Framing Parametric and Generative Structures

A Novel Framework for Analysis and Education

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In this paper we aimed at the development of a novel tool to facilitate the structured analysis of architectural construction principles, materials and production methods in digital design and fabrication practices. In order to assist the understanding and teaching of these subjects, we employed a taxonomy of spatial design construction (Vrouwe 2013). By using the taxonomy, we analysed and categorised 34 parametric structures published in the IJAC Journal (2002-2014). Informed by this study, we aligned the initial taxonomy using various framing strategies. As a result we developed a new framework for spatial design construction specifically customised for the design and fabrication of parametric structures which can potentially serve as a constructive tool to create a novel design learning environment and integrated teaching strategies.

Keywords: *Digital Fabrication, Parametric Design, Education, Framing, Pedagogy*

INTRODUCTION

As a result of the evolution of parametric and generative design strategies, over the last decade, common practices in digital fabrication have significantly transformed. With a constructive approach, computer controlled machines have been used and tested to challenge the physical and digital boundaries to produce new tectonics and to rethink the techniques for application in architecture and design. As a result, parametric design and digital fabrication have become of great significance to our spatial design education today (Kolarevic 2008).

Due to the rapid emerging traditions in digital fabrication, combined with the shortage of fitting frameworks to contextualise the projects and techniques, the end products possess a high level of complexity in terms of their structure, geometry and materiality. In practice, these projects seem inaccessible for well-intentioned design students to learn from on the one hand, on the other hand, they are difficult to teach and implement through workshops.

Therefore it is necessary to define a learning environment in which constructive education can take place with a specific focus on the understanding and teaching of digital fabrication practices. For this purpose, the development of a novel tool is required to facilitate a structured evaluation of architectural construction principles, materials and production methods, as used in digital fabrication. Furthermore, there is a need for an inclusive vocabulary for categorisation and instruction to make techniques and projects more accessible and teaching them more efficiently.

Reflecting on the above, this study aims at the development and testing of a tool for the structured analysis and teaching of digital fabrication in spatial design. This tool will be derived from a master-framework: the Supertypes-Subtypes Taxonomy for Spatial Design Construction as developed by the first author (Vrouwe 2013) based on the research of prominent research by Martin (1996), Bucquoye (2002), Ashby (2007), Kula (2009) and Engel (2007), refer to Figure 1.

In this context, we will start our paper with a brief introduction on the use of framing strategies in research and education and present the master framework (Section 'Frame Alignment of the Master Framework'). Afterwards, we will illustrate the usability of the master-framework through a survey of a wide range of cases and present a comparison of subtypes. Subsequently, we will present a reframed framework for digital fabrication (Section 'Framing Parametric and Generative Structures'). In conclusion, we will conclude by an elaboration on the implications of our findings on architectural design education and relevant practices.

FRAME ALIGNMENT OF THE MASTER FRAMEWORK

This research is a part of the PhD Thesis of the first author and is a continuation on the work presented in the eCAADe 2013 Conference. In this study, a taxonomy for spatial design construction was introduced. In this paper we will situate this framework in the context of digital design and fabrication and derive a framework particularly for this purpose. The framework will be based on a common terminology to integrate data into visual frames as a basis for computation.

Framing and Frame Amplification

We used various framing strategies to construct a framework for digital fabrication. From a wide array of conceptions on frames and framing as a theory, in this research, we limited ourselves to two of them.

In the first viewpoint, frames were used in a semantic environment as understood in social sciences. In this context, framing as a concept originates from the work of Erving Goffmann (1974) and is further developed by Entman (1993) and Benford and Snow (2000). In Frame Analysis, Goffmann (1974) discusses the relevance of a condition in which a concept is understood. When something is understood within a "world" or "reality", selective attention organises experiences and generates meaning within a certain event. In an unstable context, meaning, movements and events change and adapt. In order to participate in these changes, Benford and Snow (2000) introduced four alignment strategies; frame bridging, frame amplification, frame extension and frame transformation.

In the second viewpoint, frames were used in an ontological environment as understood in information sciences. In this strategy, frames are applied to structure large chunks of information into tractable entities (Wilensky 1987). These framing strategies have a great tradition in object centred systems and computer architectures. In these cases, frames are used to structure data for representation purposes in a stereotyped or conventional situation (Minsky 1975).

Both viewpoints bare various qualities in different applications. In this research we used the ontological strategies to construct the master-frame for spatial design construction. In order to test the frame for robustness, completeness and thoroughness in its given context, semantic strategies like frame alignment were applied.

FRAMING PARAMETRIC AND GENERATIVE STRUCTURES

During the development and customisation of the tool introduced in the previous section, we analysed a wide range of parametric structures published in the IJAC Journal (2003-2014). We made a systematic survey of these structures based on the following criteria:

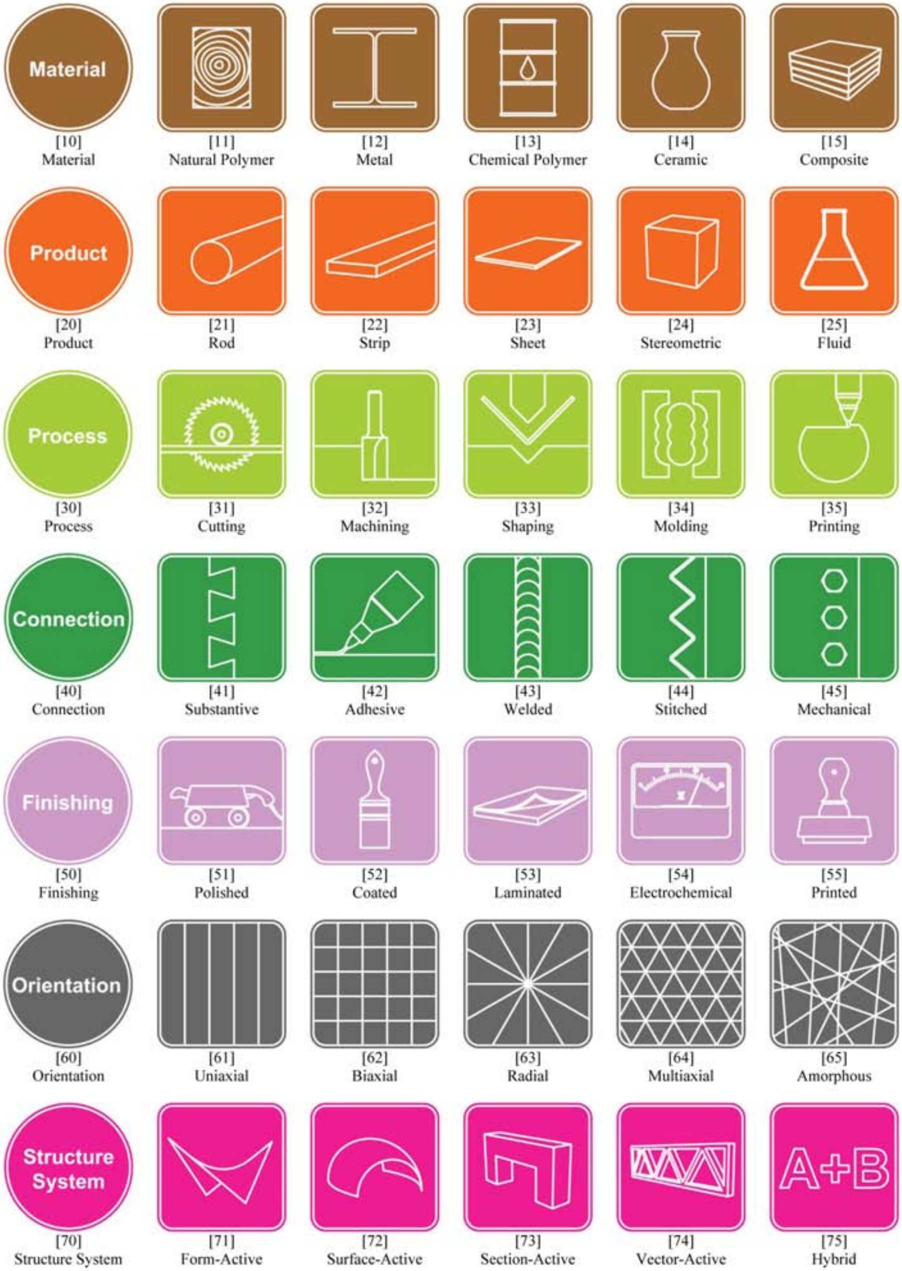

Figure 1
Master Framework for Spatial Design Construction (Vrouwe, 2013).

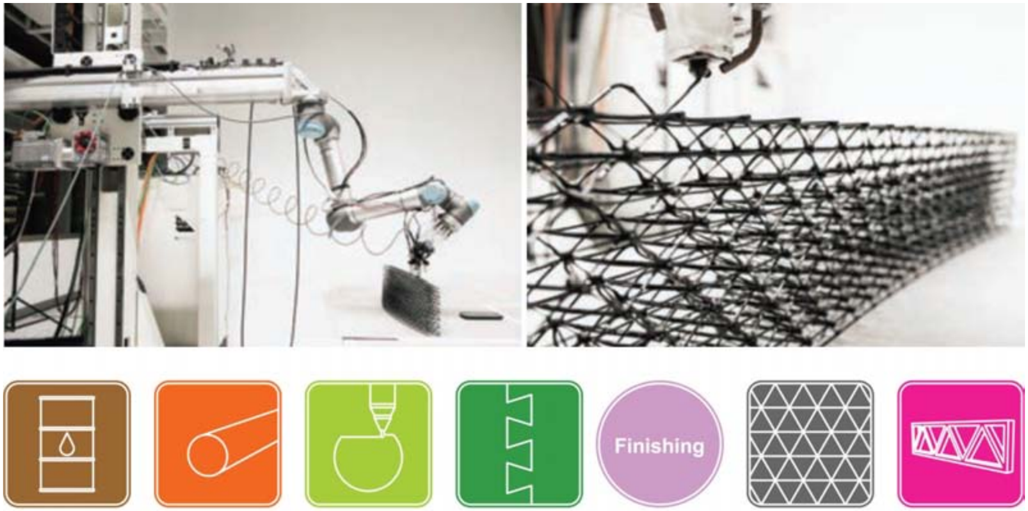

Figure 2
Vector-active construction of chemical polymer wire, processed by printing, connected substantively in a multiaxial geometry (Example structure from the IJAC paper of Hack et al. (2013))

- Digitally designed and fabricated
- Physically produced in 1:1 scale
- Included the word "parametric" in the full text of the relevant article

When multiple structures were presented in a paper they were treated as unique cases. As a result of our analysis, 34 structures satisfied the introduced criteria. Each of these cases was encoded using the subtypes in our master frame.

Figure 2 illustrates an example of this process with images of the structure followed by the relevant icons representing our analysis. After applying the encoding method presented above we were able to categorise the structures regarding the processes, orientation and structural principles as well as materials, products and processes employed (Figure 3). According to our findings, cutting natural polymers (wood etc.) in sheet form, chemical polymers in sheet form and shaping natural polymers (wood etc.) in sheet form were the most common materials, products and processes combinations (Figure 3 on the bottom left).

Moreover, the most frequently used structures were observed as biaxial/section active produced through cutting, biaxial/surface active produced through shaping and uniaxial/vector-active produced through machining (Figure 3 on the bottom right).

Reflection on framing exercise

Our survey indicated a clear need for the alignment of the master frame. In order to adjust the main construction taxonomy with the digital fabrication environment, three frame alignment strategies were employed. As the result of the use of a particular set of elements in the subtypes "processes" and "structures", frame amplification was the first strategy to be applied. With regard to processes, CNC-machinery was chosen predominantly over hand-held tools to minimise room for error on the one hand and optimise the workflow on the other. In this sense, the digital process supertype aimed at subtypes with CNC capabilities. Because most of the students and designers discussed have an education in architecture, the new framework addressed the basic background in structural analysis based on certain construction stereotypes. In order to support this theoretical background, the subtypes of parametric structures were aligned with the stereotypes discussed.

Secondly, in a great part of the projects surveyed above, behaviour of the model played a significant role. Therefore, we applied the frame extension strategy to incorporate these qualities into our framework. In these subtypes behaviour was considered as static when no movement or response is sensible in the model or the behaviour of the model is very slow and unintended; smart when the object responds in real-time to environmental stimulus; intelligent when the object aims at optimising a system within a collection of parameters or predictive

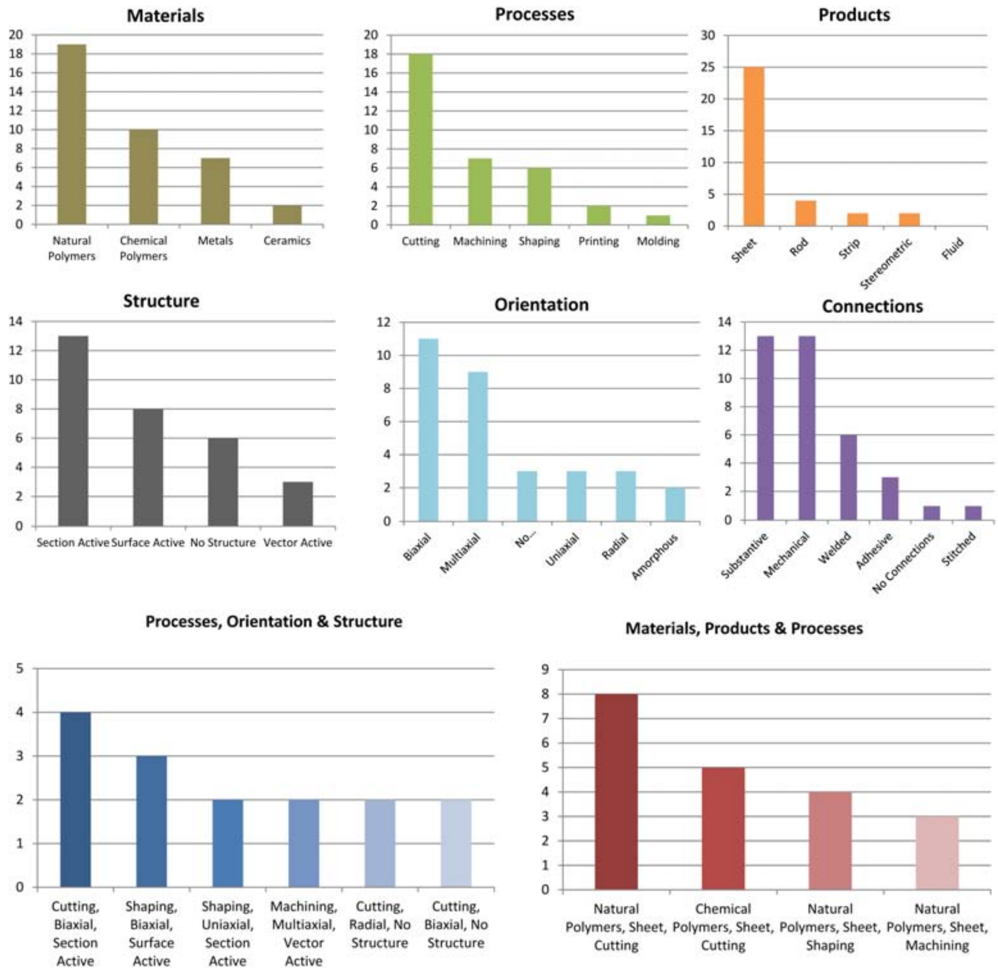

Figure 3
The frequency of materials, processes, products, structures, orientations and connections among 34 structures extracted from the IJAC Journal 2003-2014 and their combinations.

Figure 4
Supertypes for the derived framework (Moussavi 2009; Moussavi and Kubo 2006; Di Mari and Yoo 2013; Vyzoviti 2011; Weinstock 2008).

models (Negrete-Martínez 2008); interactive when human input is required to initiate response; responsive when both intelligent and interactive behaviour is included in the system (Velikov and Thün 2012; Oxman 2010).

Finally, we observed that digital designers prioritised digital geometry of surface and solid manipulation over material orientation. In order to assist this working strategy, frame transformation was used to manipulate the supertype "orientation" into the supertypes "parametric solid" and "parametric surface".

CONCLUSION AND FUTURE SUGGESTIONS

The presented master-framework enabled the structured analysis of digital manufacturing projects. Using various alignment strategies, the introduced subtypes were introduced into a new context-specific framework. Building a shared vocabulary provided a better understanding of digital fabrication techniques and made it easier to communicate the content (Figure 4). It also allowed us to identify recurring patterns and practices (Figure 3) which helped us to develop a novel and aligned framework for digital fabrication.

In the future the presented framework and framing strategies can serve as a constructive tool to create a novel learning environment and integrated teaching strategies. This environment can be an interactive mobile application which assists the students to identify stereotypes and basic elements of the taxonomy. Furthermore, the taxonomy can serve as a basis for the development of a parametric design and modelling interface which prioritises construction techniques as a starting point.

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