Rohe was abandoned for, as Lynn outlined in *Animate Form* (1998), the "free"[23] geometries found in continuous, calculus-based mathematics. In this model, the differentiation of points along a line constructs a smooth surface of "instanced" configurations, an "envelope of potential"[24] that was later referred to by architect and theorist Philippe Morel as a "logical figuration,"[25] one of an "inexact" tectonics.

This Big Data–based approach of infinite variability was suitable for the increasing degrees of computational power throughout the 1990s and 2000s, as computers were beginning to be able to "predict without understanding,"[26] thereby outperforming human capacity for calculating the best outcomes given inputted design parameters in the shortest period of time. Yet "digital design" and "parametric design" are bound to a mathematics of theoretical infiniteness, and, as Antoine Picon notes, "considering relations that can be far more abstract than what […] design […] usually entails."[27] Furthermore, as Lynn outlined in his essay "Architectural Curvilinearity" in 1993, this was a radical departure from the "conflict and contradiction" of earlier work around Deconstructivism, toward a "more fluid logic of connectivity."[28] Explored primarily through principles of "folding" inspired by the mathematics of Leibniz and the philosophy in Deleuze's work *The Fold* (1988), a logic of connectivity is a significant departure from the discreteness of the "whole" module and the Cartesian grid. Utilizing morphodynamic principles appropriated from topology, a branch of mathematics, the complex forms designed by architects using digital design tools during this period were conceptually, as Branko Kolarevic has highlighted, "less about spatial distinctions and more about spatial

21 Greg Lynn, *Animate Form* (New York: Princeton Architectural Press, 1999).

22 Mario Carpo, *The Digital Turn in Architecture* (Hoboken, NJ: John Wiley & Sons, 2012).

23 Greg Lynn, *Folds, Bodies and Blobs: Collected Essays* (Brussels: La Lettre volée, 1998), 202.

24 Lynn, *Animate Form*.

25 Philippe Morel, "Sense and Sensibiia," *Architectural Design* 81, no. 4 (2011): 125.

26 Carpo, *The Second Digital Turn*, 67.

27 Antoine Picon, "Architecture and Mathematics: Between Hubris and Restraint," *Architectural Design* 81, no. 4 (2011): 35.

28 Greg Lynn, "Architectural Curvilinearity," *Folding in Architecture* (Hoboken, NJ: John Wiley & Sons, 1993).

relations."[29] Yet the isolation of a building's structure and facade enabled by the development of the earlier steel frame and reinforced prefabricated concrete systems, as described above, meant that topological structures were often misinterpreted as curved surfaces, rather than a more holistic representation of "performative circumstances"[30] that included a design's material culture and production. And so the potential of the surface became a space of affect, perception, and the experiential, emphasizing the subjective appearance of form as a mediator between interior and exterior.

This misunderstanding by the architects of the early digital period resulted in the separation of architectural representation from forms of production. The complexity of a surface—typically a building's skin—existed in conflict with processes of materialization and was incompatible with mass production technologies that promised more efficient production chains. This is because automated mass production relied on the efficiencies of standardized, serialized repetitive actions, and here variant surfaces messily confronted physical reality. While some architects, such as Bernard Cache, attempted to resolve this dichotomy through direct engagement with the constraints of digital mass manufacturing technologies, such as the computer-numerical controlled (CNC) machine, to explore the potential of a digital continuum[31] or the relationship of manufacturing data to create nonstandard architectural objects—or objectiles,[32] as Cache and his partner Patrick Beauce called these objects—these processes were not able to be easily scaled.

The construction industry has been slow to digitize its processes. This resistance to digitization required that the possibilities afforded by the surfaces of the 2000s were "post-rationalized"—sliced into panels, ribs, and waffles—in order to be realized using existing construction technologies. This extended production chains and vastly resulted in bespoke, "one-off," iconic pieces of architecture that required large amounts of capital to be realized, best exemplified by the Guggenheim Bilbao by Gehry Partners, the Yokohama International Port Terminal by Foreign Office Architects, or the Mercedes Benz Museum by UN Studio. Post-rationalization thus becomes about maintaining an efficiency of resources, of capital, in relation to an exuberance of form. The surface became an instrument of capital, symbolic of wealth and ideology[33] that supported the

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29 Branko Kolarevic, *Architecture in the Digital Age: Design and Manufacturing* (London: Taylor & Francis, 2004), 8.

30 Ibid.

31 Ibid., 10.

32 Bernard Cache, *Earth Moves: The Furnishing of Territories* (Cambridge, MA: MIT Press, 1995).

33 Douglas Spencer, *The Architecture of Neoliberalism* (London: Bloomsbury, 2016).

"trickle" of the top-down capitalist market, a centralizing regime of accumulation. The failure of the surface as a radical embodiment of the age of expanding computational power can be traced to the 2008 financial crash, when architecture and construction was brought almost to a standstill. It is here that the potential of the digital in architecture began to be rearticulated by a new generation of architects and designers.

Parts (Architecture Goes Digital)

The recession that followed the 2008 crash brought to the forefront of the architectural community the capacity for digital innovation to be completely subsumed by capital. In the public realm the "digital" in architecture began to be synonymous with asymmetries in power and the inequities that emerged from the failures of capitalism.[34] As has been pointed out by Peter Frase's[35] analysis of the relationship of computing, automation, and scientific progress, the way we construct society has traditionally seen these processes—and the inequities they produce[36]—as inevitabilities rather than choices a society makes. As such, the digital and automation are a design problem,[37] not just a technical solution to be commodified. The power of computation lies not just in the tools we use but in how and why and for what they are used. Architectural production, as it stands, is highly analogue; new models for how architecture can come closer to the digital ubiquity of the contemporary world are necessary. To catalyze this "conceptual leap"[38] in architectural production, a radical departure from earlier approaches to the digital in architecture has begun, from the parts that make up architecture, up.

A parts-to-whole approach learns from the misunderstandings of topology embedded in earlier digital architecture. It looks back to the work of Julia and John Frazer (Universal Constructor, 1990) (Fig. 4) and Nicholas Negroponte (SEEK, 1970) (Fig. 5), who understood spatial relations not through how they appear on curvilinear surfaces but through the relationships established between discrete volumes in assembly, de-

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[34] Rowan Moore, "Zaha Hadid: Queen of the Curve," *Guardian*, September 8, 2013, www.theguardian.com/artanddesign/2013/sep/08/zaha-hadid-serpentine-sackler-profile.

[35] Peter Frase, *Four Futures: Life after Capitalism* (London: Verso, 2016), 14–15.

[36] Ruha Benjamin, *Race after Technology: Abolitionist Tools for the New Jim Code* (Cambridge, UK: Polity Press, 2019); Virginia Eubanks, *Automating Inequality: How High-Tech Tools Profile, Police, and Punish the Poor* (New York: St. Martin's Press, 2018).

[37] Claypool, *Robotic Building*.

[38] Philippe Morel, "Computation or Revolution," *Architectural Design* 84, no. 3 (2014): 76–87.

scribed later as voxels, or three-dimensional pixels. Voxels can, just like pixels, be "coded" much like the 0s and 1s of computer code. "Based on [discrete] parts that are as accessible and versatile as digital data," Gilles Retsin has written that the Discrete "offers the greatest promise for a complex yet scalable open-ended and distributed architecture."[39] A "fully generic and voxel-based architecture," as demonstrated in early Discrete projects such as Universal House and Assembly Element (2004) (Fig. 6) and Computational Chair (2006) (Fig. 7) by Philippe Morel and EZCT Architecture & Design Research, utilizes a "constructive" approach, bringing parts, and their assembly, in line with available forms of automation for manufacturing—in this case the CNC machine. Similarly, François Roche's Olzweg (2006) embeds the way in which a building is constructed into the very center of the project, with industrial robotic arms on a gantry reorganizing voxelized space in real time.

Part-to-whole thinking was further supported by a critique of Lynn's spline curve as a space of potential animation of architecture. This was first done by Daniel Köhler in his Mereological Line (2016), and then by Gilles Retsin's Discrete Curve (2016) (Fig. 8). By imagining the line comprising "bits," like computer data or in discrete mathematics, rather than "weights" reliant on the entire figuration of a spline, a new negotiation between part-to-parts and parts-to-wholes in architecture was enabled. Furthermore, serialized mass production was reimagined not through creating variable nonstandard parts to compose differentiated surfaces, contributing to long production chains, but through designing self-similar parts using combinatoric principles. This enabled parts to combine in assembly and, as in the case of Bloom (2012) by Jose Sanchez and Alisa Andrasek, through processes of game play, rather than in strictly prescribed design outcomes.[40] A single part's geometry could be embedded with tectonic and spatial agency.

It has been argued by Sanchez, myself, and others[41] that, in its scalability and versatility, as a framework the Discrete can provide a model for architecture suitable for a postcapitalist economy that localizes and decentralizes production as a means of dealing with issues of scarcity and the resultant inequity. Part-to-whole relationships customized in assembly, or through their "composition" as Köhler has argued,[42] enable a rearticulation away from a modernist, deterministic, and hierarchical ontology that relies on the imposition of pre-

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[39] Gilles Retsin, "Bits and Pieces," *Architectural Design* 89, no. 2 (2019); Gilles Retsin, *Discrete: Reappraising the Digital in Architecture* (Hoboken, NJ: John Wiley & Sons, 2019).

[40] Jose Sanchez and Alisa Andrasek, "Bloom—The Game," *FABRICATE 2014,* 2014.

[41] Jose Sanchez, "Post-capitalist Design: Design in the Age of Access," in *Parametric Tendencies & Design Agencies*, ed. David Gerber, 2014; Mollie Claypool, "Our Automated Future: A Discrete Framework for the Production of Housing," Jose Sanchez, "Architecture for the Commons: Participatory Design in the Age of Platforms," and Gilles Retsin, "Bits and Pieces," *Architectural Design* 89, no. 2 (2019).

[42] Köhler, 2016.

scriptive totalities which conceal the larger economy of production that constructs them. In a Discrete ecology the meaning and value of the relationships between different agents emerges through their appearance rather than a top-down approach, as an accumulation of self-similar parts into heterogeneous assemblies, over time. This suggests a new understanding of the ecology between things, where the relationship between individuals, society, and nature[43] should not be fixed or predetermined through top-down universalism. It also distributes the potential of what form architecture takes into the process of making and unmaking, through social engagement and participation by users who impart their own understanding and values into how parts come together, informing and deforming possible outcomes.

Architectural "wholes" are accumulations of autonomous parts into heterogeneous assemblies, emerging through action, of appearance, in different contexts (Fig. 9). The role of the architect becomes one of facilitation of a framework of production, linking the digital tools for design and fabrication in a way that makes them accessible. In this "new regime of accumulation" the Discrete presents a notion of how a new understanding of part relations—tectonic, spatial, social, economic, material—in architecture can catalyze production away from the failures presented by the deterministic and hierarchical architectural ontology that persisted well into the twenty-first century. In its attention to part-to-part and part-to-whole relationships rather than "whole-to-part" or "top-down" frameworks, the Discrete is prospective, open-ended, and anticipatory rather than prescriptive and closed.

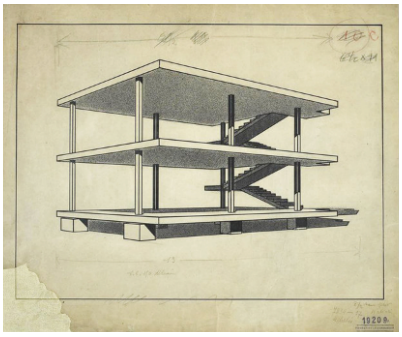

Fig. 1

BU: Maison Dom-ino, Le Corbusier, 1915

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[43] Ibid.

Credit:

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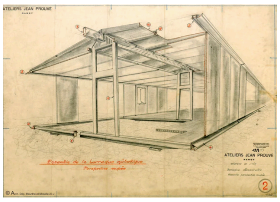

Fig. 2

BU: Maison Tropicale, Jean Prouvé, 1949–52

File: 4- Maison Tropicale_Prouve Kopie

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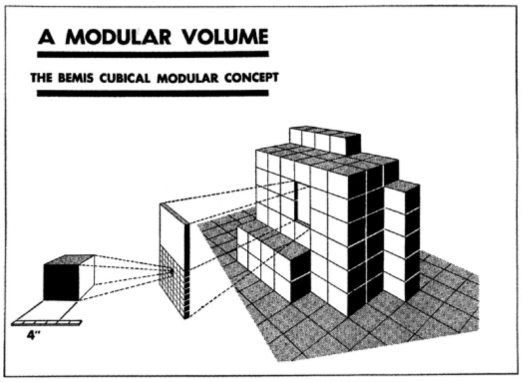

Fig. 3

BU: Alfred Bemis's four-inch cubical modular concept for housing, 1936

File: 2- Evolving House_Bemis Kopie.jgp

Credit: "A Modular Volume: The Bemis Cubical Modular Concept," in *Basic Principles of Modular Coordination* (Washington, D.C.: U.S. Housing and Home Finance Agency, 1953), 5.

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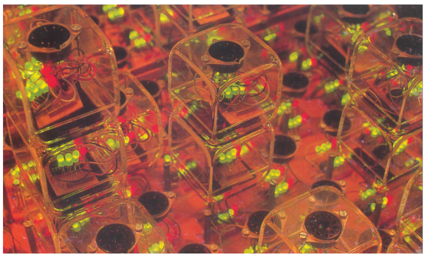

Fig. 4

BU: Universal Constructor, John Frazer, 1990

File: 6- Universal Constructor_Frazer.tif

Credit: John Frazer

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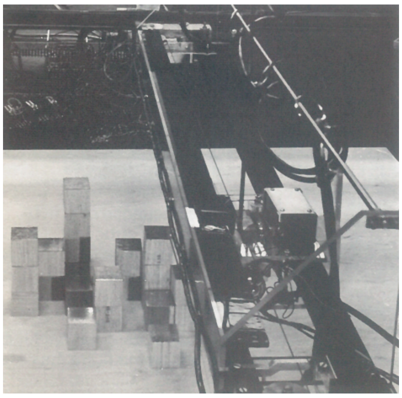

Fig. 5

BU: SEEK, Nicholas Negroponte, 1970

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Credit:

Bildgrösse: klein

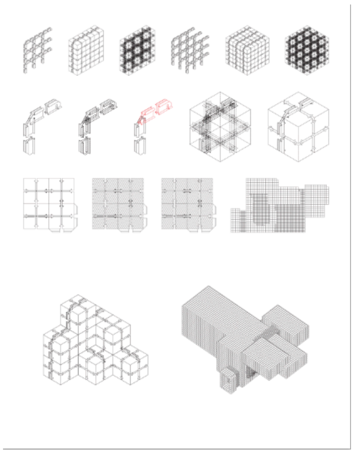

Fig. 6

BU: Universal House, Philippe Morel, 2002

File: 8- Universal House_Morel.tif

Credit: Philippe Morel

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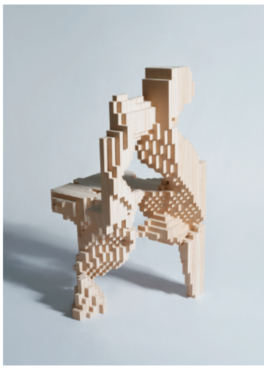

Fig. 7

BU: Computational Chair, EZCT, Architecture and Design Research, 2006

File: 9- Computational Chair_Morel.tif

Credit:

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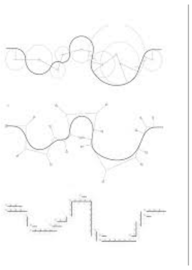

Fig. 8

BU: Continuous versus Discrete Curve, Gilles Retsin, 2016

File:

Credit: Gilles Retsin Architecture

Bildgrösse: klein

Fig. 9

BU: INT (Zoey Tan, Claudia Tanskanen, Qianyi Li, Xiaolin Yin), Research Cluster 4, Design Computation Lab, The Bartlett School of Architecture, UCL, 2016

File: 12-Mutant Chair High Res Chair Column-Bartlett RC4 INT-2016.jpg

Credit: Design Computation Lab, The Bartlett School of Architecture, UCL, 2016

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