Spaceship Tectonics

Design Computation Pedagogy for Generative Sci-Fi Building Skins

Pavlos Fereos¹, Marios Tsiliakos², Clara Jaschke³
¹,²,³ Universität Innsbruck - Institut für experimentelle architektur Hochbau
¹,²,³ Pavlos.Fereos|Marios.Tsiliakos|Clara.Jaschke}@uibk.ac.at

Sci-Fi architecture, both as digital or physical representations, despite their inherent intricacy, lack the spatial depth of a structured interior, material definition or program information. This discrepancy, combined with the plethora of available sci-fi motifs, inspired the development of an integrated teaching approach with the academic objective to utilize computational methods for analysis, reproduction and composition of generative building skins, and consequently architecture, which aims to be ‘outside of this world’ as a sci-fi design quality-enriched result of our reality. The proposed methodology is implemented at the Spaceship Architecture Design Studio at the University of Innsbruck. Its capacity to achieve a successful assimilation of design computation in the curriculum is subsequently assessed by the documentation and quantitative/qualitative evaluation of the designs developed during two academic years, in line with a generative facade articulation schema, without however undermining the rest of the virtues of tectonic spaces. The introduction of a theme like sci-fi where the design objective is not clearly defined, is examined in comparison to similar approaches, towards the corroboration of the pedagogical method proposed.

Keywords: Pedagogy, Computation, Facade Design, Generative, Sci-Fi, Patterns

INTRODUCTION

Sci-Fi Architecture
This paper sets out to document and assess the academic work produced at the bachelor design studio “Spaceship Architecture”, held for two consecutive academic years at the University of Innsbruck’s Institute for experimental architecture.hochbau with a focus on the design and tectonics of complex building envelopes and the variety of computational methodologies utilised to analyse and synthesise them. The authors are attempting to address the question of what would be a meaningful process by which design computation can be taught in a way that puts it at the centre of a methodology, rather than being a catalogue of tools. The main objective therefore is the fully integrated impartation of design computation and fabrication skills on a level befitting a bachelor thesis in architecture, using structures and nar-
ratives from the sci-fi world where the building skin systems provide a high level of intricacy, but the lack of spatial hierarchy, materiality and program render it fit for a design studio theme capable of sparking further endeavours on the articulation of space, and not turning out being a facade technology course (Figure 1).

Figure 1
Tyrell Corporation
-Blade Runner - A
Sci-fi piece of architecture as facade analysis case study, speculating on the interior.

Bermudez and King (2000) argue that we are moving towards a complex reality, using Sci-Fi movies to compare different realities of a future world. Hence, it is the authors belief that analyzing and working with Sci-Fi concepts befits the contemporary academic design studio which produces increasingly elaborate and complex designs.

**Design Computation as a Pedagogical Medium**

Without a doubt, Design Computation has laid out robust foundations in the contemporary architectural discourse both on the academic and corporate context. This transition which can be portrayed towards a Computer Integrated Design rather a Computer Aided one, relates to the fact that many designers are currently conscious of coding capabilities, but also the reality that CAD software advancement has enabled the extension of complex modelling capabilities and the parametrization of the design space, offering flexible adaptive processes and more control over variation and design optioneering. The authors' hypothesis is, that by introducing a design topic derived from science fiction, video games, comics and animation, a variety of computational design elements can be covered and explored, potentially resulting in an intrinsically computationally oriented methodology rather than a merely computationally aided one. The proposed methodology will be assessed by the documentation of the studio’s design outcome, emphasizing on the architectural skins of the proposals but also indicating the missing connection to the interior and how students were called to overcome this discrepancy in sci-fi designs. Moreover, the authors argue that providing students with an intangible theme, not limited to typical dwelling constraints, but rather drawing from a formal language previously established in physical models, illustrations or even text, can potentially result in an extensive vocabulary of computational means for addressing complex buildings envelope articulations. This grammar of notions is derived from the analysis of the aforementioned scenarios both formally, and procedurally, as concepts of computer science that can generate spatial conglomerations. This accumulated database will be explored and comprehended in order to articulate a complete design proposal. (Figure 2.)

Kvan et. al (2004) argued, that the teaching approach to digitally oriented studios should start to shift from trying to merge computing tools with architecture to finding a new understanding of architecture through the tools. Based in part on this point, the authors argue upon an autonomous approach to design computation and investigate whether the choice of theme, as in the architectural design end goal, can lead to a paradigm shift in the way computation is being approached by schools and academics. The most common question in complex geometrically contemporary designs is: “how was this made?” W.J. Mitchell explored early strategies of embedding CAD in the curriculum and noted that “[t]he more intricate and sophisticated the solution-generation procedure, the more likely it is that we shall ask in surprise of a computer system, ‘How did it ‘think’ of that?’” (Mitchell 1975). The Spaceship Architecture studio aims to offer an introduction to complex computational methods rendering this question...
obsolete, building up facade articulations from an extensive vocabulary of sci-fi motifs or permutations of those, reducing them to sets of rules and associations, processes and iterations that automated and informed by programatically combining data and computational tools.

BACKGROUND

Education and Computation

The concept of a computationally integrated design studio is not a new one. Indeed, it goes back to the early days of adopting computers and digital design for architectural education. Haglund and Sumption argued on the significance of a computer integrated learning. “We believe that it is important that the role of the computer be integral to the experience of learning to design, rather than acting as a catalyst to the creation of another faction. It is not desirable to have students thinking of design as one thing, technology as another, and computers as yet another.” (Haglund and Sumption 1988). The intention of the authors for an iterative model of design through computation, is formatted around the concept where the “algorithmic” thinking is supported by traditional design methods such as model-making (Novakova et al,2010) implementing a seamless flow of data towards the digital fabrication of the model parts. (Figure 3.)The variety of computational concepts explored and the procedural thinking behind the designs can effectively lead to a bottom-up approach on the synthesis of the building skin or the analysis of existing sci-fi facade configurations, with digital strategies constituting the framework from within which students elaborate their ideas, consistently pushing the boundaries of their skills.

Facade Design and Computation

Building skin designs and methodologies for complex building element articulations lately reside at the heart of the AEC industry. Cladded solutions of primitive volumes provide the amount of intricacy and aesthetics necessary to keep a flexible interior to the dynamics of the era, such as economy and technology. A similar analogy appears in the sci-fi models, where the interior has no direct connection to the facade. The analysis of existing sci-fi scenarios envelopes is essential to comprehend the available elements, assess the rules of generation and try to recreate them. Ben Pell argues that new tools and consequently design computation have sculpted the complex nature in shapes and patterns of contemporary facade systems(Pell 2010) As Cateano and Leitao argue, the exploration of architectural facades is not new. However, by resorting to recent digital technologies, architects can once again focus on facade design, promoting the exploration of complex patterns and geometries. Sometimes these can use shape grammars to generate completely new sys-
tems. Although the steps they follow in their facade design framework primarily examine discrete units (Cateano and Leitao 2016), while a plethora of techniques of sometimes minimal or non-existent modularity are explored in the proposed methodology.

The authors aim to utilise the full potential of Design Computation as a different approach to design. The designers need no longer focus on designing a specific artefact, or configuration. Rather, they have the opportunity to externalize the underlying “design logic” and use this to explore a whole range of alternative solutions. (Aish 2009). In addition Robert Aish states that the essential challenge here is to understand the learning curve which might enable designers without formal computational training to progressively explore the new possibilities that Design Computation has to offer. The designer must also be willing to free himself from established design patterns and rebuild his design knowledge based on a fundamental understanding of geometric and logical abstraction. This is fundamental to the studio’s curriculum as almost 50% of the total teaching time is spent on communicating computational techniques, time that will be later compensated by the capacity to quickly generate design options. (Table 1)

While most of the existing literature investigates facade pattern formation from shape schemas and sets of congruent relationships (Cha and Gero 1999), others draw inspiration from existing natural systems, whether these derive from biomimetic analogies (Erdine 2015) or computer science notions, such as CAs (Bentley 2002). The proposed teaching methodology aims not to impose any limitation neither to the sources of stimulation nor the algorithmic processes utilised no matter how dynamic or chaotic they might be. Finally, the relation between texture, pattern and massing is a fundamental question in architecture, and whether the design process begins from the massing and leads to an ornamental skin or the other way around is still under discourse (Baerleken and Riether, 2009). The authors’ objective is that via Design Computation, meticulous analysis and rule based adaptive synthesis, even starting from the exterior facade design, students will be eventually capable to inform the whole building volume, as program, circulation and structure which can effectively lead to a bottom-up approach on the synthesis of form, or the analysis of existing designs with digital strategies. The Spaceship Architecture studio introduces novelty to these concepts insofar that at its departure point, it detaches students from their preformed ideas on the conception of architectural designs by introducing sci-fi assemblies to which these notions often do not apply. Therefore, the students are forced to circumvent conceptual patterns they are already familiar with and encouraged to push their boundaries as designers.

THE SPACESHIP ARCHITECTURE STUDIO
Architecture students generally are expected to be familiar with basic CAD software knowledge by the
Table 1
Graph indicating the variety of computational methods utilised for analysing and generating Sci-fi facades within an academic year.

Table 2
Timeline of the studio structure in relation to the design computation concepts taught.

Time they join a bachelor design studio. 90% of students stated that they had used an associative modelling, or visual programming platform previously. It was observed, that the theme and brief structure naturally attracted students with an above-average interest in computational design. The Studio work is structured in two distinct parts: 1) Analysis - Skill Building: digitally modelling, analysing and further elaborating a spaceship from a well-known sci-fi example in the first semester, and the formulation of a narrative. 2) Synthesis - Thesis Project: development of the same into an original architectural proposal in the second semester as displayed in Table 2.

There is a suggested user interface for the main implementation of computation-nevertheless, other software may be used as well as pertinent to the project in question. The workshops and tutorials throughout the year included: Nurbs modelling in Rhinoceros3D, Visual Programming with Grasshopper 3D, Visualization, Polygon Modelling, Theme-Oriented Visual Programming, Scripting with Python and CSharp within GH, Digital Fabrication and Model Making workshops. Weekly critiques and pin ups, typical for a design studio, are mainly directed towards the procedural thinking behind the computational processes followed in the proposals.

Computational Analysis of Sci-Fi Skins
During the first semester, building skills phase, students are assigned a spaceship or sci-fi piece of spatial configuration from a pool of well-known science fiction examples, i.e. Mother1, Battlestar Galactica, Tyrell Corporation Headquarters. After identifying the key elements making up the formal language of its tectonics, they begin the task of recreating the spaceships skin digitally, but breaking it down into simple rule defined operations. This is facilitated by a kick-off workshop at the beginning of the
semester focused on building a solid base of skills and knowledge of associative modelling (Figure 4) using Grasshopper3d.

Building upon the findings of this sci-fi analysis serves a two-fold purpose: on one hand, it allows the students to develop a kit of computational methods and skills to draw from for the formulation of their proposal. On the other hand, it renders necessary to translate the patterns and motifs to successfully synthesize them in a project. As a general rule, science fiction tectonics are mostly detailed on the outside, without a morphologically corresponding interior. Students are given the task to recognize and analyse patterns and structural logic on the outside of their chosen spaceship, and consequently to design a possible interior based on these findings (Figure 5). This “outside-inside projection” design task familiarizes them with the concept of façade-interior relations and gives them an opportunity to apply their own ideas.

Further tutorials tailored to specific needs for the task at hand are provided throughout the semester in order to enable a toolset that allows for a seamless procedure between the visual programming platform and the CAM methods to facilitate the physical reproduction of a large-scale model. By studying the texture, color, materiality of the sci-fi vessel in depth, whilst reproducing it digitally/physically, students are familiarized with a broad spectrum of approaches, tools, methods and knowledge, such as parametric and iterative modelling, shape grammars, scalar fields modelling as well as fabrication optimization, among others.

**Computational Synthesis for Sci-fi Skins**
For the design thesis project, building skins are explored, rooted in a science-fiction narrative, but elaborated as actual architecture on a building scale. Two distinct brief were provided; the development of a
spaceport and on the following year, of a floating tower. The second semester reverses the “outside-inside” logic of the first. Students now attempt to build their work from interior spaces that host their story and actors, generating the outside of their design from within this framework. In the majority of the case studies, interior and exterior where in a constant dialogue, resulting in an iterative/looping development process. Students are expected to provide a well-structured procedural thinking for the articulation of the building skin, that is tightly connected to all the design computation knowledge acquired previously, but also in the way that sci-fi authors structure their stories. Unsurprisingly, many of the projects utilized computation, as is customary in the AEC industry for the most part, in the façade and building skin design exploring different parametric, generative and self-organisational form-finding methods (Figure 6).

More specifically these consist of simple subdivision techniques, scalar field gradients and more dynamic arrangements employing multi-agent systems to conglomerate patterns and discrete elements. In addition, some of the projects established a catholic computational approach for their development. In these instances, the form-finding derived purely from computational methods and characterized the whole system, including both the interior, structure and exterior. In occasions, computer graphic algorithms such as the Polygonal Scalar Fields of Paul Bourke (1994) were adapted to fit a specific shape grammar logic and form complex articulations of spatial elements (Figure 7).

EXEMPLARY CASE STUDIES
Four exemplary case studies are documented in more detail, two for each stage of the teaching process to further establish the structure of the teaching methodology. For the first semester, two student teams chose to analyse the Millennium Falcon and Nebulon B respectively. They found this task to be very straight forward and relayed that it helped them get accustomed to the topic of Science Fiction, while improving their software skills. Overall, both teams found the teaching approach to be well structured, and appreciated how the connection between interior and envelope of their spaceship and its topical relevance was highlighted as fundamental. The Millennium Falcon skin was exposed to a series of extensive studies, where the articulation of panels was studied as a parametric design space but also as brute-force space filling algorithms where the cladding formations had to adapt to the existing fictional mechanical parts of the spacecraft (Figure 8). In a similar fashion, the Nebulon B study explored spatial subdivision algorithms such as QuadTrees and OcTrees to generate both the skin and also to investigate a potential interior arrangement of spaces as previously displayed in Figure 5.
In order to inspire the first steps of the students’ original design proposals, a reading list pertaining to the Sci-Fi realm was handed out. It was noted that this helped them with beginning the task of formulating their own narrative, which that year was to be centered around a headquarter for a corporation operating in a future era. The CryoTower project managed to successfully combine a series of generative techniques from a twist to the traditional polygonal field isomeshing for the facade ornamentation to spatial compartmentation algorithms such as Manhattan Distance Voronois (Figure 9).

On the other hand, a more integrated approach was employed by the D.N.A Tower team—a multi-agent system was utilised to form both the building skin and at the same time generate the interior spatial and circulation connectivity graphs (Figure 10).

In this instance, a low intelligence generative system was let to run until it reaches an equilibrium adapting to parametric external stimuli, such as overall vol-
volume, entry points and solar access requirements for the respective parts of its elaborate sci-fi brief, reinforcing the authors’ emphasis on building a concise narrative with a clear connection and/or adaptability to architecture and computational design.

**DATA AND ASSESSMENT**

Data yielding and tracking of performance was collected through the weekly crits. In addition, students were asked to answer a small survey to evaluate the timeline of the studio, and to enumerate and classify the digital tool-set that they had been provided with. In Table 3, all different tutorials and design computation techniques are measured for their effectiveness and implementation in projects as pertaining to both teaching semesters. Whereas the first semester shows a comparatively low amount of distribution among the projects, the second semester sees the projects diversifying in approaches and reception of tutorials. As expected, during the second semester students managed to embrace more techniques, in contrast to the first one where Nurbs and parametric modelling were the prevailing tools. This is the result of the students gaining computational knowledge and hence themselves developing ideas and strategies regarding what software or method could benefit their proposal the most.
CONCLUSIONS
The primary difficulty encountered by the students was not computationally oriented; it was the translation of a shell used in movies to an actual piece of architecture accommodating a dwelling narrative. The increase, both in software knowledge, but also in the plethora of design computation themes explored, exhibit the emergence of a bottom-up conceptual and procedural design process which in combination with an intangible theme, results in an almost fully digitally integrated studio work. The learning development from simple parametric modelling notions, to iterative routines and even small scripting attempts to overcome issues arisen in a bespoke manner, displays a confident rate of success toward the achievement of a computationally amalgamated studio. As for further development steps, the collected data sets will be used to weigh the depth to which the respective computational design strategies will be taught, depending on their evaluated project contribution rate. Regarding drawbacks encountered so far, it can be argued that while the students leave the studio with a sound knowledge of design computation, a wider range of computational approaches and specifically simulation techniques, which are most of the time undermined, could lead to further specialization and more hands-on AEC experience within a given set of students in the second semester. Future iterations of the studio may include assessments of skills in the early phases to further tailor software and teaching-level to individual students and student groups.

REFERENCES
Aish, R 2009 'Tools of Expression: Notation and Interaction for Design Computation,' Proceedings of ACADIA 2009: reForm()
Baerlecken, D and Riether, G 2009 'From texture to volume an investigation in quasi-crystalline systems,' Proceedings of SIGraDi 2009
Bentley, KA 2002 'Exploring Aesthetic Pattern Formation,' Generative Art 2002
Caetano, I and Leitao, A 2016 'DrAFT: an Algorithmic Framework for Facade Design,' Proceedings of eCAADe34
Erdine, E 2015 'Generative Processes in Tower Design: Simultaneous Integration of Tower Subsystems through Biomimetic Analogies,' Proceedings of ACADIA 2015: Computational Ecologies
Pell, B 2010, The Articulate Surface: Ornament and Technology in Contemporary Architecture, Birkhaeuser

366 | eCAADe 36 - PARAMETRIC MODELLING | Concepts - Volume 2