

This item was submitted to Loughborough's Institutional Repository (<https://dspace.lboro.ac.uk/>) by the author and is made available under the following Creative Commons Licence conditions.



For the full text of this licence, please go to:  
<http://creativecommons.org/licenses/by-nc-nd/2.5/>

# **Ways of knowing and making: searching for an optimal integration of hand and machine in the textile design process**

Ms Rachel Philpott

Department of Textiles  
Royal College of Art  
Kensington Gore  
SW7 2EU  
UK

[rachel.philpott@network.rca.ac.uk](mailto:rachel.philpott@network.rca.ac.uk)

## **Abstract**

Textile design methodologies are evolving to embrace opportunities for innovation given by technological developments in both process and materials. Transfer of CAD/ CAM technologies from disciplines such as architecture and engineering is contributing to the dissolution of boundaries between textile and non-textile, leading to the design of exciting new products. In this changing landscape the textile designer becomes more than creator of functional, commercial products; the application of art & design perspectives and methods to technological development can expand the discourse beyond purely functional parameters, suggesting alternative futures where beauty, utility and intuition all play a role.

Our knowledge of textiles is largely mediated by touch. Much textile design practice is still carried out intuitively, informed by tacit knowledge gained through tactile, sensual exploration of materials. This paper investigates ways in which the benefits of CAD/CAM technologies can be realised whilst retaining playful, intuitive exploration that can humanize disembodied digital processes and outcomes.

A case study illustrates how hand and machine processes were interwoven to create textiles with inherent structural properties. Aesthetic, yet not purely decorative, predetermined folds transform 2-D surface into 3-D form, creating adaptable structures with potential application across various disciplines in wide-ranging scales and materials.

## **Key Words**

CAD/CAM, technology, hand making, embodied knowledge, innovation.

## **Introduction**

Textile design methodologies are evolving to embrace opportunities for innovation given by technological developments in both process and materials. Where many textile design processes used to be carried out by hand, now 'artists and artisans are ... embracing two opposites – hand and technology.' (Wada, 2002, p.145) Traditional textile techniques employ the whole body in the processes of production. Our tactile, proprioceptive and kinaesthetic senses are equally as important as vision and intellect in enabling the creation of novel textiles when using such methods. The progression of the textile design and making process towards increased exploitation of digital technologies presents the challenge of adjusting empirical craft processes to incorporate design engineering.

Since the industrial revolution machine making has to a large extent removed embodied knowledge from the process of manufacture and more recently CAD/CAM has extended this disembodiment to the process of design. This carries the danger that the distance created by such 'virtual' methods could lead to a detrimental separation of hand and head where 'both understanding and expression are impaired' (Sennett, 2009, p.20). Whilst vision, prioritised over the other senses in the CAD/CAM process, gives a detailed description of the surface features of our environment, it is a superficial mapping of the landscape. Touch provides insight as to how these elements are interrelated.

‘Whereas topography is visual, ‘topology is tactile’ (Connor, 2004, p.323). This paper investigates possible ways to reap the benefits of CAD/CAM technologies without losing important opportunities for understanding and innovation presented by embodied knowledge of hand making.

### **Exclusively CAD/CAM approaches**

CAD/CAM technologies such as laser cutting and laser-sintering enable the production of complex structures directly from 3-D computer modelled or scanned designs in ways impossible even just a decade ago. Designers are altering their approaches to integrate of these technologies into their practice. In disciplines such as architecture and product design this has lead to a precedent for increasingly intricate organic, fluid or ‘blob’ forms using complex free form geometry due to the technology’s growing ability to calculate the structural loads and stresses of such complicated forms as well as to manufacture them in a range of materials (Waters, 2007). Production methods predominantly designed for use in engineering disciplines are drifting into other areas, contributing to the dissolution of boundaries between textile and non-textile and leading to the design of exciting new products as disciplinary boundaries blur.

The Dutch based company Freedom of Creation, headed by Kyttänen has exploited the potential of rapid-prototyping technology to integrate design and manufacture into a single, streamlined process in which hand-crafting and embodied knowledge are completely absent. The disembodiment of these digitized designs is arguably reflected by their ‘other-worldly’ synthetic aesthetic, constructed as they are in the virtual world of programmes such as Rhino, before being sintered by laser to realise their physical 3-D form. This transfer of technology and its associated materials has resulted in the creation of non-textile textiles, chain-mail type constructions used for clothing and accessories in rubber, metal and plastics (Lee, 2005, pp.130-140).

There are both advantages and limitations to such methods. Although the utilisation of rapid prototyping as a tool for manufacture revolutionises patterns of production and distribution, enabling localized and on-demand manufacturing that minimises transportation and storage of goods and materials, the material output of the rapid prototyping process is currently limited, narrowing both the performative possibilities of the product and the sensual experience of the users of such items.

Another challenge facing processes that rely wholly on CAD/CAM is their removal of the intimacy of touch from the design process. I suggest that our intimate and ubiquitous daily bodily contact with textiles fosters an extremely close relationship between textile designers and the materiality of their discipline. ‘Because clothes make direct contact with the body, and domestic furnishings define the personal spaces inhabited by the body, the material which forms a large part of the stuff from which they are made – cloth – is proposed as one of the most intimate of thing-types that materialises the connection between the body and the outer world.’ (Attfield, 2000, p.124) Our experience of textiles is sensory, felt and lived as much as conceptualised.

Much textile design practice is still carried out intuitively, using hand-making processes informed by tacit knowledge gained through tactile, sensual exploration of materials. Our senses co-operate to construct a complete physical and emotional conception of an object from the feelings that are generated in the body. 'The interaction of various sensory media creates a multiple layering of meanings that 'all add up to one message'' (Kondo, 2004, p.207). The understanding given by this synthesis of the senses is far more complex than could be imparted by any single sense working in isolation. A vocabulary of touch builds up over our lifetime and is a cultural phenomenon learned along with language (Classen 2005). This whole body knowing, unarticulated and un-conceptualised is tacit knowledge, carried unconsciously within one but informing the activity of making.



Figure 1: Hand pleating textiles at F. Ciment (Pleating) Ltd

The hand is the most highly developed pre-lingual part of the body (Tallis, 2003), acquiring sensual sensory knowledge through the manipulation of materials. Driscoll (2009) identifies two distinct ways the hand touches. Manipulative, functional touch, for example folding a towel or doing up a button, is a sub-conscious action that employs tacit knowledge while sensual touch consciously seeks out the feeling of the surfaces contacted, noting the pleasure or pain that such contact brings. Both types of touch combine in the making process, facilitating deeper understanding of technical limitations of processes and physical properties of materials. Sennett describes this as 'material consciousness' (2009, p.123). New sensual knowledge acquired throughout the making activity can over time become assimilated into one's sensual vocabulary as tacit knowledge or practical wisdom.

Embodied tactile knowledge of material properties influence the forms created, the maker's physical interaction with the materials leading to a metamorphosis of material through process. Hand making can be a repetitive process but slight variances of movement, pressure or temperature affect outcomes. No two hand made objects are exactly alike. In the making process the hand becomes intellectual, enabling the simultaneous creation and analysis of work. Observation of my own practice shows my hands constantly, unconsciously adjusting and appraising the work.

It is not only the sensory information generated by the making process that is so important to retain. The speed of execution, often perceived as one of the greatest advantages of CAD could equally be seen as one of its great drawbacks; it creates temporal distortion. To make even minor alterations to the form of a hand crafted object it is often necessary to completely remake it. This lengthens the time taken to complete a design and also increases production costs. Objects constructed in 3-D computer programmes can be quickly altered without destroying previous iterations, amendments can be made and drawings redrawn with relative ease. However, the time spent redrawing or remaking by hand, although often perceived as onerous, is also time spent unconsciously but actively re-conceptualising a problem (Sennett 2009). On its unplanned journey floating through the subconscious the problem bumps up against all sorts of ideas and knowledge, making connections that can only be made if the idea floats around for a considerable time. In the easily adapted world of CAD this time for absent-minded reflection is lost.

CAD/CAM technologies distance the designer from the designed, removing opportunities for whole body knowing. Generally speaking this virtual medium is a way of working that is clinically separated from bodily experience and all of the tactile knowledge that this interaction brings. While the visual and aural elements of a physical entity can now be adequately reproduced in many CAD programmes, the tactility and materiality of the mimicked medium is missing. Even if emerging tactile simulation technologies were further advanced, as Dormer (1997) points out, there is no unexpected behaviour of materials in the digital world, virtual materials are uniform and without flaws.

In 'real' making situations designers interact with the tools of their trade and the materials out of which the object is made in a three-way conversation. Real materials invariably have flaws that have to be taken into consideration and incorporated into the design. The occurrence of unforeseen problems during the process of hand making can force novel outcomes; in the world of virtual, unflawed materials this opportunity for the evolution of process or form is lost. Additionally, whilst a prepared mind adapts and evolves to accommodate unpredicted outcomes a machine cannot so easily adjust to the unexpected. 'Machines break down when they lose control, whereas people make discoveries.' (Sennett, 2009, p.112)

### **Integrated approaches**

Intention, imagination and creativity cannot be replicated by a machine although a machine can be used as a tool to enable these traits to flourish.

Those designers who are able to employ both a practical knowledge of materials as well as CAD/ CAM expertise are ideally placed to exploit the exceptional versatility and that potential for novel outcomes that an amalgamation of the two processes could bring. Heatherwick Studios provide a methodological model for such integration, moving fluidly between CAD/CAM and numerous other means of design ideas generation and production. As he moves between product design, civil engineering and architecture Heatherwick migrates his methods, re-imagining design and manufacture in an innovative way that creates what Sennet would describe as a 'domain shift' (2009, p.127). His process moves from hand drawn visualisations and physical modelling to digital modelling and making, followed by hand finishing. His use of a giant crane mounted CNC router to lathe out a smooth circular building from layers of pre-constructed concrete blocks is a visionary transfer of technology and provides an excellent illustration of the integration of digital technologies with craft practice to create innovation. Serres writes of the unification of body and tool in practiced use, the hand becoming the hammer it holds. (Connor 2004, p.321) Heatherwick adapts digital technologies to function as a natural extension of his embodied practice. Dormer (1997) describes this happy marriage of digital and tactile knowledge as 'middle aged wisdom', due to the fact that the further we progress into the digital age the more traditional handcraft skills are being lost.

### **Case study**

My own practice interweaves hand and machine processes to create textiles with inherent structural properties. Aesthetic, yet not purely decorative, predetermined folds transform 2-D planar surface into 3-D form, creating adaptable, deployable structures with potential application across various disciplines in wide-ranging scales and materials. Handcraft skills still very prevalent in the discipline of textiles are central to my work. However, these skills have been augmented by the discriminating use of CAD/CAM, modelled on techniques used in fields such as fine art, product design and architecture.

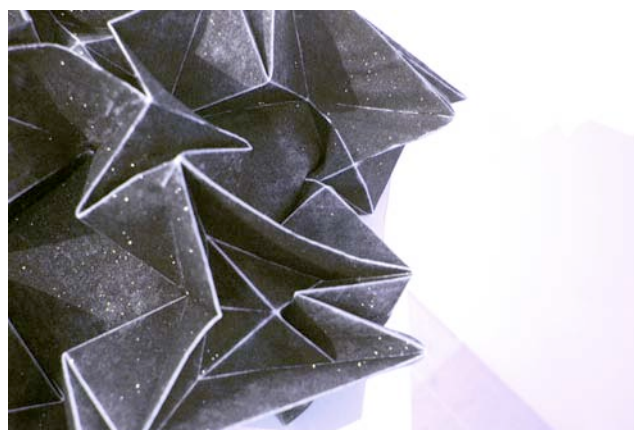


Figure 2: Deployable textile with predetermined printed folds.

### **CAD for development of concept**

As I develop speculative designs the use of visualisation using techniques such as hand drawn and computer-generated image, film and animation has been important for concept evolution and communication. Video is for me a

key method for the dissemination of my work. Initial films were made primarily to show my samples in motion, mobility being a key component of the work difficult to demonstrate within the constraints of the gallery or lecture hall. However each subsequent iteration of the film progressed further into abstraction, assisted by my expanding knowledge of filming and editing processes.

Using Final Cut Pro software various filters and effects were applied in an attempt to abstract the object to a degree that moved the image beyond the actual and into the realm of the conceptual. A very tight focus was used as a deliberate device to make scale ambiguous, freeing the imagination to perceive the object from new perspectives. The use of physical mirrors and the mirror facility within Final Cut allowed me to explore 'fictional' folds that could never exist in reality. By layering images I was able to illustrate graphically the potential of combined hard and soft folding although such pieces had yet to be physically completed. Although this overlaying of images was originally undertaken purely as an artistic device it suggested future development of work as dual layer structures. Such developments could increase possibilities for multi-functionality, like two-faced fabrics that demonstrate complimentary properties.



Figure 3: Video still with layered images contrasting hard and soft folds.

The inherent contradiction of using video, essentially coloured light, to depict tactile textile surface was turned to my advantage. Using video I was able to give very rough and ready models the appearance of resolution, shooting both paper and fabric models without there being an obvious difference between them. Obscuring the tactile transformed my relationship to the textile, creating alternative frames of reference that unleashed imagination. The videos now not only captured the dynamism of the folded structures but also intentionally abstracted their physical form to encourage a re-conceptualisation of the object, its scale, its shape, its material. This moulded the next iteration of the physical form in a cyclical process, the re-design of physical space occurring



through oscillation between physicality and immateriality, a journey from 3-D textile to 2-D screen and back again.

### **Integrated CAD/CAM and hand-making techniques**

The balance between hand and CAD/CAM processes constantly shifts as the work progresses. Initial samples were created using predominantly hand techniques, employing CAD only to create silk-screen positives by adapting drawings and photographs in Photoshop or creating geometric tessellations in Illustrator.

As my inquiry began to focus on origami structures I had to develop original folding patterns in order to control of the function and aesthetic of the textiles created. At the start of this process the use of CAD gave me an entry point into this complicated activity. 'Tess', a tessellation-generation programme developed by Alex Bateman specifically for the purpose of generating origami nets enabled the creation of designs of great complexity and allowed the effect of folding to be seen in advance. However, while the use of CAD software allowed the relatively easy generation of folding patterns, when using these computer-generated nets I found I didn't fully comprehend the connection between the flat diagram and the resultant form.

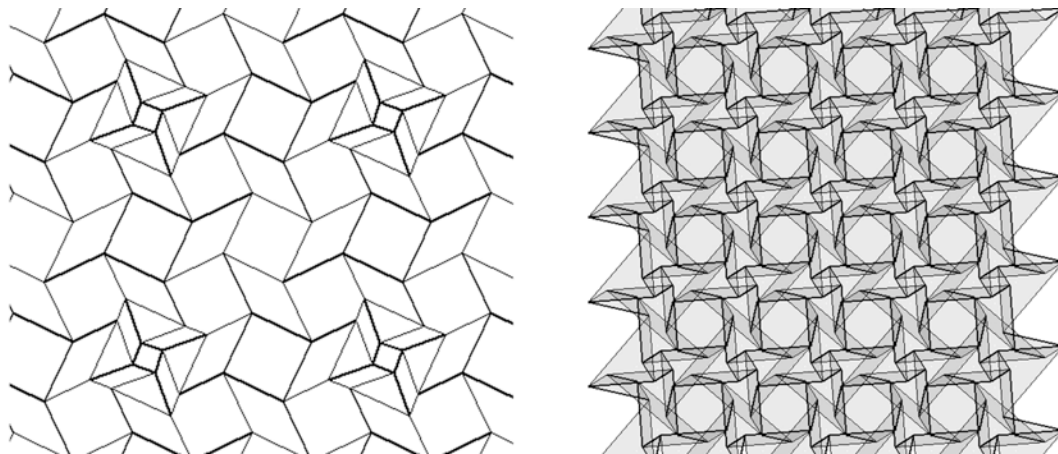


Figure 4: Origami net and fold pattern designed using 'Tess' software.

Joseph Lim notes, 'When the representational means becomes the media in which the design process operates, then the construction/ material system is constrained by the representational means' (2009, p.9). Focusing on the generation in virtual worlds of two-dimensional, linear maps of three-dimensional forms severely limited my control of the material 3-D outcomes. Although I was able to adjust origami designs quickly using the 'Tess' software I was not developing any underpinning theoretical understanding of the process.

While CAD/CAM and textile design share a common mathematical foundation, in textile design mathematical principles such as proportion, symmetry and tessellation are applied almost instinctively to real, physical situations. In a process typical of many designer/ makers, I often explore the development of my textile forms physically, intuitively employing my

understanding of the relationship between materials, process and form to create complex geometries without fully comprehending the abstract mathematical principles that govern them. For me, as for many designers and crafts people, skill in making is attained through the integration of tacit, embodied knowledge with intellectually rationalised technical understanding, overlaid with imagination. Whilst consciously considered technical knowledge informs the preparation of the task, at the moment of making touch guides my actions allowing me to work intuitively to the strengths of the inherent qualities of the material. This could be described as 'the intuition of the un-thought known' (Bollas, 1987). To be guided by touch is to put conscious action aside in favour of intuition and emotion. Using CAD to create the origami designs allowed no opportunity for such embodied understanding, leaving me unable to predict how adjustment of the diagram would affect the resultant form. I found that without this understanding I was unable to adapt the CAD designs in any systematic way.

To overcome this hurdle I began working through my ideas directly on paper, thereby incorporating the material 3-D form into the design process from the outset, meaning I could experiment more intuitively with structure and pattern. By learning how to adjust and customise traditional origami bases through physical experimentation I developed an understanding of the relationship between crease pattern and folded form. The ability to employ a variety of folding techniques and to identify the potential behaviours of such folds fostered a more fluid way of working. Structures could evolve iteratively, moving between physical and virtual worlds as tacit knowledge developed through physical folding could then be applied in virtual contexts. Origami nets could now be documented from the models as well as be computer generated to dictate outcomes in advance.

Moving from the design to production of my folded textiles and inspired by the non-textile textiles of Freedom of Creation I exploited the potential of merging of textile and non-textile elements in composite textiles. Laminating specific areas to create substrates with variable stiffness offered the possibility to enhance useful material properties and behaviours whilst down playing less desirable characteristics. I hand-made numerous samples to achieve an acceptable balance between the performance and the aesthetic of the material developed but the progression to more complex folding patterns highlighted issues of accuracy in the construction process. I already used Adobe Illustrator to develop positives for exposure of photographic silk-screens and I employed this skill in the development of digital designs for the laser cutter. Production of tiles for lamination using CAD/CAM technologies achieved the high level of accuracy required for the realisation of origami folding. The laser-cutter's constant and easy replication also avoided the need for time consuming, mindless repetition.

My first experience of laser cutting was at a two-day intensive workshop where we were encouraged to interact creatively with the technology. My understanding of the process was significantly enhanced through my full engagement with the process, programming the laser, watching as it cut and engraved, and experimenting with a variety of materials and effects. The

effect of synaesthesia and other less extreme overlaps between the senses can facilitate a whole body knowing of the material even when no physical contact occurs. This crossover of senses allows one to feel an object without touching it. Memory aroused by visual stimulus awakens haptic consciousness, as Pallasmaa says 'Vision reveals what touch already knows.' (2007, p.42) Although my making was mediated through a digital interface, feedback on material behaviour was immediately available. Burning, melting, clean cuts and scored surfaces could be observed as the laser worked its way across the surface. This playful, process rather than goal driven engagement with the laser freed my imagination, sparking ideas as to how I could employ this technology in my practice.



Figure 5: Origami folded textile with laser cut, laminated areas.

I commenced a series of laser cutting experiments at a different workshop but unlike my previous experience, I was not programming the laser directly. A technician did that task although I was still very much involved while the laser cutting took place and was therefore still able to make on-the-hoof decisions based on the results of the samples as they appeared. However, as institutional procedures changed I became much more removed from the process. I had to e-mail CAD design files to the technician before dropping off the materials to be cut. These were then cut in my absence. Institutional policy was imposing a goal-led rather than process-led relationship with the technology that limited opportunities for fully exploring its potentials. I felt that the enforced distance created between my design and the technician manufacture of the materials meant that spontaneous experimentation was lost from my exploration of laser cutting technologies in my design practice.

## **Conclusion**

CAD provides a significant opportunity for alternative methods of conceptual development, progressing practice by revealing possibilities not limited by physical constraints. CAD/CAM allows for greater design complexity at the same time as improving accuracy and reducing production times. This makes the resultant products more cost effective and therefore more commercially viable. However, in order to develop a rounded practice that fully exploits the

benefits of CAD/CAM technologies the designer must understand, at least in part, the technical aspects of the technologies used (Kavanagh, 2008). Designers cannot be totally divorced from the processes of production but must engage with the technology, mediated through a technician if necessary, for long enough to allow tacit knowledge to evolve. This requires institutional systems that allow this technological experience to grow as well as a design methodology that cycles between material and virtual methods so that whole body knowledge of materials and processes can develop.

By dissolving the boundary between design and technology, moving fluidly between production modes as appropriate, the textile designer can become more than creator of functional, commercial products. The application of art & design perspectives and methods, with their underpinning embodied knowledge, to computer-based technological processes can expand both the outputs from and the discourse surrounding these technologies beyond purely functional parameters, suggesting alternative futures where beauty, utility and intuition all play a role.

## References

- Attfield, J., 2000. *Wild Things: The Material Culture of Everyday Life*, Oxford: Berg Publishers Ltd.
- Bollas, C., 1987. *The Shadow of the Object: Psychoanalysis of the Unthought Known*, London: Free Association Books.
- Classen, C., 2005. Contact. In C. Classen, ed. *The Book of Touch*. Berg Publishers, pp. 13-15.
- Connor, S., 2004. Michel Serres' Five Senses. In D. Howes, ed. *Empire of the Senses: The Sensual Culture Reader*. Berg Publishers, pp. 318-334.
- Dormer, P., 1997. Craft and the Turing Test for practical thinking. In *The Culture of Craft*. Manchester: Manchester University Press, pp. 137-157.
- Driscoll, R., 2009. *The Art of Touch* [Lecture]. Royal College of Art, Department of Animation, Lecture Theatre 1, 8<sup>th</sup> May.
- Kavanagh, T., 2008. An Inter-disciplinary search for innovation in textile design. In *86th Textile Institute World Conference*. Fashion and Textiles: Heading towards New Horizons. Hong Kong: The Textile Institute.
- Kondo, 2004. The Tea Ceremony: A Symbolic Analysis. In D. Howes, ed. *Empire of the Senses: The Sensual Culture Reader*. Berg Publishers, pp. 192-211.

- Lee, S., 2005. *Fashioning the Future: Tomorrow's Wardrobe*, London: Thames & Hudson.
- Lim, J., 2009. *Bio-structural Analogues in Architecture*, Amsterdam: BIS Publishers.
- Pallasmaa, J., 2007. *The Eyes of the Skin*, Chichester: Wiley-Academy (John Wiley & Sons Ltd).
- Sennett, R., 2009. *The Craftsman*, London: Penguin Books.
- Tallis, R., 2003. *The Hand: A Philosophical Inquiry into Human Being*, Edinburgh University Press.
- Wada, Y.I., 2002. *Memory on Cloth: Shibori Now*, New York: Kodansha America, Inc.
- Waters, J.K., 2007. *Blobitecture: Waveform and Organic Design*, Massachusetts: Rockport Publishers Inc.