CONFIGURATIONAL MORPHOLOGY

RESEARCH PAPER

Jaka Korla

INTRODUCTION

Cities are the primary human habitat. Home to more than half of the world's population they are relentlessly growing as a result of continued urbanization.[1] This expansion puts enormous pressure on the urban fabric, already stretched to the limit of its performance, to be ever more efficient in terms of sustainability, spatial quality and density to adequately accommodate this growth. One of the most important factors determining this performance is the buildings from which a city is made, its urban form, meaning the physical characteristics that make up built-up areas including their shape, size, density and configuration.[2] In existing cities worldwide this form is predominantly defined by a small number of historically established rigid urban types building up the generic city. This genericness leads to reduced performance as a consequence of its inability to adapt to local conditions and varying requirements, which in turn creates underperforming cities at a time when efficiency and sustainability are of paramount importance. In response to this, the study aims to investigate how to create adaptive urban form capable of responding to the environmental, social and economic context in which it is placed.

One of the main reasons for the generic nature of existing architectural form is the formally biased compositional design approach operating through the top-down imposition of predefined typal solutions without regard for local conditions. As an alternative, a configurational design approach operating on a higher level of abstraction - spatial relationships instead of form - is proposed. Its lack of formal bias along with the inherent flexibility of configurations could lead to new urban forms capable of improved performance via adaptation to the site, environment and programme making them better adjusted to the pressures of contemporary cities. Although it is imaginable to employ configurations at all scales ranging from a chair to the city, if not even the world, this study will focus on a narrow range of scales from the apartment unit to the urban block. It is within this domain that the morphological disposition of urban form most affects its own performance, as well as that of a city. Programatically, the study focuses on predominant everyday uses like housing, offices and commercial spaces, which constitute the majority of the built environment and thus have the greatest effect on our well being and experience of our cities. Investigating the viability of configurational design, the main objective of the study is to uncover its potentials and limitations for the production of responsive urban form. This is attempted using a series of subquestions such as how to systematize and represent configurational thinking, how can it be used for the analysis of existing cities, what is its generative design potential and finally, how does this fundamentally changed approach to design influence the role of the architect. By doing this while questioning the established modus operandi in architecture and urbanism the study aims to uncover new possible ways to approach the construction of our cities. Cities which could not only perform better in terms of density and living standards but also respond to changing social structures, reduce our environmental impact by means of efficiency as well as strengthen identity with the help of endless diversity. These could be the cities of the future.

Due to the nature of the study proposing an alternative design approach, a fundamental aspect of architecture as a discipline and even more so in practice, it is equally important to explore its theoretical implications as well as its potentials for practical implementation. To achieve this it combines two research methods, both responding to the current state of research on configurations as well as the nature of architectural research. The use of a literature review for secondary research is paramount because not only does it provide a base and inform primary research by exploring precedents and past research within architecture, but crucially allows for the expansion of disciplinary boundaries by looking at other fields for potentially complementary ideas and knowledge. In turn, research by design forms the backbone of the primary research attempting to bridge the issue of a shortage of substantial precedents on configurational thinking in architecture. This simultaneously enables further development of the theoretical framework for configurational design on one hand and speculation on its potential practical implementations through design experiments on the other. Combined, these approaches form a research methodology that is capable of comprehensively exploring and evaluating the theoretical and practical potentials as well as limitations of an architectural design approach based on configurations.

The research is thematically divided into a sequence of six main chapters exploring different facets of configurational thinking ranging from its conceptualisation, analytical potential, generative potential and broader implications. Each chapter is focused on a specific theoretical topic while simultaneously being supported by subchapters focused on the practical application of its theoretical ideas. To start, the chapter "On designing" focuses on the theoretical potentials of configurational thinking and establishes a notational system for configurationally describing space, forming the base for the following experiments. This is followed by "On typology" which studies the issues of typology today and its renewed analytical and generative potentials within a configurational approach, as well as uses it to demonstrate the possibilities of a configurational analysis of existing urban form. Looking towards design, "On diagrams" examines the role of the spatial network diagram as a medium facilitating configurational thought and human-machine communication on one hand and its inherent capacity for flexibility and adaptation on the other. Next, "On algorithms" looks into generative algorithms as a tool enabling the realization of the full adaptive potential of configurational designs through simulation of many possible iterations and their optimization according to the environment. Further, "On the architect" explores the transformation of the architect's role in response to configurational design combined with computational approaches. Finally, "On influence" reflects on the benefits and drawbacks of configurational thinking for architecture as a discipline, its practice, as well as society at large. Together the chapters form a comprehensive outline of a configurational design approach that could lead to cities which are not only more responsive and better performing but also more diverse and sustainable.

THE GENERIC CITY

During the last few decades, cities have undoubtedly become the primary human habitat. Already home to more than half of the world's population, they continue to relentlessly grow as a result of global urbanization with Asia and more recently Africa as its main epicentres where seemingly every day new metropolises emerge.[1]

This expansion puts enormous pressure on existing types of urban fabric, already stretched to the limit of their performance, to be ever more efficient in terms of sustainability, spatial quality and density to adequately accommodate this growth. Among the most important factors determining this performance are the buildings from which a city is made; its urban form. While usually used to describe the urban grain at the scale of a city, urban form is defined as the physical characteristics making up built-up areas including their shape, size, density and configuration.[2] *As such, urban form can be used to describe the individual buildings and their groupings which act as fundamental building blocks from which a city is composed through a continuous process of aggregation.*

In existing cities worldwide this form is predominantly defined by a small number of historically established urban types, some with cultural roots such as the dutch rowhouse, while others like the tower are purely an expression of efficiency and the unending quest for profit. The main types constructing the modern (especially western) city are the detached house, semi-detached house, rowhouse, courtyard townhouse, slab and tower. Although admittedly some regions and cities are due to various reasons more strongly associated with certain types, it is telling that in practically any city in the world irrespective of culture, climate or context most if not all of the predominant types can be found. These types are the source of the generic city.

This genericness eventually leads to reduced performance as a consequence of the inability to adapt to local conditions and varying requirements, which in turn creates underperforming urban form at a time when efficiency and sustainability of cities are of paramount importance.
On top of this, the urban types themselves have shown to be fundamentally inadequate to effectively respond to the pressures of contemporary cities; ecologically unsustainable detached houses due to urban sprawl, socially unsustainable slabs and towers limiting interaction, economically unsustainable traditional types such as row houses through a lack of density.

In our search for efficiency and profit, we have spread the generic city everywhere, while trading quality for quantity in the process. Today there is a pressing need to find alternatives and the question is how to create adaptive urban form capable of responding to the environmental, social and economic context in which it is placed?

ON DESIGNING

Evolution of urban form is a crucial part of the accelerating process of global urbanization and our search for the diverse, inclusive and sustainable city of the future. This search for new forms of habitation has been and will remain one of the greatest challenges facing architecture in the coming decades as pointed out by Mumford already in the 1960s: "The paramount urban problem today is to invent an adequate urban container which will do for our complex and many-sided culture what the original Stone Age container did for the far simpler cooperations and communications of earlier societies".[3] While this is a struggle encountered by every generation of architects, today the issue is more pressing than ever considering the shape of our cities is essentially unchanged since the start of the 20th century despite a hundred years of increasingly rapid development and accompanying societal change.

What we are capable of creating as architects is directly influenced by the way we design; our design process. The predominant form-based approach in architecture today is rapidly proving to be insufficient for inspiring the production of new urban forms adapted to the contemporary city, a changing society and the increasing ecological crisis, instead perpetuating the spread of rigid, standardized and often underperforming genericness. Today, the generic city is everywhere. Manifested in sprawling shopping malls, swathes of isolated glass towers, everpresent slabs resembling walls of soulless apartments and endless expanses of repetitive suburban houses, it represents the materialization of globalization as well as being the reflection of a design approach inclined towards sameness and repetition.[4] At the level of urban form, the generic city is composed from established urban types constructing the majority of existing built fabric. Detached houses, slabs and towers are multiplied everywhere around the world irrespective of context, culture or climate, creating an urban fabric which, as a result of its unresponsiveness, underperforms and does not live up to its potential. Searching for reasons why this is so, a large amount of blame can be attributed to the fact that within the architecture, engineering and construction industry (AEC) the predominant mode of production remains Fordist mass-production, as well as to the ever-increasing pressures of the market economy driven by efficiency and profits.[5] Global capitalism effectively drives the spread of the generic city.

Although the way urban fabric is created admittedly depends on many external factors beyond the power of architects, there remains a complementary set of influences within our own design approach reinforcing this unending production of genericness. Firstly, throughout history, be it classicism or modernism, architectural design was predominantly based on simple universal principles of composition such as proportion, mass, scale and symmetry, which represented the foundation on which all architectural form was created in a top-down formal manner.[6] Whilst such rigid use of principles and "ideals" is less common today, the tendency for top-down imposition of forms, systematic simplification and reduction of complexity remains strongly present. This is most evident in project presentations where seemingly every project and its shape can be neatly reduced to a single concept sketch explaining the entire scheme. In an age in which ideas are universally shared and recycled, such a reductive approach can only work for so long before leading to generic buildings and spaces. Secondly, especially at the scale of urban form, (typological) design via precedents has been used as a method intended to both simplify design through the reuse of existing models as well as allow for innovation by their adaptation. Although this can yield productive results when used appropriately, it also introduces potentially limiting preconceptions and biases into designers minds, leading to direct formal reproduction and thus genericness.[7] Together, these influences have combined to create an environment in which meaningful formal innovation is made increasingly difficult, as visible in the lack of progress in recent decades.

While form is undoubtedly the primary spatial aspect with which an architect operates, architecturally, space can be examined at different levels of abstraction, each describing a specific system of organization. As described by John Habraken, coincidentally on the example of an urban type, any space can be viewed in many ways, three of which usually predominate; stylistic, formal and configurational. In this context, style describes ornament as well as the placing and proportions of windows and doors, for example, form describes the physical system of walls and ceilings that define space and give a building its shape, while configuration defines the network of spaces contained within, their relationships and interconnections.[8] In the existing design process, architects spend the vast majority of time consciously operating on the level of form; this becomes even more pronounced when working at larger scales related to urban form such as the scale of a large building or even an urban block. It is precisely this preoccupation with formal aspects of architecture that can become an obstacle for inventiveness and creativity as a result of our internalised preconceptions and biases which are in turn an inevitable result of past experiences, established precedents and personal ideologies. Paradoxically, our intense focus on form directly limits our capacity to reinvent it.

In hopes of countering this, a configurational approach to architecture argues for the shift of conscious design to a higher level of spatial abstraction; spatial configurations. This abstraction temporarily disconnects the architect from formal aspects by shifting his focus to the configuration of space, while simultaneously allowing a multiplicity of forms to autonomously emerge as a result of external influences acting on the designed configuration. In other words, abstraction via configuration can be thought of as a device for removing preconceptions and helping the designer to think previously unthinkable forms. Beyond mere abstraction, such spatial patterns underlying built form already constitute the elementary building blocks of cities according to Alexander: "Every place is given its character by patterns of events that are locked in with geometric patterns in space. Each building and town is ultimately made out of these patterns in space, and out of nothing else; they are the atoms and molecules from which a building or a town is made".[9] Importantly, the proposed change to configuration does not imply the total abolition of conscious formal design which will always remain a crucial aspect of an architect's work, but merely a reshuffling of priorities after which configuration becomes the primary design driver through which form is created.

Besides making the production of novel forms possible, the primary advantage of a configurational approach is its adaptive and responsive potential. Because a configuration only defines spaces and their interconnections it has enormous combinatorial possibilities allowing for a near-infinite amount of physical arrangements. Such adaptivity, combined with a lack of predefined form, enables the organic emergence of form in direct response to internal requirements and external influences, as well the highly complex interactions between them. In this way, configurations are able to merge top-down design with a bottom-up response to local conditions, which, in addition to making adaptation possible, could also facilitate their use as participatory tools capable of mediating multiple stakeholders. As a natural consequence, this adaptivity could lead to greatly increased diversity by way of specificity and potentially improved performance, be it spatial, social, economic or environmental.[10] Furthermore, by virtue of its higher order of abstraction, such an approach would also simplify and empower precedent-based design. No longer burdened by concerns of reproduction, architects could extract patterns from existing buildings and reapply them in new situations and contexts by means of a holistic process that is both analytical and generative and enables the evolution of new urban form from existing configurations.[11] Lastly, the shift from form to configuration as the primary design driver brings with it a renewed focus on socio-spatial patterns which more often than not directly correlate with the configuration of space. As Bill Hillier observes in A Social Logic of Space: "The social stuff of buildings, we may say, is the configurational stuff, in the sense that buildings are configurations of space designed to order in space at least some aspects of existing social relationships".[12] As a result, by working with configurations, an architect can consciously act on and shape the socio-spatial patterns underlying his building, making them in tune with the needs of contemporary society, which could in itself possibly turn into a source of new spatial compositions and urban form.

By way of formal abstraction and its focus on spatial relationships, a configurational approach to architecture attempts to free designers from existing self-imposed limitations to encourage new formal innovation, while simultaneously creating a new design method rooted in principles of adaptivity and diversity. By doing this, configurational design could put an end to reductive simplification, allowing us to productively channel the complexity of contemporary cities to create diverse urban forms responsive to our present-day needs for social, economic and environmental sustainability, in the process creating our the city of the future. Nevertheless, many questions remain about how configurational design could be systematized and operationalised for real-world application, as well as its benefits and drawbacks within a practical context.

CONFIGURATIONAL PRECEDENTS

Use of configurational principles in the production of our built environment is not a novel proposition, as they have been directly or indirectly applied in numerous theoretical and practical settings in the past.

The most widespread and simultaneously the most obscure application of configurational thinking is its role in vernacular architecture, where spatial relationships and response to local conditions have always taken precedent before form, which in turn organically grows as a consequence of both. Cases of this can be found all around the globe in historical city centres, Mediterranean towns and African villages among the most prominent examples.[13]

In the discipline of architecture, conscious focus on configurations first emerged in the 1960s most notably in the work of Team 10 and Aldo van Eyck as part of their reappraisal of the vernacular. As exemplified by van Eyck's essay Steps Towards a Configurative Discipline, in their work, configuration was specifically linked to questions of dwelling, meaning and identity as opposed to being used as a design methodology.[14]

This kind of comprehensive approach was later developed by Cristopher Alexander as part of this book A Pattern Language published in 1977. Here, configurations are represented by spatial "patterns"; fragments derived from existing cities at various scales, with explicit rules for connecting them into new urban tissue.[9] *While this resulted in a set of systematic methods capable of generating new form, its lack of generality as a result of the fixed catalogue of predominantly vernacular patterns prevented it from ever surpassing its value as a theoretical project and becoming a genuine design method.*

Finally, in 1996 Bill Hillier attempted to provide such a general framework of configurational design in his book Space is the Machine; A Configurational Theory of Architecture. In his work configurations become explicit, themselves systematized and materialized as topological graphs enabling them to become objects of design.[11] *Through this systematization, his theory gains general applicability and potential for practical application; this has led to the development of Space Syntax, which, while an effective tool for examining configurational aspects of cities, remains purely analytical thus leaving the generative potential of a configurational approach unexplored.*

In philosophy, the possibilities of a configurations for generating form were theorised by Manuel de Landa who connects them to natural processes of morphogenesis potentially enabling organic emergence of form based on its physical surroundings.[10] *Furthermore, throughout his work, de Landa emphasises the compatibility of configurational thinking with fields of mathematics, physics, biology and computer science, opening the door for its enhancement with ideas of automation, natural processes of growth, environmental responsiveness and more, all of which could help in one day making configurational thinking a practical design approach.*

The examples outlined here show that while configurational thinking has been explored in the past, it has yet to be systematically applied as a comprehensive design method within the field of architecture; only then will its true advantages, as well as drawbacks be clear.

FROM FORM TO CONFIGURATION

For configurations to become operative in the architectural design process, the way they abstract physical space must be precisely and systematically defined. Here, the *possibilities for such a general definition are explored via precedents in the fields of applied mathematics and architecture, finally leading to the formulation of a Spatial Network; the proposed elementary medium for the configurational design of architecture.*

Inspired by Bill Hillier's theory of configuration, the project appropriates his use of topology as the primary mechanism for the systematic abstraction of form through its underlying spatial relationships. Appropriately topology, also a branch of applied mathematics studying geometrical properties and spatial relations unaffected by the continuous change of shape or size, can be concisely represented by mathematical adjacency graphs in which nodes represent distinct spaces while links the connections between them. Due to their logical and unambiguous structure, aforementioned graphs can provide an efficient base for abstracting existing form to configurations.[15]

Nevertheless, due to the complexity and layered nature of space abstracting it purely by means of its topology would result in gross oversimplification. A possible solution to this may be contained in a tool many architects already routinely use in the process of design; the bubble diagram often used do depict functionality and connectivity. This enables the expansion of the topological adjacency graph with additional information encoded in different node and connection types. Such an information structure is also called a Spatial Network; a graph in which the vertices or edges are spatial elements associated with geometric objects, used where the underlying space is relevant and where the graph's topology alone does not contain all the information.[16]

To define the possible types of elements that can constitute a spatial network, a classification of space is developed uncovering the most important traits pertaining to urban form and architecture. In addition to quantitatively measurable parameters of spatial quality like proportions of space or the amount of sunlight, which can be assigned as attributes of individual spaces, the classification proposes three main categories through which space should be defined; interior-exterior, programme-circulation and degree of privacy. Combined, these can be used to describe the majority of spaces and their nuances in a configurational approach. Lastly, a notational system is developed which enables the unambiguous representation of all defined spatial types, simplifying the use of the spatial network as a design tool.

Although the proposed Spatial Networks and their corresponding system of notation form a sufficient basis for configurational analysis and design in the scope of this project, for their universal architectural application to be possible they would need to be further refined especially with regards to classification and definition of individual spaces.

ON TYPOLOGY

Although the capability of configurational design to enable production of new more responsive objects and forms is its most important implication, the method would gain substantially more legitimacy by also enabling their evolution from existing socio-spatial patterns in contemporary cities. For this to be possible, configurations must be applied analytically as a tool for the identification and extraction of complex spatial relationships in which established social structures are crystallized in built space.[17] It is precisely these assemblages which can act as the base for the production of new urban forms better adapted to the pressures of the modern city.

Configurations, albeit very adept at systematically mapping underlying socio-spatial patterns, are limited in analytical application due to the drastic lack of available comprehensive information on the built environment from which existing configurations could be "read" or extracted. Whilst this issue might eventually disappear with widespread adoption of BIM urban databases, even the hypothetical future existence of such a dataset brings difficulties of its own, namely the fact that the complexity and diversity of extracted configurations would far surpass the cognitive capabilities of a human designer and would thus inevitably require a degree of analytical simplification to be of any practical use to a human designer.

Both of the aforementioned issues could potentially be addressed with the implementation of a systematized typological approach to the analysis of existing. Typology, defined as analysis or classification based on types or categories, and type, defined as a distinguishable generalized instance representing a larger category, could together allow us to bypass exhaustive analysis in favour of an inquiry into a range of representative specimens which could together efficiently explain the complex entity that is a city. In the words of Moneo, "Type is fundamentally based on the possibility of grouping objects by certain inherent structural similarities. It might even be said that type means the act of thinking in groups".[18] This effectively enables the designer to only perform analysis on a limited subset of the population (of buildings), the results of which are generalizable and representative of the entire population via a method akin to statistical sampling.

Within a typological approach, types emerge through the act of grouping a series of (existing) objects by their mutual similarity, be it formal, stylistic, functional or configurational, while emphasising their common traits and suppressing divergent ones.[19] This categorisation by virtue of simplification results in generalised types serving a dual purpose; on one hand, the grouping provides an analytical and explanatory function, whereas on the other hand individual types become empowered with generative capabilities. Due to the generic nature of a type, it can be applied to any situation provided it is used as a starting point, a prototype that deforms and adapts to the circumstances. This way of understanding typology has been at its core from its inception in Architectural discourse in 1825 by Quatremère de Quincy who asserts: 'The word 'type' presents less the image of a thing to copy or imitate completely than the idea of an element which ought itself to serve as a rule for the model'.[20] In other words, type is the essence (idea) of an object, which should merely guide the designer as he develops his specific solution (model). Understood this way, the type is abstract and conceptual instead of concrete and literal. The very concept of type implies the idea of change and transformation and is effectively the frame within which change operates.[18]

Despite this openness to interpretation, in contemporary architecture 'type' is commonly misunderstood as buildings categorised by their formal resemblance as is the case in urban types such as detached houses, slabs and towers, to name only a few.[20] This reductionist understanding of type in combination with the increasing complexity of the contemporary city often leads to its misuse by designers inclined to fall back on well-known generalized examples for solving new specific problems; type as a recipe for a solution obtained by direct reproduction.[21] Although this approach undoubtedly enables fast, efficient and standardized solutions especially valued for their profitability within the global market economy, its drawbacks include lack of user control, reduction of variety and decreased performance as a result of inflexibility. It leads to "typification" of design, effectively discouraging the emergence of new formal structures[22], which has lead Rem

Koolhas to accuse typology of being a preemptive tactic that aborts history before it can happen, pointing towards its tendency to impede evolution, change and progress. As such, the powerful presence of the formal type in the mind of the designer oftentimes actively suppresses his ability for the invention of new alternative solutions.

It is clear from this context that typology needs to be rethought if it is to maintain relevance as a legitimate design approach in architecture. To release established types from their formal connotations while retaining the socio-spatial structures they embody, a configurational approach proposes their abstraction into configurations capable of recording and visualising those relationships using spatial topology whilst discarding their characteristic forms along the way. No longer represented by axonometric drawings, plans or sections, types represented by abstract configurational diagrams discourage the formal reasoning which often underlies the application of types today and encourage their conceptual application as a set of perpetually unstable and mutating relationships in a state of constant evolution, each allowing the possibility of innumerable formal arrangements.[23] In other words, type is transformed from a formal precedent imitated via repetition and reproduction to an abstract topological structure with no inherent formal expression which can be utilised in a process of evolution and proliferation.[22]

Applied in practice this could produce a comprehensive configurational typology; a collection of type diagrams representing the elementary building blocks of a certain urban area, which not only describe its spatial (topological) characteristics but through them the social dimension of which physical space is a result. As a result, types are transformed from fixed formal prescriptions to dynamic sets of relationships capable of adapting to different actors, pressures and situations, potentially allowing them to transcend their analytical origins to be used as design drivers within a renewed typological approach leading to new formal compositions adapted not only to the site and environment but also to the society they are made to serve.[7]

CONFIGURATIONAL TYPOLOGY

The potential of configurations as analytical tools for extracting existing socio-spatial relationships was examined through their systematic application to the existing urban fabric in different contexts and at various scales.

As a first analytical attempt, spatial networks were used to analyse two contrasting locations; a traditional rowhouse courtyard block located on the outskirts of Rotterdam, The Netherlands and a modernist high-density slab housing estate in the suburbs of Ljubljana, Slovenia. In each case, the analysis was performed at four distinct scales aimed towards a comprehensive description of a part of urban fabric; unit, building, block and street. Despite the drastic differences in morphology of the locations and building types, spatial networks performed similarly in both cases producing clear and legible configurations at the unit and building scales, while confronting issues of a lack of data, a (too) high degree of complexity and difficulty with the delimitation of spaces at higher scales of a block and street.

As much as a lack of data and complexity are issues that could be minimised through the digitalisation of such analysis, the issues of delimitation are of a more fundamental conceptual nature and reflect similar difficulties encountered by Space Syntax. The central question here becomes by what criteria do we define a space, what separates one space from another and how spatial overlaps are accounted for. These are crucial questions *a configurational approach should answer if it is to become universally applicable as an analytical tool.*

In response to the issues encountered in the primary analysis, specifically the lack of information and reduced performance on higher scales, the analysis was continued and expanded on the principal scale of the research project; the building scale. Focusing on generic and predominantly residential urban fabric, the analysis was conducted via the systematic transformation of exiting generic urban types and certain iconic architectural buildings to their configurational counterparts with the use of spatial networks capable of recording the number, and types of spaces as well as their interconnections. In this process, the formal traits of established types are discarded opening them to new potential interpretations, some of which immediately become visible through the comparison of formally radically different objects with the same underlying patterns; a detached house and Habitat 67 by Moshe Safdie.

The resulting catalogue produces a Configurational typology; a series of spatial networks that can effectively describe the predominant socio-spatial patterns present in contemporary western cities and the buildings that constitute them. Furthermore, due to the adaptive nature of configurations, the spatial network types can be further modified, combined and cross-bred to generate new configurations capable of generating hybrid urban forms better adapted to the pressures of contemporary cities.

ON DIAGRAMS

Within the compositional design approach in architecture the plan drawing traditionally dominates as the object of design as well as the medium through which both design and construction take place. Due to the focus of the configurational design approach on spatial relationships instead of objects or forms, the diagram eschews the plan as the predominant medium thanks to its greater capacity for describing and visualising such patterns, as well as its adaptive and ambiguous nature.

Diagrams are defined as simple drawings that explain rather than represent and since Toyo Ito's introduction of the term "diagram architecture" in 1996, their explanatory function has often been used in the architectural design process to describe programmatic, structural and formal principles to the designer, as well as an external audience.[24] Nonetheless, the true value of the diagram lies in its ability to facilitate an abstract way of thinking about organization; coincidentally a fundamental aspect of configurational thought.

Diagrams operate through reduction and abstraction. By describing arrangement, structure and relationships they shift the focus from the (traditional) object to the underlying process, which suddenly finds itself in the centre of attention becoming the object of design. It is here where the diagram exceeds its analytical and explanatory roles to become projective by anticipating new organizations and yet to be realized relationships. Beyond a reduction of an existing order, its abstraction is instrumental and not an end in itself.[25] In a configurational context, this abstraction of physical space and form not only liberates the designer from any lingering formal preconceptions and biases but, crucially, makes the usually invisible underlying configurations perceptible and conscious, enabling the designer to act on them. In other words, the diagram materializes the relationships and connections in space consequently making them operational within configurational design.

A crucial property of the diagram is its capacity to mirror the adaptive nature of the very configurations it describes. While its parts and their interrelationships may be constant, its layout is ambiguous and undefined; it can twist, bend, stretch and compress as the situation dictates, potentially in response to external influences such as site, context or climate. This inherent flexibility opens up the door for interaction between (configurational) diagrams and the environment in a process akin to natural morphogenesis and the genotype-phenotype dynamics, a subject studied at length by the field of developmental biology. In nature, a genotype is defined as the set collection of genes an organism carries which define the blueprint or map for its development and defining physical traits. The phenotype, on the other hand, represents the actual organism with all its observable traits as they developed in response to not only the internal genotype but also the external environment.[26]

This duality is possible because, like a configurational diagram, the genotype is a topological design in that it only defines relationships and induces broad constraints without determining the final formal outcome which is instead allowed to dynamically emerge as a result of external forces acting upon it. A prominent example of this phenomenon is the colour of flamingoes, which, although universally perceived as pink, is actually not a genetic trait but a phenotype expression based on their diet. Similar dynamics are even more pronounced in plant morphology where trees of the same species are never precisely the same, meanwhile on a lower scale the leaves on a single tree, although following the same pattern, are never uniform but differ according to the age of the plant, their position, climatic conditions, and other influences. In more architectural terms, the configurational diagram is a medium enabling the interaction of top-down and bottom-up design. Even though the designer can define the desired configuration (and consequently how a building should function) in a top-down manner, the possibilities of its formal articulation remain undefined and infinite, only spontaneously emerging in interaction with conditions of the site and environment. Through the diagram, function can again become the core issue, albeit released from the restrictive dogmas of functionalism.

Such a theory of design combining topological (configurational) thinking with environmental responsiveness is put forward by philosopher Manuel de Landa, who, inspired by Deleuze, asserts that all space is morphogenetically pregnant and has the capacity to generate emergent form on its own. This morphogenetic process is based on local differences in concentrations of parameters in space (e.g. amount of sunlight), but can only take place when those differences are allowed to influence the organism during its growth, something not possible in traditional top-down compositional design approaches. It is here that the genotype/configurational diagram/topological graph plays a crucial role by defining a topological solution space which does not in any way limit formal arrangement; both the diagram and the emerging form are in a state of perpetual adaptation leading to the spontaneous emergence of new more responsive forms.[27] The specificity of each location combined with the adaptive nature of the diagram results in an explosion of formal diversity which could open the door for a new contextualism in architecture; an approach where similarity is not based on repetition of historical precedents or style, but on difference emerging from similar topological spatial configurations.[28]

Inevitably, applying a configurational diagram projectively leads to an exponential increase in complexity, which can present a substantial issue for the human designer limited by time and resources. While utilization of computation within the design process can overcome this issue, for this to be possible the diagram itself first needs to be systematized.

Fortunately, due to the nature of diagrams as logical constructs, they lend themselves well to systematization, especially within a configurational context. This can be achieved by the appropriation of mathematical adjacency graphs; structures whose sole function is the mapping of topological information, usually visually represented as nodes connected by links.[15] Furthermore, they can be transformed into Spatial networks defined as expanded graphs in which the nodes or links are associated with spatial elements and can contain additional information enabling the layering of additional data into the structure of the graph itself, like architectural requirements of sunlight or privacy. The outcome is a configurational dataset of spaces, their interconnections and properties visualised by the graph diagram - a Spatial network - capable of efficiently mediating between human and machine in the design process whilst also acting as the main design driver.

Empowered by its role in configurational design the diagram is transformed from being descriptive and analytical to becoming a projective tool; simultaneously the medium through which a designer operates, a dataset of the configuration being created, as well as the actual design itself. In this way, as Somol notes, the diagram essentially becomes "the matter of architecture itself" displacing the drawing as the defining trait of architecture. [29]

DIAGRAM AS MEDIUM

For the spatial network diagram to become an efficient and practical medium for configurational design it must behave as a natural extension of the designer, streamlining the creative process while providing as less resistance as possible in its use. Additionally, they must be elevated from diagrammatic drawings to become digital datasets, not only to expand their use beyond topological mapping via the inclusion of data but also to make their mediation of human-machine interactions possible.

Based on the first-hand experience gained working with spatial networks some key areas of concern have emerged regarding their practical utility as a projective tool. From the perspective of the human designer, the biggest issues relate to comprehensibility on one hand and the act of drawing on the other. No matter the level of complexity and size of the spatial network on which a designer is operating, the diagram should remain clear, legible and comprehensible at all times to ensure effective design intervention is possible. In parallel, the drawing process should not in any way distract, or worse limit, the designer, especially with issues of network layout, a problem proving to be especially pertinent with larger diagrams.

Conversely, from the perspective of machine vision, an opposing set of requirements emerges. First, the need for continuity of information requires that all properties of a configuration must be contained within it at all times, which actively works against simplification required for human comprehension. Second, all elements and possible operations within the drawing process need to be explicitly defined to exclude ambiguity and enable the fluid conversion of configurational information to digital form.

Starting from the identified issues and contradictions, as well as the elementary requirement for the transformation of the diagram into a digital data structure, the potential of a digital design interface was explored. After examining rich precedents in the field of visual programming languages, many of which increasingly popular and successful in mediating between machines and humans, it became clear that digitalisation of the drawing process within a custom structured interface could merge the intuitive visual benefits and abstraction of the diagram with the high capacity for complexity of digital *datasets.[30] Furthermore, due to the underlying graph structure of spatial networks, numerous computational methods could be applied to further streamline the drawing process such as dynamic auto-layouts with the help of force-directed graph algorithms or the implementation of collapsible multi-level graphs functioning as a selective simplification mechanism controlled by the designer. The proposed CAD-like visual interface illustrates how a design process based configurational thinking could efficiently unfold inside a software optimized towards the use of complex multi-level spatial network diagrams, simultaneously acting as datasets capable of being utilised as design drivers in digital generative algorithms.*

DIAGRAM AND ENVIRONMENT

Adaptive capabilities are inherent within the spatial network diagram as a result of its topological nature. Despite this, for adaptation to be possible an interface needs to exist between the diagram containing configurational information and the environment in which it is placed. The possibility of conceptualising such an interface was explored by combining approaches from the areas of applied mathematics, physics and architecture to finally arrive at the construct of an Environmental Field, a systematised and abstracted representation of the environment.

Due to the mathematical nature of topological graphs that underpin Spatial networks, it is only logical to look towards applied mathematics and physics for methods capable of mapping and evaluating space in a similarly systematic way. Compatible methods, in fact, do exist under the definition of scalar (or vector) fields.[31] A scalar field associates a numerical (scalar) value with every point in space effectively creating a 3d graph mapping the varying intensity of a measured parameter in different locations thereby offering an elegant way of analysing the environment.

The issue with the real world and the space constituting it is the fact it is continuous and infinite, creating difficulties for measuring and quantifying it. To overcome this, the mathematical process of discretization is appropriated, which transforms previously continuous space by splitting it into a finite number of discrete segments suitable for efficient numerical evaluation and viable for practical application.[32] Applied to a location, this approach transforms the previously inert 2d plot of land into a 3d array of discrete voxels/cells, each of which defines a specific segment of space, meanwhile its size corresponds to the desired resolution. Each cell can be further abstracted into the point at its geometric centre which is finally used as the location at which the environmental conditions of this segment are measured. Combined, the cells generate a three-dimensional array of points spanning the entire envelope - a global field - as a result enabling the measurement and quantification of the environment.

This evaluation of the environment can be performed with a range of possible parameters such as sunlight, view and visual privacy among others, depending on the requirements of the Spatial network and the spaces constituting it. The outcome is a multiplicity of fields, one for each parameter, which can be further combined through the use of weighting factors responding to hierarchies of importance between different parameters which can, in turn, respond to varying requirements of different spaces.

Admittedly, this kind of method for quantifying the environment is only as efficient as the methods used to evaluate individual parameters. Consequently, while objective influences like wind and sun are easily measured, difficulties remain with quantification of subjective *qualities such as the perception of space and ambience. Nevertheless, research into quantifying aforesaid parameters is ongoing*[33] *and when viable methods emerge they should be compatible with the environmental field as conceptualised here.*

The environmental field, through its systematization and quantification of the environment, provides the crucially needed interface allowing Spatial networks to interact with and dynamically adapt to the context around them, theoretically enabling responsive urban form within a configurational approach. To quote Stan Allen: "Field conditions treat constraints as opportunity. Working with and not against the site, something new is produced by registering the complexity of the given".[34]

ON ALGORITHMS

Configurations could bring many benefits to architecture thanks to their adaptability and flexibility permitting them to respond to a multitude of influences and constraints, in turn making emergent designs of potentially superior performance possible. Inevitably, such an approach exponentially increases the level of complexity, often past a degree with which a human designer is capable of operating manually, leading to inefficiency at best and unfeasibility at worst. Consequently, configurational design needs to take advantage of advances in computational techniques capable of augmenting the architect by efficiently operating with highly complex configurations and their influences, thus making the approach practically viable as well as realising its full adaptive potential.

The adaptive possibilities of a configurational design lies in its capacity to be translated into a multitude of diverse spatial arrangements. To take advantage of this, the broad solution space defined by a configuration must be systematically explored during the design process to uncover all possible desirable solutions and make them visible to the designer. Furthermore, for adaptation to be possible, this exploration must also include large quantities of information about the environment to which the generated spatial arrangements can consequently respond. Although the aforementioned concept holds much promise, it brings with it a crucial issue for human designers most adept at thinking through simplification and abstraction, mechanisms which help us interpret and make sense of the complex world around us. Unfortunately, these are the same mechanisms limiting our capacity to efficiently work with large amounts of quantitative information necessary in a configurational approach predicated on extensive data-driven design exploration.

Unlike humans, machines such as computers have no need for simplification, thriving instead on explicitly defined repetitive and information-intensive tasks which they are capable of performing faster and more accurately, opening the door for their use as tools for (configurational) design automation.[35] Through the use of machine logic structured in the form of algorithms - step-by-step procedures assembled from simple logical operations - computers are able to work with large datasets describing parameters and constraints like volumetric context, programmatic requirements, environmental conditions, climate, legislation and more, and use the analysed data to generate designs in a process impossible for a human designer limited by time as well as complexity.[36] By performing thousands of calculations per second, aforementioned generative algorithms can explore a vast range of possible relationships and influences otherwise hidden from the analogue eye of the human designer, while simultaneously taking full advantage of the configurational approach by generating a diverse array of possible design solutions adapted to the specific site and its conditions. Beyond mere automation, by virtually simulating the influences competing in physical space, generative algorithms can predict possible future realities by assessing the impact and performance of generated designs according to desired criteria; more than mere technological development they enable organic inside-out planning based on functional and performative criteria.[37]

Combining adaptive configurational designs with data-driven computation transforms the algorithms themselves from simple linear processes to complex systems consisting of a web of interdependencies and feedback loops capable of unexpected emergent behaviour. By definition a complex system is one composed of many parts interacting with each other in multiple ways according to local rules, resulting in an emergent higher-order greater than the sum of its parts.[38] Such systems have been extensively observed with examples including the global climate, natural organisms, the human brain, communication systems, economic organizations and cities themselves as complex entities where the economic, social and ecological spheres collide in massive aggregations of human habitation. These systems behave based on bottom-up organization allowing for a multitude of outcomes, undefined and unknown in the beginning, only unfolding as the system evolves in time; a polar opposite of traditional architecture operating through the top-down imposition of a global order - a design - usually justified with a guiding idea, a "concept". In contrast, complex generative algorithms, even when created with a specific task in mind, can always leave space for adaptivity and variation; a direct consequence of properties like non-linearity, unpredictability and emergence associated with all complex systems.[38]

Even though these qualities make complex systems notoriously difficult to analyze, predict or control, they could be productively channelled within the architectural design process by taking advantage of the unexpected to broaden the scope of available architectural solutions beyond established and expected schemes. Designing with complexity by integrating contextual, climatic, social, legislative, economic and other forces as parameters in a virtual environment, algorithms can simulate a holistic morphogenetic process in which designs spontaneously emerge as a direct consequence of the competing conditions affecting them. As the generated forms are explicit designs precisely responding to a specific set of influences, they no longer require post-interpretation by the architect. In this way, algorithms are capable of evolving more "challenging" designs; challenging both the architect and his personal preconceptions as well as established typal solutions within architecture as a discipline.[39] This approach in which sophisticated algorithms augment the capability of the architect to uncover new design solutions could increase our capability to deal with new increasingly complex architectural problems, as well as pointing towards previously unexplored solutions to existing problems. The existing stagnant and frozen urban form is a prime example of a problem which could benefit immensely from new morphological possibilities such an approach could bring.

The implied shift from top-down compositional design to bottom-up computational processes of morphogenesis also signals a transition from one to the many and the acknowledgement that a single perfect design most often does not exist. Competing schemes always exist in a diverse population of designs where each excels in some aspects while performing worse in others and only upon evaluation through a chosen criteria can preferred designs be selected in a process akin to evolution and natural selection. As a result, diversity within an evolutionary context is not an end in itself but is operationalized as a mechanism for gradual optimization of designs over time; difference becomes the driver of evolution and dynamic change.[10] The difference and diversity enabled by automated generative algorithms make the application of similar evolutionary principles possible to configurational design in architecture where it could initially be used to optimize simulation settings and parameters to achieve more desirable outcomes, while looking forward it could potentially allow us to completely close the loop between input and output thus enabling perpetual self-optimization of both the urban fabric as well as the algorithms generating it.

Such an adaptive architecture could be made possible by computationally augmented configurational design in which dedicated generative algorithms are used as automated tools furthering the capabilities of the architect and enabling design with complexity, leading to more responsive and better performing urban form in tune with the requirements of contemporary cities.

CONFIGURATIONAL AGGREGATION

To test the theoretical possibilities of configurational computation, a dedicated generative algorithm was developed, capable of combining spatial networks and the environmental field on a designated site to produce site-specific adaptive urban forms.

Even though computational approaches in architectural design are increasingly common, the vast majority of applications still fall into the domain of parametric modelling, merely used for elaborate formal exercises. Alternatively, the existing approaches relevant for configurational design fall into two distinct categories; on one hand, we find topological algorithms mostly performed in two dimensions and predominantly used for floor plan optimization, while on the other hand environmental optimization algorithms try to connect form to climatic performance, albeit most often in a global top-down manner. In short, no existing technique successfully manages to unify topological (configurational) design with environmental responsiveness.[40]

As a result of this gap in precedents, a new approach was developed combining generative principles of shape grammars and cellular automata. The system operates by translating the nodes of a spatial network into spatial types, each containing growth instructions including topological information and spatial requirements. Responding to the environment field, the structure grows in a 3d voxel space through recursive voxel aggregation. This approach eschews computationally costly global optimization for gradual local adaptation where the structure perpetually adapts and adjusts both to the context as well as itself in a process of gradual growth. While introducing certain constraints such as the restriction to hierarchical tree-like topologies due to computational limitations, this approach was pursued due to its efficient adaptation to environment and context consequently producing better performing outcomes.

To function the algorithm depends on a series of inputs defined by the designer; the overall desired configuration defining spaces together with their interconnections and the individual spatial, and environmental requirements guiding the aggregation of each type. These inputs are fed into a simulation process during which a spatial composition organically emerges in response to external influences. This kind of simulation can be performed multiple times under the same conditions to generate a set of possible designs which are evaluated and displayed to the architect for selection.

Although the algorithm is capable of generating fuctional, rational and well-performing aggregations in most cases, its efficiency occasionally tends to suffer as it can be difficult *to manually define the optimal parameters to achieve the desired result; an issue which could be minimized with the implementation of self-optimizing parameters utilizing evolutionary systems or machine learning. Nevertheless, the aggregations generated through this configurational algorithm by virtue of their performance and spatial quality affirm the approach as a proof-of-concept, which could, with further development, once become a practically applicable tool for generating responsive urban form via configurational design.*

MORHOLOGICAL EXPERIMENTS

The adaptive nature of spatial compositions generated through a configurational approach holds the promise of improved performance compared to established urban types due to its site-specificity and complexity. These theoretical assumptions are examined using a series of simulations in a controlled setting to establish objective performative differences between typal and configurational form.

The experiment focuses on four deeply-rooted types - detached house, rowhouse, courtyard townhouse and slab - whose dominance in contemporary cities makes them good approximations of the majority of the urban fabric. The performance of each type is subsequently compared to its counterpart configurationally generated based on the original's topology. Parameters used for performance evaluation fall into three groups which together hope to provide a well-rounded appraisal; efficiency parameters of Floor Area Ratio and circulation percentage, exterior parameters of Open Space Ratio and percentage of private exterior space and lastly environment parameters of sunlight access, view quality and privacy. Furthermore, to ensure the precision of results, the programme used to divide the urban form into units on which evaluation is based had been unified according to the average household size distribution in the Netherlands. All tests are performed on two contrasting locations in Rotterdam. First, a central location of a smaller size and a pronounced context, where hypothetically the adaptive configurational approach should outperform the rigid existing types. Alternatively, the second location on the outskirts of the city with little context and of a much larger size should enable optimal performance of existing types possibly leading to better results.

The results of all simulations demonstrate the potential capability of configurationally generated forms to perform better or at worst equally in comparison to established urban types. The largest improvements in performance were apparent in low-density traditional types like the row house where configurational forms achieved a drastic improvement both in density as well as all environmental parameters. These results imply that established configurations such as the row house could be arranged in different spatial compositions better responding to contemporary requirements while maintaining their inherent socio-spatial structure. Simultaneously, in case of high-density types like the slab, a symbol of efficiency, the performative gains were much smaller or non-existent with the majority of cases exhibiting a small tradeoff in density in exchange for improved environmental performance. Much as this seems unimportant it holds a crucial implication; due to its adaptivity, configurational form can ensure much greater equality of conditions across the entire urban form. In this way, we can eliminate outliers such as shaded north-facing apartments or units on lower floors with suboptimal views and ensure the entire aggregation performs up to the minimum designated standards.

Although admittedly providing a limited sample size evaluated by a small number of parameters and eschewing important others like economic performance, the experiment *showcases the potential of configurations to enable new morphological innovation which could lead to hybridisation of existing and creation of new urban forms crucial for the evolution of the future city.*

ON THE ARCHITECT

Configurational thinking in architectural design, while already latently present in the form of programme bubble-diagrams, when applied systematically as the main projective tool presents a significant departure from traditional compositional methods. Combined with digital technologies in the form of (semi-) automated generative algorithms capable of transforming configurations and data into architectural form, questions and doubts arise about its impact on the architect and his role in the design process. The majority of said apprehensions usually boil down to two specific reasons; the architect's perceived lack of control of spatial and formal aspects on one hand and control of the automated generative algorithms on the other. Both of these are false concerns stemming from the misunderstanding of the configurational approach and the way it deploys technology along with its primary purpose.

The configurational design process can be roughly divided into three phases; pre-design, the generative phase and selection phase, each of which requires conscious and purposeful intervention on the part of the architect. First, in pre-design, the architect is required to define the desired configuration as well as its accompanying requirements; these effectively become the main object of design within the configurational approach. Additionally, due to the incorporation of a large range of spatial, functional, technical and social aspects within configurations themselves, their design primarily falls into the domain of architects thanks to our broad skill set enabling us to successfully negotiate the multiplicity of diverse parameters and influences. Second, the generative phase, even though automated, is not autonomous but dependant on specified instructions. In other words, the generative algorithms employed to transform configurations into spatial compositions, although complex in their operation, are nothing more than sequences of instructions to be performed in response to the input parameters which are in turn defined by the architect-designer. Furthermore, the instructions themselves and thus the algorithms are also subject to design and created with a specific design intent. Finally, the crucial role of the designer is again apparent upon examining the results of the generative algorithms where in most cases there exists a large number of possible solutions, none of which can be deemed the best. It is here that whatever agency the architect loses in the pre-design phase, especially regarding formal and experiential aspects, is regained as his expertise becomes crucial to compare and sift through the myriad of potential solutions and pick the most appropriate one by balancing objective performance with otherwise unquantifiable subjective aspects. In effect, despite automating the arguably most important - generative - phase of design, creative control is never lost by the designer but merely temporarily exchanged for the possibility of a greater variety of potential solutions and regained with the final selection of the preferred scheme.

Returning to the issue of process, it is apparent that algorithms are no more than tools in service of the architect used for their ability to translate the designed configuration into a multitude of possible spatial compositions traditionally out of reach for the human designer limited by time and complexity. Furthermore, this increase in efficiency by way of partial automation could help kickstart the long-overdue technological evolution within the construction industry, currently second to last in productivity amongst all sectors contributing immensely to the dwindling influence of architects within the construction process.[41] In this light, the use of algorithms represents the next step in the evolution architectural tools; a progression that started with the pencil, ruler and compass, continued with the use of drafting tables in the first half of the 20. century, the establishment of CAD software in the 1980s and increasing adoption of BIM software today. In contrast to the aforementioned tools which often prescribed the way, we design through structured interfaces, the diverse possibilities of algorithms today combined with increased digital literacy and more intuitive programming languages open up the opportunity for architects to develop our tools in ways we see fit. In other words, instead of tools defining how we work, we have the opportunity to define how our tools work.[42]

Different from existing drafting tools that often provide a generalised framework within which any architect can operate, algorithms are usually built for a specific purpose and consequently need to be designed. Moreover, this design needs to be architecture-specific and can only be developed by someone with the requisite knowledge in not only in the field of computer science but crucially also architecture, necessitating the inclusion of an architect. In this sense, the automation of the design process can be thought of as a design project in itself; a project for the development of which architects are crucial.[43] Albeit increased efficiency and productivity are the most obvious consequences, the way we automate, what algorithms we use and what type of architecture they generate can have profound economic, social and political consequences and it is the responsibility of architects to develop these technologies in a way that corresponds to our visions and desires of the future.

The benefits of appropriating and customizing technology in a way that amplifies the capabilities of the architect are increasingly visible in everyday architectural practice. Beyond pioneering examples at the end of the previous century such as Gehry Technologies, today this approach is already increasingly visible in large architecture offices with many having dedicated technological departments like UNSense, MVRDV Next, ZHA code and others, whereas in other cases this becomes the focus of complete studios an example of which are Carlo Ratti Associates operating on the crossroads of architecture, design, computation and data science.[43] Utilizing technology enables these companies to not only advance the quality of their designs but also to generate custom processes which could be protected as intellectual property and repeatedly used as design tools in multiple projects. This allows the companies to partially shift from service to product providers, making them less susceptible to the perpetual pressures of the market economy leading to greater autonomy.[44]

While configurational design may indeed bring many changes to the design process itself, the role of the architect as the head designer is by no means reduced but can in fact be expanded to new territories, which, if leveraged intelligently, could reassert and strengthen our position and influence within the construction industry, the global market economy and society at large.

ON INFLUENCE

After exploring both the theoretical and practical potentials of configurational design in architecture, this last chapter of Configurational Morphology will attempt to summarise the results, describe benefits and especially drawbacks, emphasise the limitations and point towards possible improvements. Through this reflection the starting questions about the viability of configurational design for designing responsive urban form are answered, whilst new ones are posed which will guide further research, its expansion and possibly application.

Configurational Morphology combines general theoretical principles of configurational design with their practical application through specific experiments geared towards creating new adaptive urban form. This duality is crucial due to the breadth and importance of the topic in question - the architectural design process - which must simultaneously be conceptualised as a generalised approach as well as tested through practical real-world experiments. The project intentionally operates at an intermediate scale between architecture and urbanism; more than a building but not quite an urban plan, a no man's land for which everyone and no one is responsible, but has a strong influence on how our built environment looks, feels and performs. Through the reconnection of architecture and urbanism, Configurational Morphology aims to create a holistic design process in which the complex interdependencies between scales are acknowledged and productively channelled as parameters for generating new urban form.

Configurational Morphology examines the potentials of configurational design for designing responsive urban form in the scope of two activities crucial to the architectural design approach; analysis and projective design. Analytically, configurational design has proven a valuable tool for investigating and recording the socio-spatial patterns underlying the urban fabric of our cities by reducing three-dimensional space into abstract configurational Spatial Networks. These patterns in space are important not only because they govern how our cities are constructed, but also because they are a direct reflection of our society and way of life. Additionally, a configurational analysis of space enables the extraction of such patterns while separating them from physical form and making them ready for use as design inputs for the configurational generation of new urban form. The renewed focus on the configuration of space essentially enables a refocus on the social aspects of space allowing architects to consciously design in accordance with our ever-evolving society and behavioural patterns. Contrary to existing form based on aesthetics or formal precedents, this could lead to socially responsive architecture and urban form directly based on the way we live together and interact, consequently increasing our quality of life.

Projectively, configurational design has proven a capable design approach for generating designs organically growing out of local conditions and architect-defined constraints. In the case of urban form, configurations, especially when combined with computation, can enable the production of more responsive site-specific urban form better adapted to the site and environment in which it is placed. A top-down approach imposing rigid slabs and towers is replaced with a process of configurational aggregation where urban form emerges as the direct result of both top-down forces of configuration and spatial requirements, as well as complex bottom-up urban forces of local environmental conditions. Using Spatial Networks extracted from established urban types through configurational analysis such adaptivity can be channelled to extrapolate these types into new urban fabric better adapted to the forces of contemporary urban areas. The use of configurations as a generative design medium also entails a shift to a more scientific, fact-based design approach utilising urban datasets and digital analysis of urban conditions to guide the generation of design schemes. This systematism often leads to increased building performance in various categories such as density, sustainability or spatial quality as evident in the conducted morphological experiments. Through the theoretical and practical experiments conducted the viability of configurational design within architecture has been proven, especially for the production of responsive urban form adapted to site and context leading to more socially, economically and environmentally responsive urban form.

While configurational design as a theoretical framework holds much promise for creating adaptive and sustainable architecture, its practical application explored throughout this project has been subject to numerous limitations imposed both by the restricted scope and time, as well as characteristics of the approach itself. These limitations open new questions that can guide further research into the viability of configurational design as a practical design approach for not only urban form but architecture in general.

The most glaring limitation of the current research has been its focus on generic urban tissue such as residential urban fabric. While these indeed represent the vast majority of built space, the scope of architecture is far larger and includes complex public buildings such as schools, hospitals, museums, stadiums and shopping malls to name only a few. Theoretically and analytically the approach as presented can deal with all the above-mentioned building types, it is in the computational generative phase where this is harder to apply, mostly as a result of the increased complexity of topological connections within the configurational graph / Spatial network.

Next, the practical application of configurational thinking was currently restricted to a narrow range of scales of a building and an urban block, mostly as a consequence of the desired focus on urban form. As a result, the potential of configurational design as an analytical and projective approach needs to be further explored on smaller scales such as the unit or room, as well as larger scales ranging from the street to neighbourhood to the city. It is at these larger scales where the approach becomes similar to one of its precedents, the urban analysis tool Space Syntax, along with all of its benefits and issues. Similarly to other scales, the biggest challenge here remains how to translate the analytically capable configurations into an efficient and effective generative design driver for a new architecture.

To improve the practicality of configurations as a design medium the digital design interface would need to be further developed past the conceptual sketch presented as part of this project. This would make configurational design accessible to users irrespective of their programming skills whilst making it more time-efficient and intuitive. Concerning user experience, the currently implemented generative algorithms, whilst producing interesting designs, can often behave very unpredictably as a result of their complexity and difficulty in setting optimal parameters. Sometimes this can lead to frustrating and time-consuming behaviour where the algorithms produce large numbers of inefficient results purely as a result of poorly defined settings which the algorithm is unable to optimize. Consequently, an important step in development would be the implementation of machine learning or evolutionary optimization within the generative algorithm, allowing it to self-regulate thereby leaving the designer with more time to focus on the effects different configurations and their requirements have on the quality of generated schemes.

Lastly, there remains the dilemma of selecting parameters guiding both the generation of new designs, as well as their evaluation. Due to the systematic and logical nature of the configurational design process presented here, the developed generative algorithms operate exclusively through quantitative metrics such as sunlight hours, view degrees or privacy distance. Although such parameters are very successful at describing the economical, and environmental performance of a building, one could argue that spatial quality can never be fully described merely through simple metrics like sunlight access but is also affected by subjective perception. Further research is required (and ongoing) in this field to explore if qualities such as ambience are truly subjective, in addition to if and how they could be quantified. These new metrics must then complement existing ways of quantifying spatial features such as visibility or convexity used in Space Syntax and traditional parameters already used in the configurational approach to empower the method to generate designs of superior performance on all fronts. These questions, along with many more left unmentioned, represent the next step in the research and development of configurational design as a practical design approach.

Nevertheless, in spite of the aforementioned drawbacks of the approach and the limitations of this research it is evident configurational design is deeply relevant as a theoretical design framework, a legitimate design approach for architectural practice, as well as a method for creating socially responsive and sustainable urban fabric.

As a research project, Configurational Morphology attempts to question established modes of operation in architecture by introspectively looking into the fundamental core of design activity, our design process. After critically examining the existing object-based design approach the project points towards process-based configurational design as a viable alternative often capable of better adaptation and performance, elaborating it not only through practical examples but a broader theoretical framework based on which other approaches and applications could be developed. Fundamentally, it is a case for a more scientific, objective and rigorous approach to architectural design, one capable of taking advantage of technological advancements. In the process, the project tries to crack open the shell in which architecture as a discipline sometimes encloses itself by attempting to find fertile connections to otherwise unrelated fields and disciplines such as computer science, biology, physics or mathematics. In many cases this cross-fertilization leads to new knowledge and techniques applicable within architectural design, showing both the importance of expanding the boundaries of architectural research as well as the value of speculative design as a legitimate architectural research activity through which the former can be achieved.

From the perspective of architectural practice, the project tries to show ways configurational design could empower architects to create buildings better adapted to their local conditions resulting in improved economical, social and environmental sustainability. Complemented by a proposed paradigm shift to quantitative performance-based design, adaptive designs interacting with the environment and its complex influences can be evaluated according to metrics of sustainability, economy and spatial quality allowing for improved performance projections within the development phase before the building is constructed. Applied in practice, such an approach could finally enable us to overcome the serial mass production of urban space leftover from modernism and replace it with diverse site-specific urban forms and buildings growing out of local conditions whilst utilising the full potential of available spaces. Today, such invention is more crucial than ever as the worsening climate crisis places increasing pressure on cities to be more sustainable than ever, while architecture has yet to respond effectively with sustainability usually superficially applied in the form of solar panels or greenwashing instead of being the main design driver of urban form. Furthermore, potentials of computation are explored as a tool facilitating the automation of the architectural design process. On one hand, this could increase our efficiency and productivity as well as increase our capacity to deal with complex conditions and design appropriate solutions. On the other hand, the digital algorithms enabling automation present potential intellectual property which architects could leverage to their own benefit and increased influence in the construction industry.

Although in itself Configurational Morphology is a profoundly architectural research and design project, it also carries many broader implications for our society and the cities we live in. By virtue of its focus on configurations and consequently the socio-spatial patterns underlying our cities, configurational design can empower architects to create buildings in tune with the perpetually evolving patterns of living and interaction in contemporary society. Most importantly, this improved city-making process based on previously explained adaptivity could lead to urban spaces more capable of serving our needs through higher density, improved sustainability, more porosity and social interaction, increased identity, more diversity and higher spatial quality, producing cities of increased livability crucial for our future well-being.

To conclude, Configurational Morphology shows that with further development and refinement configurational design has potential to become both a comprehensive theoretical framework and a practical design methodology for designing adaptive urban forms responsive to the social, economical and environmental pressures of the contemporary city. Moreover, by virtue of its compatibility with digital and computational techniques it encourages the long-overdue inclusion of automation in the design process thus increasing productivity and efficiency on one hand, whilst offering architects the opportunity to create our own tailor-made algorithmic design tools and processes which can be intelectually protected thereby strengthening our role and relevance in the design and construction process. Lastly, the expansion and application of configurational design to other spatial scales could pave the way for a holistic performance-based design approach empowering us to create a more livable, equitable, affordable and sustainable built environment fit for the future of our society.

REFERENCES

1. Global Urbanization. (n.d.). Retrieved July 05, 2020, from https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html
2. Živković J. (2019) Urban Form and Function. In: Leal Filho W., Azeiteiro U., Azul A., Brandli L., Özuyar P., Wall T. (eds) Climate Action. Encyclopedia of the UN Sustainable Development Goals. Springer, Cham
3. Mumford, L. (1961). The city in history : its origins, its transformations, and its prospects. Harcourt, Brace & World.
4. Koolhaas, R., Mau, B., Sigler, J., Werlemann, H., & Office for Metropolitan Architecture. (1998). Small, medium, large, extra-large : office for metropolitan architecture, rem koolhaas, and bruce mau (2d ed.). Monacelli Press.
5. Verebes, T. (2015). Cities and their specificities: standards, customs and the making of 21st-century urbanity. Architectural Design, 85(6), 8–17. https://doi.org/10.1002/ad.1971
6. Gelernter, M. (1995). Sources of architectural form : a critical history of western design theory. Manchester University Press.
7. Shane, D. G. (2011). Transcending type: designing for urban complexity. Architectural Design, 81(1), 128–134. https://doi.org/10.1002/ad.1197
8. Habraken, J. (1998). Type as a social agreement.
9. Alexander, C., Ishikawa, S., & Silverstein, M. (1977). A pattern language : towns, buildings, construction. Oxford University Press.
10. De Landa, M. (2011). Philosophy and simulation: The emergence of synthetic reason. London: Continuum.
11. Hillier, B. (1996). Space is the machine : a configurational theory of architecture. Cambridge University Press.
12. Hillier, B., & Hanson, J. (1984). The social logic of space. Cambridge University Press.
13. Alexander, C. (1964). Notes on the synthesis of form. Harvard University Press.
14. Van Eyck, A. (1962). Steps Towards a Configurative Discipline.
15. March, L., & Steadman, P. (1971). The geometry of environment: an introduction to spatial organization in design. RIBA Publications.
16. Spatial network. (n.d.). In Wikipedia. Retrieved July 05, 2020, from https://en.wikipedia.org/wiki/Spatial_network
17. Gorny, R. A. (2019). Lecture; On Types and Typology: A critique of typological thinking
18. Hays, K. M. (1998). Oppositions reader : selected readings from a journal for ideas and criticism in architecture, 1973-1984. Princeton Architectural Press.
19. Argan, G. C. (1963). On the Typology of Architecture.
20. Lee, C. C. (2011). The City as a Project: Type. Retrieved July 05, 2020, from http://thecityasaproject.org/2011/08/type/
21. Colquhoun, A. (1969). Typology and design method. Perspecta, 12, 71–74.
22. Jonghoon Im & Jiae Han (2015) Typological Design Strategy of FOA's Architecture, Journal of Asian Architecture and Building Engineering, 14:2, 443-449, DOI: 10.3130/jaabe.14.443
23. Jacoby, S. (2015). Type versus typology introduction. The Journal of Architecture, 20(6), 931–937. https://doi.org/10.1080/13602365.2015.1115600Toyo ito el croquis 1996
24. Itō, T. (1994). El croquis 71: 1986-1995. Madrid, España: ARCE.
25. Allen, S. (1998). Diagrams matter. Any: Architecture New York, 23(23), 16–19.
26. Genotype vs. Phenotype. (2020). Retrieved July 05, 2020, from https://evolution.berkeley.edu/evolibrary/article/genovspheno_01
27. De Landa, M. (1998). Deleuze, diagrams, and the genesis of form. Any: Architecture New York, 23(23), 30–34.
28. Somol, R. E. (1998). The diagrams of matter. Any: Architecture New York, 23(23), 23–26.

29. Eisenman, P. (2001). Diagram diaries. Thames and Hudson.

30. Hosick, E. (2014). Interface Vision. Retrieved July 05, 2020, from http://blog.interfacevision.com/design/design-visual-progarmming-languages-snapshots/

31. Scalar field. (n.d.). In Wikipedia. Retrieved July 05, 2020, from https://en.wikipedia.org/wiki/Scalar_field

32. Discretization. (n.d.). In Wikipedia. Retrieved July 05, 2020, from https://en.wikipedia.org/wiki/Discretization

33. Derix, C., & Izaki Åsmund (Eds.). (2014). Empathic space : the computation of human-centric architecture (Ser. Architectural design, volume 84, issue 5). John Wiley & Sons.

34. Allen, S. (2015). Field Conditions (1997). In The Digital Turn in Architecture 1992–2012, M. Carpo (Ed.). doi:10.1002/9781118795811.ch5

35. Carpo, M. (2019). Particlised: computational discretism, or the rise of the digital discrete. Architectural Design, 89(2), 86–93. https://doi.org/10.1002/ad.2416

36. Peters, B. (2013), Computation Works: The Building of Algorithmic Thought. Archit Design, 83: 8-15. doi:10.1002/ad.1545

37. Derix, C., & Izaki Åsmund. (2014). New curricula: syntonic systems. Architectural Design, 84(5), 122–129. https://doi.org/10.1002/ad.1818

38. Complex system. (n.d.). In Wikipedia. Retrieved July 05, 2020, from https://en.wikipedia.org/wiki/Complex_system

39. Janssen, P. H. T., Frazer, J. H., & Tang, M.-X. (2005). A framework for generating and evolving building designs. International Journal of Architectural Computing, 3(4), 449–470. https://doi.org/10.1260/147807705777781112

40. Veloso, P., Rhee, J., & Krishnamurti, R. (2019). Multi-agent Space Planning A literature review (2008-2017).

41. F. (2019, July 31). The Construction Labor Shortage: Will Developers Deploy Robotics? Retrieved July 05, 2020, from https://www.forbes.com/sites/columbiabusinessschool/2019/07/31/the-construction-labor-shortage-will-developers-deploy-robotics/

42. Shelden, D. (2020). Entrepreneurial practice: new possibilities for a reconfiguring profession. Architectural Design, 90(2), 6–13. https://doi.org/10.1002/ad.2541

43. Retsin, G. (2019). Discrete architecture in the age of automation. Architectural Design, 89(2), 6–13. https://doi.org/10.1002/ad.2406Algorithms in use

44. Lynn, G. (2020), Architects = Innovators (sometimes) Innovators ≠ Entrepreneurs (most of the time). Archit. Design, 90: 120-127. doi:10.1002/ad.2555