Form Active Translations: Knitted Textiles to 3D Printed Textiles

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ABSTRACT
Material translation as a driver of innovation through craft, specifically the translation from machine knitted textiles to 3D rapidly prototyped textiles is discussed in this paper. If architects and designers can develop methods to translate existing textile structures and behaviors, then architects and designers can harness the vast extant knowledge base that goes into the design and fabrication of geometric textile structures and resultant behaviors to develop new materials and tools to construct active building systems that use the pliability of textiles to advantage.

KEYWORDS: 3D Printed Textiles, 3D Printing, Architextiles, Knitted Materials

Introduction

The potential contribution textiles and textile behaviors can make to building design and architecture is enormous. Envisioning a building made of lightweight materials that can adjust or adapt to its environment or changing loading conditions is useful on an earth that is in an active phase of new land formation and changing its shape.

One of the principle problems that Semper addressed in his prospectus "Style in the Technical and Tectonic Arts or Practical Aesthetics" was the act of translation from the textile arts to building, *and* from material to material. His essays were written in reaction to what he perceived as a general lack of consideration of the processes of making relationship to selected materials or craft in industrially manufactured products witnessed at the Crystal Palace Exhibition in 1851. [Semper] In the building works of the ancient Egyptians, Greeks and Romans, he saw that that the act of translation from cloth, to wood, to stone, permitted cultural continuity and drove innovation in the craft of building. Translation is a way to develop new technologies of production from tradition. [Cache]

Translation as a focus was explored during a workshop at The Swedish School of Textiles in Boras Sweden, over the course of 4 days that brought together textile designers to translate existing textile machine knitted textiles to 3D printed textiles and then back to knitted textiles. Initial textile samples were constructed to exhibit particular dynamic behaviors and changeable states, and participants of the workshop sought to understand how these behaviors could work on textiles made by using the 3D printer.

There were three specific properties that were engaged in the act of translation of the textiles from traditional fabric to digitally created material. The first was translation of the geometric configuration of the textile. The second was translating the material quality of the textile. The last translation was the overall behavior of the textile into the 3D printed version of the textile. The overall behavior was understood as a resultant of the combination of the first two translations.

Translation and geometric representation

One of the principle issues discussed in terms making a geometric translation into 3D printed textile model was how to frame a unit to make the overall pattern and achieve transformable motion in the unit that permitted the printed cloth to return to its original position. For example, in drawings of the knit structure shown below, there are three ways to segregate the yarn into a unit. Yet there are almost an infinite number of ways to develop the parts of that unit. The configuration that is ultimately selected should provide the most information for what one is analyzing. In the example below, Figure 1A that is taken from *Textile Structural Composites in the Composite Materials Series,* the unit was developed to model the friction between the yarns; therefore the unit is based upon the overlap portion of the yarns. [Ko] Ultimately the unit looks the same as any other knit stitch however that overlap location is made information rich in terms of points set and other computations that may be performed there. This information is embedded into the 3d model data.

3D Printing Technology

In the past ten years there has been much exploration using many different kinds of 3D printers to rapidly prototype parts, but in the general market the uptake has been sluggish because printing is slow if printing large pieces, and expensive. The promise of the technology is that a designer can fabricate at many scales materials that can be customized to achieve a particular behavior by depositing or printing different kinds of materials with differing characteristics as required for overall operation of a piece. Generically 3D printing is called Incremental Forming and a piece or part is formed by adding layer upon layer. [Mitchell and McCullough] Please See Figure 1B.

To use any 3D printer, one must construct a digital model that is a solid model in a 3D software program that serves as the data that is fed to a printing machine. There are many kinds of 3D printers; the one used in the workshop squirts heated abs plastic from a nozzle building up the model layer by layer based upon digital data points. This method is called Fused Deposition Method or (FDM).

Related Work

Some examples of 3D printed textiles include the N12 Nylon Bikini by Continuum Fashion, headed by Jenna Fizel and Mary Huang. This bikini permits a close fit to the human body by changing the scale of the base textile unit or stitch, in this case a circular disc that is printed looped to its neighbors. The fabric was designed so that the higher degree of curvature on the human body, the smaller the diameter of the disc creating a snug fit rather than introducing a dart , curving the unit itself or elastic material. Here the desired behavior, curvature and close fit are programmed through changing the scale of the unit geometry. [Fizel and Huang]

Other interesting 'textile like '3D printed surfaces, with informed active behaviors is the lamp called "Volume" by Dror Benshetrit for Material mgx. By introducing slotted looped pieces the lamp can move from open state or full volume to closed state or flat. This lamp is particularly interesting in that the units not only move in a very specified way, but also one can achieve a stable shape on either ends of the trajectory moving from open to closed. [Benshetrit] There are many other examples of 3D printed textiles; however these two examples exhibit a repetitive geometry that adjusts to specific requirement and context.

Framing the Process of Translation

The workshop process is outlined in Figure 2A. Each of four workshop teams completed the process at least one time. Step 1 was to arrive at the workshop with a knit sample which teams had previously developed on a double needle bed weft hand knitting machine. Step 2 was to make a physical 3D sketch drawing or model of the team's stitch unit. Step 3 was to create a 3D Rhino model. Step 4 was done after the rhino models were finished, and was to knit final samples on the industrial weft knitting machines.

Step two: close and interpretive translations

The first sketch model done on peg board was literally

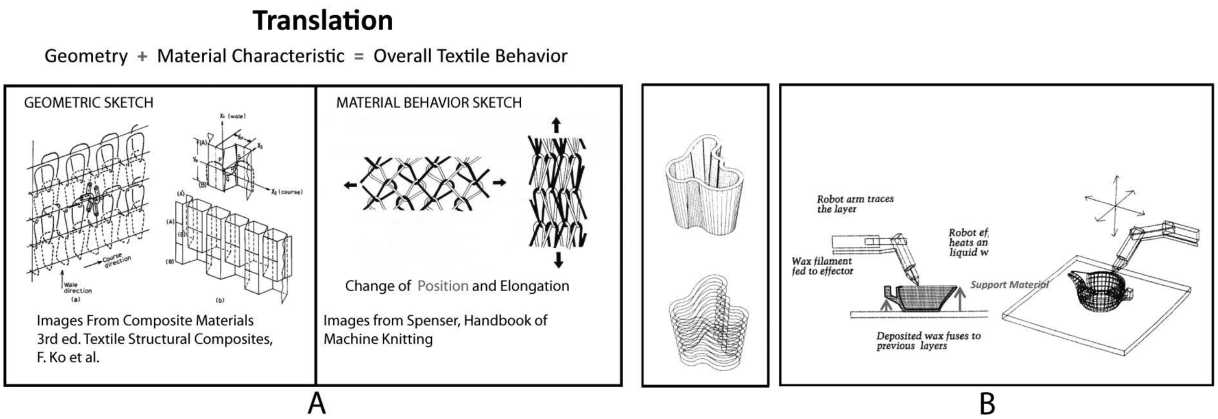

Figure 1 (A) Translation and Representation (B) Incremental Forming with Fuse Deposition Method.

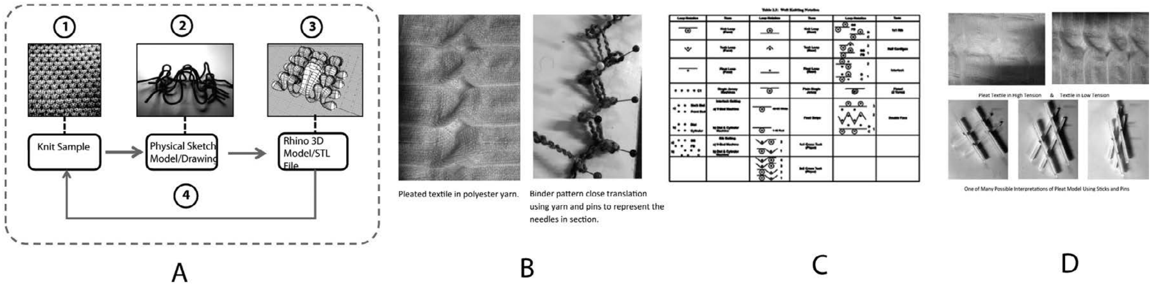

Figure 2. (A) Workshop Process Outline (B) Close Translation Model (C) Binding Code (D) Interpretive Translation Model

taking apart the stitch using the *binding pattern*, or the pattern that is used to show how the yarn is wound around a needle in a knitting machine to make the actual textile. This was known as the *close translation*. The idea of the unit is aligned with the position of the needle. Please see Figure 2B. The binding pattern is typically shown as needles in section or dots that position the yarn, the line, in some relationship to the needle bed. In the case here, each knit pattern made in the workshop used two needle beds a front and back needle bed. Figure 2C shows some standard weft knitting binding code that was used in the workshop binding patterns. This code was displayed in the computer software used in to make machine code to run the industrial knitting machines.

It was soon discovered that the binding patterns as base structure for a 3D print became long lines of stitches not linked though because no needle was interlinking the threads making the lines connect together. Another system had to be invented to hold the layers of loops together in the z direction, if this method was used. Almost none of the original behavior of the textile would be carried over into the print, and a new set of behaviors would be introduced. A second sketch model looked at an *interpretive* translation of the textile into a 3D print. The critical issue was for the units to be interlinked, and also to move, see Figure 2D.

Step 3: stitching in rhino pegboard

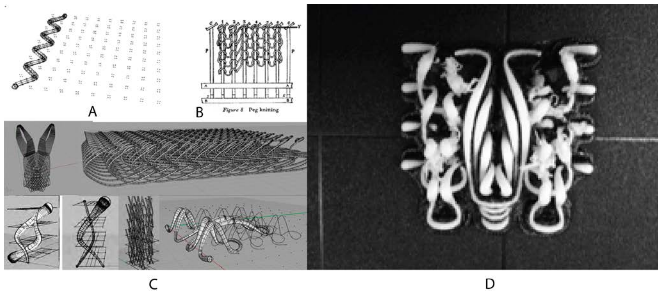

Figure 3 (A) Pegboard Method of Drawing in Rhino (B) Traditional Pegboard (C) Rhino 3D textile models (D) 3d Print.

Most of the participants in textiles had no experience with 3D modeling software so a method using Rhino 3D modeling software were taught. This method was based upon a peg board, which is historically an early version of knitting, which made the looped knit stitch by wrapping the pegs with thread and then drawing the thread up through the next layer, just like a binding code. [Spenser] See Figure 3A and B. During the workshop participants drew their own pegboards in Rhino and then connected the dots with a line to make a cluster of stitches and then that line was piped to make a yarn. Models were then saved as STL files ready to print.

Step 4: returning to knitting

After completing the rhino models participants made a translation of that 3D digital model back into a textile. Four teams produced four projects. 3 of the projects were made on double needle bed weft knitting industrial machines with the exception of one project that was made on an industrial Jacquard circular knitting machine. The difference is important because the interface software and computations are different for the two machines. For the weft knitting translations, the cross back to fabric from 3D model could not be literal. The model had to be translated in an interpretive way back into binding code into the computer for the machine code to be produced.

The Jacquard machine however, could take the literal pixels from a 2D image captured in Rhino from the 3D model. This machine used bitmaps of that 2D image in black and white and translated the image, so that each stitch was represented as a pixel that created a surface pattern onto the cloth it knitted. This is often the method one will find with home computerized knitting and sewing machines.

Project One knitters started with a sample made of two different sides of cotton and Elastane. Their study sketch models and Rhino models showed a development of a unit that could attach above and below. The knit that developed from those models in the 4th step of the process used wool yarns on one side, creating an extremely soft and stretchable textile, and on the other side mixed cotton and copper yarns creating a very scratchy, rough surface that wanted to stretch in one direction only. The differentiated yarn material qualities made the textile curve with the copper yarn bending the more flexible textiles to its shape.

In Project Two, knitters expanded the yarn thickness in their Rhino model and used this to make a knit that

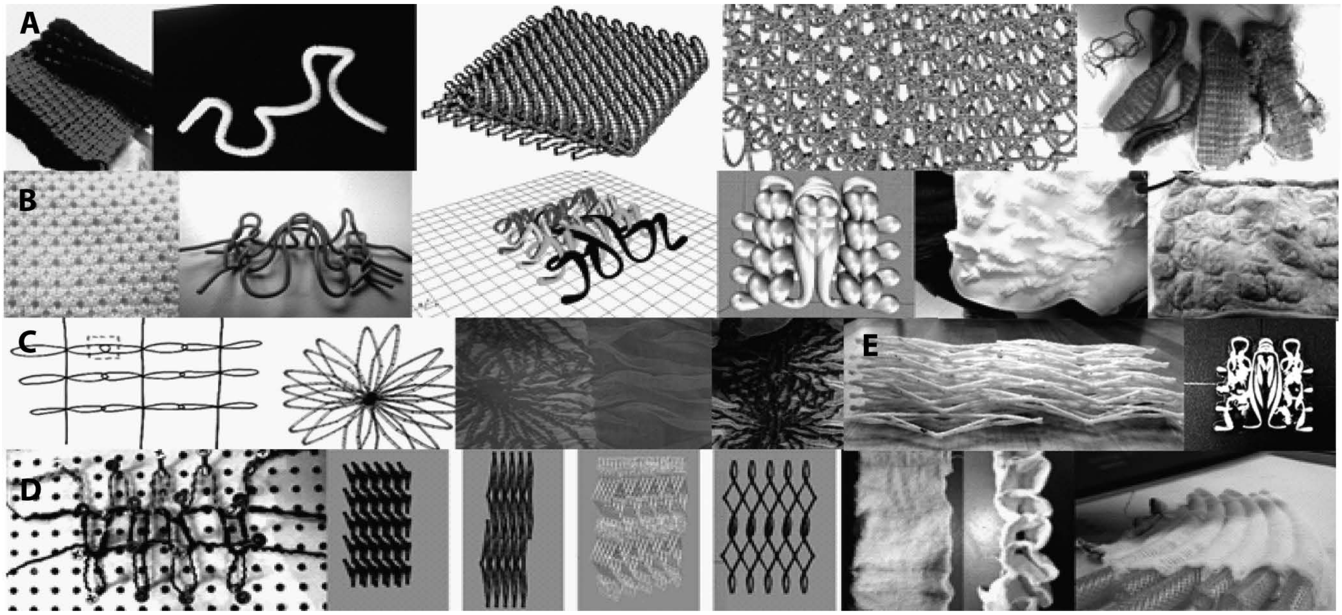

Figure 4 Four Project Teams Processes from Step 1 to Step 4. (A) Team 1, (B) Team 2 (C) Team 3 (D) Team 4 (E) 3D printed Models.

created deep pockets from the yarns that popped up above a level plane that horizontally intersected the knit pattern. This team tried several different material versions of these pockets, one set used pemotex yarns, that were then heat shrunk to make a tightened version with blisters. A second knit was made with 100% wool yarns, and then shrunk in the washer, creating a felted material.

In Project Three the knitter used a polyamide yarn in the Jacquard machine with polyester filament, which made two sides of the textile, when machine washed in cold water, the polyamide yarn puckered up from the polyester and made the tension patterning.

In Project Four, the knitter translated the Rhino model as the section of the textile, creating a spacer fabric, or fabric made up of interior tubes of space. The material selected was a Pemotex yarn that shrinks to a form with heat. It is a thermoplastic yarn that was shrunk onto some plastic tubes to mold the space between.

Questions and applications framed by the workshop

The process of translation moving from the textile sample to the 3D printed model revealed some interesting areas for synthetic research in textiles and in architecture, especially in tools and applications. There are some people who are working in this area for knits such as Mette Thompsen and Norbert Palz who have worked with the knit structure as a 3D printed textile for instance. [Palz and Thompsen]

Some of the salient research areas and questions raised in this workshop include developing methods to connect textile code or rather textile *structural* patterns to architectural software that allows for a designer to work with textiles in an experimental state in software. One application of this work could be in 3D printed textiles for example. This application may not only be utilized as a method for making new textiles, but also used by architectural designers to develop new structures of materials for building systems. A second question raised was how to include the diversity of materials available to textile designers at the start of their work into architectural thought and design processes early on as shaper of design, not an afterthought applied to an architectural representation. Predictability of the textile for use in building application for architects is a very large problem, which is not so much of an issue for textile designers. [Alquist] Computational crafting tools are needed to address the problem of play in a textile system. The craft of designing with textile materials is still very much a hands-on process in spite of the industrialization and computerization of the equipment. If architects and designers want to go beyond the abstraction of textile knowledge into software by way of patterning, then it will have to take on material constraints and the knowledge of textile design as a craft.

Contributions of the workshop

The workshop demonstrated a method of using 3D printed models to expand the traditional concept of textile material. The workshop framed the problem of connecting the structural geometry of a textile knit to its behavior separate from material conditions. In addition the workshop framed the problem of relating geometry to material behavior. The workshop demonstrated through experiments with 3D printing methods and knitted textile samples, methods of translating structural geometry in conjunction with desired behavior. The experiments in the workshop framed the problem of varying material states that offer a diversity of ways of working to both textile designers and architectural designers. The workshop framed the major question of how to closely connect textile design and tools with architectural design and tools.

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