Speculations on Tissue Engineering and Architecture

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The main aim of this paper is to speculate on opportunities inherent in the field of tissue engineering, for possible applications in the discipline of architecture. Engineered solutions based on the discoveries within the discipline of tissue engineering can yield novel building materials and construction methods. These entire conjectures mean a different approach to the trajectories of architectural production, abandoning mechanical solutions for architecture problems in favor of biological, organ driven architectonic conditions.
1 Introduction

The Architecture design field of curvilinear geometries, inherent in advanced computation driven design techniques, tends to generate continuous space conditions, and incrementally changing surface conditions. These anexact yet rigorous (Deleuze and Guatari 1980) geometries result additionally in ever changing border conditions for panels, and thus in differentiated joints. Today, it is not a problem anymore to fabricate panels of heterogeneous nature: the predominant method in this case is to fabricate individual molds for a vacuum-forming process. The results of this process are individual panels made of synthetic materials, such as Acrylic glass and PET, or natural glass. Examples of these methods include the Kunsthaus Graz, Austria, by Peter Cook and the Hungerburgbahn in Innsbruck, Austria, by Zaha Hadid. The geometry of the panels is orientated along specific trajectories that mirror qualities present in the three dimensional digital models, for example the U and V direction of the NURBS surface, or the edges of polygonal tessellations. This approach was first articulated by Greg Lynn as a response to the bland and featureless appearance to what he calls Blob Architecture (Lynn 1995) projects. In his description of the Embryological House, 2000, Greg Lynn states:

This domestic interior is enclosed in a surface composed of over 2048 panels all of which are unique in their shape and size. These individual panels are networked to one another so that a change in any individual panel is transmitted throughout every other panel in the set so that they are always both connected and variable. The variations to this surface are virtually endless, yet in each variation there are always a constant number of panels with a consistent relationship to their neighboring panels. The volume is defined as a soft flexible surface of curves rather than as a fixed set or rigid points. Instead of cutting window and door openings into this surface, an alternative strategy of torn, shredded and louvered openings were invented that allowed for openings that respected the soft geometry of the curved envelopes. Any dent or concavity is seamlessly integrated into the openings and apertures of the surface. The curved chips of the envelope are made of wood, polymers, and steel all of which is fabricated with robotic computer controlled milling and high-pressure water jet cutting machinery.

GREG LYNN, 2000
The Panelization Problem was additionally described in detail by Oliver Bertram in 2004 as an inherent problem in the fabrication of complex curved surfaces. Curvilinear entities in an architectural scale cannot be produced in one piece, resulting in opportunities to explore possibilities to subdivide the surface following the logic of the underlying geometry as well as the constraints of the fabrication means.

In 2005, during the fabrication of the installation The Gradient Scale (Figure 1) SPAN had the opportunity to explore the Panelization Problem for the first time in a bigger scale. The production resulted in a novel lineage of thought for the praxis SPAN commencing with the question on how to close the joint. How to create a surface capable of containing the temperature on the inside and keep the interior dry?

Conventional methods would include a significant amount of manual work, such as closing the joints with gaskets. Another lineage would include ideas emerging from the field of robotics. The recently presented Big Dog robot (Figure 2) by Boston Dynamics represents a splendid opportunity to speculate about spider-like building robots, weaving entire constructions and replacing manual work. This paper's goal, however, is to report and explore opportunities outside the predominant mechanical solutions for the problem of the joint, and furthermore to describe possibilities within the realm of biological wet solutions inside the realm of tissue engineering.

2 Crossbreeding Architecture and Tissue Engineering

Following the goal to explore biological solutions for the joint problem, an entire array of potential speculations on possibilities for the architectural realm emerged, which spanned aspects of material, the structural qualities inherent in biological matter and the fabrication of organic tissues.

After an initial research phase in fall 2005 it became clear that we had to form an interdisciplinary discourse basis. In fact there is a common ground between architects and tissue engineers constituted by the fact that the tools used in advanced architectural practices and laboratories for computer aided tissue engineering are very similar, if not in some cases identical. The laboratory that initially expressed an interest in the collaboration was the Drexel University's Program for Computer Aided Tissue Engineering (CATE), as the laboratory recognized the opportunity to eventually profit from the know how that advanced architecture practices, dealing with algorithmic organic modeling, can provide with. Tissue engineering can be defined as the use of a combination of cells, engineering and materials methods, and suitable biochemical and physio-chemical factors in order to alter or replace biological functions. While most definitions of tissue engineering cover a broad range of applications, in practice the term is closely associated with applications that repair or replace portions of or whole tissues (i.e., bone, cartilage, blood vessels, bladder, etc.). Often, the tissues involved require certain mechanical and structural properties for proper function. The term has also been applied to efforts to perform specific biochemical functions using cells within an artificially created support system (e.g., an artificial pancreas, or a bioartificial liver). Tissue engineering laboratories have to deal with two main tasks, the development of solvents and nutrients as growth factors for cell aggregations, aka organic tissues. The other main task is the development of scaffolds able to maintain the cellular growth and shaping the overall qualities of the tissue. The form of these scaffolds is of crucial importance as the scaffold serves as the main formation help for the cellular growth. The design of these scaffolds can be considered a possible interface between Tissue engineering Laboratories and architectural practices informed by advanced design techniques. Tissue engineers are fabulous in developing ideas on cell growth, cell behavior, manipulation of inherent qualities and similar issues, but they lack expertise in procedural computational design and organic modeling. This expertise has evolved dramatically in the discipline of architecture within the last decade. In fact there is another quality that can be interesting for a high variety of scientific fields, which is the ability of architects to deal with high number of components to be casted into one specific project. This specific quality, and model of collaboration between architects and scientists, has been pointed out by Greg Lynn at the conference that accompanied the Gen(H)ome.
exhibition opening in the Schindler House, Los Angeles in 2006. Greg Lynn stated that in the future scientists are going to approach architects to understand how components of their research will fall into place to form an entire project.

3 Collaboration
To illustrate this let me rely again on some examples of the Program for Computer Aided Tissue engineering of the Drexel University (CATE), this example is chosen because of the fact that the authors of the paper Starting had numerous contacts with the laboratories head Prof. Wei Sun and his Assistant and PhD Candidate Lauren Shore, starting 2006.

One of the goals of the program is to create artificial veins out of especially engineered tissues, to be used for example in aortoconary bypass surgeries. For this the scaffold has to be designed in a specific arterial form. To achieve this the program director Prof. Wei Sun has developed together with C. Schroeder, W. Regli and A. Shokoufandeh various algorithms to slice complex curved geometry objects into layers that can be put together with the help of a 3D Printer. Additionally he and his colleagues speculated on the use of mathematical entities such as Menger sponges for the generation of heterogeneous porous structures. This was not only a suitable technique for the generation of venereal for-
mations but also for porous bone tissues. The goal was to change the predominant use of orthogonal grids as a base for tissue engineering, as the lab observed the different behavior in terms of cell formations and structural stability between heterogeneous structures and orthogonal structures. Natural heterogeneous bone tissue for example behaves considerably more efficient in terms of material consumption and structural behavior than the orthogonal grids widely used in tissue engineering.

This Biomimetic approach marks a possible interface between architects and scientists involved in the field of tissue engineering, as it opens opportunities to speculate not only on the level of material but also in the realm of structure, form and eventually program.

Let us start the speculations with the already mentioned issue of the joint, and expand the possibilities tagging along this line of thought. The main question the Authors had, addressing CATE, was the possibilities to bridge a gap of a joint with organic matter that can provide the same qualities as normal gaskets used in such cases. Provided the necessary porosity within the material it should be actually possible to close such a gap with organic material, and it is just a question of time till this idea is realized in small scale as a proof of concept. For this proof of concept it comes in handy, that tissue engineering and advanced architecture share some tools, such as 3D printing and advanced animation software. To check the possibilities of communicating via 3D models, the Authors sent digital data to the CATE Tissue engineering lab to be 3D printed in their lab (Figure 3).

One difference within the digital fabrication tools encountered at CATE is a fabrication method that has not been used in Architecture design at all which is the use of Multi-Nozzle Biopolymer Heterogeneous Deposition Systems, that represent a proprietary system developed by CATE. It provides a biofriendly environment to simultaneously deposit multiple scaffolding materials with living cells, growth factor, drugs, biological and non-biological components. This innovative production method could fabricate responsive components consisting of heterogeneous materials, each one with a specific quality and entirely sustainable. Ready to grow together as soon as they are on site and provided with the necessary nutrients. In fact the main problem that arises within such a material and fabrication process is the same as with any exotic & rare material, the problem of scale and the problem of access to the material. For the moment being it is a material development in its infancy. Speculations on the opportunities however, are totally fair to do, in order find perspectives in the use of advanced biotechnological means for architectural projects. Engineered materials on the base of the findings within the discipline of Tissue engineering can yield building materials able to regenerate, to be responsive on environment condi-
tions, they can provide light by bioluminescence and they can die and decompose. They can transform Carbon dioxide into Oxygen. These entire conjectures mean a different approach to the issue of architectural production, as it would abandon mechanical solutions for architecture problems in favor of Biology, organ driven architectonic conditions. In fact this doesn’t even mean that the resulting architecture has to Look organic, but that it is the underlying logic of construction and material that follows the logic of organic entities. The most exiting aspect in the explorations of tissue engineers, and an instant application within the field of architecture, is the application of computational models that mimic the structural behavior of heterogeneous porous structures such as bone, tendons and cartilage. These computational models do not share the problem with the material side, and furthermore, they are scaleable maintaining the structural quality, meaning that it could be applied in architecture with ease, introducing the structural logic of heterogeneous structures. Providing higher stability with lower material consumption.

4 Conclusion: Surface changes Biology

The basic model applied within the described ideas of computational models derived from porous formations was the application of high genus entities, as they represent a specific logic within the topology of porous entities. To apply these ideas the authors employed the topological mesh modeling software TopMod, and generated a variety of study models dealing with high genus entities. This study models were scrutinized with the help of the CATE laboratory as well as the Advanced Fabrication Studio of Saddleback College in Los Angeles. The models were fabricated in 3D and examined not only in terms of structural stability but especially also in regards to its architectural qualities. These basic research models comply with the idea that surface changes biology by putting form into operation that follows specific geometric rules. In Biology the formation of material is high in energy consumption. That is the reason why as little material as possible is used. The application of form on the other hand is very low on energy consumption so it is fully employed to generate performativity. Finally this study models resulted in novel insights in spatial formations that spilled over to various competition entries such as Blossom (Figure 4), and the new Brancusi Museum in Paris (Figure 5). The design method of the Brancusi Museum included the application of Topological surfaces that served as enclosure and structure simultaneously employing algorithms and tessellation techniques (Figure 6) that are present also in biological entities such as sea urchins, turtles and various seeds. The results of this studies and speculations are still a work in progress and we expect further insights from the field of Tissue engineering into the field of architecture.

5 References