Digital Design in 'Peripheral' Contexts

Irina Miodragovic Vella
University of Malta
Irina.miodragovic-vella@um.edu.mt

Digital design, defined at its fundamental level, is a discipline grounded in systemic thinking and computation that folds the context to establish a material system that, in turn, unfolds the context within its spatial outcomes. It instigates an architecture that responds to and engages with contextual heterogeneity. In abundant resources and technology contexts, digital design derives unprecedented architectural advances with limited applicability to different contexts. The paper argues that as contemporary contexts are increasingly contingent, digital design gains relevance, particularly in contexts' peripheral' to digital 'hot spots' and at the grassroots level of architectural education.

Keywords: *Context, Computational thinking, Scarcity, Limitations, Architectural Education.*

INTRODUCTION

Digital design discretises and externalises (folds) context as a system of generative rules, a material system, from which it derives (unfolds) context-driven solutions. Digital design, thus, instigates an architecture that operates on both contexts and content and understands the interdependencies and exchanges it participates in.

The leading digital design research and production are located in contexts of abundant resources, technology, and instrumental knowledge. The outcomes that unfold are unprecedented advancements and achievements in architecture. However, they have little relevance for contexts with different contextual realities.

As transiency, indeterminacy, and instability become contemporary tropes, digital design becomes increasingly relevant for contemporary architecture. Further, it becomes particularly suitable for contexts' peripheral' to digital 'hotspots'.

For this reason, the paper argues digital design should be introduced at the grassroots level of architecture, architectural education.

FUNDAMENTALS OF DIGITAL DESIGN

Digital design is grounded in systemic thinking that determines its relationships with the notions of context, form, and computation.

It approaches context as a comprehensive, complex network of varied yet specific realities (climate, materials, skills, knowledge, tools, technology, cultural traditions, social idioms, etc.). This approach fosters conceptual thinking that seeks to engage contextual heterogeneity and its contingent exchanges of material and energy as processes whose outcomes are affected by the change (Pendleton-Jullian and Brown, 2018).

The digital design recognises the form as an emergent outcome of a context. Its focus is not the manifest form, that which appears, but the material system from which it appears. The material system is an arraignment of interactions between internal generative rules instigated by contextual realities and external morphogenetic pressures activated by contextual feedback (Kwinter, 2008, cited in Menges and Ahlquist, 2011). In short, digital design folds the context to establish a material system, and the material system, in turn, unfolds the context within its outcomes, the manifest form.

Digital design uses computation to formulate a material system. Firstly, computation processes discretise contextual realities through their underlying mathematic, geometric, syntactic, and formal logic (Oxman and Oxman, 2010). Next, computation externalises contextual realities and their interdependencies as generative rules.

Although CAAD software facilitates and amplifies computation, it is not indispensable to digital design. Equating the two is a notion that "veils the mind-changing potential of the digital and limits the conscious recognition of computation as a paradigmatic shift within the discipline" (Kotnik, 2016, p. 43).

DIGITAL DESIGN AS ARCHITECTURAL PEDAGOGY

As contemporary contexts become increasingly uncertain and contingent, "one does not always know exactly what to do - what to design for" (Pendleton-Jullian and Brown, 2018, p.64). Teaching architectural design is challenging as established typologies or newly developed design procedures become obsolete. Digital design offers a valid pedagogical approach to architectural education since it acknowledges and engages in continuously shifting contexts.

DIGITAL DESIGN STUDY UNIT

The paper explains the premise with the example of AUD5642 Architectural Technology 2, a digital design and fabrication study that forms part of the Masters in Architecture (Architectural Design) at the Faculty for the Built Environment, University of Malta. The study unit coordinators are the author and architect, Steve DeMicoli.

The Faculty has a traditional approach to teaching architecture, and no fabrication workshop is available. As a result, the students taking the study unit have nominal knowledge of modelling software, no knowledge of parametric modelling and scripting, and no experience with fabrication tools. For most students, the study unit is the first time they are exposed to computational thinking, digital theory, and digital design processes.

The study unit relies on industry partners to provide materials and access to fabrication tools. The context in which the study unit runs, thus, changes every academic year.

Study Unit Format

The study unit has 5 ECTS and comprises seminar lectures, project tutorials, and a workshop.

Two two-hour seminar lectures at the beginning of the semester introduce the fundamental notions of digital design. Through readings and discussions, they aim to shift students' approach to the design process away from a top-down imposition onto a context that focuses on forms' aesthetics and performance. Instead, seminar lectures seek to introduce students to the design process that engages investigation and exploration to establish a bottom-up generative formation process that addresses and negotiates multiple design constraints. The focus is on problem formulation and process expression, from which a solution, or range of solutions, is derived. Seminars also introduce the study unit task and its main investigation aspects (1.) material to be used, (2.) available fabrication tools, and (3.) assembly geometry tackled.

Project tutorials guide students in developing a material system premise. The premise is developed from desktop research and interpretation of case studies through physical and digital working models. There are three project tutorial sessions in two months, giving students enough time to address feedback from each session.

The workshop consists of five days dedicated to fully developing the material system from the initial premise. It entails iterative fabrication and testing of prototypes to adjust the material system formulation.

Study Unit Task

The study unit's task is for students to develop a procedural logic of a material system and investigate variations of its outcomes. The material system is derived from the capacities and constraints of (1.) material properties, (2.) fabrication limitations, and (3.) assembly geometry. Since available funds, procured materials, and access to fabrication tools vary every academic year, so do the nature of the task and material systems developed.

For this reason, students' familiarity with the materials and material properties explored varies. Materials can be highly familiar, like paper and cardboard, to somewhat familiar, like MDF and plywood, or completely new, like clay and fibreglass.

On the other hand, students' familiarity with the fabrication tools is generally low. While this requires a steep learning curve, it allows students to develop fabrication techniques based on their understanding of the task and tool, not just following established procedures.

The assembly geometry refers to a geometric, spatial arrangement that is concurrently a whole divided into parts and propagation of parts generating the whole. It is determined by the requirements of the construction sequence, force flow, and geometric interplays within an assembly (Miodragovic Vella and Kotnik, 2017). The study unit task assigns the assembly geometry to guide the direction of students' investigations (e.g., tessellation, interlocking, friction joints, or similar). On the other hand, if material properties and fabrication are unfamiliar, assembly geometry is investigated hand-in-hand.

Study Unit Methodology

The study unit methodology is grounded in computational thinking and hands-on investigations. Iterative, hands-on investigations use physical tests on scale models and prototypes to expand students' design knowledge. Knowledge gained from investigations directly informs design decisions, further explorations, and evaluations.

The development of the task and investigations are done as group work. As students have varied skills and interests, group work allows them to take ownership of the aspect of the project that aligns with their affinities.

At the beginning of the task, based on desktop research and case studies found, students propose three material systems. Multiple proposals early in the process introduce students to broader insight and various directions of an unfamiliar design methodology. Proposals redundancy also allows several ideas to be evaluated, accepted, hybridised, or dismissed.

A material system is, thus, developed by recognising and exploring underlying generative rules and interdependencies derived from the versatility and limitations of the given material, fabrication tools, students' instrumental knowledge, component configurations, assembly configurations, and construction process requirements. In short, students develop material systems that fold and unfold their dominant, immediate, tangible and intangible contextual realities.

The materials system's behaviour is formulated as a geometric procedure and expressed as an algorithm. Its limitations and variations are recorded through cataloguing. The geometric rigour when defining the design intent sets a clear investigation direction and directs design knowledge gained from them towards informing the material system's development.

The use of CAAD software in investigations is secondary and is, in a Montessori-like fashion, matched to the nature of the problems tackled and students' affinities. CAAD software is used primarily as a constructive form generation and evaluation medium, not solely visualisation.

Varied Investigations

The following four examples showcase the study unit investigations done over the years.

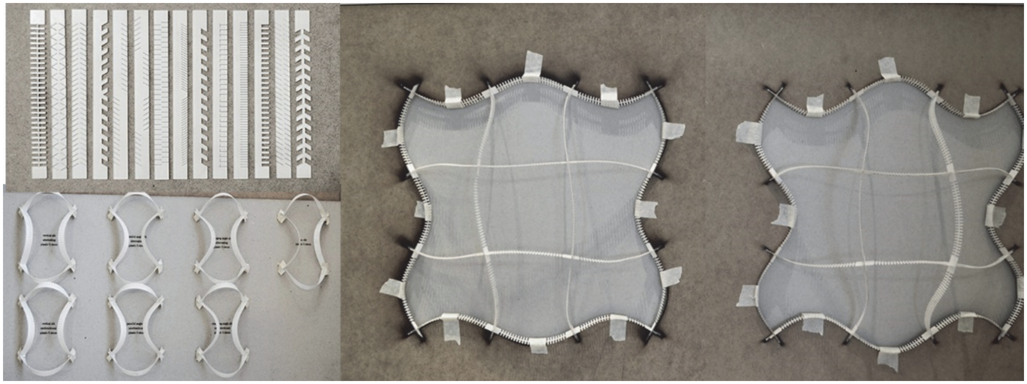


Figure 1 “Subtractive techniques in auxetic systems, exploring the relationship between geometric and material properties” Matthew Scerri, Gerald Salerno, Gabriel Micallef, Carl Tabone, Luca Cremona 2017/2018

The limited funds in the academic year 2017/2018 and the lack of collaboration with the industry focused the study unit investigations on affordable materials and fabrication. The materials available were sheet materials like paper, cardboard, and plastic. The available fabrication tool was a laser cutter. The design task was to investigate the versatility and limitations of a strip, a geometry with a dominant length, nominal width and negligible thickness.

The outcome was an unexpected diversity of geometric procedures developed and their research directions. They examined how a strip can create an auxetic system (Figure 1), weave into a self-interlocking assembly (Figure 2), and generate contact faces of osteomorphic blocks.

Study unit investigations in the academic year 2016/2017 focused on fibreglass, a material unfamiliar to students and study unit coordinators. The study unit task was for students to diversify material uses beyond utility ones, like cisterns and water tanks. More specifically, the fibreglass manufacturer asked students to develop a tessellation for an aesthetically pleasing decorative wall. Thus, students had to understand material properties and rethink fabrication away from the traditional manufacturing process.

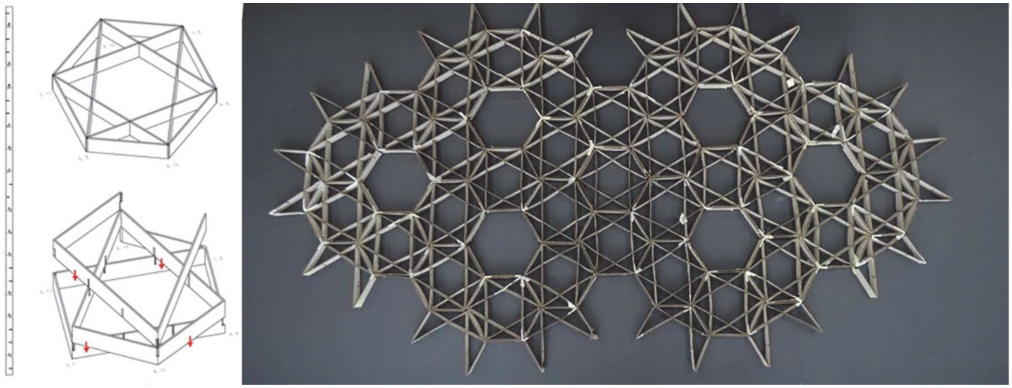
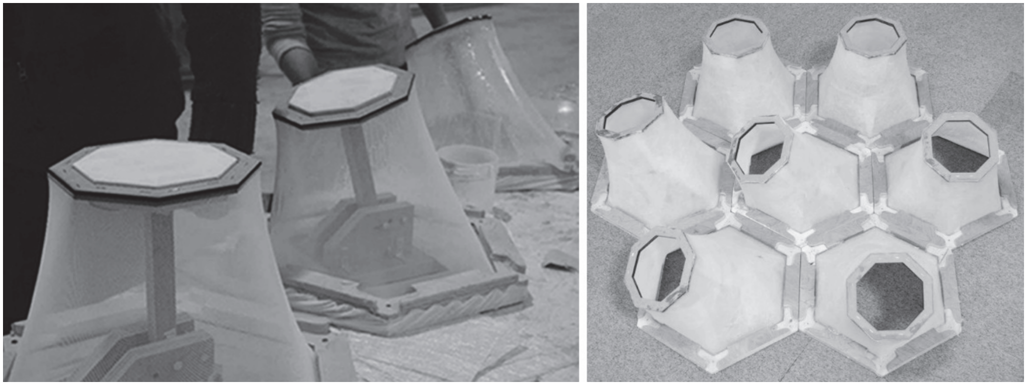


Figure 2 “Interlock” Thrisianne Busuttil, Luana Grech, Olivia Scerri, Rebecca Vella, Nadine Xuebeb 2017/2018

Figure 3
“Form Finding Jig”
Maurizio Ascione, Robert Fenech, Ella Fleri Soler, Nicholas Tonna 2016/2017



For example, a proposal that based its geometric investigations on Frei Otto's soap-fill form-finding experiments proposed a unique fabrication technique that used a jig to cast fibreglass as varied double-curved surfaces (Figure 3).

Similarly, study unit investigations in the academic year 2021/2022 tackled unfamiliar fabrication and material, additive manufacturing with terracotta. For this reason, the assembly geometry was developed as part of investigations on material properties and fabrication limitations. Firstly, students did desktop background research on historical and contemporary uses of terracotta, potentials and limitations of terracotta additive manufacturing, and possible geometric configurations for individual blocks and assemblies. Next, with trial-and-error, hands-on investigations, they sought to determine valid geometries for the material and fabrication. Albeit a steep learning curve, the results were unique.

The "Living Wall" proposal investigated tool paths and block configurations that allowed ecosystem services, such as birdnesting, rainwater capture, soil retention, and vegetation growth. It examined the porosity of block configuration through variations found at the limit of the assembly's geometric procedure (Figure 4).

Figure 4
“Living Armour”
Francesca Cassar, Lyna Loumi, Karen Muscat 2021/2022

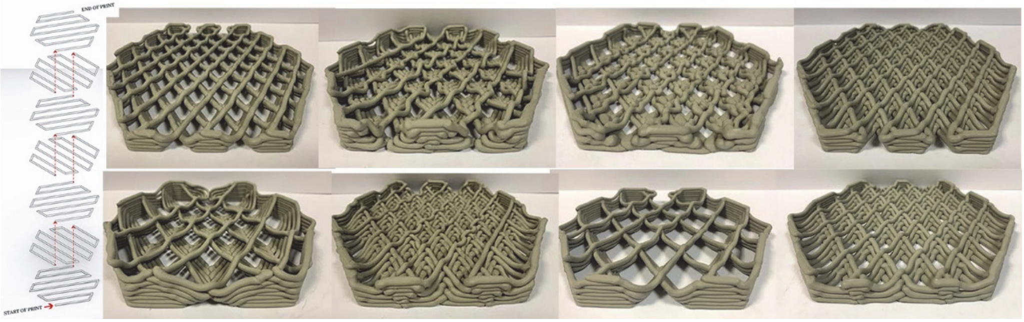


Figure 5
“Weaving Tessallations”
Andrea Borg, Kyle Mangani, Sergio Sammut
2021/2022

Another proposal sought to achieve maximum surface coverage with minimum material by offsetting the toolpath at each layer. It investigated the sagging of the material extrusion depending on the printing speed and material flow during fabrication (Figure 5).

The most challenging study unit happened in March 2021 during the second COVID pandemic lockdown. Due to health restrictions, the study unit ran online, and all the non-essential shops were closed. The study unit task started with investigations of surface tessellation. It then asked students to explore the affordances of any material and fabrication they could access. The hands-on explorations relied on stationery and household tools to explore various found materials. Access to a laser cutter was limited to several hours and, therefore, unavailable to all students.

One group developed Neil Katz's 2D tessellation (Peters and Peters, 2013) into 3D volumetric tiles. The hands-on investigations, using no fabrication tools, explored materials found in a student's garage: foamboard, flexible insulated pipes, corrugated tubing, PVC hose, and plaster of Paris (Figure 6).

Similarly, The Fabric Tessellation Study project investigated the geometry of the Miura-Ori deployable origami pattern applied on leftover felt fabric pieces using a laser cutter (Figure 7).

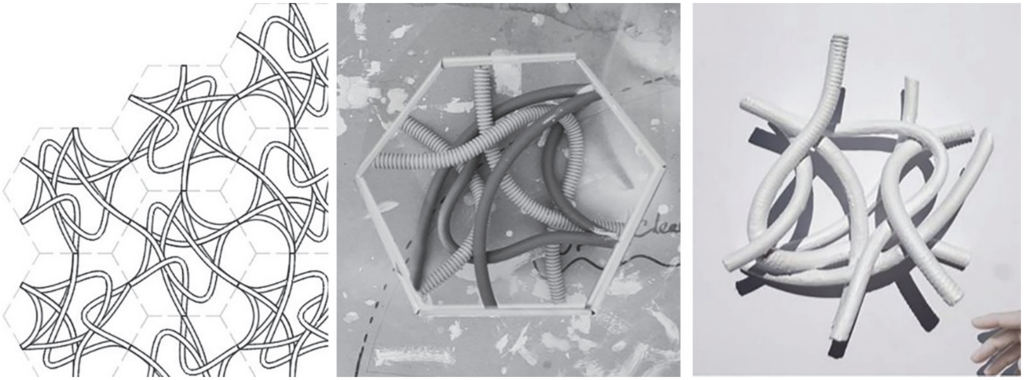
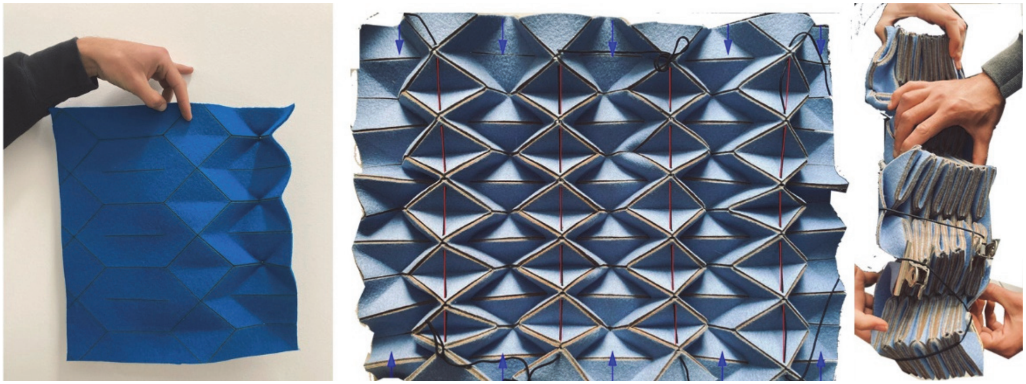


Figure 6
“Experimentation with tessellations”
Maria Bilocca, Daphne Vassallo, 2020/2021

Figure 7
“Fabric Tessellation Study” Daniel Lupi, Alessia Deguara, Gabrielle Farrugia, 2020/2021



In both cases, the design process was grounded in rigorous mythology to define the geometric procedure, conduct explorations, and meticulously catalogue various options. Investigations with materials not ordinarily used in model-making and fabrication resulted in unexpected solutions. Rigid and flexible insulated pipes created elegant, intertwining curvilinear patterns of volumetric blocks, revealing novel affordances of ordinary utility pipes. Felt, stiff yet soft material allowed foldable joints and, thus, origami to deploy. It solved a challenge often encountered when scaling up a deployable origami geometry or using a material other than paper.

Study Unit Outcomes

The unexpected quality of students' work confirmed that it stemmed from digital design methodology grounded in computational thinking and investigation-led design process, not technology and resources. Digital design folded the context of scarcity and limitations to unfold innovation and validated the study unit methodology.

The above examples reflect that introducing students to digital design enabled engaging with unfamiliar materials and tools. On a broader theoretical level, thus, students broke away from their established design thinking and work methods to develop design processes that engaged and responded to the unknown and uncertain. In short, students derived design from and for contextual realities they encountered.

CONCLUSION

Like any contemporary context, Malta is globally connected and precisely situated in space and time (Hosagrahar, 2012). Due to its high population and urban density, it can be equated with a small European city, yet its operations have neither environs nor a surrounding region to rely on. Instead, its small-scale and geographical isolation make it entirely dependent on imported resources, like food, materials, and workforce, and, thus, vulnerable to any contextual fluctuations, like wars and pandemics.

Similarly, the local building industry depends on non-local resources at every scale and each step of the construction process. Due to the lack of economies of scale, it relies on a high-volume import of a few semi-finished materials, universal solutions applicable to any context, and established formal and performative design intents (typologies). Architecture operates within a restricted design space of a limited material palette and fixed design thinking and working methods. The result is generic, universally bland built forms synonymous with the global, unremitting crisis of architecture (Cuff 2012).

On the other hand, there is an abundance of local resources that the building industry could consider viable, like construction waste, salt, and washed-up seagrass wrack. Digital design offers a methodological framework for investigating available and accessible resources as potentially valid building materials.

In conclusion, Malta, context 'peripheral' to digital 'hotspots', exposes architecture necessitates continuous innovations based on contextual explorations. Digital design offers a methodology driven by not technological solutions and abundant resources but fundamental architectural concerns.

REFERENCES

Cuff, D. (2012). 'Introduction: Architecture's Double-Bind.' in Greig, C.C., Cairns, S., and Heynen. H. (eds.) The SAGE Handbook of Architectural Theory. London: SAGE Publications, pp. 385-393. Available at: https://sk-sagepub-com.ejournals.um.edu.mt/reference/hdbk_architecttheory/n5.xml (Accessed: 30 September 2022)

Hosagrahar, J. (2012). 'Interrogating difference: Postcolonial perspectives in architecture and urbanism.' in Greig, C.C., Cairns, S., and Heynen. H. (eds.) The SAGE Handbook of Architectural Theory. London: SAGE Publications, pp. 70-84. Available at: https://sk-sagepub-com.ejournals.um.edu.mt/reference/hdbk_architecttheory/n5.xml (Accessed: 23 September 2022)

Kotnik, T. (2016). 'Structural Design, A Systemic Approach', Hernroja, A., Österlund, T., and Markkanen, P. (eds.) Complexity & Simplicity - Proceedings of the 34th eCAADe Conference, 14-23 August 2016, Oulu, Finland, pp. 43-49. Available at: http://papers.cumincad.org/cgi-bin/works/paper/ecaade2016_tko (Accessed 13 June 2022)

Kwinter, S. (2008). Far from equilibrium: essays on technology and design culture. Barcelona: Actar. Available at:

Menges, A., and Ahlquist, S. (2011) 'Introduction' Menges, A., and Ahlquist, S. (eds.) Computational Design Thinking. Chichester: John Wiley & Sons, Ltd. pp. 10-29.

Miodragovic Vella, I and Kotnik, T (2017). 'Contemporary Stereotomic Traits, an opportunity for the Development of the Volumetric Digital Architecture', Fioravanti, A., Cursi, S., Elahmar, S., Gargaro, S., Loffreda, G., Novembri, G., and Trento, A. (eds) Shock - Proceedings of the 35th eCAADe Conference, 20-22 September 2017, Rome, Italy, pp. 739-746. Available at: https://papers.cumincad.org/data/works/att/ecaade2017_108.pdf (Accessed 3 January 2023)

Oxman, R., and Oxman, R., (2010). 'New structuralism: design, engineering and architectural technologies', Architectural Design, 80(4), pp. 14-23. Available at: https://onlinelibrary-wiley-com.ejournals.um.edu.mt/doi/epdf/10.1002/ad.1101 (Accessed at: 13 December 2022)

Pendleton-Jullian, A.M., and Brow, J. S. (2018). Design Unbound: Designing for Emergence in a White Water World, Volume 1. Cambridge, MA: MIT Press.

Peters, B, and Peters, T., (2103). 'Inside Smartgeometry: Expanding the Architectural Possibilities of Computational Design', Architectural Design, pp 80-81. Available at: https://onlinelibrary.wiley.com/doi/10.1002/9781118653074.ch6 (Accessed at: 14 March 2021)