Article

IJAC

International Journal of
Architectural Computing
2017, Vol. 15(2) 134–147

DOI: 10.1177/1478077117714915
journals.sagepub.com/home/jac
SAGE

Macro-scale designs through topological deformations in the built environment

Asli Agirbas and Emel Ardaman

Abstract

Design studies are being done on contemporary master-plans which may be applied in many locations worldwide. Advances in information technology are becoming the base model of design studies, and these may be more effective than the efforts of humans in the field of architecture and urban design. However, urban morphology variables and constants must be considered while designing contemporary master-plans in the existing built environment. The aims of this study were to extend the use of computer software for different applications and to make a topological work in the regional context. Accordingly, a case study was made using the nCloth simulation tools to create non-Euclidean forms while protecting the road system, which is one of the constant parameters of urban morphology in the built environment.

Keywords

Conceptual design, built environment, simulation, contemporary master-plans, urban morphology, topology

Introduction

Mathematics has been used for centuries to develop new ideas, concepts and forms in different cultures around the world and has provided useful resources for architects and designers. The pyramids in Egypt and the decorations in Iran are the mathematical reflections of architecture from history, and in those design methods based on algorithms, such as modern parametric design and generative design, mathematical infrastructure is also apparent.

One of the sub-branches of mathematics is topology, which attracts the attention of designers, and as examples, UNStudio's Möbius House and KOL/MAC's architectural studies on minimal surfaces are all architectural works, based on topology. In topology, the properties of the objects are retained during their deformation, curling and stretching; however, tearing and gluing of objects tends to result in a loss of their topological properties. For example, a circle can be turned into an ellipse by stretching but the object's topological properties remain. Similarly, when a sphere is changed to an ellipsoid, the topological properties of

Mimar Sinan Fine Arts University, Istanbul, Turkey

Corresponding author:
Asli Agirbas, Mimar Sinan Fine Arts University, Meclis-i Mebusan Cad. No:24 Findikli 34427, Istanbul, Turkey.
Email: asliagirbas@gmail.com

the object remain unchanged. The retention of topological properties by this type of deformation is called homeomorphism. As Kantor[1] has noted, in the geometric studies made, prior to the use of virtual animations on the computer, different forms were modelled using plaster or wires. Today, modern visualization techniques, which were developed to be used by Hollywood studios of Lucas Films or by the military, are able to integrate deformations onto the computer screen. Furthermore, virtual visualization of topological deformations of objects provides a source of inspiration to architects.[1]

As Tafuri[2] says, the architecture, represented by the avant-garde concept, shows varieties in the architectural field at different periods throughout the history. However, avant-garde involves the use of new artistic methods and new artistic techniques for making better art production, instead of using classical methods. Therefore, avant-gardists argue that all forms, norms and traditions must be broken, and the values, stable things must be rejected.[3,4] Thus, for a continuous change and development, the rejection of old and long-lasting ones for the sake of new ones became the philosophy of avant-gardists.[5,6] The topology studies in the architecture became producible contemporary designs with the facilities provided by the computer technologies and became a part of the avant-garde architecture of 21st century.

In the previous 10 years, there has been a rapid development of the topological approach in architecture, and while there is no appropriate theory to underpin this, it is clear that topological aims exist both in theory and in practice in architecture. An avant-garde approach in 21th century's architecture is interwoven with scientific and mathematical thinking, and the development of modern geometry and mathematics, perceptual psychology and computer graphics, resulted in a re-shaping of architecture and an evolution of architectural ideas. Those architects who worked on the logic of flexibility and curvilinearity were motivated to understand the concepts of evolution and process. In reality, these concepts are related to the dynamics and are themselves present within the fluid and elastic configuration which today, in architecture, are referred to as the topological architecture. Architectural topology expresses the dynamic variations of the form, which were created by computer-aided technology, computer-aided design and animation programs. In accordance with the dynamic and complex configurations, the topological differentiation of architectural form causes the formation of renovated and striking plasticity in architectural design.[7,8]

According to Sola-Morales,[9] the relationship between new information technology and new architecture forms the basis of avant-garde architecture. In the field of architecture, new information technology and construction techniques cause the architect to become distanced from morphological stereotype theory and practice. Moving away from tradition and destroying the existing norms change the direction of architecture and urban design. With the facilities provided by information technology, the designer not only externalizes his feelings in an aesthetic sense but also is in opposition to the existing architectural formations (making the space functional and efficient in its use, having low ceilings for heat conservation, providing economic sustainability, making those elements such as corridors, elevator shafts, stairs with minimum spaces occupied, etc.) and can break the norms and reject the traditional system. In this way, experimental works are created. This type of experimental work can be implemented from an architectural perspective, but while many modern architects are interested in experimental macro-scale projects, as applied in the urban context, such studies are as yet only theoretical. This is due to the fact that urban contemporary projects occupy large areas and thus contain numerous items. Accordingly, those contemporary projects in the urban context must be handled more carefully, since the projects will be more greatly affected by the greater number of items that are present, and the effect of technological facilities on these items must be assessed. As Tafuri[10] says in his book 'Architecture and Utopia Design and Capitalist Development', the avant-garde movement clearly stated that it is necessary to control new powers, which arose from technology. In this study, unchanging elements in the urban morphology were envisaged as limiting elements in the avant-garde design, with which to achieve this type of control.

After the industrial revolution, fast, easy and economic constructions began with the influence of standardization. Attempts were also made to apply the effect of standardization to macro-scale plans, for example, the Villa Radieuse project by Le Corbusier in 1924. In contrast, as a response to standardization effects, new contemporary master-plan models were created in the 1960s. Groups such as Archigram, Metabolism, Superstudio and architects, which included such figures as Arata Isozaki, Buckminster Fuller and Yona Friedman, developed new ideas about the design of cities. Today, new design tools such as parametric design and generative design, as are used in order to create non-Euclidean forms, can be considered to be an extension of this avant-garde branch, which is becoming increasingly important in the light of new developments in the fabrication sector, for example, 3D printing and robotics, which are becoming widespread and cheaper on the global scale. In addition to this, as in the study of Duarte et al.,[11] new tools can be developed using parametric design and generative design methods for urban design and urban growth.

Archigram, which is an example of the quest of the avant-garde model within urban form, is a neofuturist group of the London-based AA (Architectural Association) and was established in 1960, with the aim to create new realities with hypothesis projects by taking inspiration from technology. Some pioneers of the group are Peter Cook, Ron Herron and Warren Chalk. The group who established a belief in advancing progress to the point achieved by technology, but came into question with those suggestions which comprised the use of the technology as being more rational and progressive.[12–15] The Metabolist Movement which is established by Japanese architects and city planners in 1959 is an architectural trend. Metabolists (Kenzo Tange, Fumihiko Maki, Kiyonori Kikutake and Kisho Kurokawa are among them) have developed innovative ideas related to settlements and cities of the future and have focused on the particular issues attendent to finding solutions to meet the needs of a society which is undergoing economic and technological changes. According to Metabolists, technology changes the distinction between private and public areas and the structure of society is seriously affected.[16–18] Concluding that the traditional methods would not be sufficient for the future of a society and its culture, they focussed instead on requirements of space and functional transformation and thus developed organically growing structures and flexible large-scale designs for a city. For example, in 1951, Metabolist Kisho Kurokawa developed the Helix Urban Project inspired by the (then) newly revealed structure of DNA. The Project, which is based on organic urbanization, contains towers that are connected to each other by bridges, can grow by addition and has repeatable tissue between land and sea. In this period, the other alternative group was Superstudio which is an architectural firm that was founded in 1966 in Florence. The firm constitutes an important aspect of the 1960s radical architecture movement. They proposed projects that differentiate the city by the inclusion of mega objects.[19]

However, the common approach of these groups was to establish a new city or design while ignoring the existing built environment. Although buildings (with the detachment from the existing built environment, no connections with the existing structures) remained as an utopian figure, these projects and illusions have been the source of inspiration for many architects of that period, working on an architectural scale. However, if the projects were considered to be integrated with the built environment, they could no longer be regarded as an utopia.

Contemporary urbanism in built and non-built environment

There are differences between creating a completely new built environment and applying macro-scale designs to the existing built environment. Christopher[20] considers that a city can only be formed slowly and gradually by human activities over time. But, to create a new city (as a city on another planet or as a city in a desert), no consideration is necessary of either a gradual development or aspects of socio-cultural identity. Rather, this may be a deductive process that can be both formed and changed by inhabitants over time. Ramot Polin apartments include non-standard geometrical repetitions that were designed by the Architect Zvi Hecker in the 1970s and can be taken as an example of this deductive process which was issued in Venice Biennale in 2008. The inhabitants of the apartments, who have three to four rectangular bedrooms and a pentagonal kitchen, changed and modified their houses according to their needs or preferred lifestyles. As

De Landa[21] said, transformation in cities will always exist. It is just a matter of time. The regeneration process that exists in the example of the Ramot Polin apartments is actually one of an imbalanced progression between the evolutionary process of technology and the evolutionary process of the human. Since the technology evolves faster than the human does, the changes in his or her environment are the more rapid. On the contrary, technology changes the lives of humans, and so our thoughts and behaviours also change in response to the effect of technology.[22] This interaction will modify both the human and the technology and accordingly the future of architecture and the design of cities. It is a reality that the lifestyles of humans will achieve a different future dimension.

In the process of evolution of the human lifestyle, a transition period of changes will occur in the built environment. During this transition period, new cities will be formed and most of the existing ones will need to be developed further. These developments can be defined as new nodes in the existing city which should be integrated with its existing structure. De Landa[21] defines the system of a city as a ‘meshwork’ which has mutually interconnected nodes. Meshwork is a self-organized system which includes complexity and heterogeneity. The new nodes which may be added to the existing system should be themselves integrated into the system. However, within the present transition period, regional applications are always designed as independent parts of the system, which may create boundaries in a city and may damage the existing meshwork as a consequence of their isolation. Alternatively, such applications of master-plans should be integrated within the existing structure and should be permeable. To create such a permeable, integrated system, we examined the urban morphology components. As the size of the projects increases to a regional or urban scale, different parameters must be included in the design, and the city’s variables and constants must be considered. In this study, we have attempted to integrate road system (which is one of the important elements of urban morphology) within the large-scale contemporary designs as a constant.

A case study with the nCloth simulation in the built environment

Simulations are mostly used for sustainability and energy performance analyses in architecture. However, the form-finding phase in architecture and urbanism is begun via different simulations which are based on biological growth, development and change. Students, academics, architectural groups and companies try to benefit from these simulations in order to create non-Euclidean forms. For example, in the Kartal project of Zaha Hadid Architects, Maya nHair dynamic simulation was used.[23] In addition, the studies under the direction of Gage and Friddle[24] at Yale University, which produce non-Euclidean forms by using nCloth and similar animation techniques, are seen. In such studies, the continuity of the evolutionary form situation in animation and simulation, which Lynn[25] mentioned, is expressed by Oxman and Oxman[26] that it can be seen as a series, created by the features of topology, time and parameters together. In this design approach, overall potential products are formed spontaneously as a result of established rules and the system of relations.

nCloth is one of the dynamic simulations in the Maya software and is actually a feature that is generally used in character modelling. According to Kolarevic,[27] architects have always envisioned beyond their disciplines. Thus, they brought developments from other professions (such as materials, animation, computer and construction science) into the world of architecture and in so doing, contributed to the developments of design and applications. Today, in architecture and urban design, many simulations are generally used for performance analysis, but have only just begun to enter the form-finding stage. In this study, the study was carried out on the use of the simulation with nCloth specificity for the form-finding process in the design. One of the advantages provided by new computer technologies is the creation of many design alternatives that the designers can choose from.[28,29] In the conceptual design stage, the designer actually performs digital sketches in the form-finding process by using the alternatives brought by the computers. At this stage, the designer, as in the process of traditional sketching, revises his ideas or discovers new relations, which can be used to develop the ideas.[30–34]

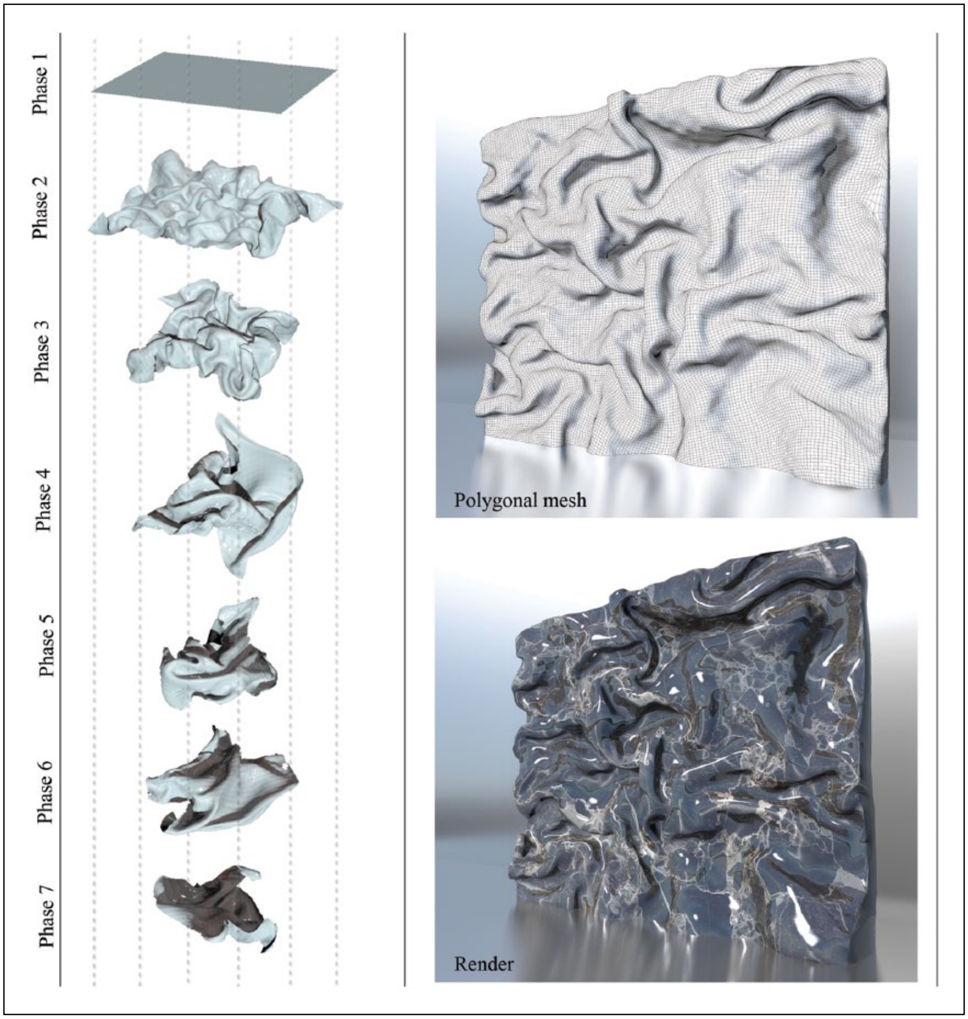

Figure 1. Topological deformation of nCloth.

Before beginning work on the macro-scale, studies were first made on the architectural scale. The design of the project (Figure 1) was developed by the author, using topological nCloth simulation. In the process of forming a mass of marble, we distanced ourselves from the standard geometry and instead explored curvilinear elements as a means to differentiate the form. Using nCloth simulation, topologically different formations (homeomorphics) of a plane were obtained. In the nCloth simulation, one of the developed forms, which is suitable for the mass, in terms of width, height and depth, was selected with the intention to assume this form on one surface of the mass.

In the other experimental study, nCloth collision was used (Figure 2). The collision affects the form of the polygonal plane of nCloth, and the same effect can be observed in the form change that such a collision causes in nature. However, unlike the natural creation of form, nCloth simulation allows us to observe how the forms occur in different frames by stopping the simulation at any chosen time. In this study, the simulation was stopped at different frames throughout the simulation process and the changes and transformations

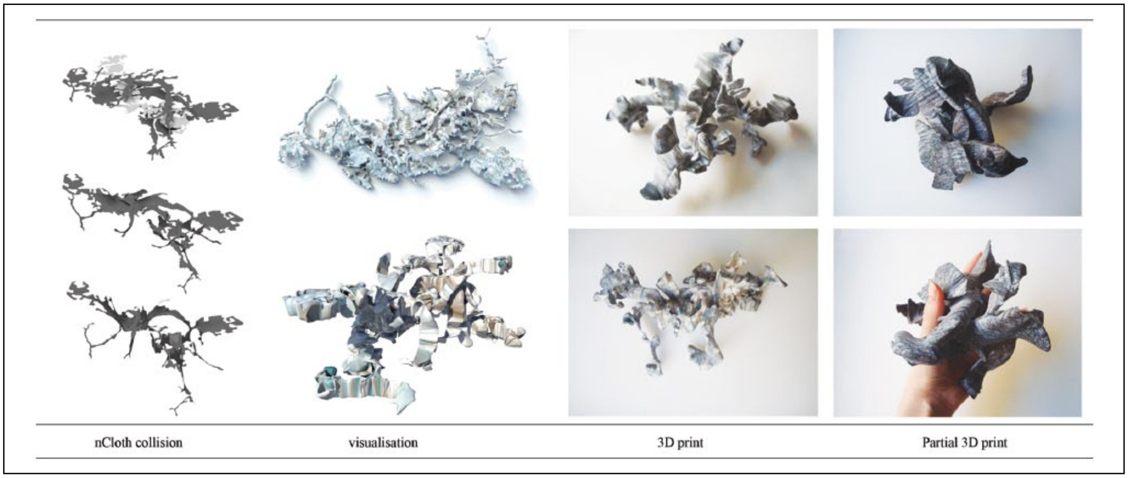

Figure 2. The 3D prints of nCloth collision.

of the formal topological morphogenesis were observed. By the collision of three amorphous planes using two nuclei (in other words, using nCloth collision pairs), with the effect of given gravitational parameters, forms were obtained which were apart from the standard geometry and showed topological deformation. One of the emergent forms in this collision was selected and found appropriate to transfer from the virtual to the real medium. First, a model of the collision was obtained using a 3D printer, and then one part of the model was selected and a large-scale version of a partial model was obtained again by 3D printing. While working with emergent forms, the designer can conceive new ideas about how the form can be applied to architecture.

Urban morphology, which is an area of research on the analysis of physical forms of the cities, deals with the analysis of formation and transformation of the urban tissues. Morphologists are in agreement with their investigations of the city over the years that it was formed along with its later conversions. Buildings, gardens, roads, parks and monuments are among the morphological elements and are related to each other. These elements change and transform over time.[35–38] Urban morphogenesis was developed by the studies of M.R.G. Conzen, who, in his urban tissue transformation studies, examined the regions by means of their historical development process. In these studies, he took three basic elements – street pattern, street-plot pattern and building fabric – as the basis for the urban tissue.

We chose to preserve the road system of the existing built environment as a critical parameter, since Conzen defines the road system as the least variable element of the urban morphology. This author has concluded that changes in the road system can only take place after the kind of destruction caused by a war, by natural disasters or by an extensive renovation. Already, when we look at today's ancient cities, we see unaltered main arteries of road system. Although street-plot pattern is permanent, as time progresses, a change of the plots may occur, and in the longer run, these plots may be combined or divided.[39–42] With this in mind, those road systems with different typologies have been selected and held constant, while we have attempted to develop a contemporary draft master-plan using nCloth dynamic simulation software, which contains evolutionary design logic.

In our experimental study, nCloth objects are differentiated through the topological changes of a planar object. Thus, a road system involves the differentiation of the plane, where the plane deforms according to a fixed route system. In the simulation process, each frame is homeomorphic to one other (as a sphere becomes an ellipsoid). This topological formation can be achieved by creating polygonal geometry in Maya. Thus,

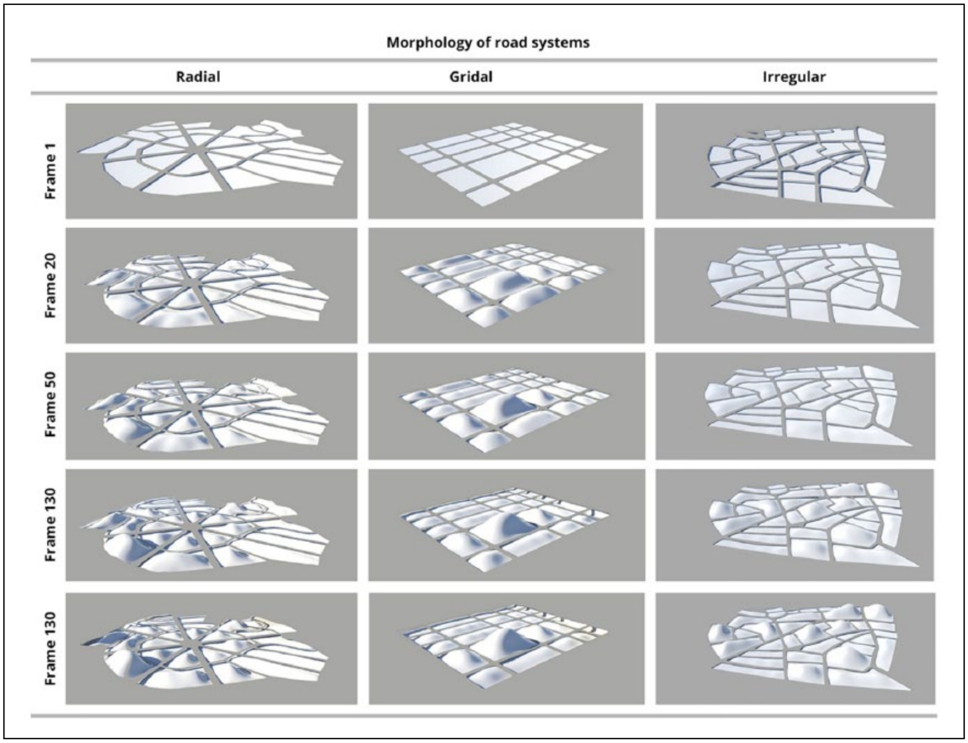

Figure 3. Different types of urban morphological tissues and different nCloth formation results.

each vertex on the polygonal plane is present in every frame throughout the simulation process. A new vertex cannot be added to the object in nCloth simulation, and this allows us to make a topological deformation in nCloth.

First, a flat polygonal plane was chosen (polygonal plane size: 25 cm, horizontal subdivisions: 40, vertical subdivisions: 40 and presets: WaterBalloon) and the evolution of its form was observed in different frames in a particular atmosphere. Then, certain nCloth parameters were determined and a collision was created, in which the nCloth plane was collided with a road system that is determined as a constraint. In this case, the formation of the nCloth plane simulation continued with the influence of the constraints and different formations were derived. The same collision simulation was applied to different types of urban morphological tissues and different formation results were obtained (Figure 3).

With the nCloth, which is a dynamic simulation, a search for form-finding has been carried out while developing a contemporary macro-scale concept phase design study. In this process, Conzen's urban morphology theories have been taken as principles, and the city's road system has been considered to be protected. Therefore, the road tissue was added as a limiting parameter to the search for form-finding via simulation. The results of the nCloth simulation (preset: honey) study on organic (irregular), grid-shaped and radial (as three different types of road morphology) have been found to be different from each other. The growth of Y axis (height) of parcels and building blocks was observed to be proportional to the size of the parcels and building blocks. This study is an indication that the parameters to be protected, or that their protection concerning the city is desired, could be included in the search for form-finding in the design process.

In the experimental study, a gridal road system has been added to the dynamic simulation as a constant (Figure 4). The first simulation of nCloth (with 'honey' preset) growth on the Y axis, which is shown in

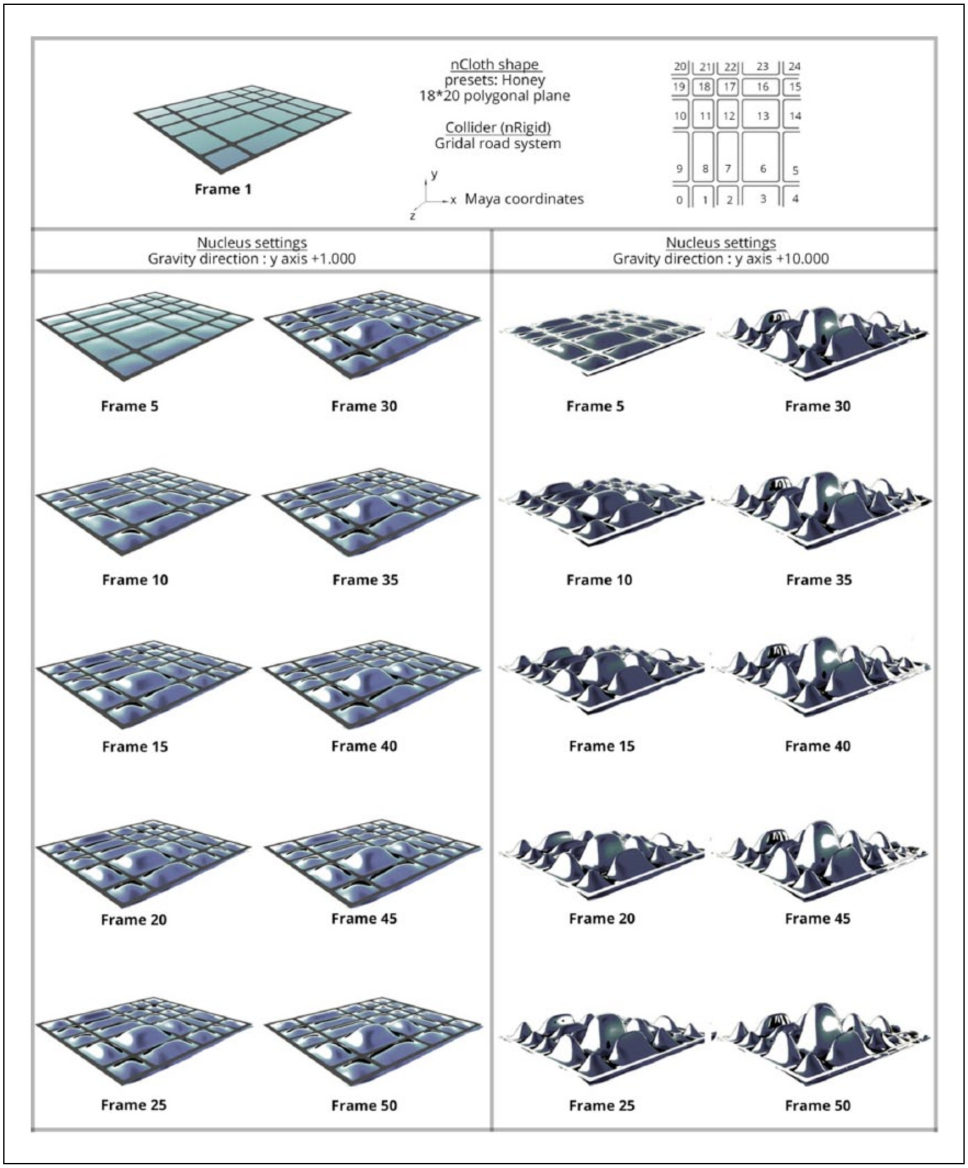

Figure 4. The ratios of increase in building blocks at 'honey' presets at Gravities: +1000 and + 10,000 in the gridal road system morphology.

detail with the intervals of five frames (Figure 4), has been carried out with the Gravity: +1000 (gravitational force: +1000). Hence, a gravitational force has been applied in the opposite direction of the normal gravitational force of the Earth, and so the growths in the nCloth object are observed to form a volume on the Y axis (in the other 3D programs, the vertical axis is generally specified as Z, but in Maya software, it is specified as Y). In order to make detailed measurements of the values of these growths on the Y axis, a script has been written in Grasshopper which is a plug-in of the Rhino program. For the application of this script, building blocks in the gridal urban morphology are numbered. After the determination of the highest

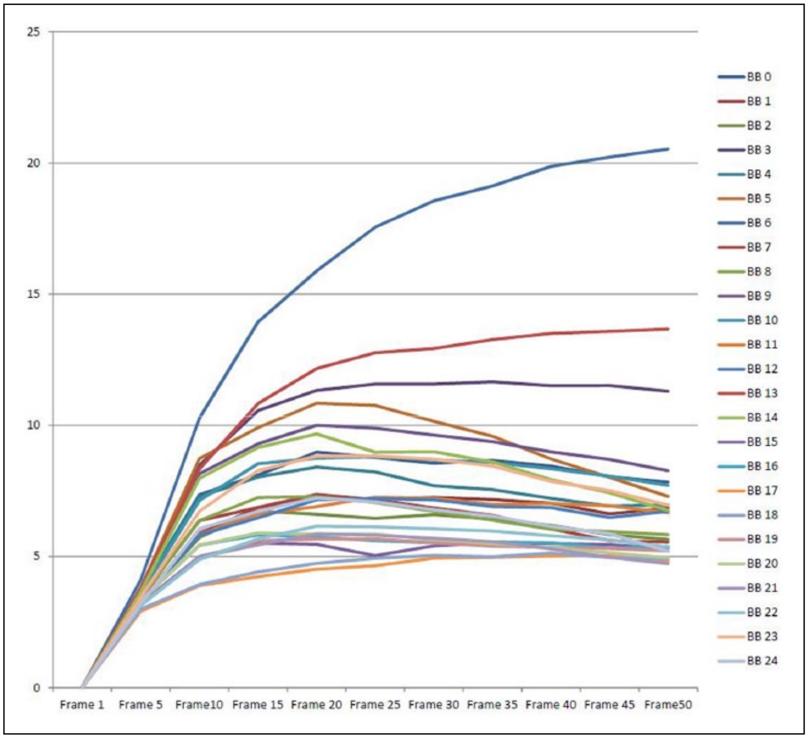

Figure 5. The ratio of increase in building blocks at 'honey' presets at Gravity: + 1000.
BB: building block.

peaks of the forms, as occurred in each fifth frame, the peak points have been defined in the Grasshopper script. In Grasshopper, the projections of these points in the ground plane were determined, and then the distance between the projection points and the points were measured in each five-frame interval. In the measurements from Frame 1 to Frame 50, a rapid and accelerated rise (5–10 m) was observed from Frame 1 to Frame 10, which then continued to increase up to Frame 15. After the frame 15, the increases continued in some building blocks with a reduced acceleration. In the others, it can be seen that the increases begin to fall, but this decline ceases after the frame 45. In the graphic (Figure 5), a fixed rise and very little decline can be observed.

In the other experimental study (Figure 4), the same simulation is made by increasing gravity settings. Gravity settings in the Y axis were extended to the value of +10,000 (gravitational force: +10,000). In the measurements from Frame 1 to Frame 50 of this simulation, a rapid rise from Frame 1 to Frame 10 (10–20 m) occurred, and then continued up to Frame 50, but only a very small acceleration was observed (Figure 6). Between Frame 40 and Frame 50, the rise in some building blocks decreased by very small amounts. This situation was considered to be related to the overflow of the nCloth object from the specified limits after a period of time. Thus, even though the size of building blocks may be the same or very similar, the nCloth increase shows a variation for each building block.

When two graphics are compared, it can be seen that the rise of the form at Gravity: +1000 setting is maximum about 20 m and the rise of the form at Gravity: +10,000 setting is about 60 m. In the graphics, the increase in Gravity: +10,000 setting is more proportional and close to linear, and at Gravity: +1000, more variation is apparent. Furthermore, significant differences in the formal formation have been observed. At

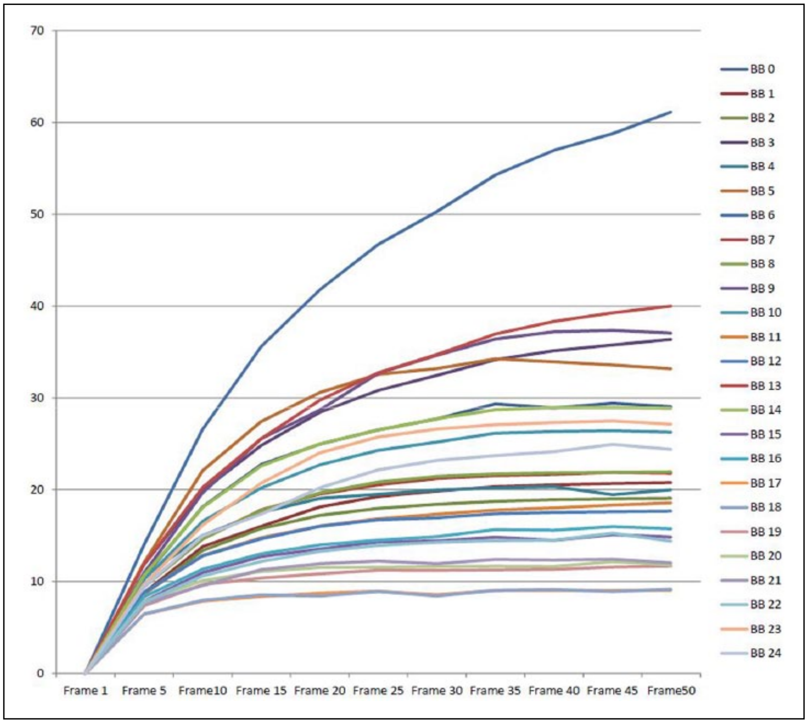

Figure 6. The ratio of increase in building blocks at 'honey' presets at Gravity: +10,000.
BB: building block.

Gravity: +1000 setting, the increases in simulation reveal more bubble-type structure and indicate that the form undergoes changes based on volume and size. However, in the simulation made using the Gravity: +10,000 setting, after a certain time interval, each form is found to differentiate in each of the building blocks along with the differentiation of size and volume, whereupon the unique form formations occur.

In the 'WaterVolume' presets, the formal formations made using another set of nCloth simulations (which employed the Gravity: +10,000 setting) appear to be very different from the previous experimental studies (Figure 7). In simulations which were made previously with 'Honey' presets, a more proportional and linear formal growth was observed. However, the formal formation using 'WaterVolume' presets appears to be more random. This may be observed more clearly seen from the results of the ascension measurements. Severe growth is observed until Frame 10, following which an accelerated decline is observed (Figure 8).

After the continued decline out to Frame 25, an accelerated rise occurs in many building blocks up to Frame 40, but less steeply than the initial increase. In some building blocks, decline also continues after Frame 25. However, in addition to the ascension of the form formation with its variations, the forms (after reaching a certain height) create the lateral growth which is an important point of form formation. This is because the occurrence of the lateral growth differentiates and individuates the forms.

Conclusion

Currently, animation and simulation software are frequently included in the development and updating of computer programs, which confer benefits to design, architecture, interior design, game and industrial product design areas. Across the world, many architectural companies closely follow these innovations and adapt

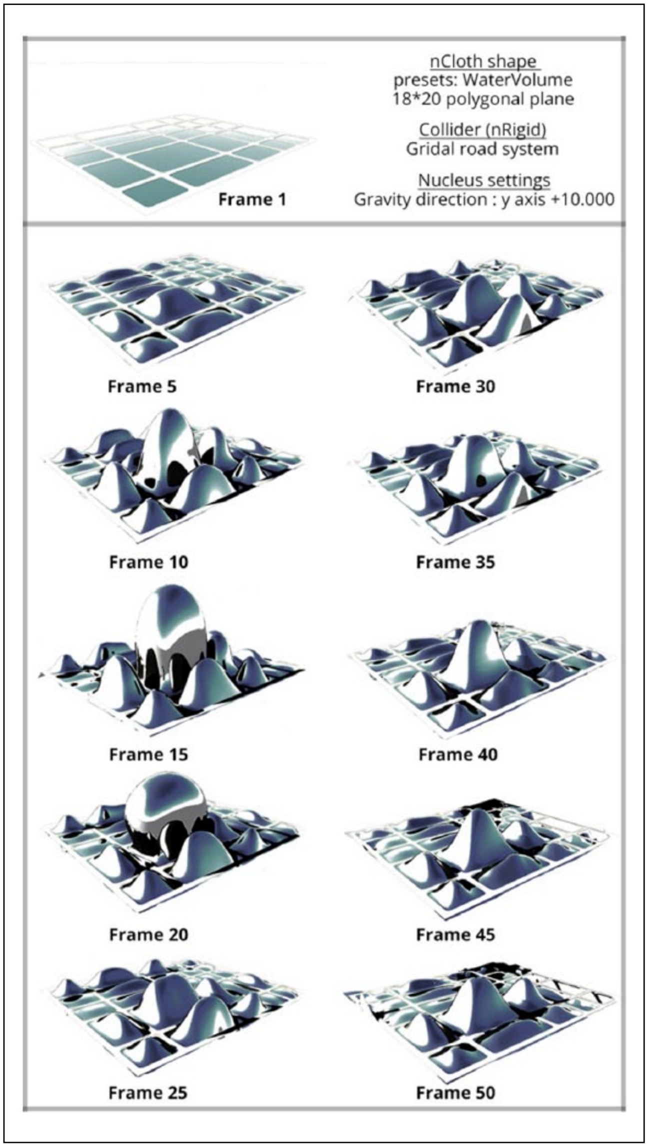

Figure 7. The ratios of increase in building blocks at 'WaterVolume' presets at Gravity: + 10,000 in the gridal road system morphology.

their designs. It is the case that simulations that are related to building performance are added to computer-aided design programs and are commonly used to make sustainability and energy performance analyses. In addition, different simulations, which are based on topological development and change, have begun to be used as a tool for form-finding.

In this study, urban morphology theory has been proposed as a restrictive element for contemporary macro-scale designs to be created in the built environment. We have added a constraint element as a restrictive parameter in the nCloth topological dynamic simulation. This constraint element was determined as a

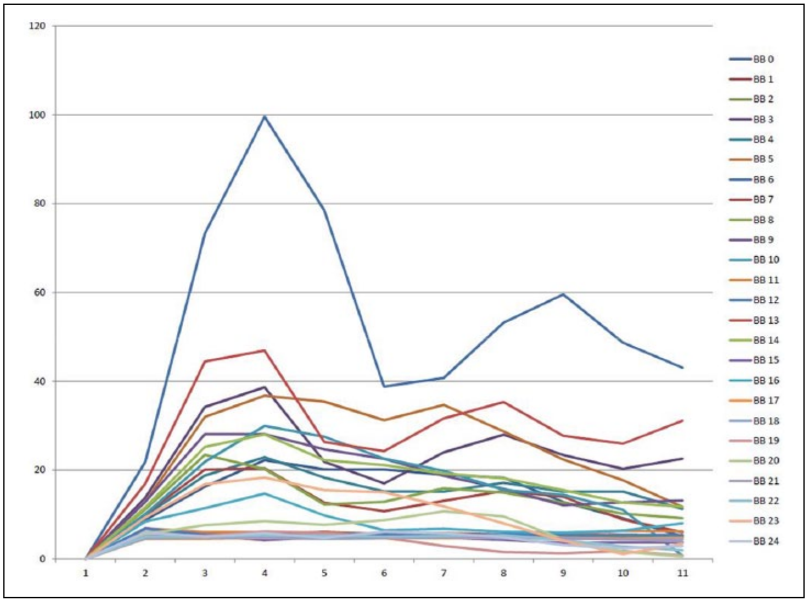

Figure 8. The ratio of increase in building blocks at 'WaterVolume' presets at Gravity: + 10,000.
BB: building block.

road system, which is accepted as unchangeable or least changing in the urban morphology. Accordingly, a conceptual design experiment for contemporary macro-scale designs has been done while maintaining the road system (which is considered as the main artery of the city) as a constant. With this kind of design thinking, contemporary macro-scale designs can be connected in an integrated manner to the built environment and can be included within the meshwork without creating borders.

As can be seen from the results of our experimental studies, when the road system is kept constant, non-Euclidean forms that differ from one other can also emerge, while additionally, different results can be obtained when different parameters are employed. The basic principle of avant-garde, which has the theme of being both the precursor and the new, can be achieved by using a constant element. In future studies, in addition to the road tissue constant of Conzen,[40] Panerai et al.'s[37] and Morris'[43] threshold and topography constants, and Caniggia and Maffei's[36] special buildings constant can all be included in topological simulation studies of this kind.

Every formal formation in this conceptual design process which extends from the whole to individual parts, and represents movement with inverse perspective to the theme of the 'form following the function' principle of Modernism, can contribute alternative dimensions to the designer's ideas: each form forces the designers to rethink their designs. The designer begins to investigate the stages of the conversion of the form to the structure and considers the functional possibilities. At this stage, which may be described as the sketching stage or concept design stage, the use of dynamic simulations as we have exemplified above can be defined as a guiding element of the designer for the definition of the building or building block with their general outlines.

The forms (in this study, through nCloth collision) can be considered to be the designer's sketchbook or digital sketches. Contrarily, in the conceptual design stage of conventional methods, an architect or designer uses, first, pencil to reflect his or her ideas on paper. The forms improve the designer's ideas from the initial paper version. Although both methods may seem to be useful tools with which to develop ideas, there is a significant difference between them, namely, that the computer is a means for the formation of the forms. The designer who produces sketches on paper develops his or her ideas by himself or herself, but when a computer is employed by a designer, it plays a significant contributory role in producing forms and in the development of his or her ideas.

Computers have a number of advantages: since many different topological formations that cannot be drawn using a pencil can be created by a computer. Even invisible topological formations, such as occur in nature, can be seen in computer simulations. However, in the computational design, the effectiveness of the designer in the designing process decreases. Thus, the programmatic control of new powers of technology is necessary. Therefore, for new construction forms to be controlled, some parameters need to be considered. In this study, invariable elements of urban morphology were used to provide this type of control. It is possible that in future contemporary urban formations (only in a formal sense), by this means, designs might be created which can integrate with the existing urban pattern, do not form urban boundaries and do not disturb the gradual formation of urban characteristics.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship and/or publication of this article.

References

1. Kantor JM. A tale of bridges: topology and architecture. *Nexus Netw J* 2005; 7(2): 13–21.
2. Tafuri M. Toward a critique of architectural ideology. In: Hays M (ed.) *Architecture theory since 1968*. Cambridge, MA: MIT Press, 1969, pp. 2–36.
3. Heynen H. What belongs to architecture?' Avant-garde ideas in the modern movement. *J Architecture* 1999; 4(2): 129–147.
4. Calinescu M. *Five faces of modernity: modernism, avant-garde, decadence, kitsch, postmodernism*. Durham, NC: Duke University Press, 1987.
5. Bürger P. *Theory of the avant-garde*. Minneapolis, MN: University of Minnesota Press, 1984.
6. Heynen H. *Architecture and modernity*. Cambridge, MA: MIT Press, 1999.
7. Di Cristina G. *Architecture and science*. Chichester: Wiley-Academy, 2001.
8. Emmer M. Mathland: the role of mathematics in virtual architecture. *Nexus Netw J* 2005; 7(2): 73–88.
9. Sola-Morales I. *Differences: topographies of contemporary architecture*. Cambridge, MA: MIT Press, 1999.
10. Tafuri M. *Architecture and utopia: design and capitalist development*. Cambridge, MA: MIT Press, 1976.
11. Duarte JS, Ducla-Soares G, Caldas LG, et al. An urban grammar for the medina of Marrakech: towards a tool for urban design in Islamic contexts. In: Riitahuhta A (ed.) *Design computing and cognition'06*. Dordrecht: Springer, 2006, pp. 483–502.
12. Walters D. The architect as superhero: archigram and text of serious comics. *Architonic* 1994; 3(2).
13. Cook P. *Archigram*. New York: Princeton Architectural Press, 1999.
14. Sadler S. The brutal birth of archigram. In: Harwood E and Powers A (eds) *Twentieth Century Architecture 6*. London: The Sixties, life, style, architecture, 2002, pp. 120–128.
15. Sadler S. *Archigram: architecture without architecture*. Cambridge, MA: MIT Press, 2005.
16. Kurokawa K. *Metabolism in architecture*. Boulder, CO: Westview Press, 1977.
17. Tafuri M and Dal Co F. *Modern architecture*. New York: H.N. Abrams, 1979.
18. Koolhaas R and Obrist HU. *Project Japan metabolism talks*. London: Taschen, 2011.
19. Lang P and Menking W. *Superstudio: life without objects*. Milan: Skira, 2003.
20. Christopher A, Ishikawa S and Silverstein M. *A pattern language: towns, buildings, construction*. New York: Oxford University Press, 1977.

21. De Landa M. *A thousand years of nonlinear history* (Swerve editions). New York: Zone Books, 2000.
22. Ingraham C. Post-animal life. In:Harrison AL (ed.) *Architectural theories of the environment: posthuman territory*. New York: Routledge, 2013, pp. 44–52.
23. Schumacher P. Parametricism: a new global style for architecture and urban design. *Archit Design* 2009; 79(4): 14–23.
24. Gage MF and Friddle T. *Disheveled geometries: the digital stone project*. New Haven, CT: Yale School of Architecture, 2013.
25. Lynn G. *Animate form*. New York: Princeton Architectural Press, 1999.
26. Oxman R and Oxman R. *Theories of the digital in architecture*. London; New York: Routledge, 2014.
27. Kolarevic B. *Architecture in the digital age: design and manufacturing*. London: Spon Press, 2003.
28. De Landa M. Deleuze and the use of genetic algorithms in architecture. In: Leach N (ed.) *Designing for a digital world*. London: Wiley-Academy, 2002, pp. 117–120.
29. Jabi W. *Parametric design for architecture*. London: Laurence King Publishing, 2013.
30. Schon DA. *The reflective practitioner: how professionals think in action*. New York: Basic Books, 1983.
31. Schon DA and Wiggins G. Kinds of seeing and their functions in designing. *Des Stud* 1992; 13(2): 135–156.
32. Garner S. The undervalued role of drawing in design. In: Thistlewood D (ed.) *Drawing research and development*. London: Longman, 1992, pp. 98–109.
33. Goel V. *Sketches of thought*. Cambridge, MA: MIT Press, 1995.
34. Suwa M and Tversky B. What architects see in their sketches: implications for design tools. In: *Proceedings of CHI'96*, Vancouver, BC, Canada, 13–18 April 1996, pp. 191–192. New York: ACM.
35. Moudon AV. Urban morphology as an emerging interdisciplinary field. *Urban Morphol* 1997; 1: 3–10.
36. Caniggia G and Maffei GL. *Architectural composition and building typology: interpreting basic building*. Firenze: Alinea Editrice, 2001.
37. Panerai P, Castex J, Depaule JC, et al. *Urban forms: the death and life of the urban block*. Oxford: Architectural Press, 2004.
38. Knox P and Pinch S. *Urban social geography: an introduction*. Essex: Pearson Education Ltd, 2006.
39. Whitehand JWR. Background to the urban morphogenetic tradition. In: Whitehand JWR (ed.) *The urban landscape: historical development and management* (Papers by MRG Conzen). Toronto, ON, Canada: Academic Press, 1981, pp. 1–24.
40. Conzen MRG. *Thinking about urban form: papers on urban morphology, 1932–1998*. Bern: Peter Lang, 2004.
41. Petruccioli A. *After amnesia: learning from the Islamic Mediterranean urban fabric*. Bari: ICAR, 2007.
42. Samuels I. Classics in human geography revisited, Conzen, M.R.G. 1960: *Alnwick, Northumberland: a study in town-plan analysis*. Institute of British Geographers Publication 27. London: George Philip. Commentary no 2. *Prog Hum Geog* 2009; 33(6): 859–864.
43. Morris AEJ. *History of urban form before the industrial revolution*. Harlow: Longman Scientific & Technical, 1994.