Inkjet4Tex: Creative implications of 3D inkjet printing technologies for textiles

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Abstract

This project expands future applied-design capabilities for textiles as a function of inkjet deposition technology. The project investigates 3D inkjet rapid-production tools' potential, focusing on creative gaps in the developing technology in its application to the textile design process. As such, the research investigates future design possibilities for inkjet printing technology in the creation of 3D textile structures and surfaces. The research "demonstrates how tacit knowledge can be employed, observed and created in a methodical way, with new artefacts playing a role in provoking insights based on tacit understanding"… (with a) focus on developing and employing tacit insights that would not be revealed in situations where nothing has been changed." (Rust, 2007)

As inkjet textile technology evolves past a rapid prototyping tool into a series of responsive manufacturing techniques for textile products, designers, textile technology developers and soft goods industries will be able to use the results of this research to maximize their creative development. By developing and employing modified 2D/3D textile design processes with the technology future creators will be assisted to conceptualise and manufacture locally, creatively and with more accessible technologies.

Keywords

3D textiles, surface design, technology-driven design process, inkjet printing, fused deposition modelling, novel textile design

Research Context

In the last ten years a surge of new technologies have filtered into the broad range of craft/design disciplines. Many of these technologies are applicable across disciplines as they employ the capabilities of digital imaging. Several digital prototyping and production techniques enable the designed object to transcend traditional material properties, constraints and disciplines. The creator of the "One Shot Stool" shown in figure 1 completely dispensed with the need for separate joining elements such as bolts or nails to connect components; instead the twist-folding stool is created in one step using rapid prototyping (RP) tools (http://www.materialise.com).

Figure 1. ONE SHOT STOOL by Materialise

Increasingly, the relationships between the act of designing, prototyping, producing and consuming have become more symbiotic through the application of computer-driven RP technologies. In our society of design conscious consumers, the flexibility of design and computing technology reinforces the trend for customization, personalization, experience and exclusivity to be built into the design of products (Pine & Gilmore, 1999). How can we creatively apply new technologies to integrate these concepts into design? For the technology-driven designer, the boundaries between the craft/design disciplines have drastically blurred (Treadaway, 2004). Selecting computer-driven manufacturing processes functions similarly to selecting drawing tools from a palette. The physical outputs are now a direct extension of digital imaging technologies.

Developers such as Microfab and Dimatix have recognised the potential for inkjet technologies to be used as a manufacturing process, but often are unaware of how to translate the capabilities into creative applications that can become (or be incorporated into) products (VTT PUBLICATIONS 635, 2007). It is likely that the true innovations will occur in discipline-specific applications of the tools. The use of these tools could be described as an intervention to traditional textile design processes, as they provide entirely new possibilities in both process and product for textiles. An innovative approach to integrating 3D inkjet technologies into a textile design process needs to be developed.

As a deposition technology, inkjet printing provides a wealth of alternative applications that allow for the development of completely new products and categories in fabric design and textile product production. Previous research (Author & Co-Author, 2005. p. 10) suggests that the technology can be approached in a very holistic manner to incorporate complex design effects into manufactured textile products. From a textile printing perspective, inkjet printing is unique as the only non-contact printing process for fabric. Droplets of ink are released from a printhead mechanism that travels above the textile surface, thus functioning as a 'deposition' process (Author, 2006). This process in textiles has traditionally been a two-dimensional (2D) design process, but through manipulating inkjet heads to also traverse on the Y and Z axis, three dimensional (3D) printing necessitates the development of a 2D/3D textile design process. Organisations such as the Information Management Institute (IMI, 2008) have supported symposia on "Inkjet as a Manufacturing Process", but to date no published literature or organisation has suggested a cohesive design-process approach to creating 3D flexible textures for surface effect.

Research Question

This project expands future applied-design capabilities for textiles as a function of inkjet deposition technology. The paper focuses on one strand in a series of lateral investigations by the authors with existing inkjet technologies employed in the design and development of textiles. The project investigates the tools' potential, focusing on the creative gaps in the developing technology that are either too risky for the industry to invest time in, or apply the technologies in a manner not directly related to its intended purposes. As such, the research investigates future design possibilities for inkjet printing technology in the creation of 3D textile structures and surfaces.

How does this work relate to previous research in this area?

In 2003, a design firm called Freedom of Creation (FOC) conceptualised and developed new structures for three-dimensionally printed textiles (http://www.freedomofcreation.com). Their research resulted in a series of flexible textile-like structures, like the one shown in figure 2, that were 'printed' using Selective Laser Sintering technologies. The designs resembled chain-mail-like fabrics, created using fairly rigid polymer interlocking rings and chains. The project demonstrated potential for new applications in responsively-produced textiles, but were limited in usability by their weight, scale and relative cost. 3D inkjet deposition technologies have begun to show greater potential for continued development in this area, due to the reduced cost to produce and greater flexibility in substances that can potentially be printed, but there are some limitations to their applications in textiles. Investigations into reducing the scale of 3D textile structures, improving the designs for usability and producibility need to be undertaken and will help to enhance design for this area.

This project responds to 3D textiles created by FOC, but focuses development to inkjet-only output possibilities, primarily for surface effect as opposed to structural textile designs.

Figure 2. Freedom of Creation – Laser sintered textiles.

What makes this interesting from a research perspective?

As an early stage investigative project, this research has straddled a wobbly balance between design-led and practice-based research. Through investigating the technology's potential we sought to "illustrate how designers can act as provocateurs in the early stages of interdisciplinary work, indicating a wider role for their work in taking responsibility for the genesis of a project as well as, or instead of, its conclusions. (Rust, 2007)"

We do not claim the potential for the research to lead directly to marketable products; instead we have removed many standard design constraints (indeed possibly even reason) as a means to freely investigate and expose non-linear opportunities in their application to new modes of textile design.

Aims and objectives

The research goal was to use practical testing and development as a means for investigating and generating a 2D/3D textile design process. Much theoretical research has gone into developing software to approach 3D design of textiles, mostly focused on replicating existing textile structures in 3D visualisations such as those of Dong and Chantler (2005), but little research has demonstrated design principles that can be applied to enhance the physical creation of 3D textile concepts through the application of rapid production technologies. This research is not simply about creating working samples; it follows on a program of research previously demonstrated by the authors (Author et. al, 2002) about developing appropriate methods for integrating new technologies for continued design development. Through the project we have embodied a type of design research described by Chris Rust (2007, p. 73) in a recent International Journal of Design article:

> *This set of practices developing in design, in both research and practice settings, demonstrates how tacit knowledge can be employed, observed and created in a methodical way, with new artefacts playing a role in provoking insights based on tacit understanding.*

To borrow Rust's description of Bowen's work (2007, p. 72), our goal is to

> *"develop new methods for designers of physical products that embody computer-mediated functions, … (with a) focus on developing and employing tacit insights that would not be revealed in situations where nothing has been changed."*

The overall aim of the research was to work together to build a comprehensive picture of potentially significant 'breakthrough methods' for future design applications in the use of inkjet technology for textile design. This paper presents initial results of the following objective: To design and print both 3D textile structures and topographical surface effects that can be adhered to a fabric base, focusing on evaluating the technology's potential for changing the scale of 3D structural textile designs.

Approach

The investigations used inkjet fused-deposition modeling methods for 'printing' three-dimensional (3D) fabric structures and surfaces. Two approaches were employed to design 3D inkjet textiles: a) building up the surface texture of an existing textile by conceptualizing, designing and printing 3D elements that adhere to the fabric surface; and b) printing 3D textile structures that are novel variations on knit and woven structures. The experiments focused on evaluating the technologies' potential for changing the scale and structural elements of 3D textile designs, as a means for finding the most workable and flexible structures for use as actual fabrics. To conceptualise methods for 'capturing' or generating the 3D designs, the team employed a design process of 3D scanning and reverse modeling techniques devised by one of the authors.

The research group developed criteria for visual and structural concepts to be explored in the testing of 3D surface structures. The goals were as follows:

- Attempt to investigate 3D surface structures that are novel developments for textile design effects. For example, the team did not want to spend time trying to replicate existing fabric structures for 3D effect; i.e. we would not attempt to create surfaces that mimic known weave/knit/non-woven structures or to imitate yarn or fibre structures in 3D as this type of research has been previously attempted, primarily by material scientists and textile engineers, and mostly focused on creating algorithms for generating randomised visualisations of woven or composite fabric textures in three-dimensions (Quinn, McIlhagger, and McIlhagger, 2003) (Texture Lab, Heriot Watt University).
- Determine methods for creating and predicting 3D surface structures that would enhance (or at least not excessively inhibit) flexibility of the substrate.
- Combine goals for flexibility with an ability to create structures that would not collapse or crumble with flexing or bending of the substrate. This involved a visual investigation of the types of geometric and/or organic shapes or motifs that are optimal for these criteria.
- Develop design approaches and techniques that focus on the advantages of 3D inkjet fused-deposition modelling printers. This involved determining an approach to the technology's need to include lattice or structural supports as part of the 3D 'build' process, as well as investigating methods for taking advantage of the rigidity of the nylon-based polymer used as the printing medium. Future investigation will include comparison of these approaches to possibilities and constraints that exist in other rapid prototyping techniques, such as selective laser sintering, stereolithography, etc.
- Experiment with creating 3D designs from existing images that have been used by the authors in investigating potential for other digitally-driven output technologies for textiles, such as laser etching, digital printing and digital embroidery. This allows for the researchers to visually demonstrate the transformation of a designed image/idea as it is re-represented in multiple output technologies.

Results

Investigations involved analysing and developing textural constructs that could be re-represented through 3D technologies, yet be used functionally as an extra-dimensional surface of a textile. Structures inspired from images like the electron microscope photograph of carbon nanotubes shown to in figure 3 functioned as a starting point for the designs. From these, a series of 3D designs were created. The designs were printed while testing a series of techniques for adhering the dimensional print to existing fabric structures, as well as attempting to generate an embedded textile-like ground within the body of the 3D printed file.

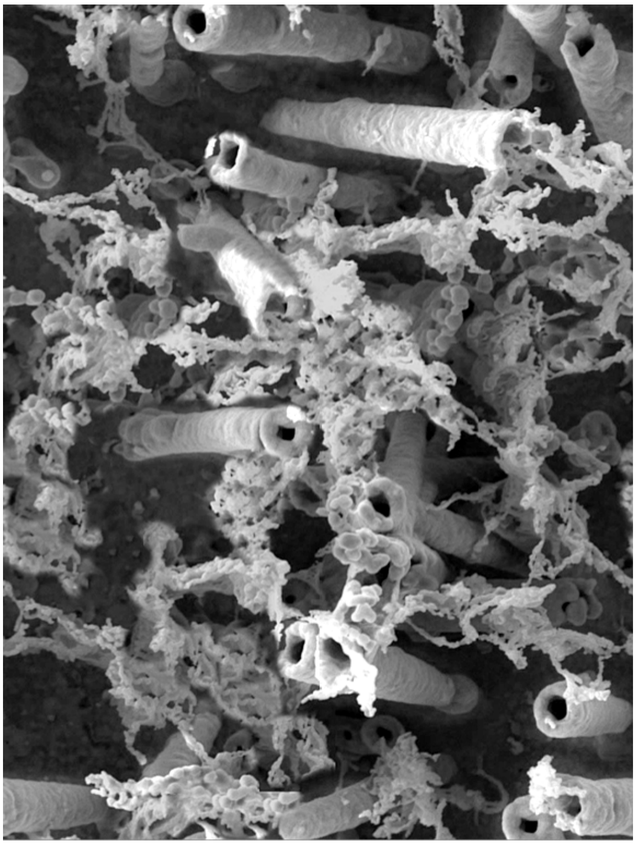

Figure 3. Inspirational image of carbon nanotubes

Initial results were variable, but provided excellent artefacts for visual and structural evaluation, leading to refinement of the designed-effects.

Pliability/Flexibility

The researchers discussed ways in which we might approach the creation and/or retention of flexibility of material while using the 3D FDM printer. Since the material printed is an ABS Nylon, which is melted for inkjet deposition and then hardens after cooling, the team had to explore the potential for maintaining flexibility with the rigid material. Our initial approach was to think in small modular units that could be adhered to a flexible textile substrate, such as the concept shown in figure 4.

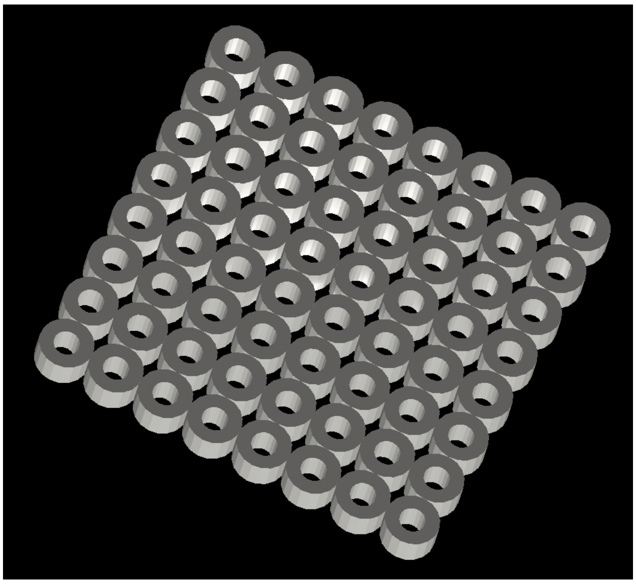

Figure 4. Modular tubes desgn for 3D FDM printing.

While the tubes shown in figures 5 and 6 represent a possible solution, visually they are of minimal interest in their application to a fabric, and would certainly have been producible through other cheaper means (such as cut segments of extruded tubing). The cylindrical shape did allow for a high degree of motif density with moderate flexibility (only in the concave or outward direction).

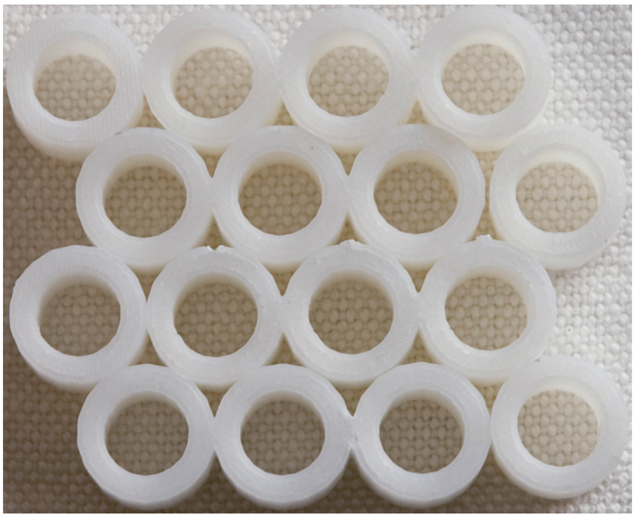

Figure 5. 3D FDM-printed modular tubes.

Figure 6. 3D FDM-printed tubes on fabric; side view.

Mixing flexibility with structural integrity

As a means for mixing flexibility with potential for 3D textile surface designs that could only be created using RP technologies, one of the most complex tasks is creating dimensionally effective designs that are structurally able to deal with the requirements for either being adhered to a fabric surface or printed directly onto a flexible substrate design. Figure 7 shows our initial attempt at a novel and potentially flexible structure. The goal was to create a structure that could move with the fabric, made up of modular elements.

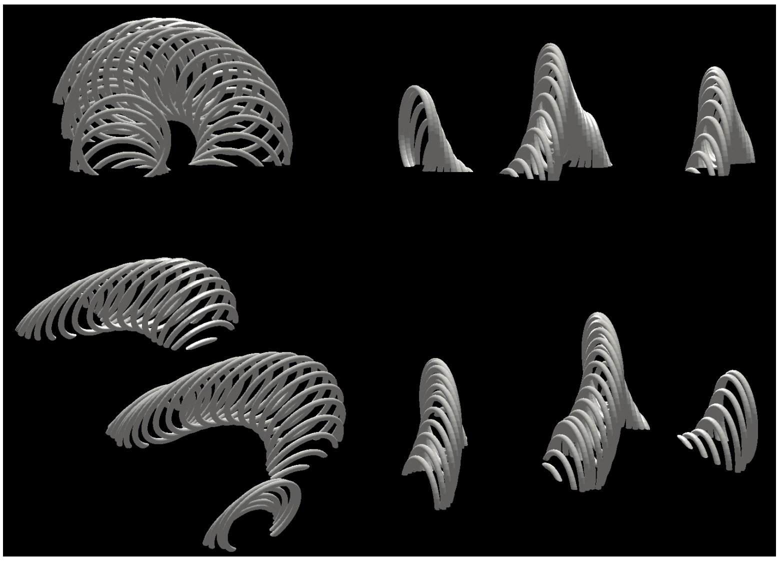

Figure 7. 3D 'coil' concept as it intersects with a flat plane (textile substrate).

While conceptually the design idea had good potential, the type of FDM inkjet printer that we used provided an obstacle that couldn't be solved. The printer we used printed a 'support' material of a slightly more brittle polymer substance, which normally would be snapped away from the design after printing. Because this design had floating elements in almost every angle internally, the support structure was so entangled that it could not be removed without the entire structure crumbling. Figure 8 shows the printed effect with the support structure. Future variations on this concept will likely involve creating more supporting linkages manually (to minimize the automatic support structure added by the RP software) and printing the structure directly onto an RP-generated 'textile' substrate as a means for support. Variations in scale and complexity will be attempted to determine thresholds for sustainability. With further testing, the research group will also print this design with a version of FDM printing that allows the substrate to be dissolved in solution.

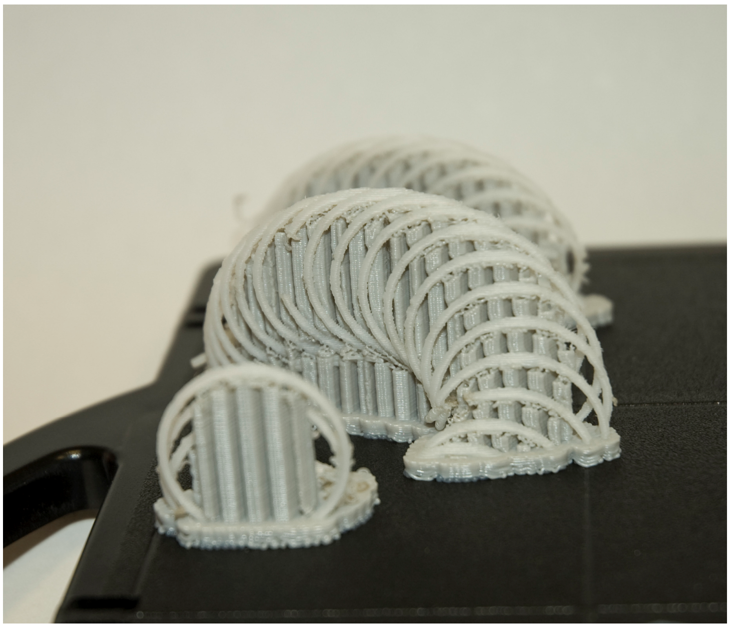

Figure 8. 3D printed 'coil' showing the inseparable nature of the "support" structure added by the 3D printer's software.

Dealing with lattice/support materials

While dissolving the support material in an FDM printed structure may help to solve some of the design constraints, it creates added levels of complexity and environmentally challenging chemicals into the design process in such a way that the designer/researchers involved in the project deemed to be undesirable. In slightly stubborn defiance, and in suspension of quick reasoning, we are continuing to explore means for using basic FDM printer technology to create structures that minimize the need for entangled support. The goal is to determine an approach that can inform recommendations for creating future structures effectively.

A textile-like structure, such as the one shown in figure 9, could potentially have very different requirements for support material when printed at different scales. If this type of structure could be effectively repeated at a very small scale to create the substrate, then a structure such as the own shown in figure 7 could be more intricately fused to this one, reducing the need for support lattice. Attention will need to be given to retaining flexibility. This type of investigation will form the next phase of the research, as the team becomes more adept at manipulating and mixing structures in 3D software applications.

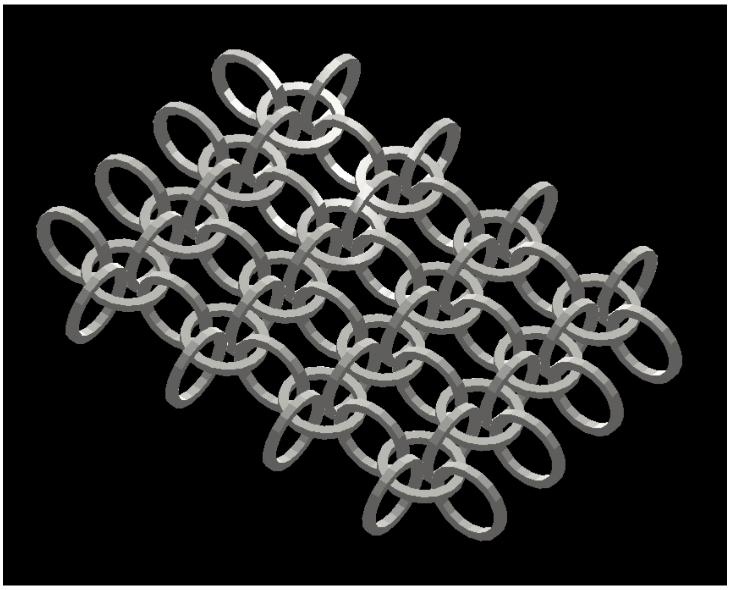

Figure 9. Textile-like structure for use as a 3D substrate.

3D designs from existing images

In order to visually explore the changes to a textile design concept as it is translated through different types of digital output technologies, we selected an image developed by one of the authors that had previously been explored through digital printing, laser etching and digital embroidery design processes (shown in figure 10). The original image was imported into a 3D software design package and then extruded into a 3D shape using a filter algorithm in the software.

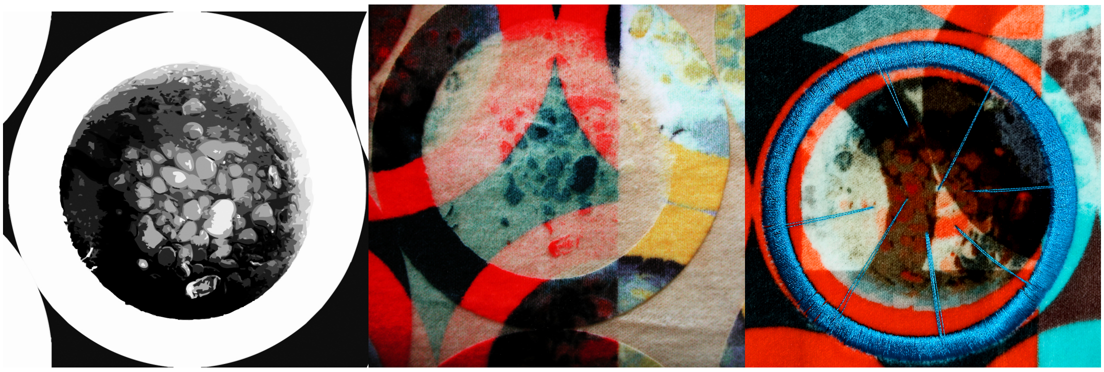

Figure 10. Original image captured from a photographed element in a stained-glass window (on left), translated through digital textile printing and laser etching (in middle) and with the additional translation of digital embroidery (on right).

Figure 11 shows two views of the extruded image as it appears in 3D visualisation. The image was selected partly for its use of a circular motif, as it relates to its use for flexibility once adhered to fabric. Issues of resolution and complexity of the extrusion had to be dealt with so the file could be prepared for 3D printing. Ultimately, the number of 'peaks' for the texture housed inside the circular motif had to be reduced. In addition, the extrusion process creates just a mesh without thickness, so a method had to be devised for creating a wall thickness that did not inhibit the visual aesthetic and yet provided a degree of structural integrity needed to be able to print the file. The initial attempt to generate the file to be sent to the FDM printer failed, so the printed output could not be completed within the timeline for the project.

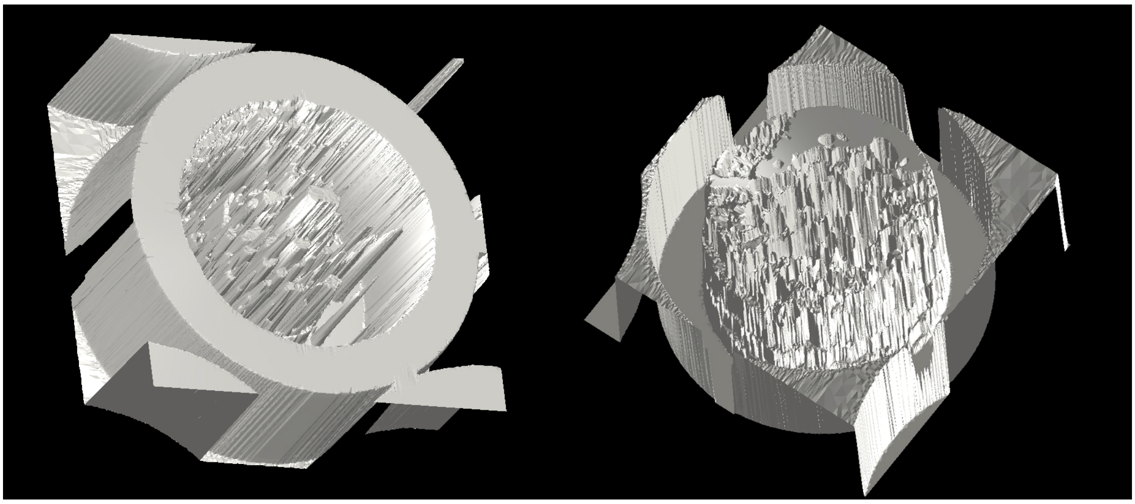

Figure 11

Potential applications and benefits

As inkjet textile technology evolves past a rapid prototyping tool into a series of responsive manufacturing techniques for textile products, designers, textile technology developers and soft goods industries will be able to use the results of this research to maximize their creative development. Though we are early in the investigative stages of the project, many possibilities have presented themselves for further exploration. The authors hope that by employing modified 2D/3D textile design processes with the technology future creators will be assisted to conceptualise and manufacture locally, creatively and with more accessible technologies.

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J.R. Campbell

Campbell has been researching, designing and creating artwork with digital textile technology for over ten years. His work pushes the limits of imaging technologies as they relate to clothing, our environment and the human form. Campbell's work has been shown in over forty national or international exhibitions, receiving twenty awards, including the Lectra Outstanding Faculty Award for the International Textile and Apparel Association Design Exhibition in 2002.

Following are Campbell's continuing research interests:
Digital Textile Design; Printing and Media; Surface Design Applications; Inkjet Deposition Technologies for Textiles; Mass Customization of Textile and Apparel Products;
Ethnicity in Clothing Design; Colour Theory & Colour Management in Digital Textile Printing;
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