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Quilting Space: Experimental Form-Finding with Knitted Fabrics

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ABSTRACT This paper outlines an ongoing project exploring the potential for knitted textiles to create architectural forms. The project is inspired by the processes of the engineer Heinz Isler who used textiles as a form-finding medium and subsequently set those forms into permanent structures, using the knowledge acquired during that process to create large scale forms inspired by the maquettes. This project examines how this approach could be explored using a textile design route and incorporating knowledge of the textile design process as both a technical and aesthetic act. The first part uses a collaborative workshop to transform tubular-knitted fabric into small and large sculptural models. These are then recontextualised with a focus on photographic output to present the outcomes as architectural forms. Second, thermoplastic polyurethane yarn (TPUY) is used to create knitted structures that exploit the innate potentials of knitted fabrics when used with heating methods to find forms to create architectural maquettes. These knitted structures are created on electronic Stoll knitting machinery and rely on tacit knit knowledge to create structures that capitalise on the adaptability of the

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knitting process. This reduces the need for seams or other areas that may cause weakness and allows the creation of both flat and three-dimensional shapes. Using various techniques, concentrations of TPUY and conventional knitting fibres, the project proposes an exciting future application for knitted textiles in the process of designing structures with potential in architecture, engineering and sculpture. Finally, the discussion moves to further potentials for this process in both research and teaching scenarios.

KEYWORDS: Heinz Isler, textile architecture, thermoplastic polyurethane, knitting, sculptural

Introduction

This project takes place over several stages exploring ideas about the nature and potential of simple and more complex knitted fabrics for 3-Dimensionality. The initial catalyst for the approach came from a fascination with the processes of the Swiss engineer Heinz Isler. Isler developed a series of processes using gravity to produce novel textile shapes stiffened using materials including concrete and ice (Chilton 2000). These forms were then analysed, and their measurements transposed into dimensions suitable for permanent, large-scale structures. Isler's approach used a type of serious experimental play as a catalyst to produce non-cubic architecture (Chilton, 2000: 47) with similar results, but different methods from those of his contemporaries such as Felix Candela (Garlock & Billington, 2008: 30–41). Tensile architecture is not uncommon in contemporary architecture and uses the concepts of textile panels (membranes) under tension to create canopies or structures. This approach ranges from simple sunshades and tents to structures like the 150-metre-tall Khan Shatyr Entertainment Centre in Nur-Sultan, Kazakhstan (Foster & Partners, 2022).

Other architects have used playful experiments to find original forms using a variety of materials. Frei Otto and Bodo Rasch used inflated rubber skins, soap films bandages and sand among others to experiment with how materials can create shape when used on their own, when used in combination with forces such as gravity, or when constrained by limited frameworks (Otto et al., 1995). Using textile experimentation specifically, Agkathidis and Schillig (2010) used textile methods (e.g. knotting, stitching, lacing) to develop 'spatial design strategies' using movement and interaction with bodies as a key element in creating new forms. Latterly, Agkathidis et al. (2019) and Kycia (2018) experimented with the notion of using the inherent stretch properties of lycra fabric by anchoring the stretch in place by using selective 3D printing on the stretched surface before allowing it to retract and buckle into new 3D (or distorted planar) forms.

Contemporary projects such as the KnitCandela pavilion in Mexico City (Popescu et al., 2020) show the flexibility of bespoke knitted fabric and construction towards creating 3D structures and incorporating methods that minimise waste material. Tensioning knitted fabrics is something that has been done by a number of architects, designers and researchers over the years; Thomsen et al. (2019) and Sabin (2021) have created knitted canopies using flat and tubular methods; Ahlquist et al. (2017) using knit as a limiting factor in the free movement of pneumatic tubing and Snedker (2019) tensioning knitted chairs onto formed steel tubes. Similarly, several architects have used textile processes as shape-finding exercises such as the examples discussed by Spuybroek (2009: 94-188).

Building on a previous project using knitted tubes as starting points for interaction through a play-based methodology (Glazzard et al., 2014), this project revisits the potential embodied by a simple, knitted structure that can be realised through tacit knowledge and investigative manipulation. This approach relies on the ability to creatively 'push back' against tight restraints caused by the inherent form of the original structure. In the previous project where a costume output presumed that the tube was already a garment, 'Quilting Space' presumes that the tube is already an environment. By using threads, stitches or programmed knit structure to join the 'walls' and anchor layers, the connections transform the open space into a chambered structure. In the initial workshops this was done with stitch, weights, and hand processes. In later bespoke knitting by using the structure of the knit to join walls and make connections between inner and outer sections. It is useful to differentiate between the internal and external forces placed on textiles in order to create 3-Dimensional forms. The distinctive shape on many tensile structures comes from the anchoring of specific parts of the membrane, which created peaks (as shown in several examples in this paper). Whereas in inflatable structures such as the Fuji Group Pavilion, 1970 (Ishii, 1995: 94) or Luminaria Pavilions (Architects of Air, n.d.) the structure was created in pieced-together panels and inflated from the inside to show the 3D form. In this paper some of the later methods combine these approaches by creating bespoke knitted structures forming informed shapes by securing walls of fabric together and then revealing these with tensile anchoring.

The capacity of a knitted material to be infinitely adapted and engineered to complex forms, paired with the soft, changeable and sometimes unpredictable nature of the outcomes allows for 'happy accidents' to occur. This is such an important part of using experimental play as a method, working well in studio teaching practices and research-focused practices. This project not only embraces the mistake-making and the harder-to-anticipate outcomes produced by the complicated and stretchy knitted structures but also works with them as a resource to pull from to create unexpected outcomes that have potential for a range of areas including architecture, sculpture and fashion.

Initial Student Workshops

In late 2018, as part of the Arcintex research network the author facilitated[1] a workshop using tubular knitted fabric as a starting point to create architectural designs. Using small scale tubes (approximately 15 cm diameter), participants consisting of PhD and master's students from across architecture, textile design and product design worked individually to make alterations to their tube using a variety of materials including scissors, threads, needles, screws, pins, sticks, weights, etc. These forms were then photographed and edited using professional equipment. Due to the playful method of prototyping these tube structures, the photography was seen to be the final outcome as it allowed for de-contextualisation of the small-scale structures and for them to be presented as if they were architectural or sculptural forms. This is a process similar to designing by fabric draping in that it is not very analytical at the start of the process and instead creates knowledge by simply trying something and adapting it through tacit knowledge as the work progresses.

After the small-scale tube experiments, larger tubes were used (approximately 1 metre in diameter) and participants worked in two groups to experiment with the form. The tubes were knitted in two distinct styles to allow for the incorporation of the fabric design into the structure design (if desired). One tube was knitted with wide stripes of different colour and texture yarns including elastic and sheer yarns; the other tube was knitted using two colourways of thin stripes.

Participants in the workshop were given complete free reign over the task. Both groups used clothes rails and weight to create tension on the structures and several participants put knowledge of knitted structures to good use in developing targeted areas of laddering. A circular use of photography as a documentation and feedback tool

Figure 1
Example of small-scale tube experiment with cutting, stitching and incorporating sticks.

Figure 2
Outcome for large-scale tube experiments using striped and banded knit with ladders, elastic sections and anchoring.

throughout the process allowed for a real time appraisal of the final outcome – the photographs.

The playful nature of the workshop promoted experimentation and was not attached to any assessment. Instead, the limiting factors were solely to do with the fabric itself (the original tube) and the imagination of each participant. The workshop was left semi-structured in order to capitalise on the tacit knowledge each design student brought to the activity (Figures 1 and 2).

Subsequent Student Workshops

Studio Workshop

The initial Quilting Space workshop was repeated for undergraduate Textile Design students, this time taking place in a photography studio so that lighting and photography trials could be used to a professional standard throughout the development stage. This workshop followed the same format as the Arcintex workshop, using small-scale individual experiments before progressing to large-scale group-work. This workshop had similar results to the original student workshop, though having the extra space and the lighting from the photography studio made it easier to develop the ambitious shapes that the groups attempted (Figure 3).

Stiffeners and Working from Home

Due to the impact of Covid-19 and the onset of working and teaching students from home, the Quilting Space format provided a clear

Figure 3
Work in progress during student experiments in photography studio.

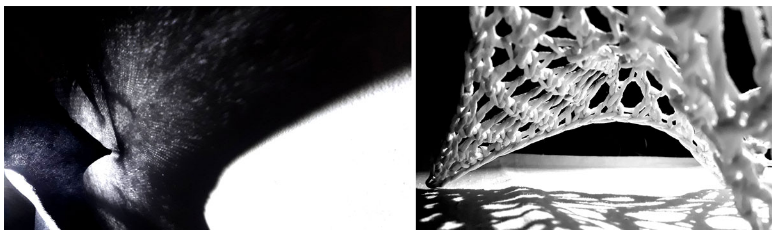

Figure 4
Section of tubular fabric (L) and hand-knitted fabric (R) stiffened with starch.

opportunity to tailor the low-tech approach for students and staff working in under locked-down conditions. The Quilting Space idea could be very easily adapted to use common household materials and was readily available as a workshop to be implemented within a tight time window of moving to online teaching. The students used fabric sourced from old t-shirts and tights, or other stretch fabric examples. Weight and tension could be easily provided by a clothes horse, pegs and kitchen objects used as weights, or yarn used to tie structures down using extremely non-specialist, make-shift tensioning frames. Finally, this workshop introduced stiffeners to make these objects permanent or semi-permanent, free standing to allow for clearer photography. Simple uses of cornflour starch, mixtures of PVA glue and water, or melted wax were used to stiffen fabric into sculptural forms (Figure 4).

Thermoplastic Polyurethane Models

Building on the work from the previous experiments with tubular knitting as a potential for form-finding, the author continued to experiment with knitting bespoke shape environments using thermoplastic-polyurethane yarn. The TPUY used was a 'meltex' yarn consisting of a core yarn coated in thermoplastic material from Assems (2017). This meant that the fabric and the stiffener could be comprised in one material, and that material could be designed to have inherent physical properties beyond that of the simple tube.

The following sections discuss the work carried out on using a Stoll ADF electronic knitting machine, that embraced the material

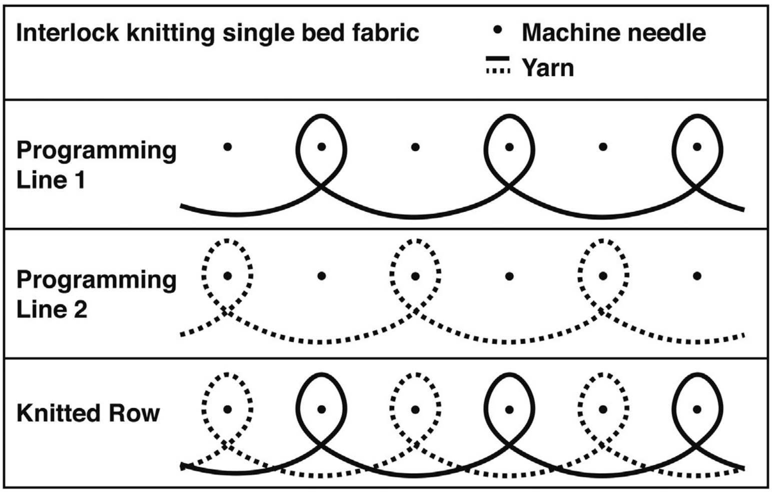

Figure 5
Diagram showing process of interlock knitting on single-bed fabric.

potentials of the TPUY as well as the creative potentials of the knitter as designer, programmer and maker.

Considerations When Working with TPUY

The TPUY is a brittle yarn and does not have the easy knittability of more conventional textile yarns. Knitting this yarn on the Stoll ADF required particular attention to the threading tensions and running the machine at a slow speed. Interlock structures were favoured where possible as the distortion on the yarn is spread out over two movements of the carriage rather than one. Additionally, the extra possibilities for the yarn to come into contact with itself may have been a contributing factor to good adhesion and production of stronger structures when melted (Figure 5).

The structures shown in the following section are all self-supporting but retain a high level of flexibility. After heating, when the TPU is set and cooled the finished textile structures remain flexible but have strong shape memory and can withstand a high amount of distortion while still returning to their original shape.

Full TPU Models

Isler-Type Gravity Models

Among the first samples tested in the TPUY were plain single-bed, interlock structures. These were designed to be similar to the plain fabric used by Isler in his experiments, and to allow the process, rather than the fabric, to create the effect. The notable difference between this approach and that of Isler, was that the TPU fabric did not require a secondary material to act as a stiffener, but instead a

Figure 6
Gravity models unweighted (L) and weighted (R).

secondary heating process was responsible for making the structure rigid and self-supported.

Suspended from a wooden frame, the fabric was then heated using a heat gun. The knitted fabric had two reactions to the heating process that would be less likely in a non-knitted fabric. Firstly, the fabric expanded and contracted in order to find its preferred shape during the heating process. Secondly the edges of the single-bed knitted fabric, naturally prone to curling (Spencer, 2001: 62) allowed for reinforced arches to be produced from the rolling of material into multiple – and subsequently bonded – layers. These reinforced arches provide further structural stability when the structure is upturned through no extra design feature than the fabrics' inherent properties.

This technique was tried in a free-hanging variant causing a domed model, and a weighted variant which led to a pointed model (as shown in Figure 6). The weighted model, though interesting in shape ended up with longer supporting arches and a decreased stability when self-supporting. Variations on initial size and shape of fabric as well as weight used could be used to experiment with this further.

Tubular Models

The other type of samples made solely from TPUY are based on tubular knitting principles. This structure was chosen as it allowed opportunities to create internal and external spaces but would not put the yarn through too much strain by creating dense areas of font and back bed crossover. Tubular structures are made using single-bed structures and could therefore incorporate interlock structures easily, though have limited additional patterning and texture potential (Figure 7).

The first tubular experiment was a simple 2 × 3 grid structure comprising different tubular chambers, joined only by thin lines connecting the two walls. These fabrics appeared two-dimensional when removed from the machine and were then put under tension in a makeshift rig that could be easily tightened to pull apart the 'walls' of the tubular structure and expose the 3 D possibilities. When heated with a heat gun the stretch of the knitted rows expanded and

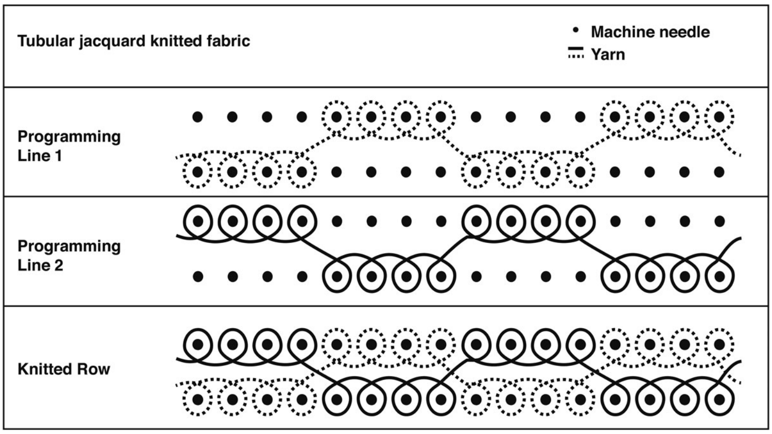

Figure 7
Diagram showing the composition of tubular jacquard fabric.

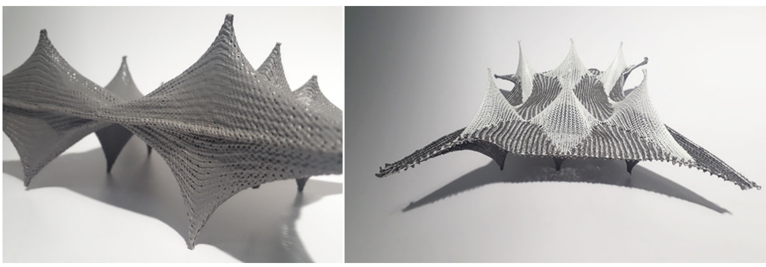

Figure 8
Tubular jacquard TPU structures in single yarn type (L) and contrasting yarns (R).

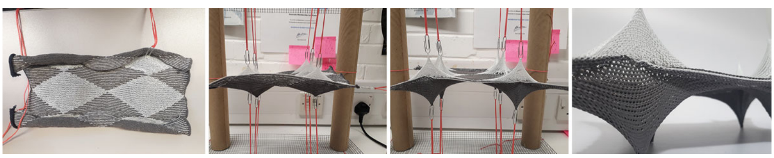

Figure 9
(L-R) process of transforming flat knitted fabric into 3 D model using tensioned rig.

contracted into bespoke shapes similar to the weighted, gravity model in the previous section (Figures 8 and 9).

The second tubular structure used two different TPUY (the white yarn much finer than the grey yarn) on different sides of the fabric and a structure design with a diamond pattern using larger areas of crossover between the wall fabrics. The finer TPUY gives a loose and open appearance that is more porous than the thicker grey yarn. This variation in porosity could be developed to further effect to highlight the differences in quality after heating. The thicker TPUY noticeably melts to fill in many of the holes inherent in the knitted structure, whereas the thinner TPUY leaves more holes in the surface, creating opportunities to explore different aesthetics and filtration possibilities.

In-Fabric Models

Plated Models

The next phase of fabric experimentation involved developing samples where TPUY sat alongside conventional, fibrous yarns. One method for this was plating – a method of knitting two yarns simultaneously, where one yarn shows on the face side of the fabric (or outer in double-bed structures) and the other shows on the reverse side (or inside) (see Figure 10). This allows the TPUY to be incorporated into a fabric, while retaining the aesthetic and tactile qualities of a conventional fabric. Using the Stoll M1+ software it was possible to plate the TPUY into bespoke configurations using methods similar to intarsia knitting (a way of creating contrasting yarn sections in the fabric without using floats) and experiment with the placement and proportion of TPU to conventional yarn.

With the addition of conventional yarn, it was no longer possible to heat the fabrics with a heat gun due to the gun's potential to burn the fabrics. For double-bed plated samples an iron was used that would warm and fuse the TPUY at the centre of the fabrics. This would cause the centre of the fabric to melt, leaving the external, conventional fibre intact. While the TPU is warm it is possible to sculpt it quickly as the material cools, which then solidifies and retains the new, sculpted shape.

Various methods were used to sculpt shape into the fabrics shown in Figure 11. These methods included: forming the pliable

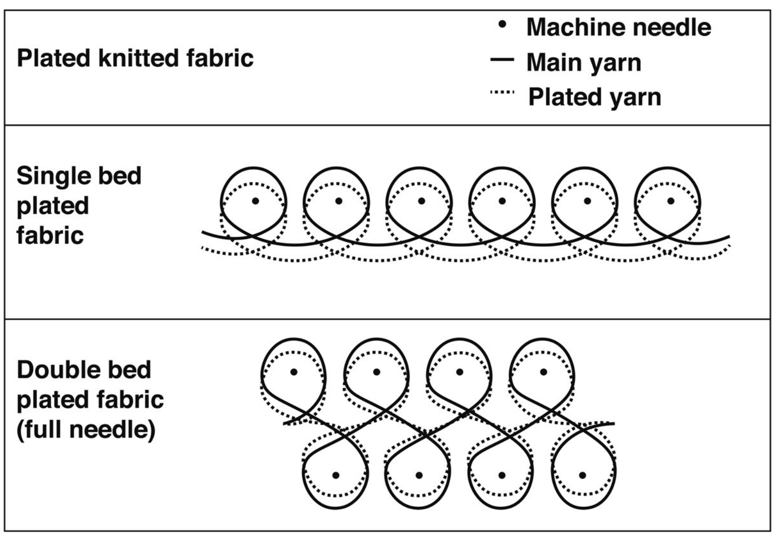

Figure 10
Diagram showing plated fabric method.

Figure 11
Plated samples showing various techniques and outcomes.

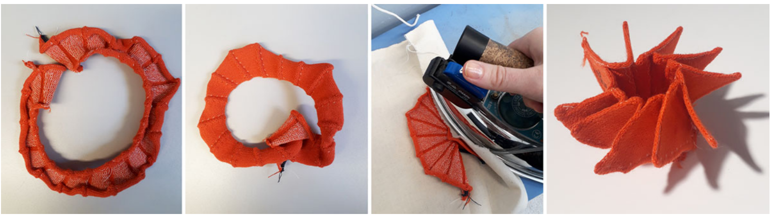

Figure 12
Plated fabric showing selective placement of TPUY and process of using heat to assemble 3 D shape.

fabric around an object; pinching shapes into the TPU; stretching the fabric in warp, weft and diagonal directions; pinning out; and hooking or pulling the fabric into peaks.

Single-bed plated structures had to be treated differently due to the exposed TPU on one side of the fabric. In these examples such as the one in Figure 12 the placement of the TPUY was planned to provide sections to adhere to each other upon heating. This required a more targeted use of the iron but meant that complex folded three-dimensional shapes could be created, from two-dimensional fabric.

Trial and Error

The playful methodology applied to designing the TPUY structures, relied on accumulated experiential knowledge of working with knitted textiles both generally and in electronically programmed ways. Some of these structures had relatively low risk for trialling purposes – e.g. a simple tubular jacquard lay out – where most of the risk taking came from the handling of the materials and the treatment of the structure (stretching and heating). In heating it was easy to over-heat the samples using directly applied heat from a heat gun. At times this caused the TPUY to melt fully, leaving holes in the surface.

In other structural experiments the programming was more trial and error. For example, plating with TPUY in sections of the fabric required the production of bespoke programming and trials with the–machine. When knitting with TPUY using a second yarn – i.e. when plating – the second yarn mitigates the risk of snapping the brittle TPUY, but when knitting it on its own, it is prone to snapping, which ruins the piece of knitting, casting it off the machine mid-way through.

The combination of TPUY and conventional knitting yarns had to be taken into account when thinking about applying heat processes. Synthetic yarns such as acrylic, when heated with very hot irons, can melt or take on a flattened sheen. Whereas cotton or wool can singe or burn when heat is applied without exact care. The combination of these different temperature considerations meant that different heat treatments and desired outcomes should be considered carefully when designing textiles that incorporate TPU.

Aesthetic and tactile resolve is particularly difficult when combining plastic yarn and fibrous yarn. The stiffening of areas can be a useful tool for creating unexpected handle and visual effects, but it does risk becoming unpleasantly rough or stiff to handle or giving a disjointed aesthetic resolve where the TPU and fibrous areas don't sit well alongside each other. This is an area that would benefit from additional experimentation.

Conclusions and Future Works

This project holds considerable potential for creating fabrics with qualities towards sculptural, architectural and performance outcomes. Being able to control both the internal and external appearances of forms will be endlessly adaptable by using different knitted structures, techniques and placements within designs.

The low-tech making methods provide useful workshop ideas for students from textile and fashion courses as well as architecture courses by allowing experimental freedom of expression through simple investigations with materials and stiffeners. Though this adoption of Heinz Isler's methods may not translate into the exacting engineering approach he used, it does start to open questions regarding tensegrity and self-supporting structures. The design input is extremely valuable in understanding the value of failed experiments and embracing the various idiosyncrasies that the designer, the materials and the processes contribute to the whole process.

The TPUY fabrics give variable porosity, which could be further explored by using different heating and bonding methods. In different structures, improved control over porosity could be used to move towards varied functional and aesthetic outcomes such as filtration, lighting and materials suited to a range of weather conditions. Tensioning stretchable forms and the production of architectural spaces using fabric methods is not a new method, but the models within this paper aim to add to existing methods to approach the building of self-supporting textile structures and to embrace the varied and unpredictable nature of knitted fabrics.

One of the main potential avenues for developing this work further is the idea of creating self-supporting structures in situ. This would have strong potential in sculptural contexts and a larger project could work towards lightweight, modular construction to form easily deployable structures. These could have many beneficial outcomes such as temporary shelters, travelling structures, prefabricated architecture, and so on.

Further work aims to explore different TPUY as well as alternative construction and fusing methods to create a range of surface texture, rigidity and porosity. Expanding this work to include using TPUY alongside materials which have conflicting qualities (for example stable, stretchy, etc.) would be a useful exploration to expand both aesthetic and functional outcomes.

Disclosure Statement

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Note

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