Automated Production: The Intersection of Digital Labour and Building Practice

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ABSTRACT

As approaches to computation in architecture are shifting from a new way of making towards a new way of thinking, we must reconsider the prevalent concept of 'digital architecture' in order to find value in increasing computing power that is centered around communities and a reconsideration of labour, instead of neoliberal paradigms or postmodern principles. [Lab Name] at [Institution], argue that 'digital architecture' is not so much a paradigm as rather a collection of methods that fails to address fundamental issues in the contemporary built environment such as the construction industry's slow digitisation and the field's inclination to adopt automated technologies such as robotics without questioning workflows. The paper discusses these issues along two main concepts, the assembly problem and the automation gap, which are utilised as starting points for a fundamental reconsideration around frameworks of digital labour in which the authors argue that we must radically and creatively rethink our practice in order to formulate a new architectural syntax that is capable of coping with increasing automation. By using discrete parts as the foundation of architectural platforms, the paper introduces a paradigm shift towards participatory community building and digital labour that instrumentalizes automated technologies for a democratising approach to the digital in which humans and machines complement each other.

INTRODUCTION

As digitisation has proliferated in architectural production, it seems to have mostly had two consequences for design - a shift towards increased precision, and a quest for ever-more complex and intricate geometries that revel in the affordances made by new digital technologies. The former, as Peggy Deamer recently pointed out, problematically has led to a development in which digital technologies (e.g. BIM) lead clients to expect, but not pay for perfection[1]. On the other hand the latter, fuelled by the field's 'new ways of making' of the early 1990s[2], such as CNC, pushes a narrative of 'being digital' which is merely a front for a design and fabrication process that imprints these technologies with mechanical tasks. We are faced with a dichotomy in the discourse that is tentatively held together under the umbrella of 'digital architecture', yet fails to problematize the wider context and ways in which we use digital technologies.

It seems that as approaches to computation are shifting from a new way of making towards a new way of thinking[3], it is precisely the former which the profession should increasingly consider - unlike architectural design, construction remains one of the least digitised industries world-wide[4], heavily reliant on manual labour practices. This not only results in dangerous work environments, but also in a productivity level that has remained stagnant since the post-war period[5]. While efforts exist to improve these factors by introducing automation to the industry these are predominantly focused on replacing human with robotic labour, exacerbating a two-pronged issue: the *assembly problem,*[6] or the inability of existing approaches to automated design strategies to reconcile effectively with existing building practices, combined with the *automation gap,*[7] or the lack of innovative solutions in construction automation around social practices in architecture and construction.

[Lab Name] argues that a recalibration of the 'digital discourse' needs to be pushed for that sees digital technologies move towards becoming active agents in a values-centred, community-led articulation of spaces from their inception, through their construction and inhabitation. In order to enable this, we propose an approach to digital labour through Discrete Automation, which centers such labour around building 'blocks' that are universal elements not unlike Lego pieces. This paper will firstly introduce the wider background and context of this approach, before providing three case studies of built prototypes to illustrate its implementation as a values-centred, participatory building system for new construction workflows augmented by automated technologies (e.g. robotics, Augmented/Virtual Reality).

We will subsequently demonstrate and discuss the potentials of Discrete Automation as a platform for integrating the 'digital' into architectural production in a way that reconsiders both notions of labour, and empowers communities to take charge in the shaping of their local built environments.

BECOMING DIGITAL - FROM TOOLS TO AGENTS

By starting to explore a shift around the notion of the 'digital' in the architectural discourse, we must firstly acknowledge

Figure 1. Automated Re-Assembly of Housing. Image [Team Name].

that there is a possibility that "digital architecture" doesn't exist[8]. The term has certainly become a buzzword for describing digitally-augmented workflows and their design manifestations over the past decades, but it can be argued that while architects jumped onto the opportunity to exploit these new tools in the early 1990s for their ability to mass-customize[9], no tangible formalisation and hence justification of the label has ever emerged in a way that would imply a reconsideration of labour overall. This can be ascribed to the fact that "digital architecture" mostly means methods and tools. Digital design uses software appropriated from CGI movie-making, the ship-building and aeronautical industries; digital fabrication methods such as CNC cutting were adopted around the same time from industrial production (e.g. cars). Hence, 'digital architecture' describes an assemblage of technical aids for architectural production rather than an actual 'paradigm' -- we have never actually been digital[10], as this results in an approach which fails to consider the object itself to be in a consistent feedback loop with its automated production in the design process.

Nevertheless, and even more problematically, as the misnomer gained traction it was increasingly absorbed into positions that do infuse 'the digital' with politics and contexts such as Patrik Schumacher's parametricism[11] , or a growing movement of 'post-digitalists' that use it to propel a hybrid formalism of postmodern principles without technological aversion.[12] Noticeably underrepresented in both streams are efforts to syncretise the by now ubiquitous digital tools and methods with similarly innovative ideas for the realisation of full-scale structures beyond the 1-to-1 replacement of human- with robotic labour.

The aforementioned assembly problem and automation gap contribute significantly to this presently underdeveloped field. While, as Carpo points out, architects were among the earliest adopters of the so-called "First Digital Turn" in the early 1990s[13], the 'Age of Automation' which has been rapidly progressing alongside an emerging digital economy driven by platforms such as Amazon, Google, Facebook and Uber have so far yielded little change in the profession. AUAR argue that unless an active stance is taken to appropriate these developments in an equitable manner, and a radical, creative rethinking of the assembly problem and automation gap takes place, we risk a further fractalization of the built environment into those who can afford to participate, and those who cannot - a status quo illustrated by, for example, the global housing crisis[14].

In this respect, the role construction practices play cannot be overlooked. Largely untouched by the fundamental changes made in sectors such as retail (e.g. digitized distribution systems) and manufacturing (extensive automation and made-to-order), construction is still entangled in long, intricate supply chains, prone to fragmentation and underinvestment in innovation[15]. It is in this frame of reference that Discrete Automation is positioned as a bottom-up reframing of labour towards a more digital approach. This expands discussions around how we use technology in architecture, and proposes routes for construction practices to be aligned more closely with design approaches in a mutual exchange that utilises automated technologies as a platform for social change.

The core ambition in this undertaking is the pursuit of automation as a breeding ground for discreteness to establish architectural innovation in construction as well as more inclusive frameworks in the conceptualisation and realisation of the digital. This is especially important as automation currently disproportionately affects those who are already disadvantaged the most.[16] In order to establish a recentering of 'the digital' and advance an equitable adoption of automation in the sector, Discrete Automation therefore utilises engaged scholarship that connects academic expertise to 'our most pressing social, civic, and ethical problems'[17], alongside a focus on knowledge exchange through participatory approaches to design. In this manner, we enable horizontal frameworks of digital design and fabrication that allow the communities who will use it to participate in the creation of

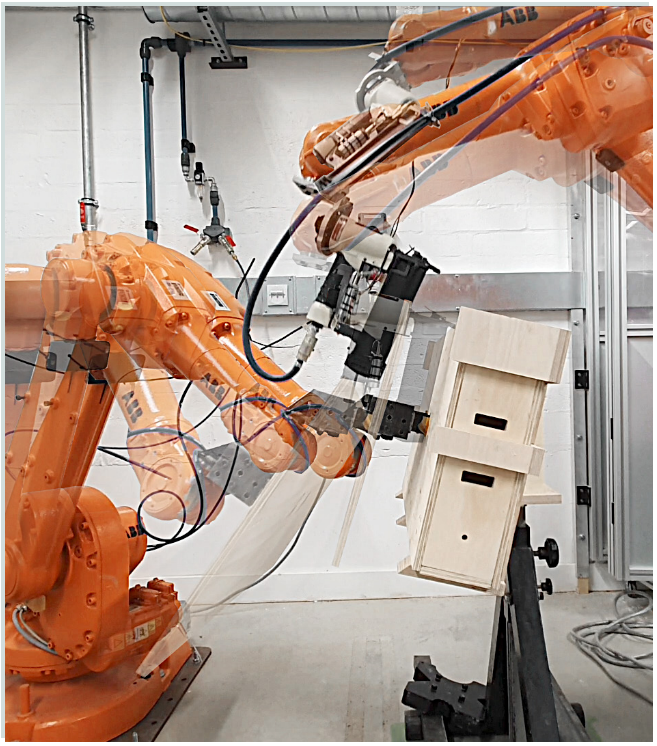

Figure 2. Robotic Assembly of Architectural Parts. Image [Team Name]

a design. Furthermore, the process familiarizes and in turn empowers such local groups to work with novel automation and construction concepts, establishing a context in which automation becomes diffused into communities instead of being centralised and extractive as is the status quo.

This approach hence begins to unravel the notion of the expert and the professional, with a further lowering of the participation threshold through the use of the Discrete 'kit of parts' that afford increased accessibility to design production also to people that are typically othered by professional practice and industry. These elements, or 'blocks', are designed in size and weight to be carried by one person, and have universal connections that allow them to be arranged in a variety of ways. The framework is completed technologically by in-house developed software that provides a 'one-stop shop' tool from design to construction with an intuitive interface and no specific system requirements since it runs in-browser. In this way, the discrete proposition of new workflows follows Laboria Cuboniks' argument that we need to 'strategically deploy existing technologies to re-engineer the world'[18], and engages the assembly problem which Skylar Tibbits outlined as the issue of a collective push in the architectural profession towards mass-customised complexities and its consequences. This development, he contends, led to the emergence of structures made of thousands of unique components taking a great amount of manual labour to assemble, yet these structures are usually celebrated in simulations as well as videos of machinery cutting parts that overlook the added human labour behind the scenes, thus hiding the assembly problem.[19]

Discrete frameworks, however, not only approach this issue through their geometry, but also their implementation of automation. In construction at present, robots are often tasked with simple replacement of human labour that they cannot replicate as well, for example brick-laying.[20] Inarguably much more could be achieved if robots were deployed in line with their original definition - to work beyond human capacity and capability, taking on tasks that the human couldn't solve as efficiently and effectively; therefore, we argue for a re-thinking of approaches to human-machine collaboration in the implementation of automation in the built environment that augment both human and machine specific strengths, instead of focusing on 'automating at any cost'.

With this approach, a twofold improvement can be achieved. On the one hand, robots can be deployed in line with their qualities, improving workflows. On the other hand, both the assembly problem and the automation gap are counteracted - the former through the properties of discrete geometry, and the latter through a strong rooting in participatory solutions. Therefore, Discrete Automation proposes a holistic engagement with the outlined issues as well as a new understanding of labour and production in the architectural field through both a rethinking of the construction process, and a radical democratization and horizontal decentralisation of the production of the built environment.

CASE STUDIES

Since its foundation in 2017, [Lab Name] has developed and centered research and teaching activity undertaken around these principles. By creating truly digital workflows instead of imprinting analogue ones with digital tools, this work recenters its contents away from static projects, to platforms. Over the past two years, one such platform was spun out into a design and construction framework and successfully applied in three case study projects.

Developed as part of the design research undertaken at [Institution, Programme Name] by [Team Names] (2019), the project [Project Name] explored new ways of living and working in a globalised society are explored alongside questions of new ownership models to make housing more affordable. Using a constantly changing spatial layout, [project name] created a vision for automated architecture that utilised custom-designed robots to adapt living spaces by moving universal 'block' elements, which are augmented with elements of the same geometry that serve as storage for their owners [see Figure 1]. The accompanying App completes the [project] ecosphere - it enables the new approach towards housing as a platform in which individuals don't own a dedicated physical space, but rather become part of a decentralised network in which one has shares. Conceptualised as a model that would

Figure 3. [Build 01 Name] in [Gallery Name]. Image: NAARO.

span several countries, a [project] owner could therefore use her App to book into any [project] building, where the mobile robots would immediately start to configure the space needed. Through this approach to automated technologies, [project] uses them as a tool for a post-capitalist society and possibility to lower the property accessibility threshold.

[Project] was first physically manifested for a test-build as showcase for the [Institution Show] in September 2019, and thereafter developed further into a building system called [system name]. Like [project] elements, [system name]'s are 'box'-shaped discrete parts, which can be assembled fully digitally, using industrial robots [see Figure 2]. With pre-defined connection points allowing for both horizontal and vertical connections, the blocks can be aggregated in a range of configurations, thereby allowing for near limitless spatial variation. Connection is achieved through global and local post-tensioning, using ubiquitous hardware materials - nuts, bolts, ratchet spanners and steel rods. [System Name] is a discrete system as introduced above in so far that only one block geometry is used to build a structure - instead of distinct stair, wall or floor elements, a block can adopt function as needed. Furthermore, the system is also inherently disassemblable due to the reversible nature of the connections, hence making the blocks reusable and the overall structure adaptable to changing needs and circumstances.

The building system is completed by a 3D design environment, the [App Name] for desktop and mobile. With a clear interface and straight-forward operability, the App currently supports modelling structures using [system name] elements, but will be expanded to include further geometries in the future.

[System Name] was initially deployed as '[Build 01 Name]' at [location], in early 2020 [see Figure 3]. As a 'living installation', the structure was used both as an office space, and as a canvas for discussions around our changing ways of living and working, increasing automation, and the challenges this poses for the current built environment. Using 55 [system name]'s, the one-storey structure covering 324 square feet was completed within two days by a crew of previously untrained builders under the intermittent supervision of experienced builders.

Slightly delayed by the COVID-19 pandemic, a second iteration of [system name], '[Build 02 Name]', was built in autumn 2020 as the culmination of the [Project Title] project in collaboration with [collaborator], in [location] [see Figure 4]. Designed and built together with the local community and trades people, [Build 02 Name] used 145 blocks, but took

Figure 4. [Build 02 Name] at [Location]. Image: NAARO.

only five days of prefabrication and five days for construction. At the core of the project, which began with a workshop in February 2020, was the ambition to develop the framework in close collaboration with both community members and local tradespeople. As such, a main driver and core objective was to facilitate both a low-threshold access point to working with automated technologies, and the utilisation of straight-forward assembly and construction methods, as had been tested with [Project Name] and [Build 01 Name]. In order to explore especially the design component of the framework, [App Name] was further developed in its use for designing [system name]'s structure. With its intuitive interface and operability, the App enabled participants with little to no previous experience in digital design to quickly and easily produce 3D models after initial guidance by the [Lab Name] team.

Another focus of the project and its development was the empowerment of the participants in their approach to automation and digital fabrication, acquainting them with AR (Augmented Reality)/VR (Virtual Reality) tools in construction and robotic assembly as well as discrete systems and CNC, and hence new entry points to what building can mean in a digitised context. In workshop sessions and tasks, questions around the need for more and adaptable housing were explored alongside the design evolution, involving the community as participants throughout the project. One participant expressed their impressions at the end of the project - *"Robots, augmented reality, new methods of construction. All this stuff is a completely new world for me. I'm a bit of luddite really. But now, I'm not scared. I can do this stuff, and now I feel a massive amount of ownership."*

In collaboration with [collaborator], the project will ultimately become a number of new housing developments across [location] as residents are empowered to take their built environment into their own hands - as one participant noted, *"The most important thing that is going to come out of it, it's going to give me ownership of my community, with my community."*[21] Hence the project achieved its technological objective of positioning discrete automation as an interface between human labor and automated technologies as well as the socio-economic ambition to utilize it as a means for people to take agency in the construction of their community's spaces using systems that are sustainable, adaptable, and have short supply chains.

The next step in the development of [System Name] and [App Name] will be a further structure in [location], to be built in the Spring of 2021. This two-storey, 7.6m high build, showcasing a chunk of a housing structure, will use 258 discrete elements and serve as a space for events and workshops for the local community. The structure follows two events held in [location] in 2019 and 2020, a workshop on 'Housing with Automation' involving local councils as well as youth representatives and a follow-up day discussing home and what it means; both were developed and realised in collaboration with social scientist [Name] and participatory artist [Name] in an effort to provide an inclusive, level space for interaction and creation.

BEING DIGITAL - DISCRETE AUTOMATION

Given its use of highly reduced families of combinatorial elements for design and construction, [System Name] can be argued to be 'fully digital' in that it corresponds to Gershenfeld's and Popescu's definition of 'digital materials' - a reversible assembly of a discrete set of components, based on a logic of serialised repetition.[22] It is also this quality which positions the concept of Discrete Automation as one that moves the discourse around 'the digital' in architecture away from design-heavy considerations, towards a more holistic discussion that is focused on underlying workflows, and therefore encompasses the entire process from conception to completion of the built structure.

In part, as we have shown, this is achieved by considering automation and digital tools not as 'human replacers' but rather as technological affordances to collaborate with. By equipping both lay and trades people with the know-how to interact and produce with such technology, a playing field can be incentivised in which the rise of automation in construction and the built environment in general is steered towards a closing of the automation gap. This is even more so important in that there is inarguably a responsibility for us as architects and designers to prevent the adoption of automation in these fields deepening inequalities through neoliberal appropriation, and instead use it to argue for a change of construction practices that currently make the industry inefficient, fragmented and slow on innovation[23], which in turn contributes to unaffordable buildings.

It is our argument that a possible way to achieve this combination architecturally is by introducing formal languages that enable this shift through their reliance on actually digital materials, instead of increasing the assembly problem; and in the process, assign human and machinic actors positions in the framework that complement Moravec's Paradox[24] instead of aiming to solve it, as is currently often observed in proposals where robots are used to lay bricks.

In order then to finally 'be digital' in architectural production, we need to fundamentally rethink the position of human labor, but from a collaborative rather than an exclusionary point of view. The universality and versatility of the discrete elements hence set a precedent for building blocks that are equally physical materials and bits of data, allowing for an approach to the assembly problem through an architecture that can be automated, adapted and transformed. In this way, the digital is shifted away from earlier notions of differentiation, variation or articulation, towards a much more social and political stance that is centered around labour and production.

This becomes especially relevant in respect to socio-economic considerations of increasing automation in construction - other modular solutions currently focusing on the use of robotics and automation, such as Katerra or BrydenWood, mostly rely on fabrication in centralised factories, and the implementation of their systems through 'installation crews' that are deployed to the building site, decontextualising the process from the structure's local context. In contrast, the presented case studies aim to shorten production chains where possible, and actively seek to empower local experts to implement them, through the use of, for example, fairly ubiquitous robotic solutions such as CNC machines. Our approach to automated construction therefore is geared towards decentralisation, which also supports more sustainable solutions through the emphasis on materials such as timber and the negation of long transport ways for people and prefabricated elements - a particularly important consideration for the formulation of 'fully digital' automated production and construction, as buildings and construction together currently account for 39% of energy-related CO_2 emissions globally.[25]

As Evgeny Morozov has argued, large-scale automation has to be understood as a political issue as well as a technological one[26], and it is in this sphere the architectural discourse should populate itself when considering the digitisation of the built environment in order to subvert the current assembly problem, and automation gap. Discrete Automation argues for the achievement of these goals through the formulation as an inclusive platform rather than a narrow 'label' - the formulation of complementary workflows between humans and automated technologies, the adoption of principles of the Sharing Economy to counteract the housing crisis, the empowerment of local communities by equipping them with tools and techniques that allow them to become active participants in the built environment, and the steering of automation in construction towards a sustainable practice in both materials and supply chains.

CONCLUSION

As architecture has digitised itself as a discipline in its design workflows, it seems that there is a clear schism between this development and the actual building practices deployed at present. Suffering from a lack of productivity, high pollution rates, and inefficient, fragmented production chains, the construction side of the built environment was also largely forgotten in the developments of 'digital architecture', which valued mass-customised complexities[27] over attempts to solve these pre-existing issues.

By introducing discreteness and its inherent tie to digital materials, we argue that a shift can take place that sees the notion of the 'digital' move away from a mere set of tools, towards a building practice that adopts and favours automation as a platform for both production, and socio-economic change regarding the most pressing global issues of our time. This provides an opportunity to rethink the role of digital labour. As the case studies have illustrated, the proposed approach to automation in the built environment can be leveraged to formulate a participatory culture which allows for accessible interfaces between labour contributed by humans, and machines. In its focus on repetitive geometries and universal connections, discrete automation as a practice for automated production can contribute to the solution of the assembly problem currently prevalent in digitally-generated designs, as well as the problem of centralisation and local de-contextualisation found in existing systems for modular building systems which contributes to the automation gap.

ENDNOTES

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