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How the process of knitting & material programmability can inform the design and fabrication of highly specified sustainable architectural structures?

1. Introduction

Architectural discourse tends to prioritize and segregate form over its materiality, as the matter follows the designed from creating a clear distinction between design and making. Whereas, craft lies upon the idea of the applied skill and mastery of the material (McCullough, 1996). In craft, the matter and its properties are the progenitor of form along with the methods of fabrication and forces applied to it (Semper, 1851).

The past decades there is a shift towards rethinking the use of materials and their relationship with fabrication methods. This is due to advancements on digital technologies, digital fabrication and material sciences. In architecture Neri Oxman uses the term *material ecology* to describe the new perspective of a new material-based design in various disciplines such as architecture, material innovation, biomaterials and responsive materials. ‘Here we are at the cusp of a new paradigm inspired by the Troika structure of craft, at the interaction of Materials Science, Digital Fabrication and the environment (’Neri Oxman, 2015).

Looking at craft, textiles can be seen as a material system that can be programmable for creating complex shapes, of variable properties and under the application of internal and external forces to self-organise in a three-dimensional space (Menges 2015). Thus textiles, and in particular knitting can become an excellent platform to explore how material programmability can inform the design of a continuous heterogenous form. Knitting can allow for various performances within a continuous single form-system (Scott, 2013). Such systems with hierarchical relations are useful for multi-performative hybrid structures (Ahlquist and Menges, 2013).

Furthermore, the intersection of textiles and architecture as a soft interactive/ pliable system can be used for the creation of interconnected envelopes (figure 1) within living buildings and be programmed to respond to environmental stimuli (Living Architecture System Group, 2019).

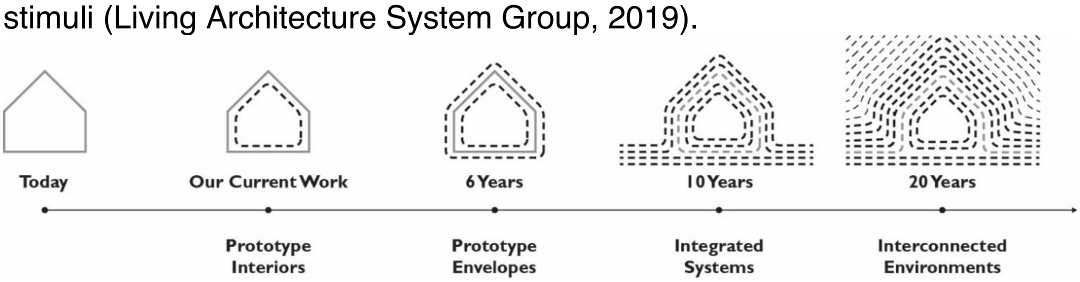

Figure 1. Living Architecture Systems Group, speculates the design of advanced, self- renewing prototypes capable of functioning within inhabited buildings, with an aim to be fully interconnected with the environments and achieving resilience and adaptability (Living Architecture System Group, 2019).

2. Subject area, aims and objectives

The proposed research by design will adopt a novel approach to the intersection of material science, textile craft and architecture. The primary aim is to introduce a sustainable and innovative design approach towards highly defined structures. This will be achieved through exploration of the knitting process as a method of fabrication in juxtaposition with material programmability, to inform hyper complex structures. The structures will be developed in response to particular programmatic criteria, such as structural and environmental parameters, which would get activated over time. This research would develop an innovative approach that benefits architectural sustainable fabrication methods and the textile industry.

Objectives

To investigate;

1. How the process of knitting can inform sustainable fabrication methods of highly defined structures?
2. How knitting programmability can lead to creation of anisotropic structures that in parts could act, form or degrade in response to the environment?
3. How material computation can be applied in knitting using physical and digital form finding methods?
4. The mechanical properties of materials from a micro to macro scale
5. A variety of materials such as thermosets, thermoplastics, biodegradables, bioplastics, UV activated and cellulose based. Also, where applicable their activation methods, which could be non-reversible or reversible, would be examined.

and;

6. Create physical prototypes, with the scope of fabricating highly complex structures that respond to the predefined criteria over time ‘4D knitting’.

3. Methodology

The new-materialist theory framework is central to the research methodology. New-materialism approach reconsiders dualism between human and non-human, material and immaterial. **Rethinking matter through new-materialism is appropriate for the aims as it provides a dynamic notion in which fibers, textile, body, technology and environment are all entangled and interconnected.** It offers an initial methodological framework to form the theoretical research basis, followed by the design research and experimentation. At all stage’s textual analysis, physical prototypes and cataloguing will be used intertwiningly.

The research will explore how the process of knitting and materials programmability can inform design and fabrication of highly specified structures. Integral part of the process is design research through a series of text analysis, underpinning theoretical notions on materialism and material practice, fabrication of prototypes, use of varied materials, analysis of materials response to environmental stimuli and structural forces. The research will be registered to a comprehensive catalogue alongside with critical analysis and reflection based on the methodology. Following on the scope would be to fabricate series of large-scale pieces that could be exhibited.

4. Methods

The proposed project would be executed under an overarching sustainability framework that would inform the design of the highly defined structure. This framework will be considered throughout the various stages of the project from the material choices, material use and to material activation. To achieve this, we require to work in tandem exploring the methods below.

1. *Knitting programmability*
2. *Material programmability*
3. *Digital simulations*

4.1 Knitting programmability

Form, scale and pattern

Fundamental part of the process would be to explore how knitting can inform sustainable architectural fabrication methods. This step requires an in depth understanding of the process of knitting and the impact the knitting patterns have to the final form. Furthermore, it would require an exploration of how this process could be scaled up to achieve a self-standing structure. At this stage various fabrication methods would be tested to scale up the process such as the use of robotic fabrication and industrial textile machines. This step will fulfil the first two objectives and would require the fabrication of multiple prototypes to test the scalability.

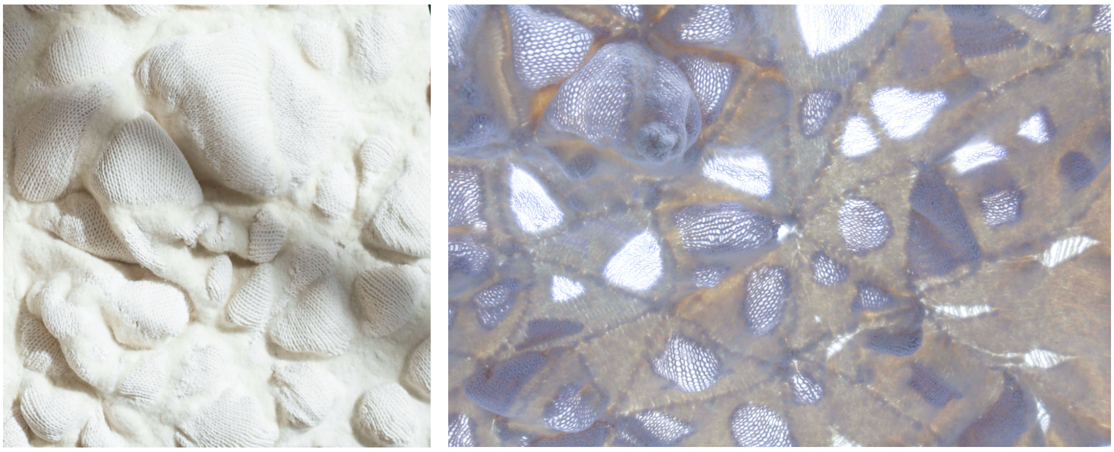

Figure 2. Work produced by Nikoletta Karastathi exploring the impact of knitting patterns on knitted forms, with the use of natural materials cotton, wool and thermoset fabric. The work has been exhibited at the Baltic Centre of Contemporary Art and during London Design Festival at Open Cell.

4.2 Material programmability

Material programmability requires an in depth understanding of the mechanical properties across scales and their response to external stimuli.

At this stage physical experiments in collaboration with material scientists will help develop a catalogue of materials, composite materials and their activation methods. Known fibres and other materials such as thermoplastics, thermoset, cellulose, metal wire, carbon fibers and polymers will be explored. Furthermore, 'bio-yarns' with various consistencies (chitosan, sodium alginate) should be tested.

The final prototypes are anticipated to be a continuous form, which is consisted of multiple-property materials that would be categorised under two types a) structural material b) infill material.

Structural

The material would respond to environmental stimuli such as heat or UV light and become rigid through time. Furthermore, the potential of testing biological solidifying methods would be tested. This material would act as the skeleton of the structure aiming for minimal use of the material.

Infill

The material which acts as a glue/ connecting /infill of the structure. This material would have multiple properties that respond to predefined criteria. The materials could have properties such as decomposing within time, absorbing CO_2 from the atmosphere etc.

I anticipate that the material consistencies will be developed and designed based on their activation. This will contribute to the final form finding experiments and will be achieved in two phases that overlap objective 3 and 4.

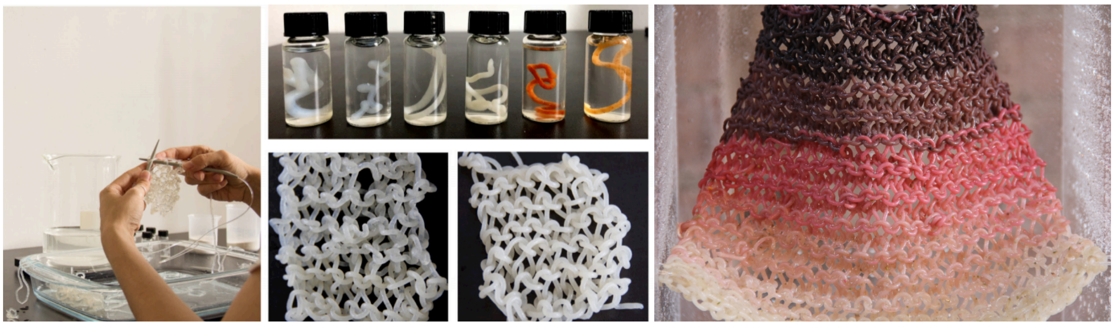

Figure 3. Work produced by Nikoletta Karastathi exploring bio- yarn made out of various consistencies of Sodium Alginate and Chitosan.

4.3 Digital simulations.

Material properties specified previously will inform simulations (through Rhino and Grasshopper for example) of the final forms. Finally, simulated design process will be tested with fabrication methods to obtain prototypes.

Prototypes will be documented in a catalogue regarding the materials, pattern and making process. Following on all the material and emergent form finding tests the scope would be to fabricate series of large scale knitted piece that could be exhibited.

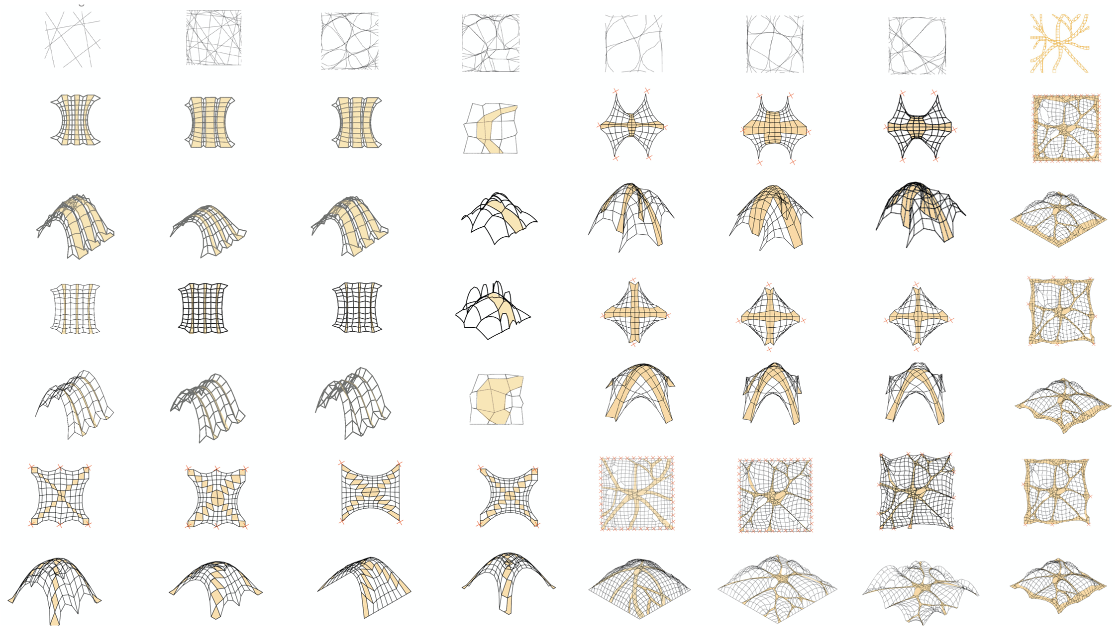

Figure 4. Work produced by Nikoletta Karastathi exploring fabric behaviour – activation in grasshopper.

5. Research Significance

The research aims to provide new tools, perspectives and a critical re-evaluation of textile-based material practice in architecture through a lens of craft, computation and material science. The interdisciplinary aspect of the study could introduce original perspectives to each field. Such as the potential of innovative sustainable fabrication methods for textile-architecture, by creating unique sensory spaces under controlled material properties and quantities. It would seek to re-establish a sustainable relationship with our build environment.

Finally, it could push the boundaries of existing simulation software and current fabrication methods.

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