Digital Computational Design: Towards A Material Culture

Chen Wang¹, Zhiyu Feng¹*
¹ Tongji Architectural Design(Group)co.,Ltd, Shanghai, 200092, China
¹*Shanghai Jiao Tong University, Shanghai, 200240, China
*Corresponding author’s e-mail: 544091292@qq.com

Abstract. The purpose of this study is to explore the relational, complementary and speculative co-existence in the design methods of thinking modes which lie in ‘New Materialism’ and computational design and their influences on architectural design applications, urban design and morphological design. As the properties of materials can give impetus to urban development, urban development can also exert its influences on materials. Similar to the beginning of all construction activities, materials are also related to all fields of design and construction in a direct manner. Taking into account the influences of New Materialism, the author then started to examine the relationship between materiality and digital diagrammatic design again. Being a new type of biomass materials, the bio-plastic is becoming increasingly popular in urban design. The environmental problems brought about by the frequent use of petroleum-based plastic have been solved by bio-plastic successfully. The computational tools can be applied to regenerate urban. Also, the critical media of geometry can launch out a new dialogue between the material and urban design.

1. Introduction
In the recent studies on design, the incorporating of material experiments into design methods serves as the centre. With the developing new material culture, it seems that the design processes and methods endow people patterns of material behavior rather than the subjectivism. The purpose of this study is to explore the relational, complementary and speculative co-existence in the design methods of modes of thinking that rest in ‘New Materialism’ and computational design as proposed by Jane Bennett, and their influences on architectural design applications, urban design and morphological design [1].

This paper aims to prove that the influences of materialism and its “in silicon” simulation in design processes are interrelated to the urban realm. In addition, it attempts to find out the methods used by material behaviours to affect the overall urban articulation. Also, this paper aims to which method can be used to establish new materiality in the field of architecture or urban morphology in accordance with the relationship between New Materialism philosophy, computational design and digital fabrication. To learn about how the material process is used as the generative morphogenetic driver in design, it is of great significance to make explorations on the material-based computational design.

To reach the goals set in this paper, an investigation about the relationship among New Materialism philosophy, computational design and digital fabrication is conducted, and a design process which tries to create a new approach is also launched out, in which a subject, as the major driving force, is applied to solve problems in the anthropocentric world.
2. New Material Culture
In accordance with the image-cultural criticism in the 1960s, digital technology has been criticized at the early stage of its development. People may think that it’s hard to echo with the inner logic of the material world. The emergence of digital tectonics narrows the gap between digital technology and construction culture gradually. In terms of design, the focus of architects gradually changed to material properties from abstract algorithms. The digital technology makes architectural design a helpful method in endowing higher performance to the material shape process. In terms of construction, digital manufacturing technology makes innovations in the construction industry easily to be realized (Fig.1), and the complex geometry of digital design has slight constructability. [2]. (Neil Leach et al.,2004)

The idea of material design thinking plays a great role in digital design. The changes to older concepts make the new vision of the nature of materiality possible. There is a linear causality between the internal relationships between subjects in the old conception causality. Holing a contrary opinion to the Hooke’s law, Manuel Delanda thought that causality is not a simple linear relationship [3]. Essentially, the New Materialism aims to examine the possibilities of construction practice in terms of materiality again, and to find out new possibilities from the perspective of the most fundamental architectural features, including material properties and environmental performance.

Like the beginning of all construction activities, materials have something to do with all fields of design and construction in a direct manner. Generally speaking, structural strategies play a dominant position due to it can decide the material selection and application, making form the first article of production, driving structure and the material. A lot of examples representing this strategy have been proposed by Frank Gehry[4].

Figure 1. Neil Leach ‘Ant Urbanism’, Taipei, 2009.

3. Digital Culture

3.1. The Digital Turn
In accordance with the inner logic of the physical world, digital design was introduced into architecture first. However, the results it made are not welcomed by people due to it lacks feasibility in terms of construction. Considering the correlation between digital design and usage of computational tools, some people think that the essence of digital design on the basis of algorithm can’t demonstrate the real architecture materiality and has nothing to do with the tectonic culture of processes of construction. However, a trend of digital design integration under the influence of the theory of digital tectonic emerged, obscuring the boundary between the abstracted computational process and the material reality. In terms of the Gilles Deleuze philosophy, especially the New Materialism of Manuel Delanda, the digital design of architecture and the traditional thoughts relevant to the ‘image’, being thought an architecture visualization media, are transformed. The first is changed into material-
performance-based formation processes from formal representation or symbolization, and the second is changed into new thinking of the ‘diagram’.

3.2. Digital Culture Revolution

Antoine Picon [5] wrote in ‘Digital Culture in Architecture’ that Picon pursed to challenge the problems in our days. The historical development of the digital culture is established and the relation between the digital culture and the traditional architecture problems is discussed by him in accordance with this historical perspective. Antoine Picon also proved that the primary position in his book of ‘Architecture and the Virtual: Towards a New Materiality’ before[6]. Two development directions which should be eliminated are also proposed by Antoine Picon in one of his later books. The former tendency that should be avoided is that digital architecture should not be worshiped blindly. The latter tendency is that there should be profound considerations of the case. In his opinion, the digital design threatens the primary dimensions of the materiality in some specific fields of construction and construction technology. Although many extreme forms of formalism are indicated by lots of digital works, it seems that computer-dominated design pays no attention to the fabrication and construction of the physical dimensions of the architecture. In addition, he raised a question that whether it is reasonable to take the current situation of computer design as the final criteria in evaluating the gains and losses of digital architecture? The answer is that we must be wary of drawing conclusions from his current character. The current digital architecture demonstrates a situation that the immateriality is impermanent. As a result, we should develop the computer from the perspective of material re-shaping instead of material experience and materiality loss in the following development.

4. Bioplastic As A New Material

The development of digital technology in the information society is a propeller for the combination of urban design with digital skills. Although the forms of digital design for the city bring about new chances in the digital culture, they can also threaten the traditional design tools, design media and design thinking. Essentially, the computational design threatens the work and thinking modes of designers when playing their roles in urban design.

Today, many new materials are being studied by scholars. Apart from providing living skins to our buildings, they can also clean up the environment and even offer food and power for themselves and us. Instead of offering restricted short-term solutions, they run within the wider ecological and economic horizons of the planet.

4.1. Introduction of New Material

Under the influences of the New Materialism, the designers then take into account the relation between materiality and digital diagrammatic design again. The material performance can be regenerated and analyzed with the adoption of the computational tools and the geometry can be applied as a critical media to launch a new dialogue between the material and urban design.

As bio-plastic can solve the environmental problems brought about by the wide use of petroleum-based plastic, it attracts much attention in urban design. The staple, plasticizer and additive can be made into bioplastic. Vinegar and glycerin are used as a plasticizer by starch based bioplastic and glycerin is used as a plasticizer by gelatin based bioplastic.

As shown in Fig.2 and implies by its name, the bio-plastic is a kind of plastic. However, it is derived from renewable biomass sources, including agar, starch and gelatin which are produced from the reusing of food wastes. To some extent, this study gives people a method of metabolizing domestic waste and other organic food waste again. In addition, it can be biodegraded and can be degraded in 6 months after being disposed of. In comparison, it takes at least 200 years for the traditional petroleum-based plastic to be degraded. Besides, being a flexible and mouldable material, its morphology can be affected by influencing the nature of its qualities. A question which hasn’t been paid attention to is raised in this study, that is, whether bioplastic is capable of solving the urban problem on a scale. Aiming to find the optimal answer to this question, the scholars carried out a lot of experiments to
their strength, flexibility and mechanical properties, exploring the material composition and assessing their performance. As a result, the major material in this study is the starch-based plastic which is formed by glycerol and vinegar. Diversified shaping and casting methods are applied to the emergent morphologies. In accordance with the structural capacities of the bio-plastic, this paper analyzes and summarizes the morphological features of bio-plastic which are influenced by temperature, gravity and air force.

Figure 2. Wrinkle pattern shoot by author, 2017

4.2. Properties of Bio-plastic

Essentially, studying the materials is studying their correlations. Through observing and feeling them, the author makes the material world meaningful. As a result, the most fundamental and primary section in this study is to establish complete understandings on the materials.

Although the bioplastic is a kind of new materials, it can also serve as the driving force. The experiments of performance control and digital simulation are conducted and the influential factors of patterns are found out by the author to acquire a better understanding of the properties and performance of the bio-plastic. It can be majorly divided into two interesting material properties.

4.2.1. Wrinkle Pattern

The airflow experiments in which the variables are controlled strictly are carried out by the author so as to assess the performance of bio-plastic and the external forces’ influences on it. Firstly, lots of comparative experiments were carried out to many detachable and adjustable experimental devices generated by the author. All these devices were composed of a main bio-plastic-filled shelf and two hair dryer-filled shelves with adjustable height and two identical hair dryers. The height can be adjusted freely in the combination of these devices. As a result, some variables in them, including wind strength and direction and other variables can be controlled freely.

Then, the whole airflow experiment (Fig.3) is completed by diversified tests, including the tests of wind direction and strength and the influences of different cell lines. Through better controlling of each variable, the author found out their features. The wind direction with two hair dryers undergone lots of comparative experiments, including top wind, side wind, corner wind and diagonal wind. Applying the variations of wind strength, the author also experiments the diversified behaviors with the four-corner wind experiment. Then, weather wrinkle pattern, which can be altered by external factors, is examined by the cotton thread. Under the influences of two diagonal winds, different cells are generated by the threads, including the small square grid, medium square grid, large square grid, contour line and magnet field line.

Figure 3. Wrinkle pattern formation changing experiments, 2017
What is found out in the experiment is that there are patterns along the wind direction in places where the wind blows along. In addition, different features are produced by different parts of bioplastic. For example, on the one hand, the smooth bio-plastic without wrinkled parts are quite tough to be folded at all time, and on the other hand, it doesn’t possess anti-force. The fold will become smaller when the winder becomes greater. The expansion and contraction can bring about wrinkles. Two kinds of force particles are inside the material, including the force particles of pushing and pulling. In addition, different forces are produce tension.

4.2.2. Active Bending

In the above experiments, the basic features of bio-plastic and those factors influencing their behaviors are demonstrated in detail. When carrying out experiments with fibers and trying to convert them into more complex shapes, it is also necessary to examine the effect of external forces or materials on them. Selecting a natural and organic structure material serves as the first step in the whole process. The branches, soft wood, paper board, and cloth rope and other different fibers should be added in order to support the bio-plastic. In addition, the adding of different fibers seems to be a better way to research the changes in their behaviors caused by different fibers. In the first experiment, there are tree stipes on a series of cells; and in the second experiment, the random shape is placed by tree stipes with various density. These two experiments aim to examine how the bioplastic behaviors are affected by the shape and density of the tree stipe.

As shown in Fig.4, the tree stipe is replaced by wood paper and their properties are also examined. Essentially, there are some differences between the wood paper and the tree stipe. It is quite easy for us to control and change the shape of the wood paper including its diameter and length. The line which is vertical to the border is placed by the wood paper in the third experiment. To better test the edge folding, the line used should be parallel to the border and at the same time, it should possess a sharp angle to the border. The fiber material and bioplastic are carried out dyeing test in the fourth experiment. This experiment contributes to getting a better understanding of the composition of the certain features of bioplastic. Ultimately, four horizontal experiments and four vertical experiments underwent the matrix experiments. In addition, control experiments of wind strength and interior structure are carried out by the author one by one.

Figure 4. Active bending experiments, 2017

It is found out that the bioplastic can contract over time as brought about by the tension which is endowed by the fiber to the material and it can also bend itself in the absence of external forces. Also, the application of various fibers makes it shrink with different angles and heights. In addition, the behaviors of bio-plastic are studied and controlled in a better manner with the monitoring of data by the sensor. Moreover, manual work-flow is changed into automatic work-flow and the production of bioplastic components is sped up under the help of a robot.

5. Material Behavior Encoded in Digital Machines

The emergence method of the wrinkle pattern possesses great potential to be studied in the future when the first series of air-flow experiments are observed carefully. Also, the primary starting point is
a careful observation, which is caused by that material information serves as a generative driver instead of an afterthought in design computation.

The reason for the shrinking of the bio-plastic is explained by the physical phenomenon of ‘expansion and contraction’. As mentioned above, the pushing forces and pulling forces which are deduced from the forces can exert their influences on it and changing it into a variable material. In addition, these forces can also be understood as ‘tension’. The ‘tension’ of the material serves as one of the important points in our research, which is like the algorithm we used for simulating the wrinkle pattern. One of the concrete behaviors of the surface wrinkling is simulated by us. Also, the growth or density of the wrinkle can be influenced by the external factors, including points and lines.

Like the method used in the air-blowing experiment, that is, the wrinkle is guided by the thread, it is constrained by the transforming of the ranges of lines. What is interesting is that wrinkle grows in the same direction as the curves and several wrinkle pockets are blocked by the curves. The wrinkle structure becomes more complicated and variable under the influences of these external factors.

The particle spring system means this algorithm. Firstly, a mesh with the same length of the slide should be created. Then, the wrinkles form in the surface should be controlled through the controlling of the edges of the mesh. Next, every vertex should be controlled within a certain volume, close to the original surface. The length can be extended when the points are moved and the wrinkles can be created when the length of the edges is increased. The self-collision component can get rid of the surface to self-intersect through generating a spherical volume around every mesh vertex.

![Figure 5. Digital simulation of wrinkle pattern of different situation, 2017](image)

6. Bio-plastic as a Driven in The Urban Scale

In view of the traditional urban design theory, it is thought that there are many well-organized hierarchies from the macro level to the micro levels, including the area, the community, the road and the architecture. However, the similar self-reproduction of the house can be seen in lots of traditional clusters, resembling the biological reproduction to a large extent. A self-organized formation can better explain the formation that is undergone by that kind of city, demonstrating collective wisdom from the bottom to the up completely. People can get a better understanding of many agents, including objects, creatures and materials, with the help of the computer program, and then they can match the formation of the city morphogenesis better. In a similar method, bio-plastic, being a kind of biological agents, can be set with many parameters and behaviors in digital technology. At the same time, urban morphogenesis can be affected by it.

What we have attempted is to draw lessons from its operation and introduce our bioplastic into the real life of people. In the future, we hope to control the influential factors of bioplastic forms in a more specific manner, producing the phenomenon that wrinkle emerges in different forms of plastic date due to tension. The perspective we use to define the urban again is different from those of before. In terms of tension, we really define the urban rather than defining the streets, buildings or some other things. A material flow (Fig.6&7) is established by us in order to better understand the pushing and
pulling forces. The negative and positive poles, which are representatives of different tension, are applied to link the field lines. Many energy flows, such as nature elements and urban elements, can be transformed into the field lines. Combining with the force of tension, this kind of new language can be applied to narrow the gap between material and urban scale.

Mario Carpo has expounded on the way that digital revolution applied to affect conceptual changes to architecture in his book [7]. That is called ‘digital turn’. To make the same copies, the alphabet and the algorithm and the key practice of modernity is of great significance. It is like the principles for establishing a material system, making the selecting of a prototype and connect unit more important. The prototype of the wrinkle pattern should be researched completely in various urban situations of different societies. As a result, many factors which can influence the emergence of wrinkle are examined (Fig.8), including field lines with various densities, points and the parameters of the wrinkle.

The rules of wrinkle deformation are found by us in the physical experiments. In accordance with the rainfall amount or temperature or input, there are dynamic changes in the wrinkle pattern. During different ages, wrinkle growth or wrinkle deformation can be used to explain the definition of the wrinkle pattern. The similar results acquired from the physical model can be seen from the Deformation tendency (Fig.9). The assumption we get from it is that the wrinkle, with the influences of various external factors, can increase or decrease or biodegrade in a dynamic manner.

![Figure 6. Positive and negative points in London city, 2017](image6)

![Figure 7. Material flow of London city, 2017](image7)

![Figure 8. Wrinkle deformation depends on different material flow, 2017](image8)
The fluctuant city refers to the method of producing conditions which are similar to the city through establishing a new metabolic circuit, which makes use of existing forces, relations and materials. Under that condition, the byproducts of our urban life will not involve organic waste. In fact, it can be the raw material of a new metabolic process when being used in the right manner. The design parts are studied by us in terms of the current human-centered approach and the attitude that makes possible the expression of material process and makes possible the inspirations of alternative and complementary views of the city is also adopted by us. As for those urban that aim to search out new responses ad establish new visions, the relations, encounters and conflicts within them are decided by the wrinkle protocols.

![Figure 9. wrinkle deformation in, 2017](image)

7. Rethink The Urban With Materialism Thinking
When the material and digital computation is combined, they can improve the prospect of the environment. The material properties can promote urban development, while at the same time urban development can give a response to the material. Being a new kind of material, the bioplastic makes the creating of new spatial, formal and social organization possible. (Fig.10)

![Figure 10. A new vision towards urban design and city possibility, 2017](image)

Usually, the urban design modeling adheres to the principles of simplicity, clarity and well-knit, and puts emphasis on order, centers and mechanism. However, the city in nature is a complicated one with multidimensional. The insufficient vitality in the city can be brought about by this mechanical
city modeling method. As a result, what should be considered by us again is the method of harnessing
the city into an energetic, diversified and complicated one with materials.

The concrete feature of raw materials can be the foundation of urban design. It is different from
others due to its solutions indeed take nature rather than the industry as the center. The nature in it
refers to life science instead of conventional construction engineering. Considering the city as a
biological creature with metabolism and resembling it to the forest or an island in nature, it puts
emphasis on recycling materials and energy. As public areas seem to be buffering zones, the
residential buildings have something to do with tribes of living things. By nature, this design aims to
prove that people are part of nature and not independent of nature.

8. Conclusion
The development of computers, the Internet, and the digital age in our lives and urban design can play
their role on us from different directions. Taking its demands into account, we should take time to
learn about and re-examine the boundaries and interaction of non-material and material as well as their
presentation and meaning for the second time. As what has been put forward by Antonie Picon in his
book of Building and the Virtual: Towards a New Materiality?, the digital revolution is indeed a kind
of material revolutions. Under the help of digital technology, many matters can be produced under the
situation that the material is taken as the starting point. Consequently, there will be great changes in
our current understandings of contemporary cities, both from the micro level to the macro level. Firs
of all, traditional digital design processes which are frequently used by scholars for expounding on
operation-oriented methods can be broken through by designers when they studying these materials
from the perspective of sociality and culture. Secondly, the interaction between us and the surrounding
environment can be intensified through participating in the evolution of life material from the
perspective of sociality and culture. Ultimately, it also has the potential to transform those observers
into the co-designers of this process.

The digital technology strategy is applied in this project in order to reorganize city organization
through intervening wrinkle pattern. It also aims to establish a new area through building a multi-
dimensional contact under the help of the medium of behavior tensioning. In this paper, material and
biometric practices adopting top digital design techniques are also expounded on. Essentially, this
paper also puts forward the opinion that our thoughts on contemporary cities can be influenced by the
new thoughts behind it.

References
[1] Bennett, J., Cheah, P., Orlie, M. A., & Grosz, E. (2010). New materialisms: Ontology, agency,
and politics. Duke University Press. Podani, J. (1994) Multivariate Data Analysis in Ecology
and Systematics. SPB Publishing, The Hague.
[2] Leach, N., Turnbull, D., & Williams, C. J. (2004). Digital tectonics. Wiley.
[3] DeLanda, M. (2015). The New Materiality. Architectural Design, 85(5), 16-21.
[4] Andrews, M., Arnell, P., Bickford, T., & Celant, G. (1985). Frank Gehry: buildings and projects.
Rizzoli.
[5] Picon, A. (2004). Architecture and the virtual: towards a new materiality?. Praxis, (6), 114-121.
[6] Picon, A. (2010). Digital culture in architecture. Basel, Switzerland: Birkhauser.
[7] Carpo, Mario. The Alphabet and the Algorithm. The MIT Press, 2011.
[8] Schumacher, P. (2010). The parametricist epoch: Let the style wars begin. The Architects’ Journal,
231(16), 41-45.
[9] Oxman, N. (2010). Material-based design computation (Doctoral dissertation, Massachusetts
Institute of Technology).
[10] Deleuze, G., & Guattari, F. (1988). A thousand plateaus: Capitalism and schizophrenia.