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Purpose Driven Computational Design Teaching

Embracing environment restrictions in computational design

Design elegance: goals and strategies

Manifesto

In mathematics, the proof of a theorem exhibits elegance if it is surprisingly simple yet effective and constructive; a computer program or algorithm is elegant if it uses a small amount of code to great effect. Similarly, our goal is to produce elegant design.

The work of F. Otto and others at IL, was a fundamental and brilliant production of research around lightness in the urge of energy reduction context. They were emphasizing how form is related to forces and matter, and setting up lightness measures such as BIC[1]. Very influenced by they work, we consider that manufacturing process shall be taken also into account, and the unit to legitimately integrate efficiency in any design should be ecological footprint.

We consider that form is driven by the balance of the three fields: force, matter and process.

Forces are determined by the functions, expected uses and lifespan of the design. They are determining which behavior is the object going to reproduce. Matter are the potentials and restrictions of the materials in use and their intrinsic properties potentials. Finally, processes are the dynamics and resources involved in the geometry emergence that affect deeply the final result both in form and efficiency. As in a morphogenetic process, form emerges form a symmetry breaking cascade: from very abstract to concrete, form upper top imposed environmental conditions, to a decision driven gradual concretization, an increasing combination of these three fields (Table 1).

Table 1

Fields and strategies.

Manifesto

Force
-Form follow forces
-minimize stresses
surface:shells, lineal: branchings, hybrid: ribs

Matter
-Low ecological footrpint
-Reuse, Renowable, Recycle
Timber, Metals

Process
-Low energetical process
-Based from standard products
-Smart/minimal manipulation
Bending, folding, cutting, drilling, sewing, melting
-Handeable

-Low tech

Force-Process
-Efficient form from simple process
Bending, Torsion, buckling, snap-buckling

Force-Matter
-Form follows performance/behaviour
-Exploit intrinsecal material properties
-Lightweight structures
-High tensile strength, low bending stiffness materials
elastic composites

Matter-Process
-Minimize cut-off
-Complex shape with lesser elements
-Big shapes from small elements (handeable)
-Fiber/crystal orientation use
scissor structures, expandables

-Avoid additive/substractive

Force-Matter-Process
-Efficient form through simple process involving material behaviour
Active-Bending, deployables, thermoforming

Designer has to be nifty enough to interpret these boundary conditions, and to define the topology, It's a rational process leaving the form acquire its metric.

Design evenly integrates forces, matter and processes in a holistic yet simple solution. Design is the least strained solution, it's the equilibrium state of a system where several energies are acting. Design process is the energy minimization problem description and further solving. Then elegance may happen.

Restriction oriented teaching

After years of virtual economical growth, and architecture fireworks, computational design teaching often lack of purpose and architectural design teaching is then mistaken with a blind teaching of limitless tools. This context is leading to the proliferation of meaningless formal aberrations, under the self-legitimation by the means of novelty of the tool itself or the oddity of the form.

Nevertheless computational design tools enhance design and intuition, not making things more complicated, but rather complex when providing a better scientific and objective frame to design.

In this collapse-risk world, academia has the responsibility of seeding environmental concerns, and good practices. It's not about moral, it's about cooperation and common sense, it's about resources running out and design solving problems and not generating them.

The challenge but also the opportunity of computational tools is to bind real world physical constraints (in behavior, properties, processes) in the digital world. Then, design tools may be given as a complexity integrator.

Permeable

The fast growing development and knowledge sharing of computational tools, suggests reliability in the increasingly faster learning of new generations, thus the potential in the bidirectional instructing.

Collective learning happens inevitably in this enthusiastic frame of mixing students and teachers. Content, after research and experimentation is thus generated by both parts, and then is set highly accessible in the net to be muted and give birth to something better.

Nevertheless teachers are indeed responsible of the scientific design of the joint-venture research process of posing problems, collecting data, and elaborating conclusions.

Optimism

Optimistic vision of challenges are key to solve them. Teaching is encouraged to integrate fun as a value and driving force.

In one hand, failure is always an option, otherwise why even trying it? It's not the content but the process which matters, the "philosophy of doing" that prevails as Otl Aicher was pointing. In this direction, "disaster workshops", the casual curiosity driven research, are fundamentally positive in design learning, leading to unpredictable results. In the other hand, fun has formats. Design, and precisely computational design, need specifically both amounts of fun and geekiness. Thus the induction of uninhibited scientific and technological frame into the course is highly profitable.

Fig. 1
Clothespin disaster workshop.

Fig. 2
FTH03: the ultimate Perovskite project

Innovation Research Teaching

We promote a transversal relationship between academy, research and innovation, where academy plays a critical experimental ground to test concepts coming from research core, that will furthermore, derive in innovation products. Classroom sparkling enthusiasm is a great opportunity to critically test concepts and goals.

Studycases

AP12: Parametric Architecture course

Dome Athletics (Fig. 3) is the collective result from Parametric Architecture course at ETSAV, where degree, master, PhD students participate. Groups have to build twice a shape: first as a laminar continuous surface, then as a discrete structural lattice. The shape received individually is a dome generated with an inversion form finding, thus a compression laminar shell. All domes are nevertheless different, and groups may find an adequate strategy.

Strict guides have to be followed. Material is given and students have to focus in their properties. Work is 1:1, thus experimentation is a fundamental part of the course to positively feedback digital abstract frame. Manufacturing is laser cutting, and assembling is strictly by geometry joinery, while mechanical help is not allowed. We encourage to minimize cut-off, and to simplify assembling, while ensuring global stiffness.

The risen knowledge is positively collective teaching: an aggregative repository of exchangeable procedures. Students and teachers generate collaboratively the class material, the unveiling typologies from the shared topology.

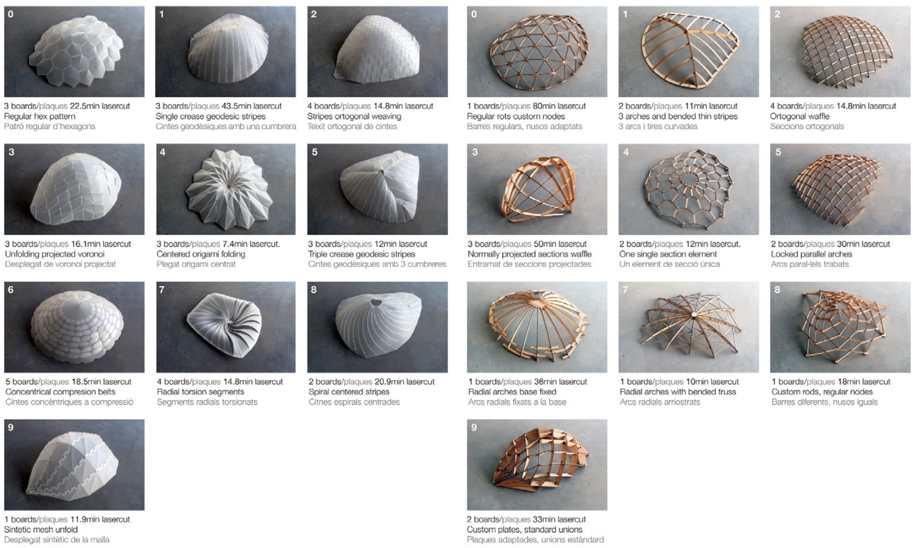

Fig. 3
Dome Athletics.

Jukbuin Pavillion

In the context of the EME3 architectural festival in June 2012 in Barcelona, the research group had the opportunity to build a self-standing structure. For this special circumstances (reduced budget and assembling time) an active-bending gridshell is chosen as design system.

Recent capacity of simulation techniques[2] and the revisions in active-bending structures[3] have provided a brilliant production of novel lightweight timber structures[4]. Nevertheless, some of these structures sharing the advantages of self-forming curved elements from straight and planar elements, seem to lose the efficiency of historical and vernacular active-bending structures, provoking material waste and demand in high technological resources and energy.

In the current challenges of energy depletion world, building solutions are called to be more efficient and requiring less resources. In this lightweight race, the potential of active-bending structures and the seduction of the slenderness and rigidity of weaving techniques, triggers the exploration of traditional basketry.

In historical structures where bending is used as a self forming process (as in wickerwork), reveal first, the empirical, behavior based approach, intuitively used historically (form out of material organization system elasticity), opposed to the analytical, geometry based approach, used by engineers to build effectively (form is predefined: active-bending is used as an economic manufacturing technique) and the geometry-behavior based approach (a more recent combination of both strategies).

The research proposes a combined strategy of building a lightweight gridshell with a low-tech fabrication process based in vernacular weaving techniques and using strictly industrialized boards. The goal is to minimize energy and material waste, in the manufacturing process of an efficient structure while simplifying assembling process.

Fig. 4
Jukbuin Pavillion.

The ultimate goal is the universalization (simple, affordable) of lightweight structures through active-bending strategies. For this challenge the complex geometrical problems are solved modeling pseudo-physical materials properties: in this behavior approach, an elastic fabric is simulated to produce the erected final shape[5].

For the festival context, the elastic gridshell proved its advantages of self-erecting while standardizing elements reduced project cost and made assembling very easy, fast, and specially feasible with non specialist builders. A crew of students helped to weave and erect this uniform and non-hierarchical fabric assimilating the building technique to the bottom up organization system: assembling small elements for a collective fabric. Characteristics: 15 UPM Wisa Birch standard boards sawn into 5 cm battens: 280 repeated pieces and 30 different pieces (257 Kg and 93 m^2 covered (2.8 Kg/m^2). No screws, no waste. 1 day erecting. Budget: 1500€

FTH Featuring the Hits

The research group behind teaching is committed to the cultural integration of science discoveries and new technologies. FTH Featuring the Hits is a series of open events to share cool things and learn new ones. Smart people sharing nifty things done with computers (or not). By this series of shifts in regular courses, students get another approach of the uses of computation as a cultural fact, and open indeed their will in parallel fields, leading lately to a more rich design environment.

Conclusions

Computational tools shall not lead to building extravaganza, but instead enhance elegant solutions. The responsible approach shall be applied both in practice and enthusiastically encouraged in academia.

As designer Otl Aicher downplays the role of pure reason and critical rationalism of modernity as a result of the predominance of a mere abstract thinking, we endorse the "philosophy of doing", and the reivindication of the analog and concrete above the digital and abstract.

Matter already computes forces, and designers should listen to it and integrate efficiently manufacturing processes. Form is emerging out of the matter, the forces and the process, we envision the elegance as the energetic minimum of those actors.

The paradigm shift that computation has brought into our society has been often misused by design fields. The increase of drawing capacity was not bonded with an increase in efficiency. Nevertheless, design is not about standing the drawn, but drawing the standing.

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Notes

1 Otto, F. et al, IL 22 *Form Force Mass*, IL 22. Institut für Leichtbau Entwerfen und Konstruieren, Stuttgart, 1988.

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4 Lafuente E, C. Gengnagel, S. Sechelmann, T. Rörig: On the Materiality and Structural Behavior of highly-elastic Gridshell Structures, Computational Design Modeling: *Proceedings of the Design Modeling Symposium* Berlin 2011, Springer; 2012 edition.

5 D. Piker: *Pseudo-Physical Materials*. http://spacesymmetrystructure.wordpress.com/2011/05/18/pseudo-physical-materials/