Deceptive Landscape Installation

Algorithmic patterning strategies for a small pavilion

Asterios Agkathidis[1], Tuba Kocaturk[2]
[1,2] Liverpool School of Architecture, University of Liverpool
[1] http://www.liv.ac.uk/architecture/
[1,2] {asterios.agkathidis|t.kocaturk}@liv.ac.uk

This paper reflects a collaborative, research led design project, aiming to explore the potentials offered by incorporating parametric / generative tools and performative lighting simulation software in order to design and fabricate a small pavilion for the School of Architecture. The Deceptive Landscape pavilion was designed in the framework of a masters level, research led, and collaborative design studio. During its intense 12 weeks schedule, student teams were asked to explore and apply generative / parametric tools such as Rhino and Grasshopper, in order to design and later construct a small pavilion, with a theme of their choice. In addition, each team was asked to optimise their design proposal by embedding environmental software plug-ins (e.g. DIVA for Rhino) in their design process, thereby aiming to re-inform their parametric models and set performance targets. Finally each team was expected to propose a file to factory fabrication technique, following all constrains of a limited, predetermined budget. The most convincing and consistent proposal, was then chosen for fabrication. The finalised project serves as verification of the effectiveness of the design system and teaching methods used.

Keywords: *generative design, parametric design, pavilion installation, fabrication,*

INTRODUCTION

This paper is a further example of seeking to incorporate research through design and fabrication of 1:1 realized construction as described in the Tree-Structure canopy project, co-developed by the author (Agkathidis and Brown, 2013) for the WestendGate tower in Frankfurt upon Main. It serves three different, but complimentary aims; firstly to explore the possibilities occurring by combining parametric tools and environmental simulation software in one single generative design tool. In addition, we are investigating how such an approach can be incorporated into an educational, postgraduate design studio environment, by engaging students into research, development, application and assessment of performative / generative design tools into architectural design. Finally, it is exploring innovative pedagogical methods, linked to collaborative teaching and learning strategies in digital integrated design.

In this framework, our main research questions can be summarized as follows:

- How can we link parametric / generative modelling methods (e.g. through Panelling tools for Grasshopper) with environmental simulation (e.g. through DIVA) in order to continuously inform the design process with regards to sustainability criteria and performance?
- How can such an approach be coupled with CNC (computer numerically controlled) fabrication parameters, embedded in a parametric system?
- How effective is the pedagogic approach that we took in making these innovative links between design/optimization/fabrication in architectural technology education?

PEDAGOGICAL APPROACH

The project described in this paper is one of the 10 group design projects developed in the context of Arch 423 Design studio module in the MA in Architecture masters course in the School of Architecture, at the University of Liverpool. One of the challenges we faced throughout the studio was to embed a rather complex computational design challenge in a design studio module with very specific learning outcomes, with students who have very little or no prior knowledge of computational design and no prior experience with parametric design tools, within a 15 credit module, with only 2 hours contact time per week. Therefore we had to come up with a rather innovative pedagogical approach to make sure to comply with the predefined learning outcomes, and at the same time to deliver some of the necessary theoretical knowledge, concepts and practical skills to the students so that they could feel confident to tackle the design challenge. Another issue we needed to consider carefully was the fact that a majority of the students were international students coming from various different educational backgrounds (e.g. architecture, engineering design, interior design) and levels of familiarity and interests in the wider spectrum of design (e.g. technical, theoretical, management).

Our main response to tackle these pedagogical challenges was, firstly, through the preparation of the brief, and secondly, through a rather experimental approach we attained in the structuring, distribution and management of the 3 distinct dimensions of learning - individual, distributed and guided - in the context of a highly technology-mediated design studio. On the distributed level, creative, technical and intellectual expertise were distributed to provide support and inspiration for students engaged in a group design project. On the individual level, students were encouraged to steer their own learning process and become self-aware of their own learning experiences. The guidance was provided by the tutors acting as "curators" instead of "instructors". In other words, instead of dispensing knowledge, we aimed to create spaces where students could build, explore and connect different knowledge elements and skill sets. In this regard, our role was to provide interpretation, direction, provocation and guidance as and when necessary. For example, students were expected to follow the online video tutorials of Rhinoceros and Grasshopper (provided on the course web-site) as part of their individual learning, at the pace and order suggested by the tutors, at the beginning of the semester. The first few weeks were front-loaded with theoretical lectures and seminars where all students were engaged in highly interactive discussions on the subject matter to form the foundational intellectual basis that was deemed minimum to build before they got engaged in any tool-driven design activity.

Although this studio module could be considered as a typical "parametric design studio", in terms of its content and the design methodology advocated throughout the semester; we deliberately avoided too much emphasis on the "tool" aspect in the formulation of the brief; but rather put the emphasis on an "informed" design process. Therefore, the parametric design process had been introduced as a means (instead of an end) in identifying, selecting, optimizing, selectively sharing, controlling and linking parameters (information) in a the design of a pavilion. The design, development and production of the pavilion had been emphasized as a collaborative design task, to be conducted as a team-work,

with team members who were assigned both individual and group tasks for this particular design assignment. The design teams were composed of 3 members, acting as;

- Design Architect
- Manufacturing and Sustainability Consultant
- Knowledge and Communication Manager

Instead of starting the task of pavilion design by solving "design problems" imposed by the instructors (through the brief); the students were expected to define cross-disciplinary challenges and possible problems, collaboratively, and then try to bring innovative solutions through associative and parametric modelling (thinking). In addition to the theory and knowledge acquired through formal lectures, i.e., know-what and know-how, group-design learning experience enabled the students to identify cross-disciplinary objectives and thereby develop know-why knowledge in a situated context.

In addition to the design task, the second part of the assignment focused on the creation, representation and sharing of new design knowledge by the students. Each design

group were asked to create an online digital portfolio (embedded into Blackboard and set as wiki-sites for each individual group) to manage, coordinate and document their team interaction during the life-cycle of the design process. The digital portfolios of each group were composed of both individual and team input. The students were required to use multi-modal representations, to articulate both the knowledge they have acquired throughout the "collaborative" design process and the relationship of this knowledge to the evolution of the design artefact. In other words, the use of the digital portfolios were not only limited to the "display" of the design artefact/information produced, but were also utilized to "personalize, share, reflect and display what they (each group) have learned and produced collectively. Therefore, the learned elements (knowledge) displayed in the digital portfolios were required to be structured and interlinked in such a way that different learned elements could be compiled, organized, represented and shared selectively. At key times during the semester, students were asked to share their wikis in conversations with their tutors and peers.

CREATING A GENERATIVE DESIGN SYSTEM

The Deceptive Landscape pavilion was conceived as an algorithmic patterning field, controlled by a set of point attractors, determined by paths of the users trajectories. It is a design approach similar to the one described in the "InfoMatters" research project (Biliria, 2011). In this case however, all attractor-points were determined by using the Paneling Tools for Grasshopper plug-in. Thus, a generative design tool was developed, able to associate the visitors movement path trajectories to variable degrees of the field's density, aiming to achieve different zones of light intensity, as well as the users visibility-visual deformation, hence deception. It is a Grasshopper script (Figure 1), based on the "c-cluster" grid and the "pt-PointAttractors" components.

The visitors walking path trajectory, defined by the designer, acts as the main parameter of deformation allowing the grid to transform its density, its size, its height as well as the diameter of the units forming it (Figure 2). In that way, various iterations associated to different path scenarios could be explored.

In order to materialise the field and achieve different degrees of light intensity, visibility and visual deformation, the team decided to use transparent, acrylic tubes. Through their cylindrical shape, radius, material property and arrangement (e.g. variable density and height), they appear to disrupt the visitors vision, visibility and perception while walking / standing in it and looking to the outside, or the

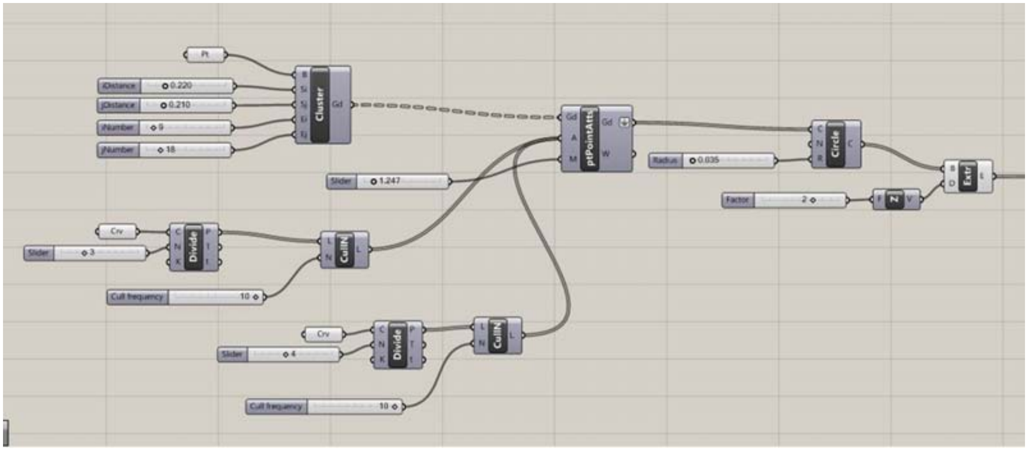

Figure 1
Generative GH script using paneling tools

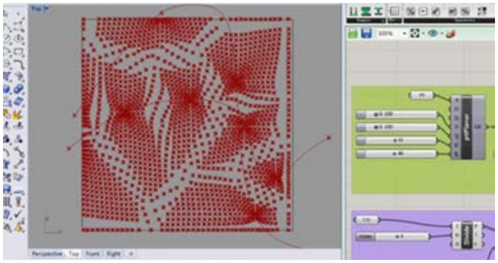

Figure 2
Transformable grid / trajectory system

Figure 3
Visual deformation achieved by acrylic tube

other way round. In addition, the three-dimensional installation, could act as a visual filter, blurring or distorting people and objects in it or behind it (Figure 3). The accumulation of all lighting and visual effects was expected to produce visual and spatial deception.

LINKING GENERATIVE DESIGN SYSTEMS WITH PERFORMANCE

In order to determine and assess the different illumination intensity occurring by the grids changing density, the team decided to integrate the DIVA for Rhino plug in, a Grasshopper component, able to simulate solar radiation maps and glare effects among others. Unlike the Geco-Ecotect plug-in for Grasshopper as explained in the "Bio Inspired Responsive Facade System" research paper (Dutt and Das 2013), DIVA doesn't require the use of an additional software package (e.g. Ecotect) and runs entirely through the Rhino / Grasshopper interface (Figure 4). It promises faster and more accurate simulation results and therefore it was preferred.

An additional base surface was added in the 3D model, in order to specify the footprint of the assessed area. The extruded pipe units deriving from the previous script (Figure 1), were then connected to the "material" Grasshopper component and then to the GM slot of the "DIVA Daylight" component. This was then connected to a "colour graph", which visualises the variable daylight intensity of the parametric grid (Figure 5).

All simulations indicated a graduate change in illumination intensity moving from the outer bound-

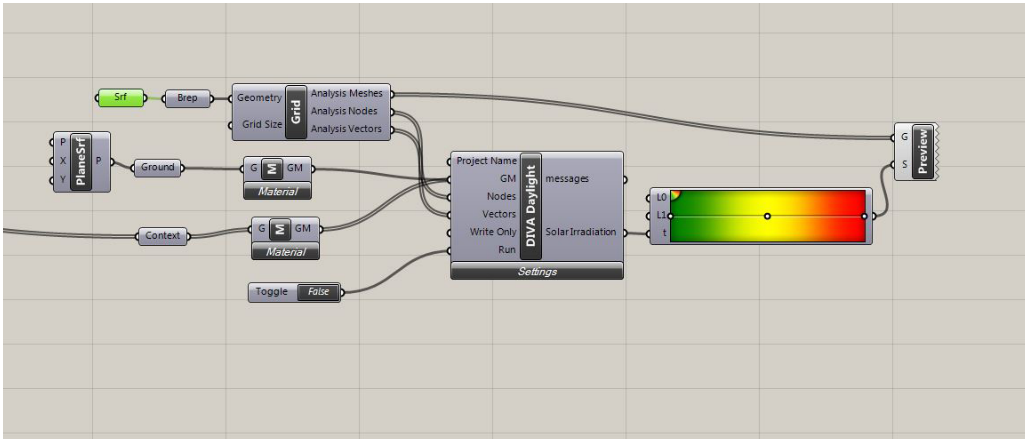

Figure 4
DIVA daylight analysis component for Grasshopper

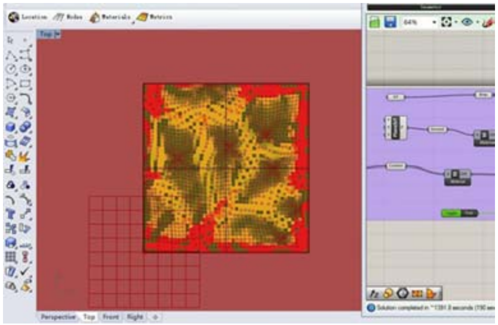

Figure 5
Solar radiation map by DIVA, square foot print, dense grid

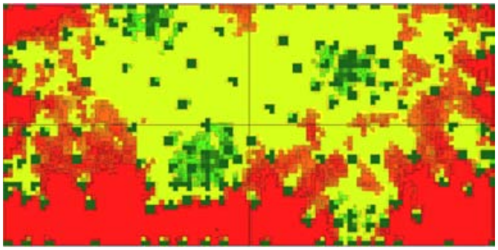

Figure 6
Solar radiation map by DIVA, rectangular foot print, reduced density grid

ary towards the centre, with the most dense areas being the darkest. The footprint's shape proved to be another relevant factor, hence an elongated rectangular shape and a wider grid of pipes, appeared to produce similar but less extreme illumination effects (Figure 6).

In order to intensify the illumination variability even more, we used the solar map as a guide to form the installation's third dimension. By using the "image sampler" component in Grasshopper, the image map (Figure 6) was translated into a three-dimensional extruded surface, where the high luminance areas (red colour) would be translated into the minimum height value (400mm), while the low luminance areas (green colour) into the maximum height value (2000mm) (Figure 7). All pipes were then trimmed according to the three-dimensional nurb surface.

EQUILIBRIUM BETWEEN FORM, PERFORMANCE, CONSTRUCTION COST AND SAFETY REGULATIONS

The final design, was realised as an equilibrium between form, desired illumination performance, construction cost, assembly efficiency, as well as the actual location and safety requirements. All these parameters were essential in determining the installation's final footprint, its height as well as the pipes diameter and wall thickness.

The choice of the actual tube type, had a crucial impact on keeping our expenses within the limited budget. After going through an intensive market research we chose clear acrylic tubes with 70mm diameter and a wall thickness of 2mm. The pipe, proved to be stable enough to stand upright in all desired dimensions as well as wide enough in its diameter to produce an optical deformation effect by looking through it (Figure 3).

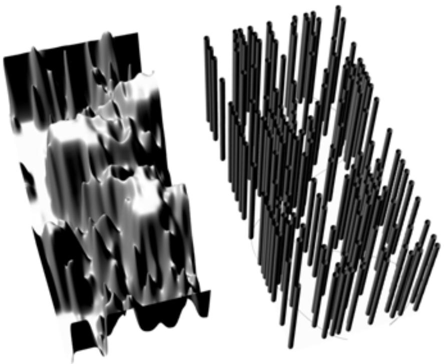

Figure 7
Solar radiation map translated into three dimensional surface

Figure 8
Visualization of final installation using Vray for Rhino

The installation's final footprint (1918mmx 3760mm) was strongly related to its actual location, a factor which proved to be highly unstable through the entire design process. Our initial intention of placing the piece on a public outdoor area (e.g a park or a square), was quickly abandoned due to health and safety regulation requirements. The installation was allocated on an internal terrace, protected from possible vandalism and destruction instead. Nevertheless, the chosen location would offer similar daylight conditions to the location initially preferred, hence appropriate for its assessment. In addition, the final position would be in a crossroad between the two main building wings, hence visitors would be almost forced to walk through it and interact with it. The installation's parametric model, proved to be a useful tool, allowing us to iterate the impact of the different footprints and location's daylight parameters, in order to finalize the installation (Figure 8).

FABRICATION AND ASSEMBLY TECHNIQUES

In the early project stages, two main fabrication techniques were examined and evaluated in relation to their feasibility, construction cost and desirable effect. Option one would consider, the use of transparent or translucent acrylic tubes, assembled on an MDF timber platform. Acrylic tubes are a standardised product, offered in various diameters and lengths, parameters which can be embedded in the initial generative Grasshopper script, thus inform the design and optimisation process. Similar tubes have been used in the " Bulgari Pavilion" for the Abu Dhabi Art 2012 project, designed by NaNA [1].

In addition, option two would consider the possibility of using a non-standardised product, such as tubes, which could be rolled together out of PVC sheets, as shown in the "Tubular Framework" design project (Ljubas 2010). In this case, the component sizes can be completely flexible, however each pipe unit has to be "unrolled" and CNC cut out of PVC sheets and then rolled up in a tubular shape. Despite the fact that the second option was less expensive than the first, it was quickly abandoned due to its higher complexity in fabrication and assembly.

In order to minimise the amount of different pipe lengths, as well as the total number of them required, we have customized all pipe-components into nine.

As the standard pipe is produced in 2000 mm long units, the final pieces were designed as complimentary fragments of the same 2 meter long pipe, reducing their total number into 92:

17 x (2m) + 21x(1.8m) + 16 x (0.4m+1.6m)+ 15 x (1.4m+0.6m) +13 x (0.8m + 1.2m) + 7 x (1m*2) + 2 x (0.4m*5) + 1 x (1.2m+0.4m*2) =92. Each height has been highlighted with a different colour (Figure 9).

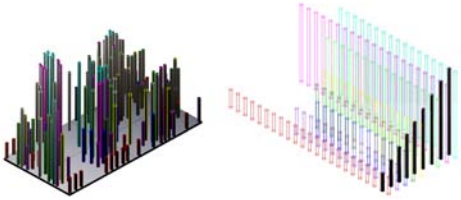

Figure 9
Final pipe components

Figure 10
3 different joint options

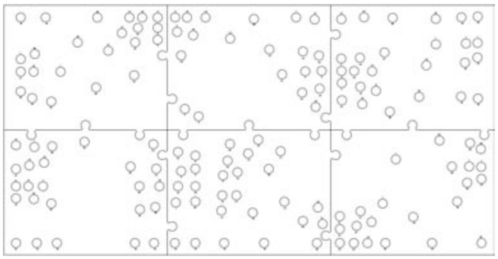

Figure 11
Installation's base components

Considering the installation's base, following parameters where crucial for its final definition: stability, material cost, simplicity in assembly, aesthetics, as well as the capability of reassembly, thus it could be re-informed with further components (eg. led lights and cables). We have examined three different material solutions including PVC foamex boards, birch plywood and MDF sheets in various sizes and thicknesses. In addition we have assessed thee different assembly joints between tube and boards.

Option 1, would examine fixing the tube on a 25mm plywood board, by using a timber ring joint, screwed on the board, pressing the tube upright. Option 2 would examine the use of a double layered base, composed out of two 25mm MDF boards. The tube would be stuck into a CNC routed hole. Finally, option 3 would examine 200mm box solution, where the pipe would be fixed in its two bases (Figure 10). Eventually option 2 (a double layered 25mm MDF board sheet) proved to be the simplest, most inexpensive and yet very stable, fulfilling all criteria mentioned. Each pipe's footprint, was routed a few millimetres smaller than the 70mm diameter, thus a perfectly stable fit was achieved. No glue, or other stabilising components were necessary. The final base (1918mmx 3760mm) is composed out of 6 boards, held together by interlocking joints (Figure 11). Each pipe's height, was engraved next to its footprint, thus easy assembly could be ensured and mistakes avoided.

DISCUSSION AND CONCLUSIONS

In retrospect to the entire design, fabrication and assembly process, many valuable outputs may be derived. Starting with the attempt to integrate the DIVA component into the algorithmic patterning Grasshopper script, it proved to be a valuable design tool, which successfully combines design driven parameters with performative (e.g. environmental simulation). The designer is able to re-inform his initial design approach with the simulated data and achieve performance coherent outputs.

The solar radiation simulation, appears to correspond with the actual performance of the final installation. Diva, proved to be a useful tool, easy to use and respectably fast in simulating, especially in comparison to the Geco plug-in for Grasshopper, which requires Ecotect as a simulation software, a parameter which increases the amount of RAM needed, thus slows down the process. However in both cases, calculation speed is always inversely related to simulation precision. In addition, the Grasshopper script developed for this project (Figure 1+2), could be easily modified or extended, thus be applied in order to design facades, canopies, other shading devises, as described at the "Performative Topologies" research paper (Castorina 2012), however, as one integrated design tool, or even for environment friendly urban solutions, similar to the Generative Components and Smart Geometry design tool by Bentley (Mueller and Smith 2013).

However, it proved difficult to predict the visual deception / deformation effects. This effects were relying more on rendering and visualization plugins, such as Vray, than the solar radiation simulation, where the conflict between appealing and realistic visual effects became evident.

By embedding parameters linked to fabrication, such as density of the grid, pipe radius, pipe height and footprint of the base into the generative-performative system, we were able to continue working on the project, despite the existence of uncertain parameters (such as the actual site) and re-inform the process with precise cost estimations.

The integration of a real scale project in the design studio's brief, proved to be a success, which motivated the students and introduced them into an entirely new set of skills, which are usually excluded from the design studio educational process, such as the consideration of cost calculation, materiality, fabrication and assembly. The adaptation of such skills in the students portfolio and CV, is expected to have positive influence in the students employability.

Furthermore, the entire pedagogical approach, including the three different student roles in every team, as well as the use of digital portfolios, encouraged students to learn from each other and improved their collaborative skills.

Never the less, the project stimulated the school's contacts to the architectural industry and served as an engine for the emergence of further research questions, which shall be addressed in future research projects.

Figure 12
Installation blurring its suroundings

Figure 13
People interacting with the installation

ACKNOWLEDGMENT

Our great acknowledgments go to the School of the Arts Research Development and Initiatives Fund, who has trusted me with this grant; the teaching team of the Computer Aided Architectural Design Project module, coordinated by Dr. Tuba Kocaturk and tutored by Asterios Agkathidis and Alejandro Veliz Reyes during the winter semester 2013-14 as well Zhang Yidan, Ye Zhou, Wu Xiaoyun who developed this pavilion proposal.

In addition we would like to acknowledge all MA students participating in the CAAD module in the year 2013-2014, for their effort, team spirit and hard work, Stuart Carroll, Michael Baldwin, Stephen Bretland and Aleksandar Kokai from the LSA's workshop, as well as our guest jurors Professor André Brown. and Mr. Michael Knight.

The online multimodal and reflective representation of design process in this collaborative design studio setting has been implemented as part of an ongoing research project funded by Higher Education Academy (HEA).

REFERENCES

Agkathidis, A and Brown, A 2013, 'Tree-Structure Canopy: A Case Study in Design and Fabrication of Complex Steel Structures using Digital tools', *International Journal of Architecture and Computing*, 11, p. 87–104

Biloria, N 2011, 'InfoMatters, a multi-agent systems approach for generating performative architectural formation', *International Journal of Architecture and Computing*, 03, p. 205–222

Castorina, G 2012 'Performative Topologies: An Evolutionary Shape Optimization Framework for Daylighting Performance Coupling a Particle-Spring System With an Energy Simulation Tool', *ACADIA2012*, San Francisco, pp. 479-490

Dutt, F and Das, S 2013, 'Computational Design of Bio Inspired Responsive Architectural façade System', *International Journal of Architecture and Computing*, 04, p. 613–633

Ljubas, A 2010, 'Tubular Framework', in Agkathidis, A (eds) 2010, *Digital Manufacturing in Design and Architecture*, BIS, Amsterdam, pp. 56-59

Mueller, V and Smith, M 2013, 'Generative Components and SmartGeometry: Situates Software Development', in Brady, P and Peters, T (eds) 2013, *Inside SmartGeometry, Expanding the Architectural Possibilities of Computational Design*, Wiley, Wiley, pp. 142-153

[1] http://www.archdaily.com/318538/bulgari-pavilion-nana