RESEARCH ARTICLE | SEPTEMBER 27 2023

The stigmergic city: Reinterpreting eco-utopia model with stigmergic behaviour

Yuankai Wang ✉; Ilaria Di Carlo

AIP Conf. Proc. 2928, 110005 (2023)
https://doi.org/10.1063/5.0170466

The Stigmergic City: Reinterpreting Eco-Utopia Model with Stigmergic Behaviour

Yuankai Wang[1], Ilaria Di Carlo[2]

[1,2]University College London, The Bartlett School of Architecture, The United Kingdom

[1]Corresponding author: ucbqy55@ucl.ac.uk

Abstract. The impact of human society on ecology has reached a great extent, resulting in a series of natural backlashes. This gradually shows us the importance of re-examining the previous ecological utopian concept, such as Paolo Soleri's Arcology. Utopia represents the ultimate pursuit of human for a better social state, but as well as the ultimate embodiment of the limitations of human beings as self-centred design thinking. It is bound to be difficult to adapt to the complex and dynamic of the ecology if we try to realise utopia as the ultimate order or result operating in a perfect state, as previous failed praxis has done. In fact, the emergence of utopia has a greater value in giving us the motivation for optimisation and progress of our human patterns in each era. Meanwhile, there are patterns of intelligence in nature that are well adapted to this complex and dynamic ecology by an optimisable system, which we call stigmergic intelligence. From the self-organisation of the swarm and flocks to the formation of the social structure of the ant colonies, from the growth of plants to the epidermal tissue of organisms. Natural species place themselves into ecology in a rather miraculous way. Besides, the development of new digital tools allows us to study the phenomenology and reprogram these intelligences. This paper tries to go further and learn from stigmergic intelligent model to form a new system, which can optimise urban ecological issues from a new perspective. Presenting an innovative computer-aided approach based on stigmergic intelligence that aims to handle both miniaturization (the revealing of the human pattern which has the minimal disruption to ecology) and complexity (the optimisation and customisation of human activity content). Study how it works as a layer stack into the urban ecology to reinterpret the utopian model in the digital era.

INTRODUCTION: ANTHROPOGENIC DILEMMA

Many overwhelming human-centred urban planning has proved to be failed as they cannot fit well into the ecology. Since the rise of humanism in the Renaissance, the design of the built environment has inevitably become human chauvinist - it is only designed by and for human. Such architectural convention neglects the fact that we are a part of the ecology and significantly compromises the environmental sustainability.

Modern urban planning theory started from human's exploration of solving urban problems from the perspective of social reform. In the past, the ecological impact of Human activities seemed to be rarely considered in each era. Nowadays, even if some projects do consider the importance of these ecological aspects, we still tend to let the ecology follow our rules in the city like Songdo new town, which emphasises a top-down technology control plan, and the overall social behaviour and ecological system of the city are controlled in real-time in the technology centre, But greening the streets, filtering the water, sprinkling sensors around the city, and increasing the amount of silicon per square meter is not enough to ensure our connection with ecology. *"It is fundamental to understand the fragility of the planet upon which we live, first and foremost that of the city, because it represents 75 percent of energy consumption, 80 percent of CO2 emissions, and 85 percent of the world's wealth".*[1]

However, there is a lot of ecological utopian theories and models in modern times. When our society encounters the problems, human tend to imagine fixing the future with a utopian vision, and the birth of utopia alongside with the awakening of human's consciousness on social and ecological issues. It also greatly affects the development direction of how human settle on earth in the future and our roles in ecology. It is the present that ecological issues more and more important today, while human's excessive destruction and waste of natural resources have led to many irreversible destructions of ecosystems, the time for re-examining the past models of eco-utopias has come.

World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium WMCAUS 2022
AIP Conf. Proc. 2928, 110005-1–110005-11; https://doi.org/10.1063/5.0170466
Published by AIP Publishing. 978-0-7354-4663-2/$30.00

THE PARADIGM OF ECOLOGY AS UTOPIAN URBAN MODELS: AN HISTORIC OVERVIEW

A Successional Review of the Development of Utopia Model

Looking back at various utopian praxis in history, they invariably contain two layers of meaning, which are the denial of the real world and the design of alternatives. In the Axial Age, Plato's "Ideal State" was dissatisfied with the decline of Greek civilization after the Peloponnesian War, and he hoped to replace the failed democratic system with the sage politics of the "philosopher king".

Thomas More's "Utopia" was written in the sixteenth century when the British Protestantism began to break away from Roman Catholicism, alongside with the enclosure movement appeared, and capitalism began to sprout. He sensitively foresaw the evils of the coming era and provided the first picturesque program before the industrial Revolution. Since then, fantasy geography, travelogue, public ownership, equality, education, etc. have become the standard configuration of a new type of literature.

With the development of technological theories such as navigation and biological evolution in the 17th century, the shift in the escaping from reality in utopia from the geographic space to the distance of time also gave rise to a new sociological realism in utopia, such as Bacon's "New Atlantis" [2]. According to these great utopian thinkers, the modern ecological utopia shown us a possible vantage point of the future that requires a shift of human cognition with natural relationships, which can hardly be seen in the past transformation of human culture. We started to set up a systematic understanding of the causes and effects behind some phenomena and replicating the technology behind these phenomena to achieve meaningful purposes on human society out of natural phenomena.

In "New Atlantis", Bacon emphasized the status of science and pointed out its operating methods, making it a tool to combine human intellectual activities, natural phenomena, and technological creation. In Bacon's description of Soloman's House, through guiding people's intellectual activities to unify with the true inner of nature, the cognition of nature and the discovery of laws can be achieved. It can also be seen that Bacon did not just stop at unveiling the law of nature, but also paid more attention to the application process to make full use of the law.

The outbreak of the Industrial Revolution in the 18th century drove a large number of peasants into the factories, turned Britain into what Engels called "hell on earth", and ignited utopian actions on this land. Fourier presented an elaborate vision of a better, "harmonious society" in which human passionate attraction, instead of being restrained, would have adequate opportunities to develop. The social system he attempted to construct in his utopian model is formed by countless "phalanxes"(a type of social group), and the people in them are classified into different "series" (different labor units) according to different passionate and skills, which drives the people living in them to work happily. This concept also refers to emerging a unique type of space that base on production and demand, regarding architecture as a means of utopian activities.

From dreams to future technologies, social forms of production and the architectural forms, these historical reviews can help us to form a systematic concept. Since ancient times, human beings have used this utopian picturesque vision to seek solutions under the predicament of the times. Taking advantage of scientific technology and other disciplines to meditate on the future and to break the limitations of existing orders free. Beyond that, the developments in modern times even started using technology to question technology itself. This phenomenon was rather extreme in the late 1960s while the radical architectural movement Superstudio and Archizoom wavered these limits with unrealistic proposals. They never made any physical buildings, but instead postulated the idea of "anti-architecture" that connected with ecology. [3][4]. The underlying structure from all these projects can be the process of redefining utopian practice in the way of bridging a diverse set of studies and experiments.

Stepping Toward the Natural Ontology: Entropy and Planetarity Thinking- "Arcology"-an Ecological Utopia Model Proposed by Paolo Soleri and the Understanding of Miniaturization and Complexity

Back to the early nineteenth century, with the rise of the second law of thermodynamics, which challenged the image of timeless universe in the mechanistic view and the idea of linear evolution. It revealed that the conservation of energy is not only inapplicable in the broad universe, but also does not exist on a single particle in the microcosm. The useful energy might be spreading out if the world running as a machine, ongoing lose energy and orders for the

whole universe. On the flip side, in the biological system, the signs of life evolution and activity seem to be looking for a way to reduce or reverse such law at the same time.

It was precisely by absorbing the theories of thermodynamics and ecology that Paolo Soleri developed his unique eco-utopia theory: “Arcology”. (Figure 1a)

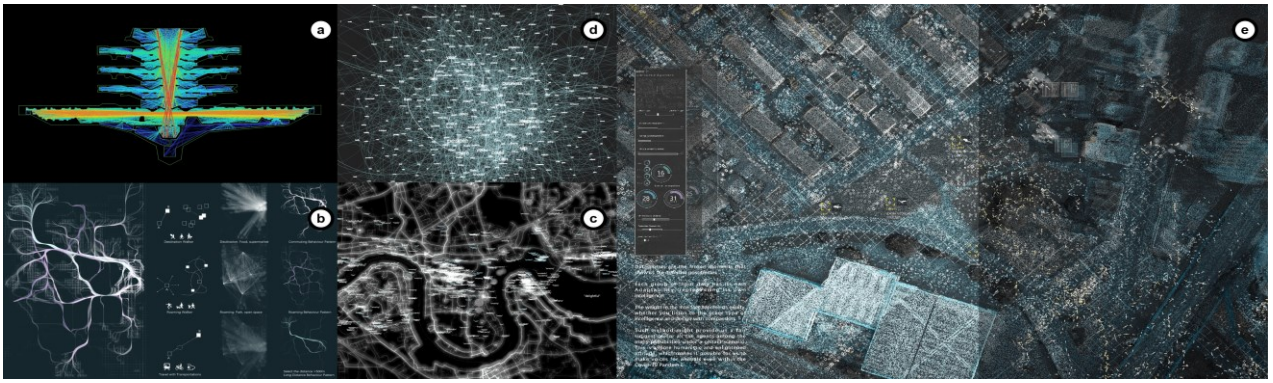

FIGURE 1. (a) Social structural network analysis of Paolo Soleri's Babel II city, 2020. (b) Spatial stigmergy behaviour simulation, 2020. (c) London Emotion map, 2020. (d) Social tag network, 2020. (e) Datascape of Eco-Utopia platform, 2020.

The development of life requires not only the ingestion of external information/energy to maintain its own low entropy state, but also a restriction mechanism to prevent the entropy increase in the external environment, resulting in the drastic change of external environment, which caused by this ingestion. The great oxygenation event in the ancient times was due to the blue-green bacteria ingesting nearly infinite energy to reproduce on a large scale. The discharged oxygen from them caused a serious ice age of the earth and also their own extinction.

Moreover, urban ecology also follows this logic with entropy. Take the suburbs of the United States as an example, *"homogenous suburban agglomerations were expending uncontrollably, and rampant development and the social structure formed by the motors assured their continuing entropic diffusion"* [5], as a price, this orderly low entropy living status needs a large number of external resources to be sacrificed to maintain, and the external society's entropy will increase greatly.

Inspired by physical chemist Ilya Prigogine‘s dissipative structures theory and evolutionary theologist Pierre Teihard Chardin’s perspective of expansion within contraction, which indicated the influx of external energy of open systems were not merely entropic but can change the configuration and system elements combined to create new organisational form, and *"attaining of material structures can achieve higher states of organisational complexity and consciousness by the spiritual striving."* [5] Soleri believed that just like the evolution of natural organisms, human beings are actually experiencing a process of miniaturization and complexity of form and function.

These discussions can help to explain Soleri’s essence of the“complexity-miniaturization” theory. He believed that human life was far beyond survival and about complexity in content, which involved countless activities. The city also needed to be frugal. *“Frugality does not mean poverty, it means the most sophisticated use of space and time through complexity”* [6][7] so that to minimise the energy spreading out. He called for a three-dimensional city that could grow vertically, a self-extending structure, not the extension on the spatial scale, but like DNA and the evolution of organs in the internal and external dimensions which constantly reconnected, interwoven and superimposed of spatial value of complexity *"Therefore, arcology entailed the enfolding of matter into itself and an elaboration of the interior of things to their most highly developed state."* This also means in terms of urban ecology *"more and more functions and forms will be contained in a single structure."* [5] The habitant living here also expand the field of consciousness by refining their interior, making them adapt to the more complex mode of mental and material interaction, thus giving the urban ecological activity a transformation, which can be understood as the path of evolution and is in the process of becoming rather than in a state of being. Unlike other utopian designers, he realised that the city was an apocalyptic instrument for the purpose of co-evolution of the natural system and consciousness itself.

However, like many other utopian experiments, Soleri's experimental city in the desert Arcosanti has not been a great success so far[8]. Most of the Utopian imagination or praxis set the geographical scope on isolated islands, wilderness or rural areas. More's utopia is an isolated island, and most of the subsequent utopian narratives follow the similar geographic location. It prefers isolated islands because it wants to eliminate the influence of the real world outside. It went to the countryside since the industrial revolution. Utopia's efforts have been to turn against industry and cities, staying away from these "sources of evil".

When going deeper to these utopian thinkers' common original intentions, they are in visioning a society that is no geographic and sociological limits. This motivation led these early utopian dreamers to prefer not having a specific location to meet the requirement of isolation, which is used to transcend the boundaries of geography, technology and sociology. However, if we examined such an idea in an ecological way, it is not possible to use the concept of isolation to forget the boundaries since any ecological discourse today start from the basic effect that *"everything is interconnected."* One definition of this indication is Timothy Morton's argument that thinking ecological means being aware of interconnectedness of all things on earth, including life forms, society, technology, culture, geography, etc. As a part of the ecology, we are more or less interconnected in a *"mesh"*, which dispels the *"boundaries between living and nonliving forms."* Other than that, *"symbiosis ensures that boundaries between life-forms are never rigid and thin; rather, they are wide and permeable."* [9] When explaining in a more physical way, any pocket of a close system has proved to be not existed in reality.

There does someone succeed in blurring the geographic limits and boundaries. Inspired by the Archigram and the Russian constructivist architect Georgy Krutikov's audacious blueprint of "The Flying City", Argentinian artist Tomas Saraceno with his "Cloud City" and "Aerocene" show us a more scientific way to make ecological suspended utopia possible. His sort of discourse has a super ecological powerful agenda which succeeded in turning the utopian vision of the predecessors in a meaningful spatial articulation. Based on the suspended utopia model, sharing the building technology and the permission of usage to create a space and experience that doesn't have any spatial limitation and political implication. Tomas took a step further by understanding the collective participation of the public and the technological engagement, which are the missing parts in Soleri's praxis.

To think about historical utopian movements in the more internal spiritual perspective of how it is born is related to humans' nature, which leads us to seek the way to establish an ideal realm that can be operated and controlled for a long period through a series of rules and principals. Ironically, the result is that most of the utopian models failed to deal with the unpredictable changes in human nature. They were rather exiling themselves in the invention of ideal living state, in which inhabitants are pious citizens that under the supervision of "Big Brother" rather than human with desires and complex demands.

As Karl Mannheim mention in his book "Ideologie und Utopie" [10], utopia born with the formation of ideology, which is the collective unconsciousness of the ruling group. On the contrary, utopia is the collective unconsciousness of the ruled group. It dreams of the future of the ruled and victims of interests. It belongs to the distortion of ideology relative to the existence of social reality. It is also subject to the collective unconsciousness of people. In other words, the emergence of utopia in each period is actually the generation of self-organising ideas in the group.

With the understanding of group behaviour, the emergence of utopia represents a group pattern that is gradually formed by an unconscious group. It is the chaotic disorder consciousness gradually forming a complex order, a bottom-up system. But when the minority try to experiment and create a final visionary entity at a higher level, such as a country or social form only based on their own incomplete ideology, these utopia experiments will never succeed. By starting at the higher levels, these minority force all the lower levels to mesh with it. Any object that cannot be coordinated with the highest level is considered as unsuitable for utopia and will be eliminated. Like many stories in utopian science fiction literature, this type of utopia always evolves into a totalitarian dystopia. This kind of top-down approach might be easier to be executed by human, but always landlubberly succumb to evolutionary pressure because the static and unchanging ideals cannot survive in a dynamic and constantly changing world. There is neither individual agent can use its simple rules to summarise or predict the whole complex behaviour of the group nor any controls can control the whole system. Utopia may not exist in the brain of one person or a group to bring about but, rather it emerges from our collective intelligence and interactions.

Some individuals or groups can only be regarded as partial representatives of a social class, but each representative in this class has the ability to think in a different ideological way. Therefore, for this ideological concept, the entire field of consciousness is a dynamic and developing unity of coherent elements.

The statement from Archizoom *"Architecture must be available for undifferentiated use, and as a free, equipped area in which it may be possible to perform spontaneous actions of experimentation in individual or collective dwelling."* [3] reminds us that utopia can also be regarded as an interface that allows all the different people to exchange their needs and ideas. Then, with collective behaviours can have an impact on creating and modifying the utopia itself.

There was a particularly interesting example during early 2020, while all the production activities are under the shadow of the Covid-19 outbreak, the video game "Animal Crossing" once became pop culture. As a virtual online game, it requires players to take responsibility for the infrastructure construction of the island, as well as running industries and dressing up communities. These labor works are based on players' individual free will, but also serve the other players and encourage more players to participate spontaneously. The utopian appeal of "Animal Crossing" presents us with a fictional economic paradigm where people are allowed to choose to work to make their society a better place, rather than being forced to work in order to live in it [4].

Utopia as an Urban Ecological Optimisation System

The high involvement of the "Animal Crossing" also implicated that the utopia is an implicit mapping for what we are missing and eager for. Utopia may not incompatible with human social life, but refers to its incompatibility with the existing orders. Utopia inherently contains the universally good yearning and pursuit of unreasonably negating the existing order. Often in the ideological field of vision of the existing order, utopian thought is regarded as a misleading fantasy that undermines the foundation of its order, but in fact utopia is a way to avoid the permanent rationalization of the existing order and challenge it to its absolute rationality social critical power.

This might remind the "negative utopias", which monitoring and warning of the impending contradictions. By using satirical images, Superstudio and Archizoom regarded utopia as a cultural media to criticize the political and realistic society and to review the relationship between utopian phenomena and human behaviours from the perspectives of anthropology and philosophy.

The emergence of utopia has a greater value in giving us the motivation for optimisation and progress our patterns in each era. In the book "The Principle of Hope" [11], Bloch thought the *"mobilising nature of utopia could be defined as 'dreaming forward'. The historical march of humanity as a succession of horizons devised by hope and implemented by force of action"* [12], which expanded and redefined the concept of utopia *"from the narrower image of a description of an alternative society designed to facilitate a better way of life to a wide understanding of the essence and prime source of human creativity, dynamism, and progress."* [13]

Therefore, what mankind has always been seeking for is a mechanism of change, progress and improvement. Merely in each process, this transformation is embodied as a building, a town and a system reform, leading the subsequent activities lost in these visualized results. With this thought, whether it is Soleri's Arcology, Fourier's harmonious society or Howard's Garden city, their value is far greater than the urban models or the literature that are presented, but to a certain extent promotes the continuous optimisation and improvement in both social institutions and ecology for future generations. There is a dialectical relationship between utopia and the existing order. Each era allows different representative groups to put forward opinions and values. They contain the unfulfilled and satisfied tendencies of what each era's needs in the form of concepts, and these factors become the breakthrough of the existing order. In other words, utopia is neither conceptual nor temporal. It is an activity to break this void homogenous time and open up new possibilities.

As a consequence, utopia is a dynamic process rather than an ultimate goal. We cannot predict what the final outcome will be. In such contexts, the meaning of "Miniaturization and Complexity" can be expanded and as an optimisable direction rather than a future form.

THE INTELLIGENCE/ORDER BEHIND THE NATURAL ECOLOGY

Forms and Patterns of Biological Behaviour: Swarm, Flocking, etc

The emergence and development of utopia representing our dialectic relationship with ecology, so far, we have not yet understood how to set up an optimisable system to adapt to the changes of ecology. However, if we see the behaviour itself as a type of intelligence, then it will be meaningful to borrow the other intelligence in nature, where there always have such complex systems to continuously optimise themselves to adapt into the natural ecology.

With the evolution for millions of years, most of the species have developed incredible solutions for adapting with a wide range of ecological problems. Despite some social systems in nature that are composed of simple individuals with limited abilities, they can still present complex collective behaviour and intelligent solutions from their self-organisation and communication mechanism. And their patterns of intelligence in nature that are well adapted to this dynamic ecology by an optimisable system, which we call stigmergic intelligence-named about fifty years ago by biologist Pierre Paul Grasse. From the self-organisation of the swarm, flocks and schools of fish to the formation of the social structure of the ant colonies, from the growth of plants to the epidermal tissue of organisms.

The Biological Intelligence and How They Adapt with Natural Orders (Entropy)

Through the transfer of pheromone, ants reduce the information entropy generated by the exploration path of other subsequent groups and reduce the unnecessary random exploration of the whole group (Figure 1b).

In the initial stage of evolution, the pheromones of all possible paths have the same chance of each ant, which means the system is totally random and disorder, and the information entropy of a single pass is the largest. As the pheromones are strengthened on some shorter paths, the information entropy will decrease, and finally the pheromones will be concentrated on the optimal path, thus making the followers spend less information entropy to find the better paths.

Ants use pheromones iterated by group evolution to help them acquire information and maintain low entropy. As Schrödinger said in his book “What is life” [14], the core of whether a thing has sustained vitality is whether it has the ability to maintain its entropy reduction by acquiring information.

Stigmergic Behaviour as a Self-Organisation Optimise System

By using what Steven Johnson said about the self-organising systems:*"What features do all these systems have? In the simplest terms, they solve problems by drawing on masses of relatively stupid elements, rather than a single, intelligent 'executive branch.'"* [15] *“But understanding emergence has always been about giving up control, letting the system govern itself as much as possible, letting it learn from the footprints”* [15] Grasse quoted *“Self-Organisation in social insects often requires interactions among insects: such interactions can be direct or indirect. Indirect interactions are more subtle: two individuals interact indirectly when one of them modifies the environment and the other responds to the new environment at a later time.”* [16] And based on these principles, ants can learn ecology even develop many complex and human-like social behaviours, such as *"livestock farming, cultivation, childcare, education, climate control, career specialization, civic duties, armed forces, security, earth movers, social planning, engineering, communications, flood control, limited free will"* [16], etc.

To understand of what Steven Johnson and Grasse said, with the simple rules performed by multiple units, some unpredictable complex phenomena can emerge. This stigmergic behaviour can be recognized as bottom-up approach, which is the opposite of the top-down approach. Start at the lowest level of unit rather than the highest level. To start at analysing the individual behaviour by creating a simple set of rules that control individuals and allow the system to organise itself. Then, from these individual behaviour to groups and even societies emerge.

One of the advantages of such a system is that it has a large elastic room, or it can self-recovery. As such a system is based on multiple subunits, the performance of the individual does not have much effect on the performance of the whole group even if some of the individuals have major failures. The accidental death of a single ant does not affect the foraging of an entire ant colony. The whole boids will return to their regular flight after a brief panic while one bird has an accident.

Another advantage is that bottom-up systems coordinate well with nature since they learn environment more ecological and they can evolve and adapt with the change from the ecology. In fact, biological evolution in nature is a bottom-up process, which is governed by the rules of survival and reproduction. They learn environment through iteration, where they dominate in numbers and then weed out those units and information that cannot adapt as the environment changes. The purpose of evolution is also adaptation and optimisation. Such an optimisable system can fit well into the complex and changing ecology since it has a self-organisation leaning system. Blurring the boundaries of their group from both geographic limitations and the ethic of different species.

Besides, no matter the ant colony or boids, swarm and other natural behaviours, what they are pursuing is not a result but the dynamic optimisation process. They never foresee what shape they will end up or which path they will choose to go. And the ecological utopia picturesque vision in our mind can only exist as an optimising direction.

Stigmergy as an Ecological Context

However, it is still doubtful that such a system can be applied to human societies, whose social structures and forms seem to be far more complex than those of natural communities such as ant colonies.

But it is clearly a mistake to interpret the stigmergic behaviour as specific to ant societies or any other single species. The main biases in such issue are the agents in this model can be only simple and without cognitive ability.

Recently, David Krakauer, the director of the Santa Fe Institute, wrote in the journal Theory in Biosciences that he offers an information Theory [17] view of individuals, including humans and other species, as a collection that transmits information from the past to the future and maintains a measure of temporal integrity. Therefore, stigmergy is a type of ecological phenomenon common among the nature of the group species. This thought suggests such agents in the stigmergy can also be heterogeneous and rational and not necessarily have to be as simple and reactive as ants.

At the same time, the essence of this intelligence lies in the social mechanism of how agents coordinating based on interaction through local modifications to a shared environment. Thus, the concept of pheromone in the stigmergic behaviours among the insects can be extended. It is more about the way that allows agents to coordinate indirectly through the information. This mechanism of coordination is also in the context of human societies and organisations. Reviewing the definition of stigmergy given by Grass is also about to achieve emergent forms of collective behaviour at the social level through the mechanism that can mediate animals' interactions.

It is true that the social structure of human beings is much more complex than the spontaneous society of a single organism in nature, but it can also be analogically understood the human connection through different media as emergent system, which is composed of the behaviours created by users. Each user will leave their experiences and tracks, and this information can be comments, shared knowledge, spoken language, written words, and recorded images, etc. In the process of information exchange, these experiences carrying the indirect cognitive interaction between the creator of information and the successor of information. Each set of thoughts represent the signal that connect the idea or feedback to something or someone.

Meanwhile, another key factor that is easily overlooked is the environment. Since this behaviour is a coordination mechanism that influences the environment based on the cognition of the environment, it is necessary to put environment in an important position in this discussion. The understanding of this environment is that they can be both physical and virtual. The boundary between these two is increasingly blurred by human technology. Therefore, for the society of different agents, including human society, it can be defined as: the so-called environment is articulated and usually consists of artifacts, through which social workspace or field are established. Therefore, in a shared and conventional sign system, the behaviour of changing the environment can be sensed.

One of the amazing points in the original explanation of stigmergy is that, when observing the behaviour of a group of social species, they seem to cooperate in an organised and coordinated manner; but when the perspective is changed to observe each individual, they seem to be working alone rather locally without an overall understanding of the entire environmental changes. In such contexts, the individual's cognition and influence on the environment can be relatively local, and each of these local contexts forms an overall environment at the same time, and then the overall environment will return the feedback to individual. This process happened simultaneously rather than sequentially.

Therefore, the key role of the environment is not only acting as the passive topography of all interactions, but rather as the mediator and ruler of interactions. These interactions and changes to the environment are usually limited to pheromones, nesting materials and other well-defined elements in nature.

In human society, as the complexity of activities increases, the definition of so-called artifacts should be extended into different data mining tools, media that can store information, and so on. The environment as the carrier of these artifacts can also be optimised according to the use of these artifacts. The context of these artifacts is more likely to be embedded in the environment, and put together with mechanisms to facilitate the emergence of local and global collective behaviours. Every moment, the environment not only presenting an observable and alterable state to every agent, but also the rules that can be initiated by interactions or events to modify the following state of the environment independently based on the agent intentions.

When it comes to the signs and artifacts, as part of the environment, these real-time artifacts provide specific applications that are useful to agents performing individual behaviours and can be shared among the agent, and this coordination not only minimises the quantity of the artifact but also maximises the complexity of the use of the artifact, which can gradually affect the social level as a whole. Another function that the artifact can provide to the agent is the realization of reinforcement and positive feedback. This progressive relationship can be expressed as a non-linear relationship, that is, when the agent realises the role of the artifact, and then the probability of using this artifact will be increased, and this increase of these local behaviours will augment the overall awareness of the whole agent society

about the utility of this artifact. Some researchers refer the signs, which have symbolic value and some sort of information in cognitive stigmergy as *"annotations"*. [18]

One of the most significant developments in the history of human being is the invention of a way of keeping our knowledge and information through the artifacts. At the same time, our cognitions are gradually extended and influenced by those what we modified. [19]

For human society, the expected function of such these artifacts points to the possibility of a sort of interface, from which a structured behaviour that generates the exchange of information embedded.

From this point of view, in the social system that we are familiar with, this artifact could be not only represented as our place, architectural space and urban space, but also manifested in our language and pop culture. For some cases such as mobile phones, which can achieve real-time effects in completely different spaces through the localized operations of agents, are demonstrate that artifacts can be linked together in a more macro abstract environment.

So that the means of optimising and perceiving the emergence of complex interactions and relationship of both agents and environments that utopian models are unable to provide might can be tackled by the utility of wider understanding of stigmergic intelligence.

Moreover, recent developments such as *"evolutionary psychology and the theory of complex adaptive systems"* [20], are providing fundamental insights in these optimising mechanisms, opening up the perspective of a utopia that using the metaphor of the *"global brain"*, which is the *"emerging intelligent network that is formed by all people on this planet together with the computers, knowledge bases and communication links that connect them together."* This led me to think about how to use modern computer algorithms to help us materialize eco-utopian vision.

DECODING STIGMERGY AND ENCODING "MINIATURIZATION AND COMPLEXITY"

Hacking and Imitating Biological Intelligence Through the Machine Intelligence

Today tools allow us to use scientific behaviour much more precise like simulating and decoding behaviours, and even blur the boundaries among multi-discipline. John von Neumann and his colleague Stanislaw Ulam used a cell-based concept to develop Cellular Automata (CA), which has mathematical models used to simulate complex systems or processes. Later on, game of life had been designed by John Conway based on cellular automata. Craig Reynolds, a British expert in artificial life and computer graphics, simulated complex boids behaviour in 1986 with only three rules: proximity, coherence and separation. Computer technology are now demonstrating a powerful ability to simulate complex behaviours.

Meanwhile, many stigmergy-based modeling tools or self-organised data mining tools can be used to discover urban activity patterns from positioning data. In the example of London's most popular areas mapped by Eric Fischer is that using the data from Geotagging, which is a sort of behaviour that involves participants taking pictures of a particular place, uploading the pictures to a public forum, and tagging with the location that the photograph captured. Using scripts to mine the Flickr and Picasa, where these participants upload their photograph collections, Fischer created the map of interest for London and visualized the trajectories of these people and analysis how they behave through their movement and shooting behaviours. From that we can see the behavioural patterns beyond our cognitions. Furthermore, these data can actually provide a direction for the future optimisation of urban space, and discover the group demand. Pattern is not only about the path. It is the mapping of how biological behaviours adapt into the ecology.

Other than that, AI and machine learning allow us to find suitable parameters and relationships between the complex social context. There is already some use of stigmergy in neural network and Nondeterministic Polynomially (NP) problem, such as in (Cimion et al., 2015) a stigmergic structure has been used to perform adaptive context aware aggregation; in (Alfeo et al., 2017) a multi-layer structures of stigmergic receptive fields for pattern recognition have been experimented for human behavioural analysis. YouTube and Wikipedia are also using complex social contexts, which analyses our behaviour and evolve based on the way we interact with it. Today's algorithms are not just technology but they are evolving. Such platforms like YouTube and Wikipedia can be regarded as a growing system, which is unpredictable. With all these progresses mentioned above, machine intelligence and digital tool allow us to component a set of workflows from perception to generation and to fix the historical utopian model.

How Systematically Setting up an Interface to Optimises the Human Pattern and Customise the Human Activity Content

Inspirated by the concept of *"Global brain"* and *"Stack"*, this metaphor can be understood as a concept similar to the Internet of Things on the technical level. Back in the middle of the 20th century, this similar concept was proposed in a more abstract perspective. It can be traced back to the idea proposed by Teilhard de Chardin [21]. The growth of the "noosphere", the network of ideas and communications that envelops the planet. Paolo Soleri repeatedly borrowed Teilhard's noosphere concept in his book "Arcology: The city in the image of man"[7]. Using this kind of World Wide Web thinking to realise Soleri's utopian ideas is not about augmenting human activity in the ecological territory, but increasing the efficiency of human activities, more fully and effectively use of the resources, space and time. Thus, the territorial scope of human activities can be blurred and miniaturized, while the complexity of human activities can be maintained and even increased. This is also in line with rules in ecology in the way of evolutionary thinking.

Individual organisms have an impact on the environment, and the environment affects the organism through evolutionary iterations in turn. This is also happening among non-living things in the biosphere, in which mankind has brought about physical artifacts, buildings, cities, or intangible digital networks. And these are all ecologically hybridized within this planetary system. Any biological behaviour in this complex system will affect non-living things to make corresponding adjustments, and facilitate the evolution of these non-living products in line with ecological thinking.

Therefore, on a more macroscopic level, large-scale human activities on earth can be connected through the network to share knowledge and transmit information in real time. Such a network is a fairly complex self-organising system. *"There is no single person, organization control system"* [20]. The entire operation process is distributed among all components, and each agent is both the user and the contributor or supervisor of the system. They make choices while obtaining information, solve others' problems while sharing, and make decisions while learning.

On the other hand, it is still possible to imagine a global brain even in the absence of network and digital technology. Follow the idea of cognition of the artifacts as previously mentioned, ideas of myriad individuals can be influenced and assimilated through the interactions from individual to individual locally. Forming a sort of collective mind for the society and *"constantly developing new thoughts that cannot be traced back to any individual contribution."* Merely, this "collective mind" cannot develop and form any new insight within several years. This process has been optimised much more efficiently through digital media, which allows ideas to *"spread and evolve in hours rather than decades."* [20] Therefore, the *"global brain"* will be no more an interesting analogy but an articulated phenomenon that can be experienced.

By using the hypermedia interface of information through the internet, we are possible to seamlessly integrate data, which are created by those individuals who may not even be aware of others' existence from the vast distributions over the entire planet. With the help of machine algorithm, self-organisation and indirect interactions between individuals enable the two users who could not be connected to each other to influence the information environment, so that the latter users can make judgments and respond to the environment under the influence in the subsequent time. This allows users with the same purpose to take shortcuts under the influence of the former experience without having to spend more resources and making mistakes. Or future users can constantly optimise the experience and solutions are based on the former users and real time information, and up-to-date complex urban problems can be intelligently solved. Thus, these indirect interactions emerge. What holds the information exchanging together can be either their geographic location, common tags or their associations-the links connecting context mutually. *"Platforms' mediation of user-input information may result in an increase in the value of that information for the user. "*[22] There is a possible way to implement the thinking of *"Network"* is to create a specialized software artifact. An online interface that works as a "Parliament"[23] of agents, autonomously sensing and collecting data (images, keywords, etc.) from different interest of the agents. At the same time, system will learn about the implicit relationships behind these behaviours. For instance, a user who searches for the reviews of a high-end restaurant also orders a bouquet of flowers on the florist's website. As a part of the creative sharing space with almost free and open access to big data, everyone can access, use it and modify it, and the results will be used as a reference to influence the subsequent users.

As for behavioural perception, location data provides an important data basis for analysing population and urban dynamics, as well as systematic modeling for discovering the urban metaphorical activity patterns from the emergent behaviours of the crowd. The self-alienation character of human agents would not be a problem for such a concept since the intelligence of this system comes precisely from the diversity and autonomy of the agents participating in it. It is because these different agents with different perspectives and different experiences that enable them to solve more complex problems

Back to Urban Scenarios Through the Use of Collective Intelligence to Create a New Concept of Ecological Urban Utopia in 21's Century

Back to the city, where has historically been situated as a space for economic and administrative relations, as what Cerda has argued, *"the planning is more about the process of dealing with the change and growth and the way coordinating indeterminacy of economic, social, cultural and environment through design"*. [24]

Meanwhile, *"cities are always 'out of equilibrium' and are constituted by a multitude of bottom up decisions which, though producing coordinated and ordered patterns, can behave in the most unpredictable ways,"* [25] and these unpredictable changes can be collected as different data in every different stage of their growth.

After the digital turn, plenty of real time data can be used such as user behaviour data, GPS navigation, user feedback and comments etc, which have valuable information and with intelligence implied in. It was proved by Shannon that information implies entropy to some extent, it is a rather important energy source ever since the life arose, a kind of energy that has been ignored by Human before the advent of information theory, allowing us to adapt to the environment and evolve with the ecology. Besides, we were actually wasting this kind of energy wantonly before the arrival of the digital turn.

Reviewing the eco-utopian theory proposed by Soleri, it is possible for us to practice in the urban scenario by using the transcendental network thinking such as the *"Global brain"* and the *"Stack"* mentioned before. In the meantime, because this systematic methodology is using stigmergic intelligence, which is already proved to be useful among the different species, so it can fit into the ecology.

Through these technologies, we can maximise the benefits of nature (resource, information) and minimise its harmful potential (disasters, pollutions, wasting). In this context, we can make maximum use of the "information", so that the "information" can not only provide complex behaviours of species, but also maximise the intensive use of various other resources in time and space. *"We could ultimately argue that it is that capacity of material organisations to develop and evolve through time and become more articulated, refined and meaningful."* [25]

As the main body of materialising behaviours, urban space will also be materialised in a more flexible and temporary way, which has already had many remarkable highlights in the trying of "cloud city" for example. Sharing and growing with the behaviours happened with a non-political decentralized approach. Furthermore, linking these spatial materials together through the global web can form a huge interface that can transcend geographical boundaries to meet different demands and behaviours.

"The shifting of relations between humans and animals, mutually co-constituted by shared interfaces, needn't be limited to placing animals in isolated control over more and more complex prosthetic technologies, letting them find their own purposes in "The Stack "[22]

Through the previous data collection, we can know the different density activities and distributions of people in the city, and how these behaviours relate to urban ecology and space, thus providing a scope for further optimisation. Minimise the human footprint is not means restricting human behaviour, but the way to extend our pattern in a more meaningful dimension rather than just in the geographical sprawl. Keeping the space more sophisticated used with multiple functions and reduce some of the unnecessary wasting space and give it back to other species to maintain biodiversity in the urban ecology. The evolution of the utopia can emerge from a dialogue between different agents and the city.

CONCLUSIONS AND LIMITS

Eco-utopia opens up a direction that we can include the multiple human behaviours into urban planning, maintaining and continuously updating. Stigmergic behaviour is a collective intelligence can be studied and used as a praxis to understand other intelligence in a much more democratic and ecological way.

To consider other intelligence by building such a global interface that using stigmergic intelligence (common for the living beings at different extent) and turn into 21th ecological utopian future, in which Every user's behaviour is part of the urban development and evolution.

Through this set of urban optimisations, a new possibility for urban development emerged, one that avoids the human centred Top-down planning.

REFERENCES

1. C. Moreno, “Beyond the Smart City” (Stream 04, PCA, 2017).
2. F. Bacon, J. Weinberger (editor), “New Atlantis and The Great Instauration” (Wiley-Blackwell, May 2016).
3. Archizoom, “The New Domestic Landscape” (1972).
4. L. C. Pearson, “From Superstudio to Super Mario” (e-flux Becoming Digital, 2019).
5. L. Busbea, "Paolo Soleri and the aesthetics of irreversibility" (Routledge, The Journal of Architecture, 1 December 2013), PP.781-808.
6. P. Soleri, “The Frugal City” Where We Live NPQ (5 November 2013).
7. P. Soleri, “Arcology: The City in The Image of Man” (Cambridge: MIT Press, 1969).
8. C. Alexander, “A City is not a Tree” (1965), PP. 12-15.
9. T. Morton, “The Mesh” (Harvard University Press, Boston, 2011).
10. K. Mannheim, “Ideologie und Utopie” (1929).
11. E. Bloch, “The Principle of Hope” (the MIT Press, 1959).
12. V. S. Marques, “Utopia and Ecology” (University of Lisbon, 2007).
13. J. Newman, “The Black Atlantic as Dystopia” (Penn State University Press, 2012).
14. E. Schrödinger, “What Is Life?” (Cambridge University Press, 1944).
15. S. Johnson, “Emergence: The Connected Lives of Ants, Brains, Cities, and Software” (Penguin group, London, 2001), PP. 18-30.
16. A. Abraham, C. Grosan, V. Ramos, “Stigmergic Optimization” (Springer Berlin Heidelberg, New York, 2006), PP. 2-12.
17. D. Krakauer, “What is an individual? Information Theory may provide the answer” (Santa Fe Institute, 2020).
18. A. Ricci, A. Omicini, M. Viroli, L. Gardelli, and E. Oliva, “Cognitive Stigmergy: A Framework Based on Agents and Artifacts” (EUMAS, 2005).
19. B. Colomina and M. Wigley, “Are we humans?” Notes on an archeology of design, (Lars Müller Publishers, 2017).
20. F. Heylighen, “The Global Brain as a New Utopia”, (Free University of Brussels, 2002).
21. P. T. de Chardin, “Le Phénomène Humain” (William Collins, 1955).
22. B. Bratton, “The Stack. On Software and Sovereignty” (the MIT Press, 2015), PP. 83-85.
23. B. Latour, “Parliament of Things” (Cambridge: Harvard University Press, 2005).
24. M. Weinstock, “System City” (John Wiley & Sons, 2013), PP. 28-36.
25. I. Di Carlo, “The Aesthetics of Sustainability. Systemic thinking and self-organization in the evolution of cities” (List Lab, Barcelona- Trento, 2016), PP. 63-100.