Digital Prototyping as a tool for architecture designing + making

An advanced educational experiment

Frédéric Delvaux
Architect / PhD student - University of Liège - Faculty of Architecture/URA - Belgium
frederic.delvaux@uliege.be

Introduction

The present experiment overall aims:
- at having students **discovering and exploring design issues** from the first stage of virtual (parametric) and physical model elaboration **including fabrication possibilities**,
- producing a functional large-scale prototype,
- exploring and practice space and tectonics matters.

To perform this aim, we focus on **new curriculum skills** :

1. **mastering numerical computation as a material to inject into the core** of the "traditional" **architectural design process**.
2. being able to **develop a hybridization of the fields of architectural design and computer science** (Couwenberg).
3. **using parametric design tools** as a specific way of thinking that can **extend design possibilities** (such as versatility, complexity integration and manufacturing) to support the practice of architectural design.

These foundations are extended and articulate another new and decisive aspect to embrace in digital design experimentation: the **'design-to-fabrication continuum'**.

In this way, we explore:
- the extended possibilities offered by **prototyping techniques as feedback**,
- the way these possibilities are generated and
- how they can be **integrated into the design process**, resulting in new materiality considerations, also need to be reflected on by students.

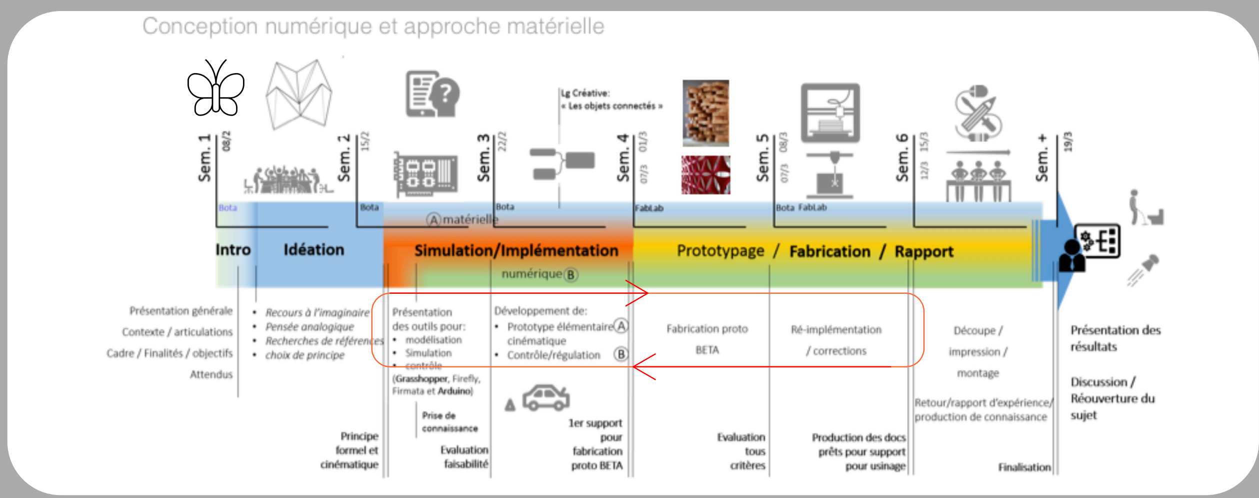
2016. First experiment: Xpanels / minimal surface model. Lasercut + manual assembly. Faculty of Architecture-ULiege.

Methods

Our teaching integrates a few **elementary theoretical principles**. As a first step, we sketch the historical background in which parametric modeling appeared and was developed. We highlight the **concept of parametric** (which existed long before the arrival of the computer).

1. Discover and analyse training of **parametric rules based modelling structure** as a network of relationship (model as an algorithm, implementation, data management),
2. exploring and training-free form generative processes (associative geometry) and versatility possibilities by introducing fundamental notions as topology and mesh surfaces,
3. Define, manage and integrate **heterogeneous (geometrical, physical, uses,) parameters** in the design process ,
4. Discover a **way of reasonning,** based on '**constraint solving' vs geometry solving** and apply resolving tasks with Kangaroo®,
5. Explore new shape behaviour: **kinetic architecture,**
6. Learning and experiment versatility by **discrete surfaces modelling and pattern studies** with the aim of perception of **space variation and fabrication possibilities,**
7. **Real scale prototyping** elements for real perception of the model, assembly checking and material fabrication possibilities,
8. **Feedback from prototyping** steps to the models by
   - the use of hand-made sketches of details,
   - implementation of new data generated by the **material** issues.
9. Improving the logic solidity of the parametric model regarding the material issues and constraints (self-weight, resistance, plasticity/rigidity, …).

The latter steps are iterated until the fabrication is reliable…

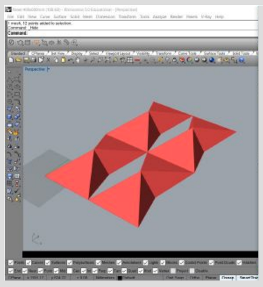


synoptic schedule: relationship of workflow steps including ressources, learning activities, creative activities, partial outcomes (iterating modeling+prototyping feedback steps) and goals.

Results

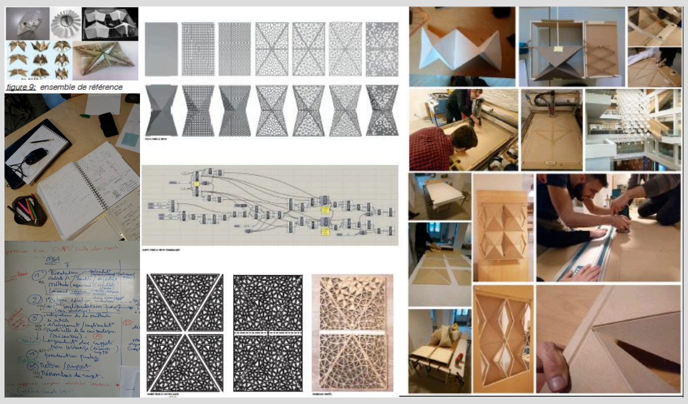
We present the results of the 2018 learning-by-doing workshop experience (Conception Numérique et Approche Matérielle).

The specific topics in this year experience are, in parallel:
- the design and the **building** of a **prototype of kinetic and adaptive architectural skin (**comfort and ambiance oriented device for light self regulation and space modification**),**
- the experiment and the refinement of a **design frame** based on the **method using the 'synoptic schedule'** as a guide line along the whole approach.



The workshop statement has determined **basic rules** :

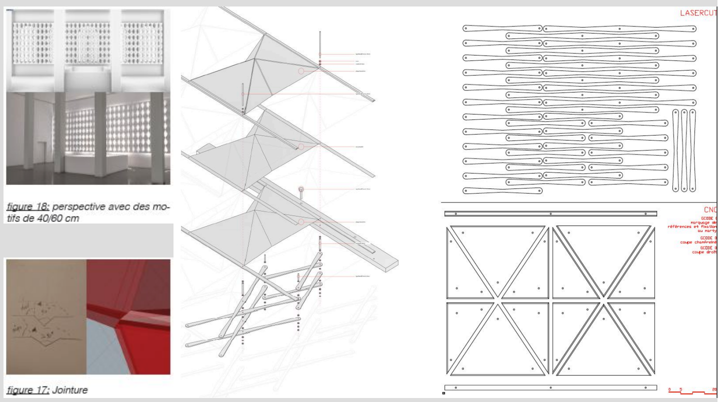
- **using the principle of origami* as dynamic behaviour** of the 'architectural skin',
- choosing the **more efficient pattern** in relation to the motion,
- be careful to create and manage **specific tectonics** ,
- managing the **CNC** milling technique,
- targeting the **limitation of mecanism complexity** by the use of basic hardware parts,
- in every work phase, **document the observations about thinking and making regarding to the tasks decribed in the synoptics schedule** (used time for digital / non-digital tasks, what kind of difficulties about the switching from physical to digital, ...)



The material results obtained consist in the realization of a prototype structured in two main interdependent parts:
1. **a variable geometry pattern**: foldable/unfoldable **origami** which ensures the **variation of light and space** (ambience),
2. **a global kinematic principle**, which distributes the geometrical variation of the pattern to the whole network (principle of interdependence): **pantographs** whose displacement of certain points of **articulation is matched to the mobilization points of the origami pattern**.

The assembly of the folded / unfolded pattern network (origami) and the mobilizing network (pantographs) **constitutes a dialectic active / passive system** where the cinematic principle causes the folding of all origamis.

Operation is partially achieved:
- the variation is in agreement with the initial objectives: **modification of atmosphere and management of the quantity of light,**
- the drive mechanism of the pantographs **does not work entirely** because the balance between the **self weight of the patterns** (wood origami) and the mechanism (pantographs) is not optimized.



Conclusions

- the proposed method is **overall acurate for its purpose**: Designing and building **architecture elements prototype**,
- the pedagogical and didactic means (time and tools disposal) we have had need to be increased to achieve a level of (high) complexity like the one we have targeted (autonomous device)**.**

The limits the students encountered are mainly due to:
- the difficulty to i**ntegrate knowledge from 'engineering' methods** (be able to associate process with creative design thinking),
- the **lack of knowledge in mecanics** and motion devices.

The benefits we have are:
- the discovery and exploration of methods for **complexity integration** in the design space,
- the discovery of the ability for the architects to be **close to the matter while designing**,
- Especialy, the use of **constraint solving vs associative geometry** as a novel and **useful method** for architectural design.
We demonstrate how it can be an accurate help for **creative thinking**, especially to manage **a kinetic architectural object**.

Furthermore, we can confirm that the **extended way of design we explore** in this workshop is not only relevant but is **becoming inherent to the design requirements** for production of architecture.

Literature

Block, P, Bhooshan. *P, S. 2016, Parametricism 2.0: Rethinking Achitecture's Agenda for the 21st Century*. Edited by Patrik Schumacher. Architectural Design Profile, no 240. London: John Wiley & Sons,.
de Boissieu, A 2013, Modélisation paramétrique en conception architecturale, Ph.D. Thesis, ENSA Paris la Villette
Couwenbergh, J-P 2015, 'L'approche computationnelle : un changement de paradigme en conception architecturale » Perspectives de recherches et d'enseignements. Journée de la Recherche et des Doctorants en LOCI [JDR+D_- 2015]. Université catholique de Louvain, p. Bruxelles
*Jackson, P 2011, Folding techniques for designers - from sheet to form. Laurenceking Ed.
Menges, A, Ahlquist S 2011, eds. *Computational Design Thinking*. AD Reader. Chichester: Wiley,.
Menges, A 2012, ed. *Material Computation: Higher Integration in Morphogenetic Design*. Architectural Design Profile 216. London: Wiley,.
Oxman, R 2008, 'Digital architecture as a challenge for design pedagogy: theory, knowledge, 9-102
Oxman, R and Oxman, R 2013, Theories of the Digital in Architecture, Routledge
Oxman, R, A 2015, MFD: Material-Fabrication-Design. Classification of Models from Prototyping to Design. Proceedings of the International Association for Shell and Spatial Structures (IASS) Symposium 2015, Amsterdam Future Visions
Picon, A 2010, Culture numérique et architecture : une introduction, Birkhauser, Basel
Sanguinetti, P and Kraus, C 2011 'Thinking in Parametric Phenomenology', Proceedings of ACADIA 2011, Cal- gary, pp. 39-48
Shon, D 1984, The Reflective Practitioner: How Professionals Think in Action, Basic Books, New York
Woodbury, R 2010, Elements of parametric design, Routledge, New York

figure 21: prototype

Acknowledgments

thanks to:

- Romuald Bianchi - computer scientist/Faculty of Architecture
- Uliege for his knowledge in algorithmic thinking and the development of digital design patterns,
- ReLab Liege for its workspace and time disposal,
- all students for their engagement, curiosity and creativity.

Poster presented in: DR_SOM Design Research (in) Practice II LISBON Session 6

Organized by **ARENA** - European Network ofArchitecture Research- and **OASRS** in Lisbon 25th and 26th MAy 2018.