The Social Physics of the Discrete

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INTRODUCTION – THE NECESSITY OF PARTS
In 1959, American chemists Stanley Miller and Harold Urey (Miller 1953; Miller and Urey 1959), from the University of Chicago, developed an experiment to simulate the chemical interaction of different molecules in a mechanism that could emulate the conditions of a pre-biological Earth. In the Miller-Urey experiment, the authors conceived apparatus that would simulate the water cycle, following a process of evaporation and condensation passing through an electric spark, which would simulate lightning. Like in pre-biological earth, gases such as ammonia, methane, and hydrogen were added, allowing the process to recombine the molecular structures of the elements present in the system. The device ran for two weeks, after which the water turned black, and further analysis demonstrated that complex molecules had formed, giving rise to amino acids, some of the building blocks of biological life. The results constitute the first step connecting ideas of chemistry with biological evolution. This experiment gave rise to theories of chemical evolution that are still in development today. This was all possible, argued Steven Johnson, because of the combinatorial power of the carbon atom.

Indeed, the carbon atom possesses a structure that allows it to connect to other elements and other carbon atoms. From this experiment, we can start to extrapolate the ingredients for the spontaneous emergence of order, and did not require a top-down design to give birth to lower entropy structures, which could perform functions.

The experiment is popularly used to argue for self-assembly and to describe what could have been the origin of life on earth, but the interest here for research has more to do with the constituent ingredients of the experiment, hoping to be able to extrapolate principles to our current design discipline.

We can recognize four ingredients present in the experiment that can be extrapolated to our current design ecosystem:

- Parts
- Links
- Patterns
- Commons

Parts are constituted by the atomic elements available to be recombined. These elements have a strict protocol

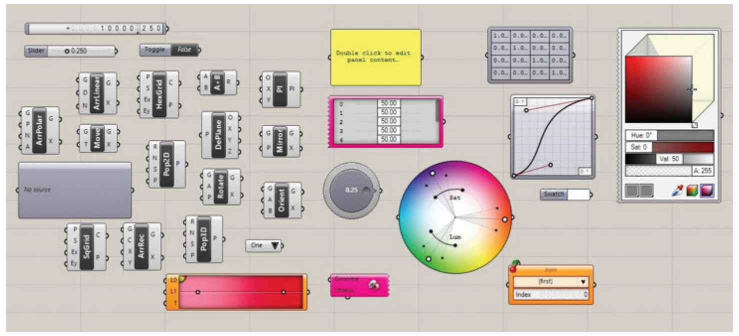

Figure 1: Grasshopper plug-in for Grasshopper; Discrete combinatorial language for parametric design

of communication, or bonding characteristics; these characteristics can be denominated as links. **Links** define the protocol of relationality between parts, and while parts cannot be fundamentally described by their links or relations, such links become the fundamental properties of larger wholes, or assemblies of parts. **Patterns** are defined by the structures that emerge from an elementary composition. Any combination of units can become the building block of another structure. Notice that designs here are defined through a combinatorial process giving rise to assemblages, not by the definition of new unique parts. Finally, the **Commons** is the recognition that for such processes to take place, there needs to be an abundant pool of easily and freely available parts that can be tried out and perhaps discarded.

Computational design strategies developed in the 1990s and 2000s have progressively attempted to describe a "formation" process that is progressively eliminating parts, but rather is the result of intensive forces. Parts have been associated with a mechanical design paradigm, one that the design discipline should overcome (Oxman 2010). But from the molecular perspective presented above, we can understand a fundamental role of parts in a creative process and potentially reconsider their role for a 21st-century agenda.

Daniel Köhler, in an attempt to trace back the lineage of mereology (Köhler 2016) has pointed out how figures like Greg Lynn in *Animate Form* (Lynn 1999) theorized the use of Splines for overcoming discrete geometries. The project of continuity developed in the 90s sought to differentiate form through field and intensive processes. Arguably, such agenda has continued uninterrupted, growing in complexity and in articulation, reaching the current parametricism of Patrik Schumacher (Schumacher 2011). What characterizes the continuous agenda is a dissolution of tectonics, one that seeks to eliminate parts from architectural form. The "gradient" becomes the fundamental mechanism to blend properties from one field to another. Form can be voxelized to articulate gradients to the level of the molecule. Such strategies can be observed in Greg Lynn's development of composite structures that operate at the level of the fiber, coming from maritime and aeronautic fabrication techniques. As Lynn has explained:

> *Intricacy connotes a new model of connectionism composed of extremely small-scale and incredibly diverse elements. Intricacy is the fusion of disparate elements into continuity, the becoming whole of components that retain their status as pieces in a larger composition. Unlike simple hierarchy, subdivision, compartmentalisation or modularity, intricacy involves a variation of the parts that is not reducible to the structure of the whole.*
>
> *For me, it is calculus that was the subject of the issue and it is the discovery and implementation of calculus by architects that continues to drive the field in terms of formal and constructed complexity. The loss of the module in favor of the infinitesimal component and the displacement of the fragmentary collage by the intensive whole are the legacy of the introduction of calculus.* (Lynn 2004)

The technology of Splines has been echoed by a series of software algorithms and tools that facilitate the design within this continuous paradigm. The Catmull–Clark subdivision integrated into Autodesk Maya software allows the transition from polygonal geometries to intensive plastic topologies. "Marching cubes" algorithms or isosurfaces allowed to generate geometries and surfaces out on any number of isolated inputs, merging discreteness into unified shells. Software like Monolith, developed by Payne and Panagiotis (Panagiotis and Payne 2016), provide the infrastructure to think of form beyond a boundary representation, as a pixel field of materials, one that can gradually transition between properties of color, elasticity, and opacity, linking directly with the most advanced 3d printing technologies currently available. Currently, the Grasshopper plug-in for Rhino (Rutten 2015) constitutes one of the most widely adopted pieces of digital infrastructure for the development of a continuous paradigm of form, allowing its users to parametrize all the possible variables in a procedural piece of geometry.

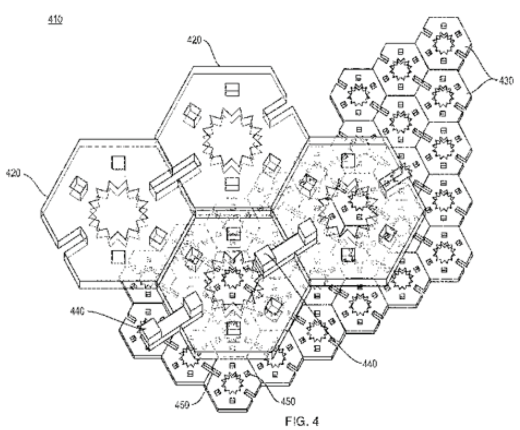

Figure 2: Patent drawings from "Hierarchical Functional Digital Materials" by Neil Gershenfeld and Jonathan Ward

Figure 3: Bloom the Game by Jose Sanchez and Alisa Andrasek. Interactive installation presented for the 2012 London Olympic Games.

It is important to point out that Grasshopper as a software platform has been developed under a fundamentally different paradigm—a discrete combinatorial paradigm. Grasshopper itself has understood the necessity to reach a larger audience and allow the work and research of different parties to contribute to a knowledge base that can accumulate over time. Grasshopper, much like the molecular model described above, is composed out of **Parts**, **Links**, **Patterns**, and **Commons**. These elements describe the social agenda of the software and its attempt to foster novelty out of the unexpected interactions between units developed in isolation. Grasshopper has been particularly good at providing an open ecosystem for the expansion of the platform, fostering the creation of new plug-ins or modules that are always compatible with any of the "core" set of operations of the platform. This is due to the fact that Grasshopper uses standard mathematical types to define inputs and outputs of capsules, allowing a lingua franca and implicit coordination between individuals. A parametric definition in Grasshopper can be understood as a Pattern describing a particular topology between the finite set of capsules. These patterns can be easily shared and altered, as they describe, like any algorithm, a formal logic. Most Grasshopper plug-ins are free, maintaining the tradition of the platform to contribute to the knowledge propagation of computational design. This access to parts, and an open engine to define new parts, constitutes the Commons of Grasshopper. The Commons are the repository of knowledge that has been developed by an active community practically for free and that, as it grows, increases in value as every new part opens new possible topologies within the system.

The combinatorial paradigm allowed by the social patterning of parts does not need to remain as a piece of software infrastructure but can quite explicitly be adopted as a tectonic and material strategy as well. The fact that all the parametric production developed within software like Grasshopper serves a form of continuous Non-Standard (Migayrou 2004) architecture defeats the purpose of the software's social innovation, as the repository of knowledge is exploited toward the advancement of an architectural niche often in the hands of competition winners that profit from a large active community. What is proposed behind a Discrete agenda is the advancement of architectural research toward a mass adoption of architectural knowledge, expanding the channels for architects with the built environment.

THE GENESIS OF DISCRETE DESIGN

The discrete combinatorial model can be traced to Neil Gershenfeld, from MIT, who proposed the use of "Digital Materials." As Gershenfeld explains:

> *Digital parts are error correcting and self-aligning which allows them to be assembled into structures with higher accuracy than the placement accuracy*

Figure 4: Bloom the Game by Jose Sanchez and Alisa Andrasek. Public engagement and recombination of discrete units.

of the assembling person or machine. For example, a Lego™ set consists of discrete parts that have a finite number of joints. The male/female pin joints on the top and bottom of the Lego™ block are discrete connections, which either make or do not make a connection to another block. By contrast, a masonry construction is a continuous (analog) material; While the masonry brick is a discrete unit, the mortar in its fluid state allow one brick to be placed on top of another in an infinite number of positions. Because the joint is not discrete, masonry construction is analog while Lego™ construction is digital. (Gershenfeld and Ward 2013)

Gershenfeld's research on digital materials points to a future where form can be patterned by "discrete assemblers" (Ward 2010), machines that do not extrude plastic but rather place small units together. Gershenfeld establishes how technologies have transitioned from analog to digital, starting with communications based on Claude Shannon's seminal contribution "A Mathematical Theory of Communication" in 1948. Computation also experienced this transition from analog to digital during the 50s. Gershenfeld explains how fabrication, while being controlled by digital machines, has remained analog, and that it is only the advent of digital materials that can establish a breakthrough toward a true digital architecture.

Gershenfeld's framework for digital materials has been taken forward by architects in notions of self-assembly (Tibbits and Tomas 2013), crowdsourcing (Sanchez 2014), and robotic fabrications (Retsin 2016) reconsidering the role of parts in design. This has brought a renewed interest in mereology (Köhler 2016), understanding that the role of a part within a whole needs to be interrogated. The architectural body is no longer post-rationalized into parts, neither is it the result of a complete emergent process, but rather of a complex iterative patterning involving architectural expertise, modes of fabrication, economic pressures, and social contingency.

DISCRETE DESIGN BEYOND COMPOSITION

By defining Discrete Architecture as a renewed interest in parts and the composition of wholes through patterning, we also need to rediscover the need to protect the Commons. Today, the struggle is fundamentally linked to forms of organization and knowledge propagation protected from the neo-liberal exploitation of established under-regulated actors.

The self-imposed constraint of using serializable parts not only allows for the "digital materials" properties described by Gershenfeld, but also encapsulates a contingent need for democratization. This might seem an arbitrary constraint, but behind it is a social and economic agenda that seeks to expand the reach of architecture beyond the 1%. By returning to serialized parts, architects can pre-engineer

Figure 5: Computational Chair by Philippe Morel of EZCT

conditions and encounters, encapsulating knowledge into formal units. This strategy shifts the production cost from high-stakes developers toward a multitude, and from a model of knowledge protection to a model of knowledge propagation, attempting to dismantle a one-to-one correlation between architects and architecture via an exponential proliferation of patterns via the Commons.

The move to reconsider serialization (Sanchez 2014) has compositional implications; the lineage of composition of parts for this Discrete agenda can be traced back to *De Stijl* (Doesburg 1952), *Field Conditions* (Allen 1999), and the Elementarism of Philippe Morel, but what is described as Discrete Architecture needs to go beyond its compositional legacy. The project has been developed as a reaction to the 2008 economic collapse, one that fundamentally decoupled the discipline of architecture at the apex of complexity, with its global practice and adoption. The technological developments in architecture since the 90s have been put to service for a neo-liberal agenda, as the arms race for complexity has been directly associated with the search for clients that can afford them.

It has not been architecture as a field who has detected or started a pushback. The acknowledgment and protection for the Commons has been a global project for many disciplines for decades, and a movement that seems to gain strength with the global understanding of the calamities perpetrated by a form of unregulated capitalism. As Negri and Hardt explain:

> *Neoliberal government policies throughout the world have sought in recent decades to privatize the common, making cultural products—for example information, ideas and even species of animals and plants—into private property. We argue, in chorus with many others, that such privatization should be resisted.* (Hardt & Negri 2009)

The rise of inequality calls not only for a political participation as citizens, but also for a reformulation of our professional practice, examining our established practices for funding, labor, and design objectives. In architecture, form and composition are not "off the hook" when we address our socio-political concerns. The field needs to be able to distinguish which strategies perpetuate a neoliberal landscape. This is not to be misinterpreted as a regressive proposition, attempting to go back to periods in which the discipline did not need to concern itself with issues of technology or fabrication; on the contrary, Discrete Architecture should be considered as a forward perspective that branches out in parallel from the surface projects from the 90s.

As Negri and Hardt argue, the Common needs to be considered as a third spectrum outside the dichotomy of public and private. While the private sector was the development of individuals under the banner of property rights, everything else could be considered public in the responsibility of the state. Today, we see a real opportunity for the social production of a third domain, one that is not relying on the public intervention of the government or the private innovation of companies, but rather a form of social production that is common and lawfully protected as such. The Common, as presented by David Bollier:

> *As a paradigm, the commons consists of working, evolving models of self-provisioning and stewardship that combine the economic and the social, the collective and the personal. It is humanistic at its core but also richly political in implication, because to honor the commons can risk unpleasant encounters with the power of the Market/State duopoly.* (Bollier 2014)

Today the production of the Commons and the attempts to protect them can be observed in technological developments concerning copyright and mechanisms for organization. Technologies such as the General Purpose License (GPL) by Richard Stallman or Creative Commons Licenses and Open Source constitute a technological infrastructure much like that allowed by calculus and spline technologies in the 90s. All of these initiatives attempt to support social production that can in itself spawn new knowledge and innovation.

From a Discrete design perspective, one of the main clauses to challenge is the "non-derivative work" attribution present in copyright laws and also an option of creative commons licenses. At the center of a protection for the Commons is the ability for remixing, or a

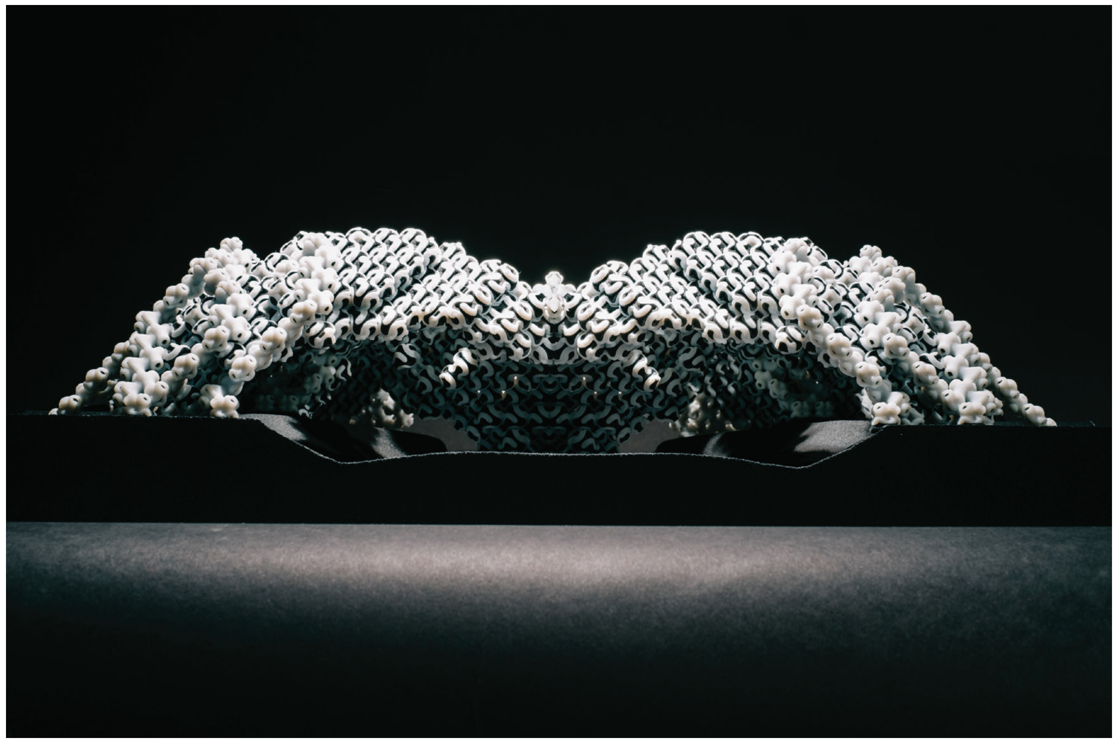

Figure 6: Polyomino by Jose Sanchez — Research developed at USC School of Architecture. "From Gaming to Making" research connecting video game engines to 3D printing technologies. Sponsored by Stratasys.

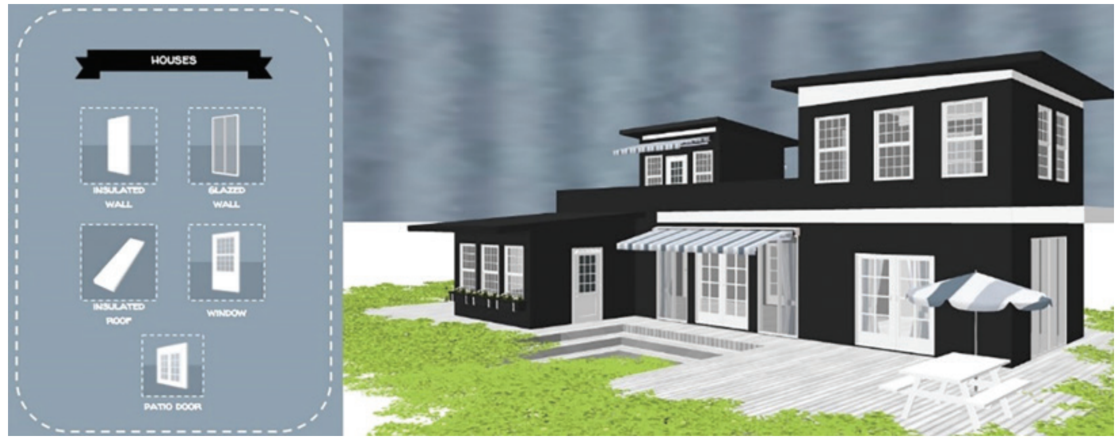

Figure 7: Open Building Institute by Catarina Mota and Marcin Jakubowski (Mota and Jakubowski 2016)

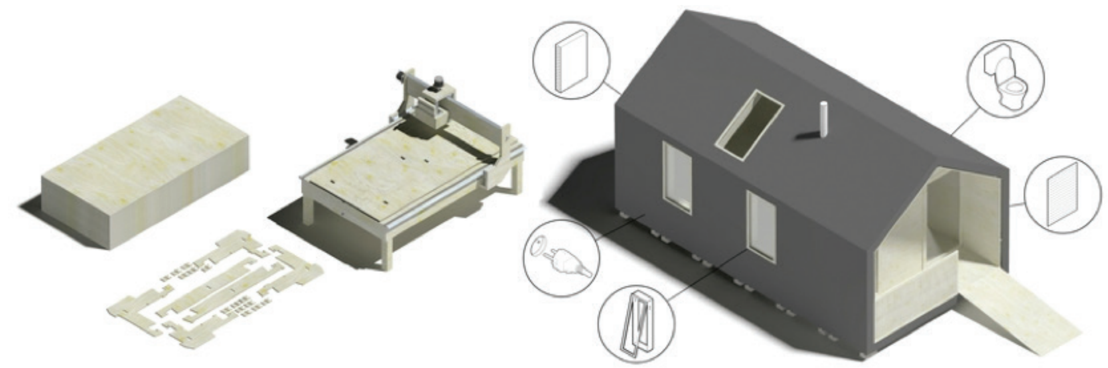

Figure 8: Wikihouse by Alastair Parvin (Parvin 2011)

combinatorial attitude toward available resources. This is a vision that was central to initial ideas of the internet; as Jaron Lanier traces back, Ted Nelson's "original concept for the hypertext was based on the idea that people must be able to create derivative works" (Lanier 2013).

The Commons must resist the attempts of expropriation by different industries to convert them into private or public property. While this struggle has remained far from an architectural debate, initiatives like Wikihouse (Parvin 2011) or Open Building Institute (OBI) have detected the necessity to address the current housing crisis in the UK and the US respectively by utilizing an open source paradigm. While Wikihouse focused on developing an idea of a home that could be fabricated by local means, particularly CNC, OBI has focused more on a strategy of modularity and parallel production, developing a catalog of a series of "easy to fabricate" modules that define a traditional construction system. Both projects exist both in physical and digital form, sharing files publicly on their websites.

With an economic and social objective in mind, both OBI and Wikihouse seem to engage the discipline from a blind-spot, leaving behind interests of differentiation of space, materiality, or composition, and while arguing for a design solution not aimed at average consumers, both building systems offer little variation for unexpected design propositions.

RESEARCH CONDUCTED AT USC

The framework of Discrete Architecture and its social physics discussed above presents a unique opportunity to spread the cost of production over a population during a long period of time, allowing for standard parts to form unique meaningful assemblies creating radical differences between one another. The knowledge production can be encapsulated in physical objects and generative software allowing the development of patterns that could be re-utilized and improved. Digital materials should inform the people that use them, anticipating problems of structure and regulation.

The framework described above defines the ethos driving the research agenda at the University of Southern California developed over the last three years by Jose Sanchez. Projects seek to reconsider the role of parts in production. By using units that can be serialized, the agenda places emphasis on design through patterning and combinatorial strategies.

Using principles of discreteness, units have unique positions and connections they can match with other units. A magnetic joint corrects the connectivity and allows for easy assembling and disassembling. This notion of reversibility is crucial when thinking of combinatorial patterns, as each assembly becomes a transient state, not a final product.

The impact needs to be understood in a broad context; as the field slowly adopts a post-capitalist paradigm, the organization of matter through data will become increasingly relevant. The ability to rearrange existing parts will come together with the design of parts that can serve multiple combinatorial possibilities. Discrete Architecture is a paradigm being developed for a sharing economy with a new role for social participation.

This research is framed through a larger interest in connecting gaming technologies with physical matter and the maker movement. Gaming is selected as a medium because of its capacity for social participation and to engage a large community of users. In this way, the design of building blocks is exposed to a large combinatorial engine that can create value and order for their own requirements. Central to the agenda is to address an ethical form of participation, one in which users are not harvested to provide value to a centralized authority or company, but rather one that envisions ways in which users own their own data and can conduct transactions over the network. The hope is to further develop the infrastructure that allows the growth of the Commons, enabling new units and patterns to define a new formal vocabulary for decentralized forms of production.

CONCLUSION

The attempts to develop an open source architecture should not need to press a "reset" button regarding architectural innovation, but rather find design solutions that foster difference and diversity. While we can standardize construction, architecture should remain open and resilient, tectonically disposed for innovation and novelty. While the recent developments in open source design have emerged out of necessity, a form of Discrete Architecture can become a long term socio-political project and a vast field of research for the years to come.

Figure 9: Polyomino by Jose Sanchez — research developed at USC School of Architecture.

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Figure 10: Block'hood video game research developed by Jose Sanchez, Plethora Project

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