The Digital In Architecture

Then, Now and in the Future

SPACE10
Introduction

Today within architecture, digital tools — from machine learning to fabrication technologies, from artificial intelligence to Big Data — are becoming more and more ubiquitous and pervasive, and quickly increasing interest in the impact these technologies are having, and will have, in our daily lives has rapidly expanded the use of these tools in architectural and design education, professional practice, and theoretical work. From augmented reality to 3D printing architectural models to design, manufacture, and animation industries, some tools and techniques are rapidly proliferated within architectural design from the late 1980s onwards, forever transforming the way that architecture design and realises projects. From augmented reality to automating construction processes, the report aims to describe the ways in which innovations in digital technologies are transforming the built environment. The report begins by looking at some of the key developments in digital thinking within this industry — ranging from the late 19th century until the present day, with continuous emphasis on parametric design. From these developments, digital design can be defined as work that is driven by parameters, where certain sets of rules influence the architectural or design outcome. It may be surprising that digital tools can be traced back as far as history. In fact, it has been argued by some architectural historians to have begun in the Renaissance. These developments have been relevant to the way that designers engage with digital tools — including software and manufacturing technologies — to design and produce architecture today.

Methodology

This report aims to describe the ways in which innovations in digital tools for design and fabrication in architecture have contributed to the way that people experience the built environment today. It does this by looking at some of the key developments in digital thinking within this industry — ranging from the late 19th century until the present day, with continuous emphasis on parametric design. From these developments, digital design can be defined as work that is driven by parameters, where certain sets of rules influence the architectural or design outcome.

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2 The Proto-Parametricists

Insight into the principles of nature, and the mathematics behind these principles, hugely influenced architects in the early to mid-20th century. While they certainly did not have access to the design technologies of today, they were able to utilize morphogenetic thinking in an analog way with whatever means they had at the time. Specifically, this led to the development of a series of works that could be argued as ‘proto-parametric’ or using analog models to compute form using parameters. During this period, Sullivan’s idiom ‘form follows function’ began to take on a new meaning. The Boston architect Louis Moret argued that if a function — a building’s purpose — could be described through a set of parameters, then architects could design form using mathematical equations that relate to performance criteria. By performing these equations, one could map structural forces, spatial or geometric relationships, and environmental or experiential qualities such as light and air. Moret proposed that the set of relationships that emerged created the notion of ‘architectonic parameter’, in which parameters are assigned to the performance of architectural components — much like the 0s and 1s of a computer code represent certain actions. (Not coincidentally, he developed this notion in the period that electronic computers were first being built.) While it is arguably the first time the word ‘parametric’ had been used to describe how one understands relationships in the processes and forms of architecture during a period of technological innovation, it is not the first time that architects sought to think in an algorithmic way. Famously, the Catalan architect Antoni Gaudí worked computationally, but in an analog way. In his models for the Sagrada Família (1882–1926) in Barcelona, the only used drawings as a method of design, preferring to work rigorously with physical and material behaviour. Indeed, he developed the catenary arch structures of Sagrada Familia using weighted interlinking strings, which were then ‘formed’ by spilling down using photography and drawn up into architectural drawings. The physical model was a tool to test for him to compute parts of the building over many years, creating a deep understanding of the structural and spatial relationships at play. When experienced by visitors to the Sagrada Familia, these structural and spatial relationships play out in the vastness and upwards spatial movement embedded in the architecture of the church’s central nave. The geometry of the church’s many structural columns changes and adapts to the different structural loads as they grow higher up in the space, with the church’s many curved surfaces intersecting. Such methods of Gaudí’s drawings and models for the Sagrada Familia were destroyed during the Spanish Civil War in 1936. A young Austrian architect, Mathias von Buru, was able to piece together the complex mathematical code that underlies all of Gaudí’s models when he


3 Buckminster Fuller with Hugh B. Stimson, “Tensioned Dome over Crystal City,” Washington, DC, 1958 (courtesy of the Collection of the University of California, Los Angeles. Image: John Frazer)

4 A spatial model of the Centre Pompidou, Paris. Image: John Frazer


6 Speculative diagram of the Centre Pompidou, Paris. Image: John Frazer

13 Other proto-parametricists of this period include architects such as: the American architect, systems theorist and futurist Buckminster Fuller; Fuller’s son Edward in understanding how the universe worked — from its atoms to nation phenomena — led to developing (proto-)biologically based architectural projects which drew from scientific and technological engineering and innovation. From geodesic domes to inventions in modular deployable housing, Fuller advocated that through technological innovation, humans could move with less and use resources more efficiently. In Fuller’s view, a system that used less resources would create a more equal economy by decreasing the overall cost of products and making them more accessible to more people. This, in turn, would lead to a more sustainable and democratic future. His work could be seen as an architectural precedent to much of the ethos behind digital design and digital fabrication today.

3 A Cybernetic Revolution

Innovations in science go hand in hand with innovations in technology. In the middle of the 20th century, rapid technological advancement spurred by the two world wars became a mechanism for developing a greater understanding of how humans and machines are controlled by, and can communicate with, one another. At the time, the systems that this resulted in were broadly collated in an emerging field of research called ‘cybernetics’ — a term first defined by mathematician and philosopher Norbert Wiener in 1948. Cross-disciplinary in nature, cybernetics gathered together concepts from many fields of work including engineering, computer science, neuroscience, biology, and network theory. Hugely influential in architecture and design throughout the latter half of the 20th century until today, cybernetics sets out a theory that all behaviour, including that of humans and machines, is part of a system of feedback loops of inputs and outputs. In any given system, these inputs and outputs continuously merge together to extend the capacity of the human or machine. Some of the concepts of cybernetics dealt with communication and machine cognition. This thinking originates in the work of Alfred North Whitehead, an English mathematician and writer regarded as one of the first computer scientists for her work with mathematician Charles Babbage. (The Analytical Engine by Babbage, to which Lovelace contributed code, is generally considered to be the first ‘computer’.) The work started by Lovelace and Babbage set off a wave of exploration that has informed architectural design, but not before it was further developed alongside groundbreaking advances in computer science in the mid-20th century. Alan Turing, a famous English mathematician and computer scientist, developed a ‘Turing Test’ that was used to determine whether a computer was capable of artificial intelligence or parallel human intelligence — forming the basis of our understanding today in deep learning and neural networks. Turing’s other research looked into how his new work on that he could apply the logic of information processing to hypothetical machines. John von Neumann is also considered one of the foremost cyberneticians along with Turing. In the 1940s, his work in cellular automata — discrete, abstract computational systems that evolve through simple steps — explored concepts of self-replicating entities that can perceive and react to their immediate surroundings based on simple sets of rules. These innovations — the cybernetics — and the logic of self-replication — are at the core of cybernetic architecture and adaptive architectural systems which use information processing, machine learning, and artificial intelligence. After all, cybernetics inspired architects and designers to take these ideas and use them to understand the relationship between human and machine. They often realized these ideas by designing utopian spaces that were imagined for humans to live, work, and relax. The Centre Pompidou in Paris is an example of this approach. The Centre Pompidou is an example of how cybernetics could be used to extend and adapt to different needs and activities. Its staircases, including long ramps and moving floors, walls, ceilings and walkways as well as a temperature-sensitive control system to mimic different climates across the world during different eras of human development and warm air. Although the Centre Pompidou never built it inspired Richard Rogers and Renzo Piano’s Centre Pompidou in Paris. The design of the Centre Pompidou is an evolved spatial diagram which provides a vast open space that can maximize flexibility and cater to different activities. In this space, people are free to wander, gaze at artworks and installations and discover the collection in the building — all without being directed to a specific pathway by the archetypical blast. The ways in which a person can move through the Centre are dictated by their own wants, needs, desires, or needs. In the book The Architecture Machine (1972), Nicholas Negroponte and his research group at the Massachusetts Institute of Technology (MIT) envisioned the future dynamic between humans and machines as a dialogue where the machine can initially learn from the

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4 Early Digital Explorations

The economic crises and recoveries of the mid-1970s and 1980s drove architects to reevaluate the way they practiced. Many architects, particularly those embedded in the relative safety of academia, began to investigate other forms of more experimental practice and look to other industries for inspiration. The shipbuilding, aeronautical and automobile industries had been using computer-aided design (CAD) software for several decades to design complex forms. The utilisation of these tools by architect firms such as Greg Lynn PORTe, Foreign Office Architects (FOA) and NOK transformed architectural design practice: for the first time, architects were able to achieve 3D, complex, variable curves using a type of curve called a spline instead of just straight 2D lines along an X or Y axis. As complex forms designed with digital tools became more pervasive in the architecture and design industry over the late 1980s and early 1990s, computational tools became more essential for not only the design process but also the production of drawings. These tools enabled architects to rationalise form — to make it more efficient, but also to assist with producing information for the construction process. The American architect Peter Eisenman was an important figure in the early years of digital tools in architecture. Eisenman’s work is characterised by the manipulation of blocks and grids that are generated through abstract steps of operations; his competition entry for Biocenter (1987) in Frankfurt was one of the first projects to use computers to code design outputs. As Greg Lynn, who worked on the Biocenter project, later recalled, the calibration of the computer ‘exploded the processes of what it was computing’ — because it was learning design outcomes at the same speed as humans would.2 In a sense, the computer was just as critical to the design process itself as the human.3

The design for the Biocenter project was inspired by biological processes and used four interlocking variable curves. The starting point was building the physical model, which is later captured in a 3D digital model. Then, a physical model is again produced from the 3D model and modified with analogue, intuitive model making. After this process, the design is captured again using a 3D scanner to further inform the digital model, and continues to be worked upon using analogue and digital techniques over many years. To enable his design to be realised with minimal alteration to his intent and to facilitate the production stages of building design, Gehry and his team created an interface for CATIA, CATIA is a modelling software originally created for aircraft industry. The software generates data that can be sent directly to manufacturers without adjusting for any specific tolerances that the fabrication machines may have. This was later developed into a separate building information modelling (BIM) software called Digital Project by Gehry Technologies. BIM is software that manages the different inputs of various stakeholders in a design process. Digital Project was used to design and model the building that brought Gehry into view of the wider public: the Guggenheim Bilbao, completed in 1997.4 With this project, digital architecture for the first time reached a large, international audience. Large (usually in-house), Gehry Technologies was later acquired by Trimble in 2016, a company that owns many software companies; as a result, Digital Project was made available to the public for purchase and downloaded in order to model and realise the complex, three-dimensional, hand-made facades that he used to design his iconic buildings and products.5

5 From Virtual to Physical

As we’ve already started to see, advances in both digital and construction technology enabled architects to express and realise forms that could only have been conceptualised previously. The period of the late 1980s and early 1990s is marked by the realisation of the concept explored in the previous decade at an architectural scale. The boom in the financial market meant that a huge amount of money was poured into architecture. Later, this would result in another recession, the one of 2008, but at the time, it was extremely exciting. Architects who had only recently explored their work in the form of drawings and animations, or at the scale of installations of small buildings (if they were lucky), could now compete for large-scale projects. The exploration of what are considered more expressive forms gave rise to iconic architecture in different cities around the world. We’ve already seen how Gehry’s Guggenheim Museum in Bilbao utilised ground-breaking digital tools, but that’s not the only factor that makes it stand out on a socio-economic level, the museum’s expressive architectural form contributed to the regeneration of the area — so much so that it joined the term ‘Bilbao Effect’, or the idea that a building could stimulate economic uplift in an area due to its ‘hidden architecture’ attracting huge amounts of visitors.6

Some consider Gehry to have pioneered an era of technological constructions, with technology that’s widely used as parametric design tools and BIM today.7 To find out why, we need only summarise the key innovations in his work and process. The double-curved titanium cladding of the Guggenheim Bilbao is considered as a turning point in architecture, as it could not have been built without the computer-aided design (CAD) software Digital Project. The physical output was a direct representation of the virtual 3D model. And the model included...
6 Collaborative Practice

Then came the internet. And new communication technologies fuelled by its rise meant that collaboration — inherent to any architectural practice — could now happen at pace faster than ever before. No longer did one have to wait for architectural drawings to arrive in the post, which made the design process painfully slow. Instead they could be emailed, faxed and uploaded, and worked on almost in real-time by people in different locations. In the 2000s, continued advancements in scientific, philosophical and technological research led to emphasis on the importance of collective intelligence, drawing from principles in nature in both academic and practice.9

This period signified a shift from the machine age to the information age, and some architects started to explore the potential of how practices can operate by leveraging advances in information technologies. Telecommunication, the internet and the digitalisation of projects using BIM allowed some to reform their practice around networked communication, increased collaboration and collective intelligence. (On a conceptual level, collective intelligence is a new social organisation based on decentralisation and collectivity.10 With telecommunication and digital design technologies as its primary modes of communication, OCEAN was founded as one of the first geographically distributed practices in the early 1990s.11 The collaborations of OCEAN had multidisciplinary backgrounds including architecture, urban design, industrial design, interior design and agricultural science. The operation of the practice is said to have been effective even to its own members while producing results as a collective effort. After gaining recognition through several successful competition entries and exhibitions, OCEAN grew into a multiple of offices and locations in countries around the world, each of which eventually operated independently with the brand and OCEAN NORTH, until studios in Chile, Helsinki and Cologne, remained active as full-time offices known for their digital modes of operation, the fluid transition of individuals and collaboration of organisation highlight both the strengths and difficulties in maintaining a network-based collective of differences in aesthetic preferences to differences in approach. In this way of networked working require adaption on behalf of each individual member, over time, for each project. Despite the challenges, the way of practicing is extremely common today — from large corporations with multiple offices worldwide to small practices being dispersed with one or two members in several cities.

7 Computing Nature

For several decades academic practice had been a place where architects and designers found settings in a weakly economic climate that had affected the building industry. As a result, academics had been the bastion of the rise of architectural theory, with design focused on the representation — mainly through drawing, such as in the work of Peter Eisenman or Daniel Libeskind — of theoretical concepts and ideas appropriated from continental philosophy as well as the new generation of architectural theorists.12

The highly charged theoretical environment was coupled with locked accessibility of new, exciting digital tools that enabled 2D drawing to come to life as virtual 3D models driven by procedural algorithms — step-by-step operations to first form then parameters. Developments in computer science, particularly our understanding of nature’s behaviour became coupled with digital techniques and tools. The ability to model natural morphological thinking in the 21st century, giving new life to old design themes, enabled architects to explore new design opportunities and new areas of research.

The constraints of the tools that architects were working with greatly informed the potential of design outputs. Industry — particularly the rapidly changing software development sector — played great importance during this period by supporting academic research and providing platforms for academic and industry partners resulted in work which experimented with generative design processes to find new shapes and forms. From these, collaborators were able to design structures with high amounts of detail that were significantly informed by the imperatives and potential of software such as parametric CAD software, GenerativeComponents. The body of collaborative, cross-disciplinary and cross-industry design research connected together practitioners into complex networks from which form emerged through the changing relationship in the network over time.9

The Architectural Association’s (AA) Design Research Laboratories (DRL) and Emergent Technologies (EmTech) programmes, as well as the Delft University of Technology’s Hyperbody Group and Sci-Arc, also engaged rigorously with the notion of complex interactions between humans and the统治 emerging patterns. The DRL emphasized an interdisciplinary approach to computationally-driven architectural research, it touched upon a wide variety of topics, yet also situating itself within a long history of speculative architectural projects and design research with projects that dealt with questions of typology, scale, urbanization and society. EmTech, on the other hand, developed frameworks for understanding the potential of emerging and new technologies in architectural design through a focus on material systems and communicative systems. The emphasis on transdisciplinary co-operative work, beyond the realm of design, into the realms of design, production and other areas, enabled the collaborative work of architects and designers in the pursuit of new forms and designs.9

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8 Parametric Explosion

For the last decade or so, one of the ongoing debates amongst architects interested in the potential of digital tools and techniques is around whether digital and parametric design tools are merely a means to an end, i.e. the ‘how’ something gets designed.15 Or are these tools themselves embedded with social and political parameters? Are they symbolic or even operating of the ‘why’ and for whom of a design? Today, it is apparent that the tools are irreversibly true-giving developed discussions around uses of artificial intelligence, data privacy, surveillance and the future of automation in the media. But in the late 2000s, there was slightly more沃e and understanding of the majority of architects who were, by then, using digital tools in their practice.

Let’s first look at the tools of digital design in the late 2000s. Perhaps one of the more important realisations in the evolution of digital design tools was the release of the tool Grasshopper Designed by David Rutten, September 2007. It is now a plugin for a common design software called Rhino. Grasshopper uses a visual, node-based component interface to create generative algorithms that can be used to create 3D geometry and other functions. The simplicity and ease of the Grasshopper interface in comparison to other available programming languages quickly appealed to many digital designers for its drag-and-drop, on-and-off, input-output system. Grasshopper instigated an explosion in generative design tools: Ladybug, Honeybee, Geco, Kangaroo, Akin.32

As the tools were excellent for form-generation, structural and environmental analysis and the simulation and optimisation of forms, they cannot be the main driver for an architectural project — they are only a component of the architectural design process. As Burry wrote, the Hyposurface ‘situated architecture not in the architectural discipline but in a larger context of social, political and economic qualities and conditions. Following that logic, even architects’ tools themselves — be it Grasshopper, Rhino and other software — bring particular socio-political implications to the ‘why’ and for whom of an architectural project.

Parametric design has proven to be ample ground for the exploration and theorisation of this problem. While the first digital generation of architects were interested in how science and innovation could enable new forms of architecture to emerge from generative digital design, more and more architects are now exploring the notion of parametric design as an enabling ideology. Patric Schumacher of Zaha Hadid Architects is one of the most prominent voices arguing for what he named in 2008 as Parametricism. According to him, parametricism is ‘the great new style after Modernism’, a paradigm emerging ‘from the creative exploitation of parametric design systems in view of articulating increasingly complex social processes and institutions’.33 At the alignment here with society, style and digital tools mack-saws within the architectural discipline, and has been heatedly debated over the last decade since. One of the more prominent areas of critique of Parametricism as a style has been how ‘digital architecture’, when realised, is, or isn’t, sensitive to contextual issues, like how buildings deal with local culture.34 Parametricism has gone from being a relatively local culture until the local culture becomes part of the parametric system;’ says Ieuan Zip, architect at ZHA. ‘It is a product of the global economy and negotiates specific parametric design as embodying ideology.

9 Augmenting Reality

Contemporary culture was changed radically by the internet and other communication technologies. As technology became more accessible in the 2000s, particularly hardware and sensor technologies, so did the sense that architecture could physically be as performative and stream and vital as the algorithmic and simulations that architects used in the design process. Digital tools enabled architecture to embody fluidly, temporality, movement and change — which, in turn, also transformed one people move through and interact with their built environment. All of this became a mechanism for gaining new understandings of space. Architects explored to what extent physical architectural elements could respond to people’s behavioural, changing needs, or even cultural, programmable or environmental conditions. As part of this exploration, architects began to augment one’s experience of the built environment, often in real time. One of the first interactive walls developed was the Aegis Hyposurface by dECOi architects, made in 2001.
Imagine a world where microchips, becoming crammed out millions of objects, to be shipped around the world on vast transportation networks, didn’t have to exist. In fact, placescale digital fabrication machines like 3D printers are taking the world by storm, taking the form of mobile or desktop tools that you make to whatever objects you needed or needed — to build a house, to 3D print furniture, to make food. A shift from consumerism to production — where the consumer is also the producer — enables transformation in take to place in how we make the objects we use, making the transformation in us fit to realizing its full potential because of a revolution in digital fabrication.

One of the driving forces behind this shift is the fablab. A fablab is a place, usually in a city, where computer-con trolled technologies, and specialists in using those technologies, are accessible to the public. The fablab was brought to the forefront of the design community by MIT Professor and Director of the Centre for Bits and Atoms Neil Gershenfeld. In his 2012 article in Foreign Agent, How to Make Almost Anything, he stated, “a new digital revolution is coming, this time in fabrication.” Today, approximately 1,350 registered fablabs exist around the world, although the number is likely much higher when including more informal ‘fab’ spaces that are not registered on the fab lab Foundation website.4

They are located from the US, where the fablab movement originated, to South Africa; the only continent that doesn’t have a registered fablab is Antarctica. WikiHouse (2011-present) is one of the more well-known architectural projects to harness the potential of distributed manufacturing using digital fabrication technologies.5 Started in 2011 by Alexander Panik, Nick DEURM and Mirja Jor, 4 fablab architecture practice WikiHouse aims to put low-cost, low-carbon building into the hands of every citizen, community and country.6 Architecture 4 fablab proposed that digital fabrication can enable houses to be fabricated and assembled much more efficiently and cleanly than what is possible with typical methods of production. To achieve this, they introduced the WikiHouse building system, which relies on using digital fabrication techniques, which enable the building of any type of house. WikiHouse has received much critical acclaim from the media. However, its limitations as a system have exposed many of the issues that we face today. In this section, we will examine the potential of these technologies, as well as the limitations of digital fabrication as a practice, to look at what the future might hold.

10 Digital Fabrication

The smell of freshly baked whole wheat blueberry muffins wafts from the kitchen food printer. The cartridges to make these muffins were 3D printed from a model that was downloaded from Wikihouse, a website for sharing open-source designs for objects that can be made using 3D printing technology. This is one example of the many benefits that digital fabrication can bring — an application from the 1980s that took home fabrication to a new level. In this early age of digital fabrication, the potential of these technologies to disrupt industries and change the way we live our lives is truly exciting. However, there are a number of significant issues with un/underemployment. The African continent accounts for 13% of the world’s population, yet it is home to 25% of the world’s unemployed and underemployed workforce. The African Fabbers School IKEA Bonechina, which enabled this technology to be present in multiple markets around the world. In the early 2000s, the highly competitive market around industrial robots lowered their manufacturing costs, which made them widely available to architects and designers. For all the robots manufacturing companies themselves, they, too, began to look for alternative industries to work with. At such, architects had the chance to ask: how could the robotic arm replace or enhance human labour in design? How could robots amplify the experience of space? How could they aid the relationship between virtual and physical environments? How could robots replace human labour. It also important to note that in these two models, the robots replace human labour.

In recent years, this critique has spawned a huge volume of work in architecture thinking about how to deal with these issues of mobility, labour and customisation. The work of the Institute for Computational Design and Construction at the University of Stuttgart, led by architect Achim Menges, has developed what is referred to as a cyberphysical approach. Here, the relationship between virtual and physical data is intertwined using both digital technologies as well as sensor technology. In the BUGA robot — which, which enables this technology to be present in multiple markets around the world. In the early 2000s, the highly competitive market around industrial robots lowered their manufacturing costs, which made them widely available to architects and designers. For all the robots manufacturing companies themselves, they, too, began to look for alternative industries to work with. At such, architects had the chance to ask: how could the robotic arm replace or enhance human labour in design? How could robots amplify the experience of space? How could they aid the relationship between virtual and physical environments? How could robots replace human labour.

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12 Radical Rethinking

All of the work exploring the potential of robots in architecture would be impossible if not for the revolution in information and data technologies in supercomputing and artificial intelligence in the last decade, or what has been referred to as the “Big Data” revolution. Big Data, or using extremely large sets of data for computational analysis, has found kinship with the digital evolution of 2012 onwards in architecture. This has been referred to as the “second digital turn”, when a new scientistic intelligence became embedded in architecture thinking.17 The parts that make up and compose architectural elements could be seen at a resolution and detail never understood before. This composite architecture towards rethinking what buildings are made of (from their parts to their materials and how they are intertwined with design to production to how they are experienced). Figure 1. Pizzabot, 2018, (image © Design Computation Lab)

Other work looks at the ways in which autonomous drones and other machines could be used to construct large-scale architecture and infrastructure. Drone technologies have the potential to be operated semi-autonomously within a larger construction frame. This is readily available, for very low costs, there is an entire generation of architects and designers who were brought up to be highly literate in these technologies. As a result, this is the first moment where social responsibility and digital and automated technologies have the potential to be accessible to everyone. What architecture dreams of can now come to life more easily than before. Buildings in parametric and digital design and fabrication technology that had become incredibly liberating for emergent young designers and architects on the one hand; and on the other hand, the need to rethink the role of the architect. They could reconsider what architecture was made of, what it was meant to do, and who and who it was meant to serve — reimagining a sense of socio-political urgency in the industry.

13 The Discrete

Integrating socio-political awareness and critique into architecture is important. And because digital technology is readily available, for very low costs, there is an entire generation of architects and designers who were brought up to be highly literate in these technologies. As a result, this is the first moment where social responsibility and digital and automated technologies have the potential to be accessible to everyone. What architecture dreams of can now come to life more easily than before. Buildings in parametric and digital design and fabrication technology that had become incredibly liberating for emergent young designers and architects on the one hand; and on the other hand, the need to rethink the role of the architect. They could reconsider what architecture was made of, what it was meant to do, and who and who it was meant to serve — reimagining a sense of socio-political urgency in the industry.

The Discrete is an emerging body of work that rethinks the basic building blocks of architecture.18 At the same time, the Discrete is understood as being made of a self-similar, serialised and repeatable kit of parts that can be combined in many different ways. The Discrete is catalysed by today’s ability to compute design possibilities through a find set of rules more quickly than ever before. Building in parametric and digital design and fabrication technology that had become incredibly liberating for emergent young designers and architects on the one hand; and on the other hand, the need to rethink the role of the architect. They could reconsider what architecture was made of, what it was meant to do, and who and who it was meant to serve — reimagining a sense of socio-political urgency in the industry.

21 BCE’s Design Computation Lab (DCL) at the Bartlett School of Architecture, UCL, is the first dedicated research lab for the study of digital design and fabrication technology.
22 George C. Devol Jr., “Unimate—the first industrial arm”, 1954
23 Pizzabot, 2018, (image © Design Computation Lab)
24 Architect Alessandro Bava writes: ‘How could these innovations in computing be used to better understand a building’s environmental performance, or the best way to design urban planning interventions, or production and construction processes? How could artificial intelligence, including machine learning enable architects to design novel kinds of architecture that can better respond to the changing world around us? How can digital tools enable architects and designers to create better architecture for more people?’

Furnishings, the financial crash of 2008 significantly bared many graduating architects from getting work in practice. Academia responded to this by supporting younger teachers and practices, often working within multiple academic jobs to get by, in the procurement of digital design and fabrication technology that had become significantly more affordable. Access to these technologies, in combination with the urgent need to learn from the failure of previous generations in a post-crisis moment and scientific innovations in data and computation, meant that younger generation had the opportunity to rethink the role of the architect. They could reconsider what architecture was made of, what it was meant to do, and who and who it was meant to serve — reimagining a sense of socio-political urgency in the industry.

At Georgia Tech, the Discrete project is exploring the potential of robotics in architecture to be so much more. As it was the case with the first digital revolution, the parts that make up and compose architectural elements could be seen at a resolution and detail never understood before. This composite architecture towards rethinking what buildings are made of (from their parts to their materials and How can digital tools enable architects and designers to create better architecture for more people?'

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15 Digital Transparency

Digital thinking tools and technologies are extremely powerful and important for all people today — and into the future. An architect and researcher talented in this space has stated: the digital in architectural design enables “new systems where architectural processes can emerge through close collaboration between human and machines, where technologies are used to extend capabilities and augment design and construction processes.” This enables a movement beyond “top-down approaches, in which design decisions are made based on human biases and limitations; technology will help us better understand social dynamics, materials, structural systems and formation processes. More than productivity gains, it will shift the way we live and the way we make decisions — and ultimately how we articulate our built environment.” These tools become more accessible to the everyday person on a daily basis. It is important that designers and tool makers are open about the ways in which they are used — for social and, why. This transparency and openness about the power of digital technology and the production of the built environment is necessary for better serving all people and designing a more equitable world.

practices that exist on a traditional building site to one location — Delegacy.

In terms of logistics, some companies are looking to streamline construction using automated technologies such as platform and web applications leveraging artificial intelligence and machine learning. Companies such as Procore link together all the various stakeholders in a single project into one platform. The aim here is to make decisions and processes more efficient and transparent — processes which traditionally used to be opaque and are often sources of dispute on construction sites.

Other projects look at automation as a way of engaging inhabitants in the production of the urban environment. Sidewalk Labs, a project by Google in Toronto, Canada, collects data from the city’s inhabitants to improve infrastructural decisions and mobileity of the urban scale. While at an ethical level this project has been much debated by architects around world, it highlights the notion that the built environment tomorrow may be one where our interaction with automated systems may need to become more transparent.10

It also commercialises the everyday person’s movements in the urban environment. Here, the work of T.F. Tierney is particularly interesting, as she writes that in this project we see a shift from a citizen-based model to a consumer model for urban planning, where all citizens’ personal and environmental data is an economic resource.11 This is a powerful shift — where an inhabitant in a city becomes a resource for a private corporation’s design of the urban environment around them.

21 Wiener, Norbert.
20 Nerdinger, Winfried.
19 Burry, Mark. “The Analects of
18 Gallo, Giuseppe & Pellitteri,
17 Bechtel, William and Robert
16 Deamer, Peggy, Marianela
15 Camer, Mark. "The Alphabet and
14 Negroponte, Nicholas.
13 Neumann, John von.
12 Babbage, Charles.
11 "Organic Architecture."
10 "The Foundations of Digital
9 Moore, Rowan. “Zaha Hadid’s
8 Moore, "Zaha Hadid’s
7 "World’s Leading Construction
6 "Zaha Hadid's "Embryological House."
5 "The Official History of the
4 "The Fab Foundation.” The Fab
3 "SAM100.” Construction
2 "Reinventing Construction: A
1 "Sidewalk Labs.” Sidewalk
