Making sense of those batteries and wires

Parametric design between emergence and autonomy

Sherif M. Abdelmohsen and Passaint M. Massoud

The American University in Cairo
{sherifmorad, drpassaint}@aucegypt.edu

Abstract. This paper reports on the process and outcomes of a digital design studio that integrates parametric design and generative systems in architectural and urban design projects. It explores the interrelationship between the emergence of innovative formal representations using parametric design systems on the one hand, and design autonomy; more specifically the conscious process of generating and developing an architectural concept, on the other. Groups of undergraduate students working on an architectural project are asked to identify a specific conceptual parti that addresses an aspect of architectural quality, define strategies that satisfy those aspects, and computational methodologies to implement those strategies, such as rule-based systems, self-organization systems, and genetic algorithms. The paper describes the educational approach and studio outcomes, discusses implications for CAAD education and curricula, and addresses issues to be considered for parametric and generative software development.

Keywords: Parametric modeling, generative design, emergence, autonomy, design exploration, CAAD curriculum.

1 Introduction

The adoption of parametric modeling in CAAD education is becoming increasingly prevalent. With parametric modeling software tools emerging, comes the low-hanging fruit of intuitive manipulation of parametric relations, and capture and evaluation of design information and geometry. Such capabilities have mostly aligned with researchers' goals in transforming traditional design studio from focusing on representational aspects of design into an information-centric process that embraces conceptual thinking and intuitive design exploration [1-2].

Young graduates are now carrying significant technological innovation into practice that moves beyond graphical representation into technical aspects of building performance and constructability [3-4]. One of the challenges however in implementing such transformation at the undergraduate level in CAAD education involves the students falling into the trap of tool thinking rather than comprehensive ways of thinking that extend to incorporate design, process and production [5-7].

Gabriela Celani, David M. Sperling and Juarez M.S. Franco (Eds.): The Next City: 16th International Conference CAAD Futures 2015, pp. 279-296, 2015.

This paper addresses the following questions: Does the ability to computationally visualize complex morphological representations guarantee an in-depth understanding of the essence of architectural ideation and concept generation? In CAAD education, especially that involves concepts of parametric design and digital morphogenesis, does a dichotomy exist between the emergence of innovative formal representations on the one hand and the conscious process of generating and developing an architectural concept on the other? If so, is such a dichotomy reconcilable, and how?

More rigorous foundations for CAAD education have long been called for in academia, where the principal issue is not of mere technology, but rather one of architecture and design principles [8]. In this context, how can design studio then foster advanced digital design thinking methods without compromising conscious design decision making? Can designers implement parametric and algorithmic design methods while still maintaining "control" of their emergent designs? In order to attempt at responding to these inquiries, this research explores the process of form generation and concept development, between emergence and design exploration, in the context of a digital design studio.

One of the major challenges in "digital" design studios is the gap that exists between presenting the fundamentals of architectural design using digital media on the one hand, and providing the digital toolset, skills and techniques necessary for implementing those fundamentals on the other [9]. Some studies highlight the problems arising from this gap, where students fail to fully capitalize on the digital skills acquired during a given semester in actual design exploration till very late in the process, often not really coming to fruition and full maturity until subsequent semesters, therefore presenting challenges in terms of knowledge acquisition and application [10]. More recently, parametric and generative design systems have been viewed as much more valuable than mere "tools", but as complementary processes to design conceptualization, thinking, development and production in architecture [11], where both formal *and* conceptual approaches are assumed to develop concurrently into emergent designs and innovations.

This paper goes further into exploring closely the process of cultivating intangible concepts, understandings and meanings into tangible formal representations in parametric and generative design tools. Groups of students working on designing an exposition center are asked to explicitly identify a specific conceptual parti that relates to an aspect of architectural quality (such as expressing motion, flow, growth, coarseness, abundance, complexity, etc.). They are required to define strategies that satisfy those aspects, and computational methodologies to implement those strategies (such as rule-based systems, self-organization systems, genetic algorithms, etc.). Then they are required to implement the basic procedures in Rhino's graphical algorithm editor; Grasshopper, to achieve those methodologies and strategies.

The following sections explicate the theoretical framework that drives this research, followed by a brief description of an architectural design studio focusing on parametric and generative design. The paper discusses the main observations pertaining to design exploration, emergence and autonomy, and presents a detailed observation and discussion for two of the student projects. Finally, the affordances and limitations of parametric and generative systems as exploratory tools are discussed, with specific focus on their role in CAAD education, and on future opportunities for software tool development.

2 Between Emergence and Autonomy

Traditionally, the shift of CAAD from solely aiding drafting, increasing efficiency and representing geometry to generative and parametric methods that embody “the representation and use of knowledge to support or carry the synthesis of designs” [12] has widely contributed to expanding possibilities of design exploration, both formally and conceptually. Visual parametric modeling tools and graphical algorithm editors such as Grasshopper have added another dimension, whereby conceptual and visual explorations precede – to some extent – intense computational and programming proficiency, therefore assuming wider acceptance in the architectural design community.

According to Neil Leach, the *logic* of a design is more at stake in generative design systems rather than the designed artifact or product itself [13]. This notion is further augmented by Dino, where generative systems are said to encode the making of artifacts or procedures in the design process through higher-level specifications, where *form* follows *formation*, therefore allowing for an expanded design search and exploration space [14].

An important caveat here is what the nature of generative and parametric systems implies in terms of *emergence* and *autonomy*. Within the dynamic mechanism of assigning rules, constraints, parameters, and generative procedures, an implicit process takes place that addresses this presumed dichotomy. On one hand, designers experience much more than conventional problem solving procedures, but are rather granted diverse routes of inquiry and probing of the design problem and solution possibilities. In a more complex and richer problem and solution space, they produce and are challenged with consequences of their limitless and unforeseen solutions in a way that is very different from their original intent, planning and design strategy.

On the other hand, the autonomy of the generative system and that of the designer are both questioned. According to Peter Eisenman, autonomy should be given to the architectural object itself or more precisely its becoming, rather than its discipline or the designer involved in its becoming [15]. Watanabe argues that autonomy (which he coins ‘autonomy of process’) is more of a way for unraveling novel architectural solutions without being bound by the mind [16]. Dino describes the notion of autonomy – specifically in relation to the use of generative design systems in architecture – as one that exhibits a certain level of system autonomy besides the autonomy of the designer [14]. In this context, the system does not fully supersede the human designer, but some design tasks and intelligence are passed on from the designer – or more accurately externalized and programmed – into the system. It is this delegation of activities that steers the inherent relation between the conscious process of developing an architectural concept and the emergence of innovative formal representations.

The consequences of this recent perspective on autonomy of process are twofold: (1) it shows how objective processes (related to scientific methods and systematic procedures, relations and rules) and subjective processes (related to best judgment and domain-specific knowledge of designers) can be explained, and (2) it suggests the level by which architects and designers can or cannot maintain control over their designs using generative and parametric design systems, and more significantly the implied design intent.

In an educational setting, and specifically CAAD education, this perspective is significantly relevant, as the conscious act of design*ing* and maintaining control of design actions based on domain-specific knowledge need to guide or *tame* the often irrational and groundless nature of emergent solutions resulting from novice paths of exploration with parametric and generative design systems. The paper introduces in the next sections the process and outcomes of an architectural design studio that implements parametric and generative design methods.

3 Design Studio Outline and Process

This architectural design studio was one of the required studios of the undergraduate program at the Department of Construction and Architectural Engineering at the American University in Cairo (AUC), Cairo, Egypt. 18 students were enrolled in this studio, under the supervision of two instructors and one teaching assistant. The studio ran once a week for 14 weeks during the period from September to December 2014.

The aim of this studio was to explore the full potential of computation, parametric modeling, algorithms and generative systems in architectural design. Students were free to explore and build on an extensible palette of parametric modeling, scripting, and analysis tools during their experimentation with form generation, evaluation and optimization methods, in order to investigate the potentials of digital design beyond preconceived notions and crossing conventional boundaries of form generation.

The project that the students worked on was an exposition center in the heart of the city of Cairo. Its components consisted of a hotel (500 rooms), an office building tower (20 stories with a multi-storey area of 10000-17000 m2), a conference center, including 3 main halls to accommodate 800-1000 persons each and 10 small halls to accommodate 300 persons, a shopping center including a mega store and 120 small shopping stores, and an exhibition area.

The studio was mainly divided into two parts: (1) group work and master plan, and (2) individual work and design development. In part (1), the main focus was on the relation between architectural function, structure and material properties, in discovering alternate methods of form generation. The students, divided into four groups, were evaluated based on their development of 3D models of the exposition center using parametric and generative design tools, in addition to addressing site conditions and constraints, and satisfying the identified performance criteria.

In this stage, the students worked to develop a masterplan collectively, focusing on utilizing parametric design methods at the urban design level. Each group was advised to formulate a conceptual idea pertaining to an aspect of architectural quality, such as expressing motion, flow, growth, coarseness, abundance, complexity, and so on. The goal was to guide the students consciously through a conceptual rather than a purely formalistic approach to achieve their designs. They were advised to carry on these ideas throughout their individual work as well.

In addition, each group conducted research on generative and parametric design strategies, and was required to define strategies for their group projects that satisfied the formulated conceptual structures. They were then asked to develop computational methodologies to implement those strategies, such as rule-based systems, self-organization systems, genetic algorithms, computational geometry, and so on, based on their specific approaches. Finally the students were required to implement the basic procedures in Grasshopper to achieve those methodologies and strategies. The goal was to let the students utilize parametric design skills and techniques early in the process, especially alongside the concept generation phase.

In part (2), the students had to use parametric and generative design techniques to reinterpret their initial ideas and approaches into a more comprehensive building design exercise. The students worked individually in order to realize their individual components, and were encouraged to reflect on their group work back and forth. They were encouraged to develop models involving evaluation methods and using simulation and analysis tools regarding a topic of their choice. The final outcome of this stage included 3D models and developed plans, sections and elevations for the individual buildings, with considerable attention to the impact of this development on the group work and masterplan components.

4 General Observations

Students in this design studio were all previously exposed to basic parametric modeling concepts and skills in computational design courses throughout the CAAD curriculum, and have had some experience with using tools such as Autodesk Revit, Rhino and Grasshopper. Despite this prior experience, integrating these concepts and skills in the design studio was a different challenge, especially that this studio demanded a highly technical and early implementation of computational concepts. In addition, the implementation of these concepts was required at different scales and levels of detail, including the urban design level as well as the architectural design and detailing level.

Four groups of students developed the required master plans and further worked on their individual building components, using four main concepts: (1) responsiveness, (2) expression of time, (3) flow-ability, and (4) magnetism. The groups varied in their approaches and in how the emergent formal approaches guided their design process.

4.1 Project 1: Responsiveness

Group 1 designed their project as an exposition center that responds to multiple factors in the surrounding environment, including contextual, environmental and cultural constraints. Their concept was based on swarm intelligence systems that work with multiple objectives, and sense and respond to exterior parameters in the surrounding context, such as wind, solar radiation, noise levels and site landmarks. The group assigned three rules for their system logic: *alignment*, *cohesion* and *separation*. The ratio between those variables achieves an infinite number of solutions. Each of the building forms was generated through a process whereby different values were assigned to those rules based on the logic and requirements of each building type (Fig. 1). The group used multiple software tools and plug-ins in their form generation and analysis process, including *Rhino* and *Grasshopper* for the parametric modeling component, *Processing* for running the swarm intelligence logic, *Millipede* for structural analysis, *Autodesk Ecotect* for environmental analysis, *Autodesk Revit* for documentation, and *3DS Max/Vray* for visualization and rendering.

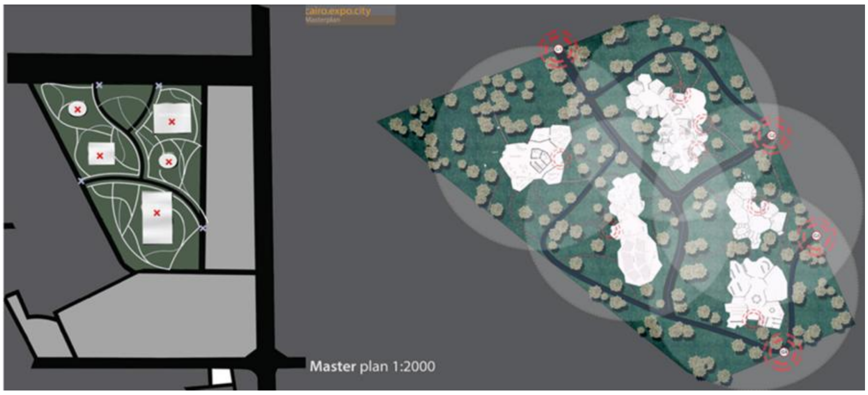

Fig. 1. Master plan logic using swarm intelligence to express responsiveness (Group 1)

4.2 Project 2: Expression of Time

Group 2 looked at time as a variable and divided their theme into three main factors: quality of spaces, spatial experience, and playing with light. They were inspired by the dynamic and seasonal features of change in nature such as the generative formation of snowflakes, flowers blossoming during spring, crystallization, leaf life cycle, and fruition. They used the meta-ball concept which is based on cell divisions using attraction and repelling fields based on change in time (Fig. 2).

Fig. 2. Master plan and individual projects using the meta-ball concept (Group 2)

4.3 Project 3: Flow-ability

Group 3 devised the concept of flow-ability, which they defined as an inspiration for form generation from both nature and human behavior. The main conceptual basis and source of form generation was derived from wind flow as well as the flow of people in the project site (Fig. 3). The group aimed at designing the pedestrian network within the site in such a way that follows wind direction. They first generated preliminary forms then conducted wind flow studies using Autodesk Vasari in order to produce an adjusted masterplan. The building components in the masterplan were explicitly shaped such that they respect the existing wind patterns based on the wind flow studies. This was consciously formalized by the students in order to maximize desired wind conditions for their designed buildings and provide enhanced wind flow at both the urban design level among the group of buildings and their interconnected spaces, as well as the three-dimensional level of each of the buildings, where each of the individual designs was fine tuned to achieve improved flow-ability. This was a back and forth exercise in Autodesk Revit and Vasari.

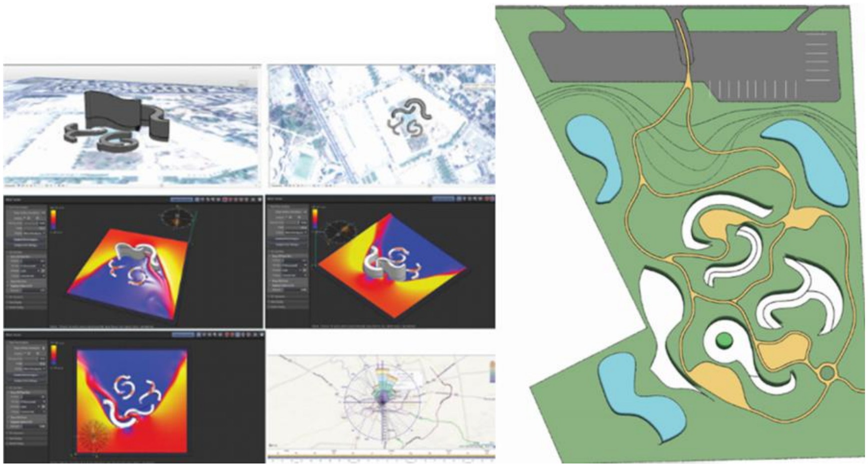

Fig. 3. Master plan using wind flow studies in Revit/Vasari to express flow-ability (Group 3)

4.4 Project 4: Magnetism

Group 4 explored the concept of magnetism and attraction and repulsion, where arbitrary positions of nodes representing different buildings are adjusted, relocated and optimized based on attractor points developed in Grasshopper that denote relative weights of multiple objectives such as shading, wind flow and site accessibility (Fig. 4). The students worked with each of the objectives to satisfy the required contextual and environmental conditions, and then specified an adjusted location for each of the building components of the masterplan. The specific location for each of the buildings was justified and optimized according to the students based on the relative weights and strengths among each of the variables they set, such as shading and thermal comfort, accessibility and circulation, wind flow and other dimensions. They then attempted to work on the level of each of the individual buildings in order to achieve the concept of magnetism and attraction in terms of circulation paths, adjacency and spatial relationships among detailed functional spaces. This varied according to building type and design concept.

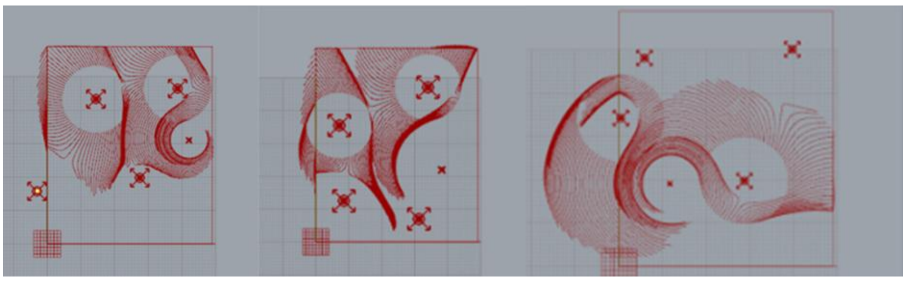

Fig. 4. Master plan using attractor points in Grasshopper to express the concept of magnetism, connectivity and accessibility (Group 4)

5 Case Studies

In the following subsections, we discuss in detail two of the group projects (group 1: responsiveness, and group 2: expression of time), with specific attention to the relationship between the emergent formal representations and the dimension of design autonomy within the explored parametric generative design systems.

5.1 Case Study 1

As mentioned in the previous section, Group 1 developed the concept of responsiveness in their group and individual work. As their concept was to create a multiple objective responsive and intelligent system, the group had to use more than one parametric design strategy. They decided to use two strategies: Kangaroo physics, and swarm intelligence systems.

In Grasshopper, the group used Kangaroo physics in order to quantify the bonds between the different elements of the master plan and simulate those bonds as either attraction bonds or repulsion bonds, as some spaces were assumed to be “attracted” towards some spaces and conditions, while others were “repelled”. This process of attraction and repulsion of particles until equilibrium is achieved represents the building and their location within the project site, where “equilibrium” is achieved when the location of each of the buildings is set with respect to the different environmental and contextual factors.

The group also implemented swarm intelligence to develop a guiding logic for the form generation and organization of each building within a unified formal language. This logic depended basically on permutations between three main variables: alignment, cohesion and separation (Fig. 5).

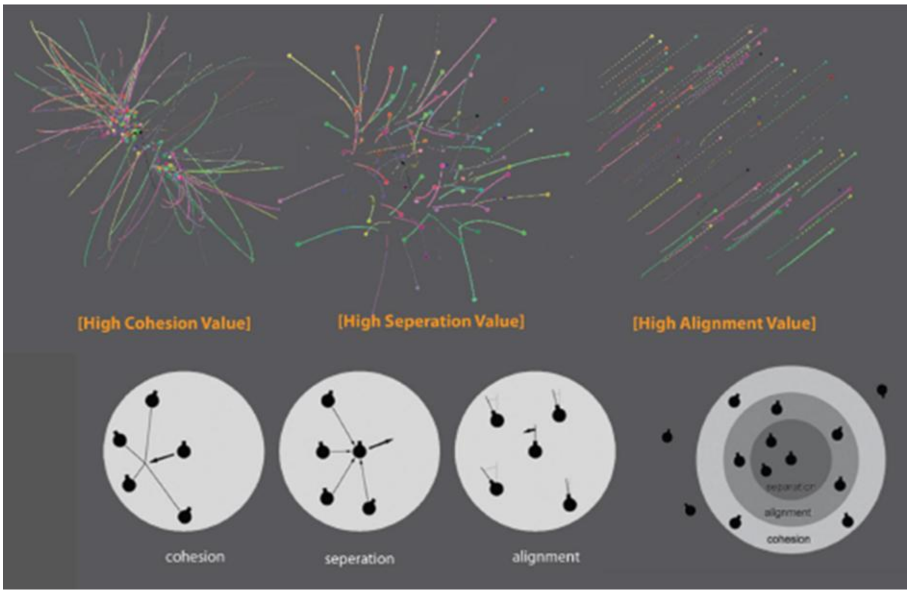

Fig. 5. Swarm intelligence form generation logic developed by Group 1 using three main variables: (1) cohesion, (2) separation, and (3) alignment

Applying different values and relative weights for those variables yielded infinite alternatives and 3D configurations. At first, the students explored these possibilities and their consequences, and how the formal outcomes reflected on the overall design solution. They then developed a justified logic for the specific five buildings in their master plan such that the values they assigned for those variables generated the required form using a rational and intuitive process, where later modification of those values could be easily comprehended in terms of its formal, functional and spatial consequences (Fig. 6).

For example, the exhibition building and shopping mall were consciously assigned higher *separation* values, as the nature of those building types was seen by the students as requiring more segregation, spread and distribution of horizontal spaces through a main circulation element. The hotel and office building towers were given higher *alignment* values, as they were seen to require vertical alignment and stacking of modules and spaces in a monotonous and repetitive fashion. *Cohesion* values were relatively lower than the other values, but were assigned the highest value in the shopping mall to denote the importance of the inner circulation spine as a binding element in the building space configuration.

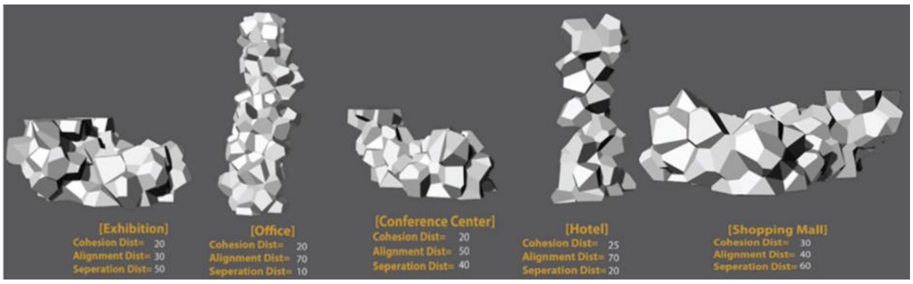

Fig. 6. Permutations between swarm intelligence variables developed by Group 1 to generate form for each of the buildings

By modeling the buildings with these variable relationships, the students took their design into a deeper level of evaluation. Within those variations and evaluation tools in Grasshopper, the students varied the number and distribution of structural elements, their cross sections, the horizontal inclination of the glazed walls between structural elements in response to orientation and sunlight. They used Millipede for structural evaluation and Ecotect for evaluating solar exposure (Fig. 7). Then they started documenting their work and extracting the necessary plans and sections using Autodesk Revit.

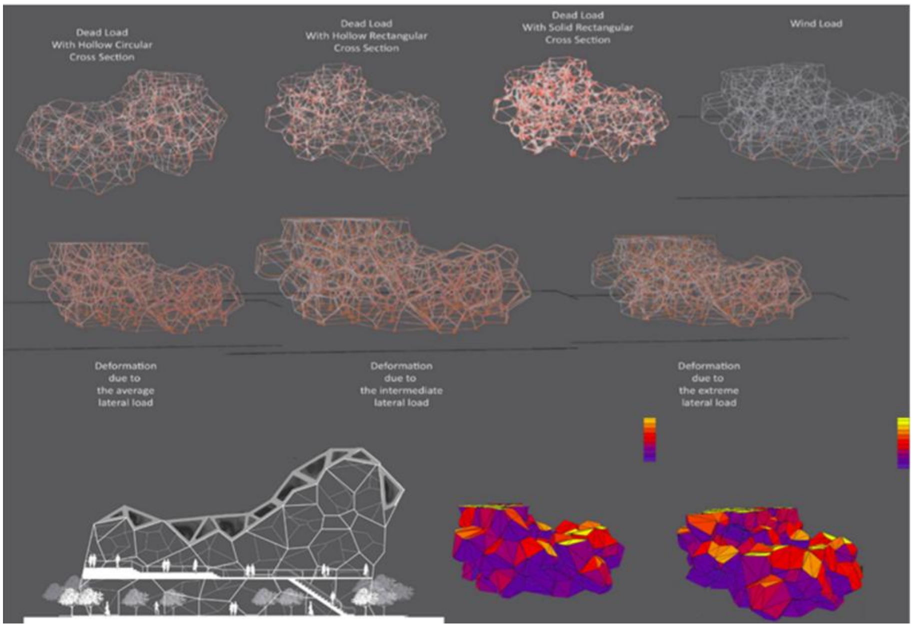

Fig. 7. Structural analysis (in Millipede) and solar exposure analysis (in Ecotect) conducted by Group 1 for the exhibition building

Although the students seemed "in control" of the logic of the generated emergent forms, where they could consciously develop a unified grammar and 3D configuration for each of the five projects, in addition to conducting their environmental and structural studies further, their designs did not go further in terms of design development and detailing, as the formal approach was not sufficiently grounded in spatial and functional requirements (Fig. 8).

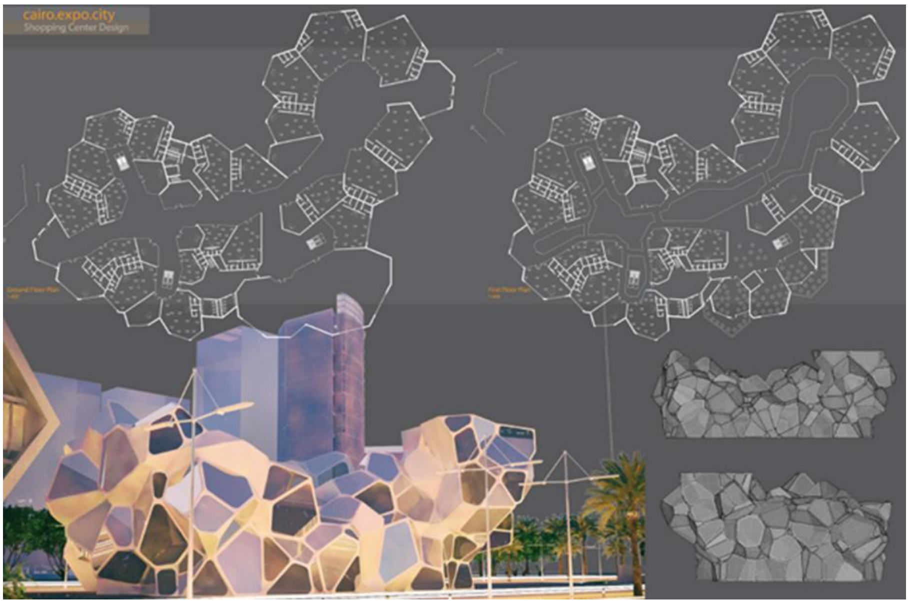

Fig. 8. Documentation and rendering of shopping mall building (Group 1)

5.2 Case Study 2

The students in Group 2 initiated their analysis with maps and diagrams exploring a number of possible user behavior and activity scenarios along specific daily and seasonal durations of the exposition center operation (Fig. 9).

Fig. 9. Analysis maps and diagrams studying user behavior along expo time schedule (Group 2)

The meta-ball systems that the group implemented for their analysis were based on cell divisions and generative forms inspired by natural formations (Fig. 10). The students began to work with the three elements they identified in their conceptual phase, which were: quality of spaces, spatial experience, and playing with light.

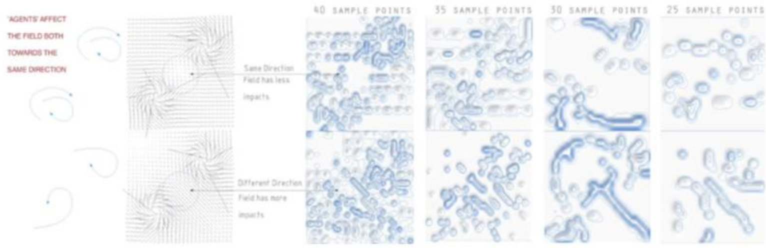

Fig. 10. Transformations of meta-ball agents in Grasshopper

The students used Grasshopper to simulate the design after studying transformations of meta-ball agents and their desired directions, starting by scripting a master pattern and developing it to create the final form (Fig. 11). The value of the agent change and its directions varied based on building function and type (Fig. 12).

Fig. 11. Experimenting with potential forms and circulation patterns

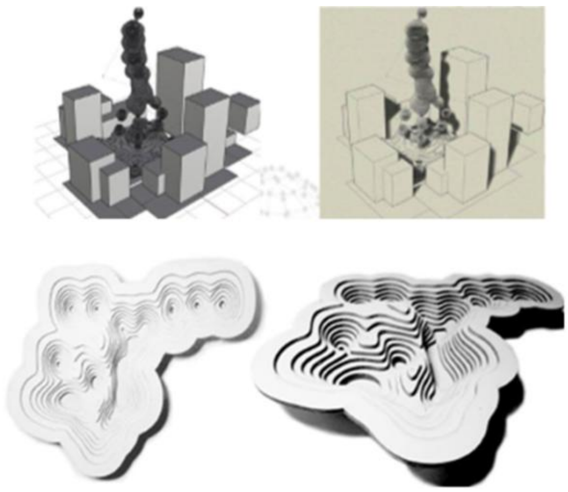

Fig. 12. Examples of resulting forms for the shopping mall and office tower

Following the form generation process, the students began to conceptually evaluate the produced forms. They extended their system autonomy to a level of detail where they could explore detailed design and development. This was the primary focus of their investigation. While the students did not fully explore opportunities for further development of the meta-ball concept, they jumped directly into spatial adjustment and functional detailing (Fig. 13). They explicitly expressed a need to be "in control" of understanding and detailing their designs, without much exploration into further emergent possibilities.

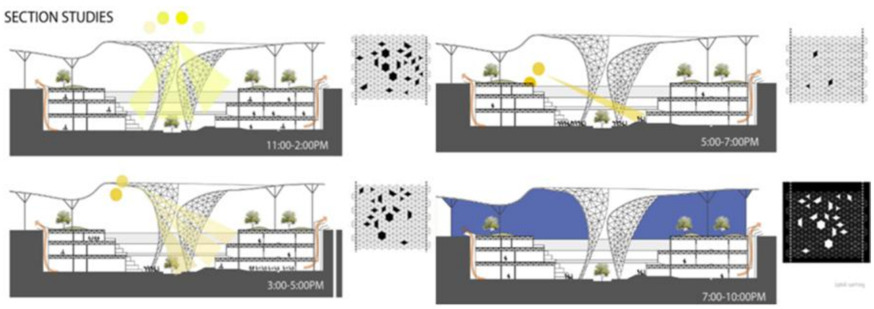

Fig. 13. Detailed architectural documentation for the shopping mall building (Group 2)

6 Discussion

In general, the results showed throughout all the observed groups of students that using the parametric and generative tools allowed for a larger pool of possibilities for design search and exploration in the very early phases of the design process, especially at the level of collective work. As students moved more into their individual work and design development phases, approaches largely varied. Some groups succeeded in developing their master plan and individual designs through a coherent and informed process, while others demonstrated full segregation between the formal representation and the subsequent design development. Section 6.1 outlines how we see the parametric design process between emergence and autonomy based on this study. Section 6.2 proposes further work and poses future research questions.

6.1 Parametric Design between Emergence and Autonomy

Although results cannot be fully generalized from such a limited study, it can be argued that there were much richer nuances in this parametric design exercise between design autonomy and formal emergence than the presumed firm dichotomy. Both were catalysts for design search and exploration. It cannot be explicitly stated that either were dominantly visible in the process. From our understanding, these nuances resulted from a number of factors, each of which had a direct or indirect impact on the nature of the process. These include: 1) the point of conceptual departure, 2) user experience and background, and 3) algorithmic thinking.

Point of conceptual departure. Each of the student groups typically had a different conceptual departure for their design projects. Group 1, although presenting an approach involving responsiveness, had originally adopted a more formal approach which was more biased to the capabilities of parametric and generative design systems rather than a conceptual parti as required from the exercise and objective of the design studio. The group thinking was mostly directed from the very beginning towards using multiple systems in conjunction, including swarm intelligence, cellular automata, Kangaroo physics and other systems. The architectural concept came actually as a post facto process when the students realized and were informed of a bias to using the tool per se versus using it to implement an architectural concept. This bias impacted the choice of the computational approach and tools, and guided the students throughout the phases of the project, regardless of a coherent set of design guidelines. This was clear in the design development effort, where the formal exercise consumed more time than the actual development and refinement of aspects of spatial quality and functional requirements.

The point of conceptual departure in group 2 was on the other end of the spectrum. The group spent a considerable amount of time in the early conceptual phases searching for an architectural concept and an intangible element that they could later express in the computational tool. The notion, expression and representation of time – in its different interpretations and connotations – was an intriguing concept for the group, and was a driving force for the overall conceptual structure of the project in its collective and individual format. The computational methodology and tool always came as secondary for the group. The process was always driven by the conceptual approach of expressing time rather than the form of the meta-balls which presumably represented that approach. The group continually searched for processes and structures in the tool – although often unsuccessful – that could augment that conceptual approach.

Group 3 departed from a specific environmental consideration, which was wind flow, and continued to augment the idea of flow-ability through other natural and behavioral dimensions in the surrounding environment. This conceptual departure highly affected the resulting forms as well as the selection of the necessary computational tools for modeling and simulation. The group however was fixated in terms of design development, as the initial developed forms remained unchanged for a considerable time. Individual attempts to develop the same conceptual approach in much more detail in each of the individual buildings were also limited.

Group 4 departed from an urban design concept related to connectivity, accessibility, as well as some environmental considerations, which they coined magnetism. In this approach, as in group 1, the students capitalized primarily on the software capabilities in terms of allowing for a justified adjustment and relocation of building elements as nodes in the project site based on attractor nodes and parametric interrelationships. As the students continued to develop their individual projects, this approach was not so evident or translated sufficiently, and all went separate ways.

User experience and background. Background and tool expertise played an important role in how parametric and generative design was experienced in this exercise. All student groups had prior experience using parametric design tools, but students belonging to group 1 were the most proficient. In their research of design precedents, they explored the projects that used multiple and complex generative systems. This provoked the team to explore computational tools to their maximum potential and to explore different generative design systems and their capabilities. They investigated in depth cellular automata, swarm intelligence, kangaroo physics, and genetic algorithms, and went beyond the course objectives. They did not only use Grasshopper to develop their initial cellular units, but also explored and used Processing to develop code for the swarm logic. This explains some of the bias this group demonstrated in terms of precedence of computational logic and formal representation and emergence versus down-to-earth architectural concept generation and design development.

The other three groups however were less proficient in parametric modeling and using generative design tools. Moreover, some of the students could not absorb the fact that parametric design methods could help them manifest their designs from inception and throughout development. They expressed the need to be in full control of their designs throughout the process, without ironically being limited in the overwhelming space of emergent outcomes and formal representations that forced many of the students out of their comfort zone.

Algorithmic thinking. One of the main challenges in this exercise was to realize and materialize intangible architectural concepts using parametric and generative design systems and tools. For the students involved in this exercise, this presented a big question mark: how can intangible concepts such as flow, time, magnetism and responsiveness be translated into lower level input parameters and more tangible components that represent those concepts and approaches? After some preliminary testing and exploration with the available software tools, most of the students began to realize that there was no straightforward way of performing this convoluted process, and that parametric design tools were not tailored for their method of design thinking, but required an explicit way of algorithmic thinking and a logical breakdown of the required concepts and approaches into parameters, values, constraints and variables in order to come up with tangible solutions. This was not typically an easy task for all groups. There were three main approaches attempted by the students in this challenge. Students who were proficient with the tools could develop a clear logic and breakdown of concepts into explicit parameters and constraints, as was the case with the students of group 1. Others developed workarounds, such as students of group 2, who worked with a higher level computational concept such as meta-balls, and developed a separate logic for the form generation procedures and outcomes of their building designs. The approaches of groups 3 and 4 featured a complete segregation between the intangible concepts and the low level computational techniques implemented to achieve those concepts, and relied more on conventional design thinking methods in their design development exercises.

6.2 Implications and Future Work

Now back to the original question of this study involving parametric and generative design systems: does a dichotomy exist between the emergence of innovative formal representations on the one hand and the conscious process of generating and developing an architectural concept on the other? According to the demonstrated results and observations, there is no such clear dichotomy. The ability to visualize and generate complex morphological representations can guarantee an in-depth understanding of the essence of architectural concept generation when aided by algorithmic thinking rather than being fully biased to the capabilities of generative design tools. At the same time, the development of design ideas can be fully exploited by emergent formal representations that offer a multitude of possibilities.

Implications for design and CAAD education are numerous. The focus on parametric and algorithmic thinking rather than tutorial sessions or software tool training is evident. This has its ramifications on the structure of CAAD curriculum in general, both at the level of CAAD courses and workshops, and digital design studio. The integration of parametric thinking – rather than just modeling – and form generation as a bottom-up approach – rather than a purely formalistic top-down approach – in design studio becomes more and more pressing. These new ways of thinking should include form as one dimension of many in the concept generation and development process, instead of an authoritarian element within which every other aspect of the design idea has to be blindly accommodated. Students should learn how to explore conceptual structures in computational tools, and not just parameters that drive a totalitarian form making process. A rather form finding approach requires that students incorporate different datasets and ideas early on in the process. The role of CAAD software vendors is not to be taken lightly in this context. A higher level understanding of relevant dimensions of architectural quality, such as the notion of space, complexity, circulation, adjacency, density, abundance, and other concepts should be explicitly embedded and integrated within computational tools to allow for a wider space of design search and exploration.

Conclusion

This paper reported on the process and outcomes of a digital design studio that explored the relationship between the emergence of innovative formal representations and design autonomy while using parametric design systems. It was observed that no clear dichotomy exists between both aspects, but rather a complex relationship that is highly affected by three important factors: the point of conceptual departure, user experience, and algorithmic thinking. The study concludes that design studio should incorporate algorithmic and parametric thinking rather than top-down form making approaches in order to integrate form as one of a multitude of dimensions of architectural quality to inform the design ideation and development process.

Acknowledgements. The authors would like to thank all the participating students in the AENG 4556 class of Fall 2014 at the American University in Cairo (AUC). We would also like to thank the teaching assistant Ahmed Elshafie for his dedication and great efforts with the students in their parametric and generative design explorations in Grasshopper.

References

1. Aish, R: CAD Support for Intuitive and Strategic Design Thinking, Colofon, Amsterdam (1991).
2. Friedman, D.S.: Architectural Education and Practice on the Verge, in M. Broshar, N. Strong and D.S. Friedman, American Institute of Architects: Report on Integrated Practice, Washington DC, Section 0, 3-7 (2006).
3. Johnson, R. and Laepple, E.: Digital Innovation and Organizational Change in Design Practice, Connecting Crossroads of Digital Discourse, ACADIA 2003 International Conference, Indianapolis, 179-183 (2003).
4. Holzer, D.: BIM and Parametric Design as Game Changers: Exploring their Effects on Practice Culture and Epistemology, CAADRIA 2014 International Conference, Kyoto, Japan, 379-388 (2014).
5. Kolarevic, B.: Digital Morphogenesis, in B. Kolarevic (ed.), Architecture in the digital age: design and manufacturing, Taylor & Francis (2003).
6. Ambrose, M. and Fry, K.: Re:Thinking BIM in the Design Studio - Beyond Tools… Approaching Ways of Thinking, ASCAAD 2012 Conference, Manama, Bahrain, 71-80 (2012).
7. Ibrahim, M.: Thinking the BIM way – Early Integration of Building Information Modeling in Education, eCAADe 2014 International Conference, Newcastle, UK, 427-435 (2014).
8. Mitchell, W.: CAD Technology, Its Effects on Practice and the Response of Education - an Overview, eCAADe 1984 International Conference, Helsinki, Finland, 10-15 (1984).
9. Kvan, T.: Reasons to stop teaching CAAD, in M.-L. Chiu (ed.), Digital design education, Garden City Publishing, Taipei, Taiwan (2004).
10. Schnabel, M.: Architectural Parametric Designing, 24th International eCAADe Conference: Digital Design Education, 216-221 (2005).
11. Ahlquist, S. and Menges, A.: Computational design thinking, in A. Menges and S. Ahlquist (eds.), Computational design thinking, Wiley (2011).
12. Gero, J.: Preface, in J. Gero & E. Tyugu (eds.), Formal Design Methods for CAD, Elsevier, Amsterdam (1994).
13. Leach, N.: Digital Morphogenesis, Architectural Design (AD), 79(1), 32-37 (2009).
14. Dino, I.G.: Creative Design Exploration by Parametric Generative Systems in Architecture, METU JFA, 29(1), 207-224 (2012).
15. Eisenman, P.: Autonomy and the Will to the Critical, Assemblage, 41, 90-91 (2000).
16. Watanabe, M.S.: Induction Design – a Method for Evolutionary Design, Birkhauser Architecture (2002).