Theoretical Outlines for a Complex Approach to Architecture

F. Alves[1*]; V. Rato[1;2]
[1] Instituto Superior das Ciências do Trabalho e da Empresa;
Avenida das Forças Armadas; 1649-026; Lisbon; Portugal
[2] Department of Architecture and Urbanism; ISTAR – IUL / ISCTE – IUL;
Avenida das Forças Armadas; 1649-026; Lisbon; Portugal

*Corresponding author: E-mail: fmtalves@gmail.com; Tel +351 913 338 826;

Abstract
This paper focuses on the built environment studying disciplines and their established or yet to establish connections with complex thought. It asks if there's a path for the integration of Architecture and Urbanism on Complexity Theory. Complexity Theory is a disciplinary paradigm that often takes interdisciplinary stances upon looking at phenomenon that transcend the classically defined frontiers of science. Most phenomenon that ask for such an approach are emergent, as they represent a change in a system that cannot be irreducibly explained by decomposing it into its constituting parts. This idea allowed for complex ways to understand cities. Here, we use it to go forward on the built environment analysis and reach the building scale. If emergent phenomena result from interacting simple parts, firstly, one can imagine such simple parts to be people and their surroundings' physical elements; but on a second look, technical advances allow us to design buildings' physical elements as interacting parts themselves. If there's optimization to be done in the building system, it will most certainly occur through linking these two points – as it allows for us to conceive open work adaptive structures that react to the stimulus of human occupation.

Keywords: complexity; system; architecture; interdisciplinary; post-occupancy

1. INTRODUCTION

Complexity, or Complexity Theory, is an interdisciplinary paradigm that studies a wide array of phenomena believed to transcend the strict limits of classically defined disciplines [1]. Thus, a complex way of thinking has both technological and philosophical/-epistemological repercussions: one can easily understand it since most subjects dealt with under this approach were left out by traditional *reason* [1]. Warren Weaver, the North-American mathematician, was the first to suggest the idea underlining Complexity, in a 1958 text [2] – and although the theory is still missing a clear definition, researchers do usually agree towards what is complex [3].

Were one to list the main subjects studied under the approach of Complexity Theory and the process would leave out disciplinary fields such as Architecture and Urbanism – that is, the ones that struggle with the spatial condition while trying to better understand the world we live in. Of course, one can argue that spatiality has been addressed in a *complex* way as part of Sociological and Economic models – but then we would need to narrow the scope of these models to find the ones that do not omit spatial structure, and do more than to produce statistical distributions of functional properties [4].

This paper first starts by looking at the established or yet to establish connections between the built environment and complex thought. Some complex systems' properties allow us to work on those connections. As we understand here, the complex way in which cities' literature has been revisited ask for a qualitative leap that seeks the same for the smaller scale of the built environment. As such, we first try to follow the path through which Complexity entered the spatial minded disciplines (Chapter 2 – On Complexity and Space); and later address how such path is a paradigm shifter for the discipline of Architecture and architects (Chapter 3 – On Complexity and Architecture).

2. ON COMPLEXITY AND SPACE

At first, there seems to be a valid reason for the integration of Architecture and Urbanism on the scope of subjects dealt with within Complexity Theory: it's academic and disciplinary positioning. A disciplinary paradigm that sets apart from a simplistic reduction of the world [1] cannot ignore the spatiality in it. On the other hand, professionals dedicated to the study of the built environment cannot ignore the complexity in our actions. There's even an historic precedent of great importance: Jane Jacobs. Not only did the widely cited Canadian-born New Yorker understood how Complexity Theory was deeply related to urban planners' field of work, as she also referenced her seminal book The Death and Life of Great American Cities on Warren Weaver's 1958 text [2].

Jacobs understood city streets as effusive places and metaphorically compared their daily dynamics to an intricate ballet: a dance where different intervening parts perform distinctive roles and constantly reinforce each other, composing at the end a complex order [5]. Cities evolve, we understand here, in the absence of centralized control. Cities are very much an emergent phenomenon, as they're spatially produced throughout the years by the actions and interactions of large numbers of individuals, and cannot be irreducibly explained by looking specifically to any one of those individuals. Steven Johnson, the popular science writer, revisited Jacobs' work on his 2002 book Emergence: The Connected Lives of Ants, Brains, Cities, and Software and quite clearly exposed the idea that underlines the influence of people's movement on cities: "Driving a car has short-term and long-term consequences. The short-term influences whether we make it to soccer practice in time; the long-term alters the shape of the city itself" [2].

A wide array of literature produced during the second half of the 20th century understood the connection between *complex* thinking and the urban theme: social approaches have been tested [6]; functional distributions have been tied to economic forces [7]; models for understanding the morphology of urban spaces have been developed [4]; and we've realized our patterns of living to be influenced by the built forms [4]. Ultimately this approach meant reviewing previously synthesised work with a Complexity mind-set. A question remains unanswered, though: can we do the same in the field of Architecture? That is, can we lead this built environment's analysis forward as the problem's scale gets smaller, and try to postulate theories about the way we use buildings? And how do our long-term actions eventually alter their shape and design assumptions? Is that something for designers to consider? One can draw on an idea exposed by Edgar Morin [1], the French philosopher, to first outline and legitimate such approach: "(…) toute réalité connue, depuis l'atome jusqu'à la galaxie, en passant par la molécule, la cellule, l'organisme et la société peut être conçue comme système (…)" which roughly translates to "every known reality, from the atom to the galaxy, going

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through the molecule, the cell, the organism, and society, can be interpreted as a system". On a somewhat fractal, mental process, we can question neighbourhoods, streets, and buildings in much the same *complex* way we do with cities – minding of course the rightful dangers in the process of doing so, so that established comparisons go beyond romantic metaphors [1].

Upon confronting Complexity's key idea – that of simple parts following simple rules whose interactions produce changes that are not easily predictable in the status of the system they compose [8] – with the field of Architecture, we can first outline some important topics to look at, such as:

- The interplay between a building's physical structure and its occupants; as well as the interactions between these individuals and to what extents are they influenced by the morphology of the space where they occur [4;5]. We can refer to this as "building/user(s) interplay";
- The interaction between building parts, following simple rules. A search for material, structural and formal optimization underlines this topic. We can refer to this as "Building Relations", as defined in the work of Kas Oosterhuis [9];
- Both previous topics conjugation. We can refer to this as Sensori-Motor Intelligence, in line with the definition proposed for the term in Swarm modelling – The use of Swarm Intelligence to generate architectural form, by Pablo Carranza and Paul Coates.

3. ON COMPLEXITY AND ARCHITECTURE

3.1 Building/User(s) Interplay

A better understanding of the relation between built structures and the ones who use them figures as important data for building designers. But is it just that? For it to be just that would mean that buildings remain statically unchangeable to the dynamics of their occupancy. Knowing such an assumption to be impossible we can see the study of the aforementioned interplay to be of the utmost importance in both design and post-design stages of a building's life. To imagine a building as a somewhat adaptive, elastic structure, that changes throughout the years, reminds us of the non-trivial way in which complex systems evolve. This evolutionary life similarity that a system exhibits occurs due to the influence of constantly interacting agents that can change their own behaviour [3] – and it's, we understand here, for this same reason we say cities are emergent phenomena.

Upon cities, we project the notion of life in two different connected manners: it's the daily intricate ballet in which different intervening parts reinforce each other [5]; and its long-term repercussion – the evolution of urban settlements despite the intervening parts constant renewal [4;2;1]. Our assumption here is that cities' vibrant daily life does sometimes crosses the threshold between street and building (Figure 1). Of course, this mainly verifies with buildings that house specific functions, and where large numbers of people are expected to cohabitate. One can list several examples that make such a case: transport hubs; schools; hospitals, or even ephemeral structures such as music festival venues.

Not only scale matters, though. If that was true we could imagine the interactions between individuals on an abstract place and look at them through Sociology's lens. We know ourselves sensible to the built environment, and that leaves a role to be played by spatial configuration on the shaping of our actions. There's a deep transdisciplinary effort in the work of Nikos. A. Salingaros [10] that seeks to root Architecture and Urban design in the natural world. This is not the approach that we're following here, but this author's words are particularly aware of the influence the built environment has on our subconscious: "Human

Figure 1. Pictures taken by the author at 9:00 am on a week day, at ISCTE – University Institute of Lisbon. Illustration of the street/ building threshold crossing.

beings connect with their surroundings (...). There is a built-in human reaction to threats from the environment, and structures threaten our primeval sense of security when they appear unnatural." [10].

On pointing out the edges for the individuals/surrounding interplay there's an important reference to look at in Biology. Social insects have been long studied on the fields of Complexity, and exhibit a behaviour that is of the most interest to explain here: the ability to communicate only through stimulus on their environment. If an individual insect alters the configuration of its surroundings, that modified configuration will act iteratively on a second insect behaviour.

Individuals response to their surroundings has been dealt with and studied on the field of Environmental Psychology. We are, therefore, again led to think that whereas a complex approach must be followed it is important to revisit previously done work, and that an interdisciplinary knowledge is a mandatory asset for designers.

The building/user(s) interplay composes a rich and complex system (which makes it difficult to manage), but can we optimize it? Or, in other words, can we introduce a bias in it? The subsequent sub-chapter tries to establish the theoretical outlines for such an approach.

3.1.1 Post-modern Way

Edgar Morin's work has been scarcely translated to English, which is unfortunate since the author quite clearly synthesizes why we need complex thought, particularly on <u>Introduction à la pensée complexe</u>. Morin [1] roots it in the last centuries scientific evolution: the classic search for order, that looked at the cosmos as a perfect calculable machine ruling beneath the apparent world of complex phenomenon, faced its own limits upon discoveries itself perpetuated. Physics showed us the atom was not the ultimate particle, and the second law of thermodynamics introduced disorder and degradation where they could not be conceived.

At this point, one ought to ask: should a complex Architecture reflect all of this? We can draw on Umberto Eco's <u>Opera Aperta</u> (<u>The Open Work</u>) for a first approach to such question: "In every century, the way that artistic forms are structured reflects the way in which science or contemporary culture views reality" [11]. So, where current scientific knowledge allows for indeterminacy, art "allows for a number of possible readings" [11] – in opposition to "The closed, single conception in a work by a medieval artist (…)" that "(…) reflected the conception of the cosmos as a hierarchy of fixed, preordained orders" [11].

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To look at architecture as an open work is a real paradigm shifter: to the static assumptions with which buildings were designed succeed adaptable and evolutionary structures, responsive to the ones who occupy them. Such a process introduces the transdisciplinary strategies of Complexity to Architecture – looking at Physics for the concept of indeterminacy and of open systems; to Biology for the concept of adaptable (homeostatic and resilient) organisms and of metabolism; and to Mathematics for the iterative processes and fractals [8;10]. Even though technical and constructive constraints do sometimes impose, the 60's were a particularly productive decade for such a way to look at Architecture, for instances through the work of the English collective Archigram and of the Japanese Metabolists [12].

To face architecture as an open work introduces Complexity. Firstly, because it reflects contemporary scientific thought, which walks towards Complexity; and on a second instance, because adaptable structures are a needed part of the bias we look to introduce in the building/user(s) interplay system – exhibiting of rich and complex non-trivial behaviour.

3.1.2 Post-occupancy

The concept of open work legitimates an intervenient post-occupancy scenario in a building's life; and as technology advances, the possibility for built structures to react to the stimulus of human occupation. In both mentioned instances the aim is to ultimately optimize the building/user(s) interplay – setting a bias on the system. The following list maps in a somewhat schematic way the possibilities for such bias:

It can be applied:

- To a less flexible structure, not designed to endure any kind of post-design or post-construction intervention;
- To a building constructed on adaptable constructive assumptions, designed to withstand interventions without it being perverted;
- In a functional/-administrative way, that doesn't impact a building's physical configuration.

It can be grounded:

- On users' intuition (in this event the aforementioned adaptable constructive assumptions could reveal important, as they allow for a quick reversion should such intuitions be proven wrong);
- On an adequate study of people's flow and moving patterns, processed with tools created with the same epistemological assumptions that firstly raised this questions.

By people's flow and moving patterns we understand the extended record of the interactions between individuals and their environment. Or, put in another way, the rich complex life the system exhibits translated to elements we can comprehend. So, what are the methods and tools that allow us to intervene on such system?

3.1.3 Agents and Flows

Optimizing the daily usage of buildings with demanding functions is a difficult problem, one which a lot of interacting variables compose. Facing such a difficult problem the technical advances of the last two decades in the field of computational simulation [6] come to our help. On the one hand, we have simpler models known as cellular automata: a set of cells organized in a matrix, capable of changing their status according to other cells in their immediate vicinity. These models are important and simple to process, but are only indicative of a population development within specific, limitative geometries [3]. On the other hand, we have more advanced models, that make use of virtual entities known as agents and are able to compute each single individual with specific attributes. These models are particularly useful, as they bestow these agents with the capability to make decisions, and hence, instead of focussing on a population status development within a defined space, it relates to the process that makes individuals choose that specific space in the first place [3].

Alan Penn and Alasdair Turner best describe these methods' significance by stating: "Understanding the way in which pedestrians move around their environment is important for predicting congestion, for evacuation planning, pedestrian traffic and crowd control, as well as assessment of the social and economic function of buildings and urban layouts" [13].

Late rapid advances in such computational techniques are an important boost: as they get faster and simpler to use, designers go from using them for analytics purposes to embrace them as auxiliary tools in architecture and urban design [9;14].

Not only through the Complexity path is it possible to conceive and use such models as described here. We do recognize, however, that a true understanding of the transdisciplinary ways of the complex thought is an important asset in dissecting results produced in this manner.

3.2 Building Relations

It was already mentioned here how a key idea to Complexity allows for some different approaches when looked at from Architecture's disciplinary field point of view. In the previous chapter, we addressed the idea that people and their surroundings' physical elements can be looked at as the simple parts that interact ending up to produce complex and not easily predictable results. But the physical elements of our surroundings, be that the different components that sum up to form a building, can also interact with each other: we call it parametric design. We address this issue here, even though it's worth mentioning this topic is not an end in itself. It is rather a loose end we intend to tie with the previous chapter.

Parametric design is strongly connected to mass-customization, as opposed to the idea of standardized design that links to mass-production [9]. Advances made both on the computational domain and on production methods allow for a new relation between designers and industry: the high costs associated with non-conventional solutions are no longer a constraint in a F2F process (file to factory); and the designer plays a different role, creating the generative rules of a product, instead of the product itself [9]. To master the base rules for a product design makes it possible to explore every variation for the interplay between a product's parts, including the specific variation that creates the standardized solution – to design a standardized solution, however, it's a process that has its end in itself [9].

We draw here on the work of Dutch architect Kas Oosterhuis, who we understand to be closing the gap between theory and practice on parametric design. This architect's designs, he says, start on a first intuition about a site that is rapidly translated to a three-dimensional geometry [15]. On a subsequent stage, the architect withdraws himself as a classic designer and creates the rules that underline the interplay between vertices (Point Cloud) of the previously drawn geometry [9]. Oosterhuis mentions in A New Kind of Building that not only through the influence of the designer is it possible to order a building's components to a consistent whole – which relates to the notion of Swarm Behaviour, a concept studied simultaneously in the fields of Biology and Computer Science.

On the one hand researchers look at Swarm Behaviour to study self-organization [2], on the other for its translation to the computational domain [16]. Living beings' ability to form groups is emergent phenomena of self-organization, in which we recognize collective intelligence [2]. On the computational field, self-organization relates to the concept of "Boid",

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as defined by Craig Reynolds [17]. Reynold's boids are virtual entities that follow simple rules, like birds in a flock. In both cases – computational and biologic – such simple rules translate into the formation of a consistent whole [16;9;7].

There's a biomimetic argument beneath Kas Oosterhuis' work that reveals itself as the architect translates boids into space defining vertices, and sets the rules according to which such boids interact. As Oosterhuis puts it: "Boids (…) are active members of a flock calculating in real time their position in relation to each other" (…) that "(…) can be interpreted as the flocking nodes of a constructive mesh. (…)" [9].

On a subsequent design stage, new rules can be applied to the previously generated points to design constructive details – replacing each of the primitive points with the needed ones to form the structure of the mentioned detail. Repeatedly, Oosterhuis withdraws himself of the process as a traditional designer. One can argue about such stance, but in it we recognize the leap from a system to another, the openness to the unknown that Morin [1] identified as necessary knowledge production.

3.3 Sensori/Motor Intelligence

Crossing the two previous chapters is possible upon remembering the second scenario we said legitimate by looking at architecture as an open work, that is, the possibility for built structures to react to the stimulus of human occupation. To static structures succeed adaptable, responsive and evolutionary ones. This gets us closer to the concept of Swarm Behaviour, as we go from a last stage inert result produced by the interplay of simple parts following simple rules, to a dynamic consistent whole that keeps changing itself and its formal configuration as a response to its surroundings. In Morin's work, we find the hypothesis of an artificial self-organized, self-reproductive machine, to be impossible [1], but through Oosterhuis' words we get here: "This new kind of building is not only designed trough computation, it is a computation" [9].

What are the assumptions that rule the response of a non-cognitive structure to its surroundings and perpetually changing constraints, though? If a building is to be a real time adaptive computation it needs to operate on some sort of reactive intelligence – and as such, again we occupy the spaces between Biology and its computational translation, finding there a most useful notion, that of Sensori-Motor Intelligence [16]. This idea has been getting greater attention in the field of artificial intelligence by being shown as effective as higher levels of cognition in behavioural description [16]. Sensori-motor refers to an intelligence that is capable of performing simple tasks through reactivity, instead of planning, and that operates/reacts (motor) as a response to stimulus (sensori) [16]. This also relates closely to the idea of Swarm or Flock Behaviour, by describing the individual actions underlining such formations.

On a first look at it, we can imagine a Real-Time Behaviour adaptive structure (RTB – as defined by Oosterhuis [9]) as the modular façade of a building – whose several components interact with each other altering its positioning and orientation towards an established goal (weather factors, for example). On a second instance, one needs to take the full complex approach forward and imagine structures whose "(…) Point Cloud of nodes starts moving like the birds in a swarm" [9] by reacting to changes in the surroundings, by reacting to us.

There's a paradigm shift for architects and designers in such stances, that of being able to conceive structures that get unpredictable in real time beyond our imagination and influence.

3.4 Towards an architecture?

There's a dilemma under the approach of Complexity Theory that can be referred to as such: should knowledge synthesizing, i.e. the creation of research databases, be something researchers set themselves to do, or should we face it as an emergent phenomenon – assuming the effort spent on these issues will eventually lead to the creation of such databases, through a process that escapes one's control. At the same time, taking a step backwards to look at the dilemma on a wider scale we can ask whether researchers setting themselves to produce these databases is not a part of the emergent phenomenon itself, readable when looked at from a different time.

Motivated by this same spirit we ask the following question: should we drive for a complex Architecture that builds on the principles we have been establishing (imagining how it should be like), or should one assume it as an emergent phenomenon that will eventually manifest? By reflecting the ideas that underline the concept of sensori-motor intelligence it's aesthetics will be the outcome of a bottom-up process. We point it out remembering that modern architecture was once advertised for as "historically necessary in a technological culture" [18]. Even though we do construct on this same premise, we cannot avoid to think that such aesthetics (as to what International Style is concerned) can be perceived as a top-down attitude. The argument Reyner Banham constructs upon a Marcel Breuer lecture pretty much singles it out as "(…) in the difficult pause of 1934, (…) Breuer could look back and speak with commendable frankness of the struggle to persuade the public that they ought to accept the asperities of the Machine Age style along with the comforts and conveniences of technology" [18]. We then ask for an architecture that truly reflects contemporary thinking, which principles do not get elapsed in predefined ideas of what that should be like.

4. CONCLUSIONS

The process here exposed shows how local classic defined disciplines progress by exchanging knowledge with other disciplinary fields. Upon that, one remembers Morin's openness to the unknown as a driver for knowledge synthesizing.

As we've demonstrated, there's a possibility for the various scales of the built environment that compose human surroundings to be interpreted in a complex way. By doing so, we figure ourselves more capable in describing the phenomena we observe.

A particular phenomenon that benefitted from such approach is the process through which cities grow and change – a process that, as described here, progresses without any central controlling entity, and on a greater timescale than that of the interacting individuals that push it forward.

Upon analyzing cities, as complex systems whose spatiality is an emergent phenomenon of self-organization, we got to one of Complexity's key ideas: simple parts following simple rules do sometimes manifest into not easily predictable changes in the status of the system they compose. This idea acts as common ground on looking at the different scales that form our built environment.

One recognizes that people interacting with each other and with the physical elements that surround them is the driver for the non-trivial way in which the city-system progresses. We must recognize however that such a vibrant daily life is not an urban space exclusive characteristic – it sometimes crosses the threshold between streets and buildings. Fighting for space is as much a driver for interaction inside buildings as it is on city streets. Infrastructures

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where a great number of individuals cohabitate can go through problematic stages, as undesired occupation patterns occur.

Complexity allows us to better understand the phenomena we observe, but we're as much interested in it as in the possibility to optimize them. As such, researches that mind the spatiality of the built environment must come up with ways to bias the interplay between individuals and their surroundings where undesired occupation patterns occur.

We've explored here that as technology advances the static assumptions with which buildings are designed give their place to adaptable and evolutionary ones, conceiving structures responsive to the ones who occupy them; and defended that to look at a building's physical components interacting with each other in a complex manner is a legitimate way to produce such adaptive structures.

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