MASTER

Undergroundscraper
from ant nests to architecture

Liu, Mo

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UNDERGROUNDSCRAPER
from ant nests to architecture

Mo Liu
Undergroundscraper
Graduation project
Digital Architecture

January 2015

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This report is the result of the graduation project, Digital Architecture, in the Department of the Built Environment of Eindhoven University of Technology in 2014. It is not possible to finish this report without the help and support of a number of people to whom I would like to express my sincere gratitude for a variety reasons.

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Mo Liu
January 2015
This report focuses on the theory of undergroundscrapers and how to use parametric way to design an undergroundscraper by simulating the ant nest.

Undergroundscraper is a new concept which is from skyscraper, referring to the ‘high’ rise buildings underground. This new kind of buildings may solve problems such as population explosion, the shortages of earth and housing and urban canyon effect which is caused by skyscrapers. The new design used the parametric tools to simulate the movements of ants and ant nests to get the basic form of the building. Emergence is the theoretical foundation of this design. It is used in many areas including human beings, urban, buildings, ant nests and computers. Biomimicry is the method of this design. It finds the design solutions by mimicking nature’s time tested strategies. Ant and their nest are the inspiration and origin of this design. The building is in a canyon with a depth of 100 meter with multi-functions. It will provide a new thinking for future.

Seven chapters constitute the main content of my research, i.e. general introduction, concept of undergroundscraper, theory, ants and nests, computational design, architectural design and conclusion.
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0.1 Theme

The theme of this graduation project, ‘Digital Architecture’, has been developing rapidly during the past decade. It is generally considered that Digital architecture, which is a broad concept, refers to aspects of architecture that features digital technologies, using computer modeling, programming, simulation and imaging to create both virtual forms and physical structures. It contains many new theories of digital techniques including Computer-Aided Design (CAD)/Computer-Aided Manufacture (CAM), Building Information Modelling (BIM), and parametric and generative design.

Computer-aided design (CAD) is the use of computer system to assist in the creation, modification, analysis, or optimization of a design.[1] CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing.[2] Today, CAD software is used in all aspects in architectural design. Some only can create two-dimensional drawings, while others are capable of highly sophisticated three-dimensional models, renderings and animations.

Building Information Modelling (BIM) is a process involving the generation and management of digital representations of physical and functional...
### Parametric Semiology: Semio-field

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**Fig. 2** Parametric Semiology: Semio-field, differentiation of public vs. private as parametric range.

**Fig. 3** Parametric Semiology: Semio-field, master-plan with program distribution.
characteristics of places. BIM covers the whole process of a project life-cycle from planning to building. It is not only used for designers and planners but also supporting cost management, constructing management, project management and facility operation.

Parametric design is a new term of the logic of digital design thinking which focuses on a logic of associative and dependency relationships between objects and their parts-and-whole relationships. It expresses the parameters and rules that together, define, encode and clarify the relationship between design intent and design response. The word ‘Parametric’ is from mathematics and refers to the use of certain parameters or variables that can be edited to manipulate or alter the end result of an equation or system. Parametric design is not a new concept and has always formed a part of architecture and design. The consideration of changing forces such as climate, setting, culture, and use has always formed part of the design process.

Digital tools and machines are also used for digital architecture, especially fabrication and Prototyping. Laser-cutting and three-dimensional printer are the common tools to translate digital models to physical objects. These machines make a more fluid process than traditional approaches.
Fig. 4 Laser-cutting in TU/e

Fig. 5 Full-size model printed by D-Shape printer
0.2 Background

With the development of society, human beings face increasingly more problems. From the end of 19th century, the population explosion became one of the most serious problems. Increasing population and the developing needs and aspirations of humankind for our living environment require increasing provision of space of all kinds. The world’s population is becoming more urbanized at an unprecedented pace. There were 21 mega cities with the populations of more than 10 million people by the year 2000, as predicted earlier. The shortages of earth and housing make many governments feel overwhelmed. At the end of 19th century, high rise buildings were widely built and they were considered as the best way to solve these troublesome issues. However, after ‘9/11’ terrorist attack in 2001, the security of high rise buildings also has attracted controversy. At the same time, growing public concerns for both conservation and quality of life are rightly giving pause to unrestrained development of the cities at ground level. Provision of new urban infrastructure may either coexist or conflict with improvement of the urban environment. Architects are seeking new methods to solve these problems. Therefore, underground buildings get into the field of vision. Underground space is available almost everywhere, which may provide the site for activities or infrastructure that are difficult or impossible to install above ground or whose presence aboveground is unacceptable or undesirable. Underground buildings may either be developed by open excavation in soft strata or soil, the top of which is subsequently covered to get the space below, or created by excavation in hard strata or rock. Despite underground buildings face big challenges such as sunshine, climate, structure, and psychological and physiological considerations for people, they will become a trend in future.
0.3 Research questions

Skyscrapers were designed to solve the problem of people explosion at the end of 19th century. Human beings has used underground space for living for a long time. How to combine a skyscraper and underground building is primary problem. The design idea originates from the ant and their nests and how to get the form of the ant nest is another big issue.

Therefore, the main research question is how to design the undergroundscraper by simulating the ant nest.

Ant nest is only the home for ant. While for a real human beings’ building, many architectural problems should be emphasized, such as structure, construction and material. And also how to transfer the ant nest to building is a important problem.

The sub research questions are what is undergroundscraper; what are the interrelated theories among computational design, ant nest, architecture and urbanism; what the nest of ants looks like; what are the differences between ant nests and buildings of human beings; how to simulate the ant nest; and how to transfer the ant nest to the undergroundscraper.
0.4 Social relevance

The population problem is one of the most important in the world. According to the statistics of United Nations, the population will reach 100 billion in 2100. Mega cities, similar to Shanghai where the population exceeds 30 million, will dominate Africa and Asia. The demands for space have resulted in cities that have spiralled upwards. Nearly all the big cities have skyscrapers. However, the urban space would not bear so many people, therefore developing the underground space is one way to solve the problem of housing shortage and improve the land utilization rate. After the 9/11 terrorist attack, people realize the skyscrapers would become the targets of the terrorists. For the security reason, underground-scraper will be safer. In nowadays, buildings are becoming increasingly higher. The skyline and environment of the cities are damaged by these high buildings, especially to the historical area. Another big problem caused by skyscraper is urban canyon effect. The tall buildings within many urban areas provide multiple surfaces for the reflection and absorption of sunlight, increasing the efficiency with which urban areas are heated. It is manifested by streets cutting through dense blocks of structures, especially skyscrapers that form a human-built canyon. The other problems, such as building shaking, ground movement, land subsidence and waves problems, cannot happen underground.
Fig. 6 World population estimates from 1800 to 2100, based on “high”, “medium” and “low” United Nations projections in 2010.

Fig. 7 Map of countries by population density, per square kilometer.
0.5 Scientific relevance

For answering the research questions, first, a definition of undergroundscraper is given. Furthermore, relating theories, such as emergence, to find the relationship among ants, ant nest, urban, architecture and computer science are described. The biomimicry is the method to design the building transferring the nest of ants to building for human beings. And the research of ant nest help to understand what the real nests look like and how ants build their nests and what we can learn from ant nest. The conclusions summarize the differences between ant nest and real buildings.

To get the form of the undergroundscraper, a plug-in for Grasshopper, Anemone, is used to simulate the movement of ants to get the trajectory. And Maya is used to design deeply. 3D printing model helps to get the overview of the design and the main idea of design.
Fig. 8 The structure of knowledge
0.6 Research methodology

This design would combine the knowledge of biomimicry, computational design and architecture. Biomimicry is design method that looks for design solutions by mimicking nature’s time tested strategies. The biomimicry help people to solve problems from the nature world. Computational design is a hot issue of design method. Parametric tools can simulate the complex natural phenomenon. And the undergroundscraper is from the skyscraper which is a concept of architecture. The combination of these three tracks will help people to build undergroundscrapers.
0.7 Report outline

This report is divided into six distinct interrelated parts, respectively referred to as concept of underroundscraper, theory, Ants and nest, Computational design, architectural design and conclusion. The preceding sections are considered the overall introduction of Part I, whereas II discusses the relating theories among ant nest, urban, architecture and design. III is the description of the ants and their nest and how they build the nest. IV and V are considered the main part of this report. These two parts show the process and results of this architectural design including the thinking, scripting, drawings and models. The overall conclusions, as well as a short outlook, are provided in VI.
I. CONCEPT OF UNDERGROUNDSCRAPER
1.1 Underground space

Human beings have a long history of using underground space. In approximately 3000 B.C., the age of Neolithic, caves which were underground or half-underground were used as the shelters to protect from the threats by animals and nature. The world’s biggest cave is 207 meter high and 152 meter wide in a Vietnam forest named Hang Son Doong cave. Following this period, the construction of underground tunnels were used in China, Egypt, Mesopotamia, Greece, and Rome. Some of them were used as the tombs of Empires. There are 23 known large-scale underground cities in the Cappadocia region in Turkey. Hundreds of rooms in the underground cities were connected to each other with long passages and labyrinth-like tunnels. The corridors were made long, low, and narrow to restrict the movement of intruders. Shafts were used for both ventilation and communication inside the underground cities. During the Second World War, underground buildings had a military use. It was said that there was another city of Tokyo underground which was planned to resist the US army during the Second World War. However, this project was classified as confidential event and few people knew it. In some other countries, metro has another function which is bomb shelter. In Harbin, one of the biggest cities in China, many bomb shelters were constructed in case of the invasion of Soviet Union during 1950’s. After the cold war, some of them were connected to form big shopping malls underground. In Shanghai, the biggest city in China, more than two million square meter of subsurface space has been developed as underground buildings for various uses, such as supermarkets, warehouses, silos, garages, hotels and subways. Another fundamental characteristic of underground space lies in the natural protection it offers to whatever is placed underground. This protection is simultaneously mechanical, thermal, acoustic, and hydraulic. However, these seem still not enough for human beings. How to build and what the underground buildings look like become a chal-
lenge for architect.
Fig. 9 Cappadocia

Fig. 10 Derinkuyu Underground City
1.2 Concept of undergroundscraper

The new term ‘undergroundscrapers’, which is an analogous derivative from ‘skyscrapers’, refer to those ‘high’ rise buildings underground. Similar ideas of underground buildings have been thought for a long time. At the start of 20th century, a new frame, Depthscraper, resembled a 35-story skyscraper of the type familiar in American large cities; but which is built in a mammoth excavation beneath the ground. It is cylindrical; its massive wall of armored concrete being strongest in this shape. The whole structure will vibrate together, resisting any crushing strain to protect from earthquakes. As in standard skyscraper practice, the frame is of steel, supporting the floors and inner walls. In recent years, thinking of underground buildings emerge in large numbers. The Taipei 101 was the world’s tallest building from 2004 to 2010. After it was finished, some people doubted the security of the building and asked if a building which mirrors it could be built just under it. Despite it was impossible, the idea of undergroundscrapers would not stop. In 2009, an earthscraper designed by a Mexican architects drew attention of people. The Earthscraper preserved the iconic presence of the Zocalo which is a famous plaza in the center of Mexico City, and the existing hierarchy of the buildings that surround it. It is an inverted pyramid with a central void that allows all habitable spaces to enjoy natural light and ventilation. The first ten stories are dedicated to a pre-Columbian museum. The next ten stories are retail areas and housing while the deeper 35 stories are offices. In 2011, a Chinese architect put forward the idea of ‘Underground Metropolis’ to use the underground space caused by coal mining. Another underground idea was from the Taisei Corporation in Japan called Alice City. In their infrastructure areas, they plan power generation, regional heating, waste recycling and sewage treatment facilities.
CONCEPT OF UNDERGROUNDSCRAPER

Fig. 11 Underground Metropolis

Fig. 12 Earthscraper
1.3 Skyscraper and undergroundscraper

1.3.1 History of skyscraper

Skyscrapers are one kind of high rise buildings which has a long history. In the 26th century BC, the Great Pyramid of Giza was built in ancient Egypt. It was 146 meter high, Equivalent to about 50 storeys and was treated as tallest buildings in the ancient time. It was not surpassed in height for thousands of years. Until the 14th century, Lincoln Cathedral exceed it with the height of 160 meter. It kept the title of tallest in the world for almost 300 years until the 169-meter Washington Monument in 1884. However, because they were uninhabited, none of these structures actually comply with the modern definition of skyscrapers. High rise for living also has an early origin. In Ancient Rome, it is said that the apartments would reach 10 or more storeys. Several emperors, such as Augustus, even attempted to establish limits of the buildings due to reason for city planning, but they were not successful. The residential building of 12th century Bologna was built, the tallest of which named Asinelli Tower is 97.2 meter high. The high rise buildings were popular around Italy at that time. Even in some medium-sized towns, some towers were constructed more than 50 meter, such as a tower with 51 meter in San Gimignano.

In the Middle East, the history of high rise buildings also dated back to 10 century. Nasir Khusraw, who was a Persian poet and philosopher, described some of them rising up to 14 storeys, with roof gardens on the top floor and completed water system. Cairo had high rise buildings which was for both commercial and living in the 16th century. At the same time, the city named Shibam in Yemen had many high rise buildings for housing. Shibam consisted of more than 500 tower houses rising 5 to 11 stories high. The city still has the tallest mudbrick buildings in the world, with many of them over 30 meter high.[11]

In 19th century, it came to be accepted as a dog-
Fig. 13 Lincoln Cathedral
Fig. 14 Home Insurance Building
Fig. 15 The Empire State Building
Fig. 16 The Two Towers of Bologna
ma that steel skeleton construction is the initial cause of the true skyscraper with the invention of elevators the real skyscraper came into being. One of the definition of skyscraper is that the modern skyscraper thus rests on three fundamental inventions: passenger elevators, steel skeleton construction and electricity, and may be defined as a building of great height constructed on a steel skeleton and provided with high speed electric elevators.\[12\] It is considered that Home Insurance Building is Chicago which was constructed during 1883 and 1884, designed by William Le Baron Jenney, was the first real skyscraper. The building originally had 10 stories and in 1890, another two stories were added with the total height of 54.9 meter. It had an iron and steel supporting frame on account of which it is considered the pioneer ‘skeleton skyscraper’. This iron and steel supporting frame comprised the entire exterior walls and also the interior court walls. It went down to the granite base line above the first story.\[13\] In 1931, this building was demolished. After Home Insurance Building, most early skyscrapers emerged in the land-strapped areas of Chicago and New York at the end of the 19th century, and also built in Europe. In 1898, a building called ‘Witte Huis’ was built in Rotterdam in the Art Nouveau style. It was 43 meter high with 10 storeys. It was the tallest building in Europe at that time. The building was constructed from iron and steel and cement, and includes two thick interior walls which increase the building’s strength. Unlike many other contemporary buildings of the time, wood was not a significant construction material due to the fear of fire.\[14\]

When it was in 20 century, increasingly more skyscrapers were built, even a competition occurring between Chicago and New York to get the ‘world’s tallest building’. Until 1931, the appearance of the Empire State Building ended the competition. The Empire State Building is a 103-storey skyscraper located in Midtown Manhattan, New York with the height of 443 meter in total. The Empire State Building was the first building more than 100 floors. It has 6,500 windows and 73 elevators, and there were 1,860 steps from street level to the 102nd floor.\[15\] Unlike most of today’s skyscrapers, the Empire State Building features an art deco design,
typical of pre–World War II architecture in New York. The modernistic stainless steel canopies of the entrances on 33rd and 34th Streets lead to two-storey high corridors around the elevator core, crossed by stainless steel and glass-enclosed bridges at the second-floor level. It even was listed in the Wonder of the World. It kept the record for almost 40 years. The World Trade Center and Willis Tower were built in 1970’s and both broke the record of the tallest buildings in the world. After them, the disadvantage of skyscrapers had caught the debate. Especially after the September 11 attacks of 2001, American buildings quitted the competition of skyscraper.

However, in the 21 century, with the economic development of Asia, another round of tallest competition has attracted the attention of people in the east and west of Asia. In 2010, Burj Khalifa became the tallest skyscraper with the unbelievable height of 828 meter, surpassing the Shanghai Tower in China, Makkah Royal Clock Tower Hotel in Saudi Arabia. It can be referred that the competition of the world’s tallest building will not end.

1.3.2 Comparison between skyscraper and undergroundscraper

In nowadays, though skyscrapers make the contribution to some problems, such as housing shortage and land utilization rate, some serious problems caused people’s worries, the disadvantage of skyscrapers are gradually realized.

People worried the security of skyscrapers especially after September 11 attacks. In the attacks, thousands of people were trapped in the two towers which were on fire, and could not escape from them waiting for death without any help. Finally, almost 3000 were dead. Not only terrorist attacks, even a small fire could cause a large number of casualties. Despite as far back as 1940s, it was required in New York that skyscrapers must be fireproof.[16] The doubt about security of skyscrapers still exist.

Another big problem of skyscrapers is the air pollution. An urban heat island (UHI) is a metropolitan area that is significantly warmer than its
surrounding rural areas due to human activities. The main cause of this problem is that the tall buildings within many urban areas provide multiple surfaces for the reflection and absorption of sunlight, increasing the efficiency with which urban areas are heated. It is manifested by streets cutting through dense blocks of structures, especially skyscrapers that form a human-built canyon. The UHL would be harmful to the health of people in the buildings and on the street.\footnote{17} In addition to these, traffic problem, buildings shaking, ground movement, land subsidence and wave problems are also the problems faced by skyscrapers.

By contrast, undergroundscrapers have the benefits which skyscrapers do not have. The underground buildings offers great safety against all natural disasters and nuclear wars, ultraviolet rays from holes in the ozone layer, global warming, electromagnetic pollution, and massive solar storms.

- Energy use

Generally, the greater the percentage of surface area in contact with the earth and the deeper the structure penetrates into the earth, the more the structure will benefit in terms of energy conservation. However, direct access to the surface and window openings are required for a variety of psychological, physiological, and safety reasons. Energy related benefits are therefore constrained by the requirement for these openings, as well as by the structural costs of supporting extensive earth loads at greater depths.\footnote{18}

- Harmony environment

A skyscrapers might damage the protection of historical area. To protect the historical area is not only to preserve the valuable buildings themselves but also to preserve the environment around the building. Today, many historical areas are surrounded by new buildings which would be harmful to protect. The Forbidden City in Beijing is one of the most famous world cultural heritage. However, in 2001, the National Center for the Performing Arts looking like an egg with a huge volume was built only one street way from the Forbidden City. Obviously, the context of this historical area was destroyed. The underground-
scrapers would avoid this trouble due to the main part of the building underground.

Not only for urban environment but also for natural environment, underground scrapers would be useful. A well designed underground scrapers can blend with the surrounding earth and become part of the natural landscape. In addition to the positive aesthetic effect on the environment, underground buildings provide the opportunity to improve or enhance the natural environment, particularly in urban areas. Another benefit is the revitalization of the natural landscape that results simply from the increase in the amount of plant and animal habitat in a given area. Water and air quality are enhanced and the soil is enriched by allowing the natural ecological processes to occur within the boundaries of a built environment.\[19\]

-Fire protection

Underground structures are mostly built of concrete surrounded by soil or, in the case of mined space, rock caverns. These fireproof materials provide a great degree of fire protection and prevent the spread of any fires to or from other buildings.\[20\] In spite of the fireproof nature of underground buildings, materials within the buildings may still be combustible. Since these structures often have fewer openings to the surface and the path of exit for occupants is upward rather than downward, some unique life safety problems may arise. Careful design and consultation with building code authorities is necessary.\[21\]

-Surface noise and vibration

The underground scrapers would be effective on prevent the urban noise. Similarly, if the vibration sources are at or near the ground surface, levels of vibration will diminish rapidly with depth below ground and distance of the source.\[22\] This could be desirable for two reasons. First the function to be enclosed may require quiet and isolation from the surrounding environment. The second reason is that the function itself creates undesirable noise and the outside environment would benefit from any reduction in the noise. Manufacturing facilities or transit systems are examples of such undesirable functions.\[23\]
-Cold or hot climates
Although advantages can be achieved for reducing the energy demand when building underground, people may also benefit largely from the fact that do not have to endure extremely high or cold temperatures during the day and night, when infrastructure and other facilities are also being provided for underground.[24]

However, several important considerations should be highlighted.

-Geological considerations
Geology is the first basis for land use and town planning. Geology controls the landforms and hence the geometry of any site, from a wide plain to a narrow valley or a mountain slope. Together with climate, geology controls the flow and actions of surficial water, the extent and location of groundwater resources, and the designs for foundations of buildings and other structures.[25]

-Engineering consideration
Underground structures must maintain stability of the surrounding geological environment. In some cases the ground can be self-supporting up to certain span limitations. In cases where support is used, maximum opening sizes are limited by the increasing relative cost of supporting larger openings. Such support costs typically rise more rapidly with clear span than for superstructures.[26]

-Psychological and physiological considerations
Negative associations with underground space generally include darkness combined with humid, stale air, and no light. With no direct view of the outdoors there may be a loss of connection with the natural world and no simulation from the variety of changing weather conditions and sunlight. Physical concerns with the underground focus primarily on the lack of natural light and poor ventilation. People do not want to feel like prisoners in underground facilities.[27]

-Safety considerations
Safety issues may also represent disadvantages for underground facilities. The ability to exit an underground facility in case of an interior fire or explosion is hampered in deeper underground facilities by limited points of connection
to the surface, the need for upward travel on exit stairs, and the difficulty of venting poisonous fumes from a fire. In ground containing dangerous chemicals or gases, these may potentially seep into the underground space, causing health problems. Heavier-than-air gases from the surface may also fall into underground structures to create higher concentrations than would exit on the surface. Disasters that occur with relatively higher frequency include flooding, oxygen shortages, and gas leakages. Factors that may increase risks when underground space is developed on a larger scale. In addition, safety and disaster prevention measures are suggested for fire, oxygen shortage, flood, and power failure.
2.1 Emergence

2.1.1 Definition

Emergence is a concept that appears in the literature of many disciplines and is strongly correlated to evolutionary, biology, artificial intelligence, complexity theory, cybernetics and general system theory. Generally, emergence is most commonly understood as the synonym for ‘appearance’. In the sciences fields, the word refers to ‘the production of forms and their behavior, by system that have an irreducible complexity’. [28] Another simplest commonly understanding of emergence is applied to the properties of a system that cannot be deduced from its components. The same general principle underlines all other emergent process. For example, in a biological organism, a single cell multiplies into exponentially greater numbers of cells that share the same DNA rules. These cells create structures in a higher dimension, tissues and organs, which form the entire organism.

John Henry Holland, an American scientist and professor in psychology and computer science, in his book ‘Emergence from chaos to order’, illustrated

‘We are everywhere confronted with the emergence in complex adaptive system – ant colonies, networks of neurons, the immune system, the internet, and the global economy, to name a few – where the behavior of the whole is much more complex than the behavior of the parts.’ [29]

‘…It is unlikely that a topic as complicated as emergence will submit meekly to a concise definition, and I have no such definition to offer. I can, however, provide some markers that stake out the territory, along with some requirement for studying the terrain…’ [30]

He did not define ‘emergence’ specifically. Another famous book about emergence, ‘Emergence, the connected lives of ants, Brains, Cites
‘In discussion of complex, adaptive system: The movement from low-level rules to higher-level sophistications is what we call emergence and …a higher-level pattern arising out of parallel complex interactions between local agents.’[31]

This definition covered four principles of emergence, local interaction of neighbors, pattern recognition, feedback and indirect control.

Francis Heylighen, a Belgian cyberneticist, in his article ‘Self-organization, Emergence, and the architecture of Complexity’ defined clearly and accurately. It said ‘Emergence is a classical concept in system theory, where it denotes the principle that the global properties defining higher order systems or ‘wholes’ can in general not be reduced to the properties of the lower order subsystems or ‘parts’. Such irreducible properties are called emergent.’[32]

2.1.2 Origin of emergence

The oldest understanding of emergence may be from Aristotle, the great Ancient Greek Philosopher. Metaphysics, his one of the most famous publication, referred ‘The whole is something over and above its parts, and not just the sum of them all’. Properties ‘emerge’ that are more than the sum of the parts. The ‘whole’ have distinctive properties that merge though the process of successive interactions between different levels of organizations and integration.[34]

The naturalist and geologist Charles R. Darwin published his theory of evolution and nature in the book ‘On the Origin of Species’. The evolutionary theory the main idea of which is natural selection did not allow radically new phenomena in nature, like the human mind. Darwin frequently quoted the popular canon of his day, ‘natura non facit saltum’- nature does not make leaps. In ‘On the Origin of Species’, Darwin emphasized repeatedly the incremental nature of evolutionary change and he called these ‘law of continuity’ and ‘descent with modification’. Emergent
evolution theory’, was advanced comprehensive combining Darwin’s gradualism and ‘qualitative novelties’. It also has relationship with Herbert Spencer’s concept that was a trend in evolution toward new levels of organization.[36]

In 19 century, the British philosopher John Stuart Mill gave the example of water to explain essentially the same idea:

‘the chemical combination of two substances produces, as is well known, a third substance with properties different from those of either of the two substances separately, or of both of them taken together.’[37]

At the same era, according to Conwy Lloyd Morgan, a British comparative psychologist emergent and writer, was the prominent successor of Darwin’s theory. He said the evolution was not really a scientific theory that the boundary was not very clear. He researched the relation between emergent evolution and humankind and ultimately published three volumes on the subject, Emergent Evolution, Life, Sprit and Mind, and the Emergence of Novelty.[38] In the book, he concluded

‘If we may acknowledge on the one hand a physical world underlying the phenomenal appearances with which we are acquainted by sense, and, on the other hand, an immaterial Source of all changes therein; if, in other words, we may acknowledge physical events as ultimately involved and God on whom all evolutionary process ultimately depends, then we may, with Kant, but on different grounds, accept both causation and Causality without shadow of contradiction. But unless we also intuitively enjoy God’s activity within us, feeling that we are in a measure one with him in substance, we can have no immediate knowledge of causality or of God as the source of our own existence and emergent evolution.’[39]

The analytical, experimental approach to biology and genetics grew up in the 1920s and 1930s causing the development of emergent development. At that time, reductionism swept aside the basic field of emergent evolutionists that wholes
had irreducible properties that could not be fully understood or predicted by examining the apart alone. The famous British philosopher Bertrand Russell argued that analysis

‘enables us to arrive at a structure such that the properties of the complex can be inferred from those of the parts.’\textsuperscript{[40]}

In the start of 20th century, philosopher David Blitz in his book about the history of emergence, ‘Emergent evolution: qualitative novelty and the levels of reality’, said the term of emergence was put forward by the psychologist G. H. Lewes in his multi-volume problems of life and mind.\textsuperscript{[41]} Despite the reductionists considered that it was not possible for science to make such inferences and predictions at that time, this disadvantage was a reflection of the situation of the art in science and not of some superordinate property in nature itself. In time, it was conceded that reductionism would give a full explanation to emergent phenomena.

2.1.3 Self-organization, emergence and ants

Organizations play roles in the original nature of emergence. Most cases of self-organization are also the cases of emergence. Self-organization came into being before emergence. According to Wikipedia, Self-organization is a process where some form of global order or coordination arises out of the local interactions between the components of an initially disordered system. The spontaneous creation of an ‘organized whole’ out of a ‘disordered’ collection of interacting parts, as witnessed in self-organization systems in physics, chemistry, biology, sociology… is a basic part of dynamical emergence. Self-organizations only have two-level structure: the ‘microscopic’ level where a multitude of building blocks or elements interact, and the ‘macroscopic’ level where these interactions lead to certain global patterns of organization.\textsuperscript{[42]}

Self-organization is able to help to describe many building activities. Ant nest is a big organization, which is a cooperation project. An individual ant does not accomplish all the work. Nest are erected and maintained; chambers and shafts are ex-
cavated; and territories are defended. Individual ants acting according to simple local information that is chemical carry on all of these activities and no one supervises the whole colony and gives order to the individual workers. Each individual ant processes the partial information available to it in order to decide which of the many possible functional roles it should play in the nest.

There are four different roles for an adult harvester-ant worker in one ant colony: foraging, patrolling, nest maintenance, and midden work. It is primarily the communications between ants doing these tasks that reflect to emergent phenomena in an ant nest.

There are many nest-maintenance workers around the entrance of the nest if there is work. The decision of each individual ant has the influence on the whole colony, such as the task changing. Task allocation depends on the performance of ants, which take an active part in these jobs. These decisions are based on the local information. Despite every colony has a ‘queen’; her job is just to lay eggs. Therefore, there is no center in a colony to control the entire colony.

A forager only works inside of nest. When a large cleaning work arises on the surface of the nest, new nest-maintenance workers are recruited from ants working inside the nest, not from workers performing tasks outside. When there is a disturbance, such as an intrusion by foreign ants, nest-maintenance workers switch tasks to become patrollers. Finally, once an ant is allocated a task outside the nest, it never returns to chores on the outside.

This example shows how interactions between different types of ants can give rise to patterns of global work allocation in the colony, emergent patterns that cannot be predicted that cannot even arise for isolated ants.

2.1.4 Self-organization and emergent urbanism

In recent time, the research on self-organization is developed to provide the solution to the problem of dynamical emergence. The emergence of cities was treated as one kind of self-organiza-
tion in the early time. With the development of urban designing in the 20th century, new concepts, like morphology and fractals, was imported to the design process, and emergent urbanism theory came into being.

Between 6,000 and 5,000 years ago, the range of deserts around the world had broadened and developed the arid ecologies and spatial extent. In the hot regions of the Levant and southwest Asia, Egypt and the Indus Valley of southern Asia; and in the cold regions of northern China, and the northwest coast of South America, river valleys provided a perfect location of the development and blossom for human civilization.[43] As the result of stress of climate and ecology, cities emerged in these five regions within a few hundred years. These five regions are far away each other; however, cities emerged in these five regions almost at the same time. This phenomenon suggests that ‘cities emerged first in one region and spread by culture diffusion to the others’. Cities emerged within different topographies and ecological systems, and the emergence of larger building forms and development of cities followed the flow of energy from intense cultivation, increased social complexity and the evolution of information system.[44] The emergence of cities was a completely spontaneous behavior.

Urban design is different from others in the domain of designing. The design of cities was attempted after cities became normal and ordinary in the human being’s life. The other kind of design, for example the industrial design, can be traced to a definite, deliberate act of invention. And the building design is also rooted in known processes. Urban design may damage the self-organization system. An emergent city similarly begins with a network structure, which is much more sophisticated than open land. For instance, in modern design the typical street produces a network, but also has the unfortunate side effect of cutting pedestrian networks that normally enjoy the entire surface in a spontaneous city.

2.1.5 Morphogenesis and architecture

Emergence is significant to architecture which requires substantial revisions to the way in which
we produce designs. Emergence demands that the buildings are recognized not as a single and mixed objects, but as a complexity including energy and materials, as a part of other building of environment and as a long series of iteration that are benefits from evolutionary development of smart ecosystem. In the field of architecture, the task of architecture is to delineate a working concept of emergence and to outline the mathematics and processes that can make it useful to us as designers. It is involved in the evolutionary processes for not only the design buildings, but also the new materials and structural design. In the article ‘morphogenesis and the mathematics of emergence’, written by Michael Weinstock who is the founder of Emergence and Design Group, has the statement

‘The logic of emergence demands that we recognize that buildings have a life span, sometimes of many decades, and that throughout that life they have to maintain complex energy and material systems. At the end of their life span they must be dissembled and the physical materials recycled. The environmental performance of buildings must also be rethought. The current hybrid mechanical systems with remote central processors limit the potential achievement of ‘smart’ buildings. Intelligent environmental behavior of individual buildings and other artefacts can be much more effectively produced and maintained by the collective behavior of distributed systems.’[45]

Therefore, architecture is a new level of complexity as it seeks to match the restless perfection of system in the natural world.

In recent years, the mathematical approaches can be used for generating designs or parametric designs, which have relationships with forms and structures in morphogenetic processes within computational environment. As used in the sciences, the term ‘morphogenesis’ refers to the ‘emergence’ of forms and behavior from the complex system of the natural world. As ‘emergence’ is used in many fields, ‘morphogenesis’ also is found in the domains of biology, physics, chemistry and mathematics. The emergence and morphogenesis are based on the mathe-
matics and applied to other domains which have the analysis and production of complex forms. Mathematical approach in architecture is more comprehensive. The mathematics and morphogenesis produce emergent forms and behaviors in nature and in computational environments.
2.2 Biomimicry

2.2.1 Concept of biomimicry

Biomimicry, also called biomimetic, means the design and production of materials, structures, and systems that are modeled on biological entities and processes. Living organisms have evolved well-adapted structures and materials over geological time through natural selection. The term ‘biomimetics’ has been in use since the 1960s when Otto H. Schmitt defined it as ‘biology + technology’ but applied it mainly within the field of engineering. In the field of architecture, biomimicry has only been used since the early 2000s. Biomimicry is a design method that looks for design solutions by mimicking nature’s time tested strategies. The purpose of imitating nature strategies is to create products, systems, processes policies etc. that are well-adapted to life on earth over the long term. Biomimetic has given rise to new technologies inspired by biological solutions at macro and nano scales. Humans have looked at nature for answers to problems throughout our existence. Nature has solved engineering problems such as self-healing abilities, environmental exposure tolerance and resistance, hydrophobicity, self-assembly, and harnessing solar energy. The term ‘biomimetic’ first appeared in scientific literature in 1962\[46\], and grew in usage particularly amongst materials scientists in the 1980s. Julian Vincent defines it as the abstraction of good design from nature, while for Janine Benyus it is the conscious emulation of nature’s genius. The only significant difference between ‘biomimetic’ and ‘biomimicry’ is that many users of the latter intend it to be specifically focused on developing sustainable solutions, whereas the former can be, and on occasions has been, applied to fields of endeavor such as military technology.\[47\] From an architectural perspective there is an important distinction to be made between ‘biomimicry’ and ‘biomorphism’. Modern architects have frequently used nature as a source for unconventional forms and for symbolic association. In
Fig. 17 Study of the Construction and Control of a Wing
Fig. 18 Vitruvian Man
the esoteric realm, Le Corbusier used allusions to natural forms extensively for their associated symbolism.\[48\]

2.2.2 History of bio-inspired design

The important Greek philosopher and polymath Aristotle put nature at the center of his scientific studies. In his Historia Animalium he describes many zoological pheonema. In the ancients’ architecture, nature’s forms are used symbolically and metaphysically.\[49\] With the Age of Exploration, and increasingly after the discovery of the Americas, an influx of European naturalists documented their field observations in the form of drawings replicating nature. History’s greatest naturalists, such as Leonardo da Vinci, Konrad Gessner and Ulisse Aldrovandi, among others, produced stunning informative drawings. Gessner’s Historiae animalium, published in Switzerland around 1555, is considered the first encyclopedic work dedicated to documenting all known animals, particularly through the inclusion of illustrations, drawn mainly by Lucas Schan. The book generated such an impact that a few tears later all of its illustrations were collected in a separate book, Icones Animalium.\[50\] Less tangible and seemingly invisible aspects of nature also inspired the development of technologies that allowed further investigation. The invention of the microscope in the late 16th century in the Netherlands and later the compound microscope by Galileo Galilei in 1625 allowed scientists to study the incredibly close and small as well as the distant using the same technology. Robert Hooke is considered the first to bring the public astonishing microscopic images from the invisible to bare eye from the world of nature. In fact, Leonardo may be regarded as the first biomimetic designer, considering his investigations on the flight of birds, which developed into the invention of the first flying machine- the Ornithopter. Another critical da Vinci contribution is the elaration of Vitruvio’s de Arquitectura text, from which he extrapolated and developed the geometric relationships of the human body to the pure geometric forms of the square and circle. This advanced way of ‘observing’ opened the world to what we call the ‘relational aspects’. Leonardo’s drawing provided and essential link to early relational observa-
Fig. 19 Falling water

Fig. 20 the SC Johnson headquarters
tions in demonstrating that everything in nature is interconnected, and that clear, relational rules from nature can be applied through geometry.[51]

The 19th century saw a proliferation of engineering and other applied sciences, with bright minds applying their efforts to the testing and discovery of many devices. A big shift happened in 1857, when Jean-Marie Le Bris, during one of his long sailing strips following the flight of an albatross, designed and built the first bio-inspired flying machine, the ‘artificial albatross’.[52]

Responsibility for this trend can be attributed to, among others, the work of D’Arcy Wentworth Thompson. The rediscovery of the 1917 book On Growth and Form by the mathematician has influenced generations of architects and designers including organic morpho-architects. His meticulous work looked at the correlations between biological forms and mechanical phenomena, and his descriptions of the interrelation between form and growth helped biologists, architects, and engineers find fruitful starting grounds for collaborative explorations. In 20th century architecture there are few relevant case studies designed by architects informed by nature. Influenced by his mentor, Luis Sullivan, Frank Floyd Wright put at the center of his career his interest in nature. In his book An Organic Architecture, he describes how he believed not only that every building should grow naturally from within its surroundings, but also how the building’s design should be carefully thought of as if it were a unified organism, in which each element of it relates to the other, similar to ecosystem in nature. Villa Mairea, designed by the Finnish Alvar Aalto, is one of the finest examples of nature’s influence in architecture. The forest that surrounds the house becomes the driving element for the conception of the interiors made of irregular columns and posts. The interiors resemble the diversity and beauty of nature, from materials to forms, in the intent to dissolve the separation between the indoor and the outdoor environments, as in Aalto’s words

‘nature is the symbol of freedom.’[53]

Another famous architect, Frei Otto, in his prolific
Fig. 21 The detail of Sagrada Familia

Fig. 22 The interior of Sagrada Familia
career, concentrates on finding the basic principles of structures in nature. His contribution and influence are still, today, predominant in the fields of minimal surfaces and complex geometry.

2.2.3 Biomimicry and architects

Nature is the original thinking of architects from ancient time. Stanislav Roudavski, in his article Towards Morphogenesis in Architecture, stated the biology in architectural designing that

‘1. Architectural designing aims to resolve challenges that have often already been resolved by nature;

2. Architectural designing increasingly seeks to incorporate concepts and techniques, such as growth or adaptation, that have parallels in nature;

3. Architecture and biology share a common language because both attempt to model growth and adaptation (or morphogenesis) in silico.^[54^]

The biology has influence on many aspects of architecture, such as structures, materials, environment and energy. From the start of 20th century, several architects got their design ideas from natural biological world.

The famous Spanish architect, Antoni Gaudi, was a Naturalist^[55^], which was closed to the biomimicry. The purpose of imitating nature strategies is to create products, systems, processes policies etc., which are well-adapted to life on earth over the long term. Humans have looked at nature for answers to problems throughout our existence. Nature has solved engineering problems such as self-healing abilities, environmental exposure tolerance and resistance, hydrophobicity, self-assembly, and harnessing solar energy.

Antoni Gaudi was born in the Campo de Tarra-gona, a small city in Catalonia in 1852. At the age of 16, he moved to Barcelona to continue his education. When he was 22 years old, he entered the Llotja School and the Barcelona Higher School of Architecture and graduating in 1878.

‘The abstract nature of the subjects taught there made them increasingly unappealing to him and
he developed further into his own meditations on humanity’s great building achievements and particularly on the construction methods that made the enormous monuments of antiquity possible, on the static characteristics of different building style, and other considerations, and it was only if, by chance, some explanation related to these architectural cogitations was begin given that Gaudi remained spiritually in class. If not, he would be far away, as was usually the case.\textsuperscript{[56]}

His first professional work was Casa Vicens in Barcelona, which was built from 1883 to 1889. This style was called Mudejar-moorish. During this time, his works were built outside Barcelona, such as Guell Estate Hunting Lodge, Villa Qui-­jano, Casa Guell pavilions and gate, and Palau Guell. After that, Gaudi evolved in the Gothic. He came into the conclusion that

‘Gothic are is imperfect, unfinished. It is the style of the compass and the formula, of industrial repletion. Its stability is based on the permanent shoring of the buttresses; it is a defective body held up on crutches. It has no overall unity. The structure is not connected to the geometrized decoration that adorns it; the decoration is false and could be eliminated without marring the work in the slightest. The proof that Gothic works are deficient in their plasticity is that they are most moving when they are mutilated, covered in ivy and lit by moonlight.\textsuperscript{[57]}'}
After this time, he focused on naturalism which was a vitalist modernism born from the Baroque. Gaudi was not content with the superficial character endowed by an external whirlwind, but instead imbues it with the vibration of a living being that, beginning with the structure and finishing with the plasticity, takes on a cosmic sense, even in the smallest details. It began with the decoration and ornamentation of the façade of the Sagrada Familia and in the Casa Calvet. In the upper church at the Colonia Guell he had used a geological naturalism also seen in the viaducts at Guell Park, which reached its park in the Casa Batllo and the Casa Mila. The Bellesguard mansion, described above, and the completely new elements used in the restoration of Palma de Mallorca’s Cathedral, represent a fusion of this style with the preceding style, moved by Gothic's heavy hand. Actually, the Sagrada Famillia was one of the greatest masterpieces in the world that applied many natural elements. It evolved the whole life of Gaudi to devote designing and constructing the church.

Another famous architect about nature and biology, which was called new organic architecture, is Toyo Ito. His most important idea is beyond modernism. In his several speech, he stated that modernism architecture is closed off from the natural environment. Modernism architecture increases homogenization by artificial environments. Modernism architecture separates space by function. These are the disadvantages of modernism architecture, so he thought architecture should escape from cube. His works practice his own ideas, especially in the 21th century. In 2002, he finish the building for TOD’s, which is an Italian shoe and handbag brand, in the fashionable Omotesando area of Tokyo. Ito designed trees on the façade of the building. These trees lose their living materiality and become something neutral and abstract, like a sign. This exterior surface is not only graph pattern but also structural system. This design is for escaping the conventional notion of a wall structure. He found a new pattern for walls and openings. His anther project, Fonds regional d’art contemporain de Picardie in France also used this pattern. The project ‘meiso no mori’ municipal funeral hall
is surrounded by mountains and the idea of this building was to respond not with a conventional massive crematorium but with an architecture of a spacious roof floating above the site like slowly drifting clouds creating a soft filed. The freely curved reinforced-concrete shell was considered as the continuation of mountains. His next few works, like I-project in Fukuoka, Vivocity and Culture center in Taichung, used organic forms. He summarized that architecture in the 21st century must be released from homogeneous grid and build flexible relationship with natural environment, must try to save energy by the maximized use of natural energy and must restore vital energy by symbiosis with nature.
Fig. 24 The idea of TOD’s facade

Fig. 25 The building of TOD’s
III. ANTS AND NESTS
3.1 General information of ants

Ants are social insects of the family Formicidae, belong to the order Hymenoptera. Ants evolved from wasp-like ancestors in the mid-Cretaceous period between 110 and 130 million years ago and diversified after the rise of flowering plants. It is said 22,000 species of ants are in total and scientists have identified more than 11,000 species of ants. The size of ant is very small. The range is from 0.75 to 52 millimeters. The largest species being the fossil Titanomyrma giganteum, the queen with the queen of which was 6 centimeter long with a wingspan of 15 centimeter. Ants use pheromones, sounds, and antenna to communicate. All the ants live in colonies of females, with some sterile and some reproductive. There are four different roles in a colony of ants. The first one is ‘queen’. Actually, the ‘queen’ is a misleading name. There is nothing queenlike about her. Her job is only to lay eggs, and she is important to the colony, as ovaries are important to a woman, but she has no special authorities. Only queens mate and only queens can produce females. They generally live for fifteen to twenty years. The second one is male ants. The male ants come from unfertilized eggs. Most of them have wings, and their job is to mate with queens. However, they only can live for several weeks. The third kind is worker ants which have the task of searching food and taking care of eggs without reproductive capacity. Another species of ants is forager ants. They take the responsibility defense and battle and the size is bigger.
Fig. 26-30 The Detail of ant nest
3.2 The nest architecture of ants

The nest of ant architecture, also called ant-hill which is the house of ants, are composed of two basic units: descending shafts and horizontal chambers. Shafts from helices with diameters of 4 to 6 centimeter and descend at an angle of about 15-20 degree near the surface, increasing to about 70 degree below about 50 centimeter in depth. Chambers begin on the outside of the helix as horizontal- floored, circular indentations, becoming multi-lobed as they are enlarged.[58] Chamber height is about 1 cm, and does not change with area. Chamber area is greatest in the upper reaches of the nest, and decrease with depth. The distribution of chamber area is top-heavy, with about half the total area occurring in the top quarter of the nest. The ground is like concrete for 2 or 3 meter down and below that is a layer of large, dry rocks. The nest chambers are 3 to 5 centimeter across, with beautiful curved ceilings and walls, and flat bottoms, all lined with damp soil that dries to an adobe like surface. The chambers strongly resemble the nearby cliff dwellings built in the twelfth century on a larger scale, but with similar materials, by Pueblo people. Shafts connecting chambers can be many ant-widths across. The mass of chambers is roughly cone-shaped and about as deep as the mound is wide: maybe 25 centimeter for a 2-year-old colony, and 1.5 meter for a 6-year-old one. Some of the chambers contain seeds stacked in neat piles, often the long, narrow grass seeds layered on the bottom and the round hard ones on top. Some chambers contain brood with the larvae laid carefully on the floor of the chamber.[59]
### 3.3 Comparison between ant nest and buildings

<table>
<thead>
<tr>
<th>Problems</th>
<th>Architectural</th>
<th>Ants</th>
</tr>
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</table>
| **Light**      | 1. Large deep atrium spaces  
2. The use of solar optics  
3. Replicating the spectral compositions of daylight  
4. The application of Virtual Natural Lighting Solutions (VNLS) |                                                |
| **Ventilation**| 1. A flexible mechanical system  
2. Proper use of air purification techniques | 1. The pressure differences  
2. The temperature differences |
| **Water leakage** | High-quality waterproofing system | Saliva of ants with clay                       |
| **Structure**  | 1. Concrete  
2. Steel tubes frames with smart skin | 1. Saliva of ants with clay  
2. Slightly domed ceiling |
IV COMPUTATIONAL DESIGN
4.1 Computational thinking

Computational design comprises both an immense chance and a considerable challenge to architecture and related design disciplines. With the development of the software and computer-aided design, computational thinking is widely used in architecture. The emergence of new computational modelling software, which allows parametric systems and complex biological organizations to be generated and explored, offers new avenues of holistic design production and detailed component manufacturing for the architectural designer. In recent years, computational design is widely used in the field of design which is about simulating the complex biological phenomenon from nature. A good example is the project of Sagrada Familia which directed by Mark Burry. He used many computational thinking to continue the design thinking of Antoni Gaudi. In this undergroundscraper case, the computational design are used to simulate the movement of ants to get the basic lines of the building. This is the foundation of design.
4.2 Grasshopper

Grasshopper, which is a plug-in for Rhinoceros, is used to simulate the movements of ant to get the form of the nest. The movement of ants is random, so the Brownian motion is used as the basic principle of the simulation. Brownian motion is the random motion of particles suspended in a fluid (a liquid or a gas) resulting from their collision with the quick atoms or molecules in the gas or liquid. However, it has some changes. According to the result of research, ‘each 10% depth increment of the nest contains 25 to 40% less area than the decile above it, no matter what the size of the nest.’ This building is 100 meter depth. From the position of 60 meter, it only has three branches, so the system from 30 meter to 60 meter has 5 branches. From 20 meter to 30 meter has 10 branches. From 10 to 20 meter, it has 16 branches. From 0 to 10 meter, there are 26 branches. So at the start of the simulation, there are 26 particles. And the movements of these particles are random at the X axis from -1.7 to 1.7 and Y axis from -1.7 to 1.7, but only get the negative number at the Z axis which means the ants only move to deeper place. And then getting the polyline are from the motion track.
4.3 Results

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C: Number of particles  R: Number of movements  N: Number of segments of curves
4.4 Finding form
5.1 Drawings

5.1.1 Position and contour
5.1.2 Overview
5.1.3 Plan

Ground floor plan 1:500
5.1.4 Section

Section A 1:800
5.1.5 Elevation

East side 1:500
5.1.6 Living unit plan
5.1.7 Living unit section
5.1.8 Detail

Detail A

- White elastomeric waterproofing finish
- Gypsum render with metallic mesh 8mm
- Fibreglass board insulation 75mm
- Vapour barrier 10mm
- Concrete slab 200mm
- Ceiling in gypsum board panels with white elastomeric finish 15mm

Detail B

- Water proofing sheet 20mm
- Insulation 200mm
- Metal sheet 80mm
- IPE 270mm
- Steel frame
- Plaster board 25mm
- Finish 5mm

- Scree 75mm
- Insulation 150mm
- Concrete at least 400mm
5.1.9 Function

- Service
- Education
- Entertainment
- Health
- Commercial
- Culture
- Office
- Living

Community
5.1.10 Models
5.1.11 Renderings
In this chapter, the conclusion of this design will be summarized depending on the research questions, start idea, design process, design result and design problems.

Undergroundscraper is a new word which is created in this design. It means a building has a lot of floors underground. How to design this kind of building is the original question. The way that ants construct their nests give the inspiration of design. Several videos on the website show the process that how people get a complete ant nest. These demonstrate amazing nest of ants a huge ‘undergroundscraper’ which has a complex system of constructing. Meanwhile, the research on ant nests from three dimensional or even four dimensional side tell people the detailed information.

Emergence, which is a popular topic in a large number of areas, such as philosophy, systems theory, science, and art, is the theoretical foundation of this design. Emergence was just understood for appearance. In nowadays, it is conceived as a process whereby larger entities, patterns, and regularities arise through interactions among smaller or simpler entities that themselves do not exhibit such properties. Ant nest is considered as a complex self-organization which is the solutions to dynamical emergence and also, the appearance of cities is one kind of self-organization. Ant nest and human beings cities both have the systematic characteristics. Simple individual forms a complex system based on simple rules. In architecture, Emergence usually refers to considering the influence on urbanism in architectural design. Morphogenesis is a common used concept which refers to emergence of forms and behavior from the complex system.

Biomimicry is the method applied in this design. Actually, many architects get inspiration from natural world in structure, materials and zero-waste system. For example, the termites’ building use zero-waste construction methods with solar powered air-conditioning and even sustainable agriculture. The Eastgate Center, a shopping center and office block in central Harare, Zimbabwe, which was designed by Mick Pearce, was
just inspired by termite mounds that maintains comfortable condition close to the equator without mechanical cooling.

The ant nest also gives people the solutions to solve architectural problems despite people have many mechanical methods. Ants use pressure and temperature differences to boost the air circulation. When they are constructing, ant can secrete saliva which is really strong with clay for stopping water leakage and structure components. In addition, the ceiling of ant nest is slightly domed to support the pressure of earth.

The form of this design is from ant nest. It also has two main parts, shafts for transportation and chambers for living. Grasshopper, the plug-in for Rhinoceros is used to simulate the movement of ant to get the basic form as the digital tool. The result of grasshopper is only lines in the vertical direction. Some planes are interacting with those lines to get points at the same level. Then, connect all the points at the same level and chose the reasonable geometries as the different rooms. The upper part is the public functions and the lower part is for living unit.

3D printing model is used as the final result to show the relationship between the building and environment.

Despite the design finished, there are still some problems in the design due to the capability of design and computer. Firstly, the simulating is not satisfied. The result of Grasshopper is just the vertical lines. After that, all the processes are manual. Secondly, the concrete structure is only an idea. It still need to research how to realize it. Thirdly, the details of some part are missing. Lastly, sunlight is very important in this design, however, the model is too huge that software could not deal with it.
APPENDICES

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