



Weaving Futures: Adopting alternative postures to develop new methods for the construction of textile-forms in the context of micro-manufacturing

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Abstract

The aim of this research is to adopt a transition design “posture” of zero waste system design to develop processes for garment manufacturing. It seeks to uncover approaches and methods which are viable in the context of Manzini’s Cosmopolitan Localism – aiming to pair digital distribution with flexible local manufacture and micro-factories – utilising technology in alternative ways and propose new methods for whole garment weaving. Makerspaces and Fab-Labs have traditionally been the domain of hard materials, while forays into soft materials have explored the use of laser-cut textiles, ‘smart’ electronic textiles, 3D printing of wearables, and the cultivation of bio-plastics. Options available for automated manufacture of entire garments and textile-based forms are limited to whole-garment or fully-fashioned knitting – weaving has been mostly missing from this discourse. Conventionally, weaving is a two-dimensional practice – which through cutting and sewing may become form. Cut-and-sew is the most common method of garment construction used in industry; however, it is also exploitative, time-consuming, and wasteful. The current shallow understanding of the relationship between woven textiles and form limits how designers could transform industries and the built environment. This research questions how technology can further shape form-making – what if we treat the jacquard loom as a tool to enable a kind of 3D printing with yarn? It follows some of the lines of design inquiry forged by the work of Issey Miyake and Dai Fujiwara in A-POC, and recent explorations on digital whole garment weaving by Anna Piper, Jacqueline Lefferts, Linda Dekhla, and Claire Harvey and colleagues. This research undertook a series of experiments which aims to expand the design methods available for whole garment weaving in the context of zero waste system design. This paper presents three experiments using a variety of prototyping methods to deepen understanding of the complex ‘reverse origami’, or ‘flattening’, methods required and are intended to test the processes in specific contexts. This multimorphic and analogue-digital craft practice develops new understandings of conventional textile design and manufacturing

elements, such as jacquard looms and weave structures, for use in micro-manufacturing contexts. This holistic and disruptive reshaping of form-making has the potential to future-make the industry, our cities, and our social fabric.

Keywords:

Transition design, Micro-factory, Weaving, Textile-form, Waste, Fashion design

Introduction

This article discusses the development of new design methodology and processes for garment manufacturing for textile-based forms which emerged out of adopting a transition design “posture” of zero waste design. ZWST draws from posthumanism, and Kate Fletcher and Matilda Tham’s Earth Logic to expand our understanding of who, what and how we design for the world, decentering the human in favour of the holistic whole. This paper discusses the journey to uncover approaches and methods which are viable in the context of Manzini’s Cosmopolitan Localism – aiming to pair digital distribution with flexible local manufacture and micro-factories – utilising technology in alternative ways and propose new methods for whole garment weaving. This paper is focused on the artefact or outcome of the design process situated within and as a result of the proposed system. Therefore, this research also adds to the ongoing discourse around the role of the artefact in the development of design research.

The fashion industry is massively globalised, and as eighty percent of a garment’s impact occurs in the production phase, including transportation and manufacturing. How can we further develop the use of technology to enable the redistribution of garment manufacturing closer to users? A suggested approach to the development of local manufacture is through the development of Fab-City’s. Building on maker-spaces such as Fab-Labs, the notion of a Fab-City envisions a hyper-local ecosystem of supply and production linked with digital tools for collaboration. However, maker-spaces have traditionally been the domain of hard materials, and while forays into soft materials have explored the use of laser-cut textiles, ‘smart’ electronic textiles, 3D printing of wearables, and the cultivation of bioplastics. The options available for automated manufacture of textile-based forms in makerspaces and micro-factories has been limited to whole garment knitting (such as Kniterate and Unmade). Weaving has been mostly missing from this discourse, and this paper proposes methods that enable it to be included.

Weaving is conventionally seen primarily as a two-dimensional practice, the making of cloth which through cutting and sewing may become form, a process which is wasteful, labour-intensive, and often requires a high level of skill. Cut-and-sew is the most common method of garment construction used in industry; however, it is also exploitative, time-consuming, and wasteful. The current shallow understanding of the relationship between woven textiles and form limits how designers could transform industries and the built environment. This shallow understanding is the result of a relatively recent conception of the fashion industry – one built on speed and volume of production which therefore separated the various roles and actions required to make a garment or textile-based form. This separation constrains the

relationship between textiles and form and has impacted on the aesthetics of textile-forms.

This research questions how technology (such as a jacquard loom) can further shape form-making – what if the jacquard loom was treated as a tool to enable a kind of 3D printing with yarn? The recent arrival of the TC2 Loom, a relatively small, low cost, digital, hand jacquard loom and the emergence of the use of the jacquard looms for so-called '3D weaving' opens a space for discussion around the use of what is very old technology, in the context of makerspaces and micro-factories to produce garments on the loom. This research follows some of the lines of inquiry forged by the work of Issey Miyake and Dai Fujiwara in A-POC, and recent explorations on whole garment weaving by Anna Piper, the use of the digital jacquard loom for garments by Jacqueline Lefferts, Linda Dekhla and more recently fully woven footwear by Claire Harvey and colleagues. Primarily this kind of work has been explored by textile design specialists, and the particular focus of this research in terms of the design method is on the design and form-making process through pattern cutting for the loom.

Background

In light of the environmental crisis, theorists have sought to unpack the relationship between technology, design, and sustainability goals and its relationship to aesthetics. Victor Papenek suggests that we might need to be open to new aesthetics emerging as a result of considerations for the environment. Ezio Manzini wrote:

"it should not be forgotten that design was born and developed within the context of the development model in crisis today. Likewise, fundamental concepts such as form, function, client, user, and market must be revisited. The same is true for the role of technology, aesthetics and design itself"

Technology has shaped, literally and conceptually, the forms and details of all of our garments, and yet we barely consider it. Why are garments the shapes they are? History, convention, movement, comfort, sexism, sizism, racism and any more have all had a profound impact on aesthetics, but also the technology we use itself has helped shape what we wear and accept. So, what if we used technology differently? What might change?

Design and Anthropocentrism

Design industries adherence to function, aesthetics and cost are inherently anthropocentric. Design impacts on things outside of our aesthetic and functional enjoyment of human life, therefore the way we assess the viability of a product needs to step outside of the merely human. Thomas Wendt argues that 'if humans are at the "center," then things like environmental sustainability, social justice, care for ourselves, economic equality... most political aspects of design, cannot be adequately considered'. Laura Forlano states that posthumanism 'greatly expands our understandings of the multiple agencies, dependencies, entanglements, and relations that make up our world' and flows through into and from ways of working that 'better address the challenges we face as a planet.' It is essential to consider how emergent design practices, including those that might decentre the human, might simultaneously support equality and justice for humans and nonhumans alike. From this perspective, posthumanism could aid

attempts to utilise a holistic approach to design for which this research program aims.

In the specific context of the fashion and textile industries, the ethos of transition design points also toward what Matilda Tham and Kate Fletcher call for in Earth Logic. They argue that fashion needs to centre the Earth and not growth, transitioning the industry and our experience with garments utilising six holistic 'landscapes'. Traversing both fashion activities, and processes to create, maintain and evaluate outcomes, the notions of Less (the rejection of the logic of growth, and the centring of Earth), Local (decentralising production and economic power), Plural (decolonisation and rejection of an Anthropocentric view of the industry) and Governance (cultural level changes to support the other landscapes and promote diversity and resilience) are highly relevant to this research. It suggests that the outcomes need to be centred not as a result of form, function and cost (as is conventionally done in design), but due to an expanded understanding and attention to the holistic context.

Transition Design

Assuming that we currently have an anthropocentric approach to design raises the question of; how do we transition away from this, and to what? Grand and Weidmer agree with Simon when they say that design and design research fundamentally focus on the world 'as it could be, on the imagination and realisation of possible futures, as well as on the disclosure of new worlds'. Transition design argues that there exist many frameworks for what kind of different world we need to have (circular economy, permaculture design, sustainable design, speculative design, and others), and many calls for change from the design community but that there is little exploring how we transition from our existing situation into the desired alternative. There exists a gap between the discourse and the practice. Transition Design as conceptualised by Irwin and colleagues provides a framework in four parts that provide clear intent and purpose for design that cares in the twenty first century: vision, theories of change, mindset/posture, and new ways of designing. It imagines a design world where designers could apply the deep understanding of the 'interconnectedness of social, economic, and natural systems' that is needed for addressing the complex issues we are facing.

Zero waste systems thinking

Zero waste system thinking (ZWST) is a posthuman, transition design posture or lens that argues for a wider frame of reference beyond that of the design of the form and aesthetics of a product. Design enters into the realm of 'how things ought to be' which in ZWST centres the Earth. Part of the current posture of the fashion and textile industry assumes that waste will be created – its monetary cost is built into the system and paid for by consumers when they purchase goods. At the same time, its environmental cost has been historically ignored and considered an inevitable unfortunate side effect of the reality of business.

The zero waste design thinking (ZWDT) model was first developed as a result of a series of in-depth field tests undertaken at the start of this research which attempted to apply zero waste design methods into the context of the current garment industry. In this model, inputs and outputs cascade in and radiate out of the design process in a modified version of the (existing) design and production system. On reflection, the posture adopted when undertaking the field tests, and when developing the initial model, was

that the existing system is 'how it is and always will be' we just need to make it 'better' by designing better. The revised ZWST model (Figure 1), borrows from Kate Raworth's Doughnut Economics Model, which proposes that we need to rethink this posture and system at a fundamental level if we are to transform the industry in the way we need to.

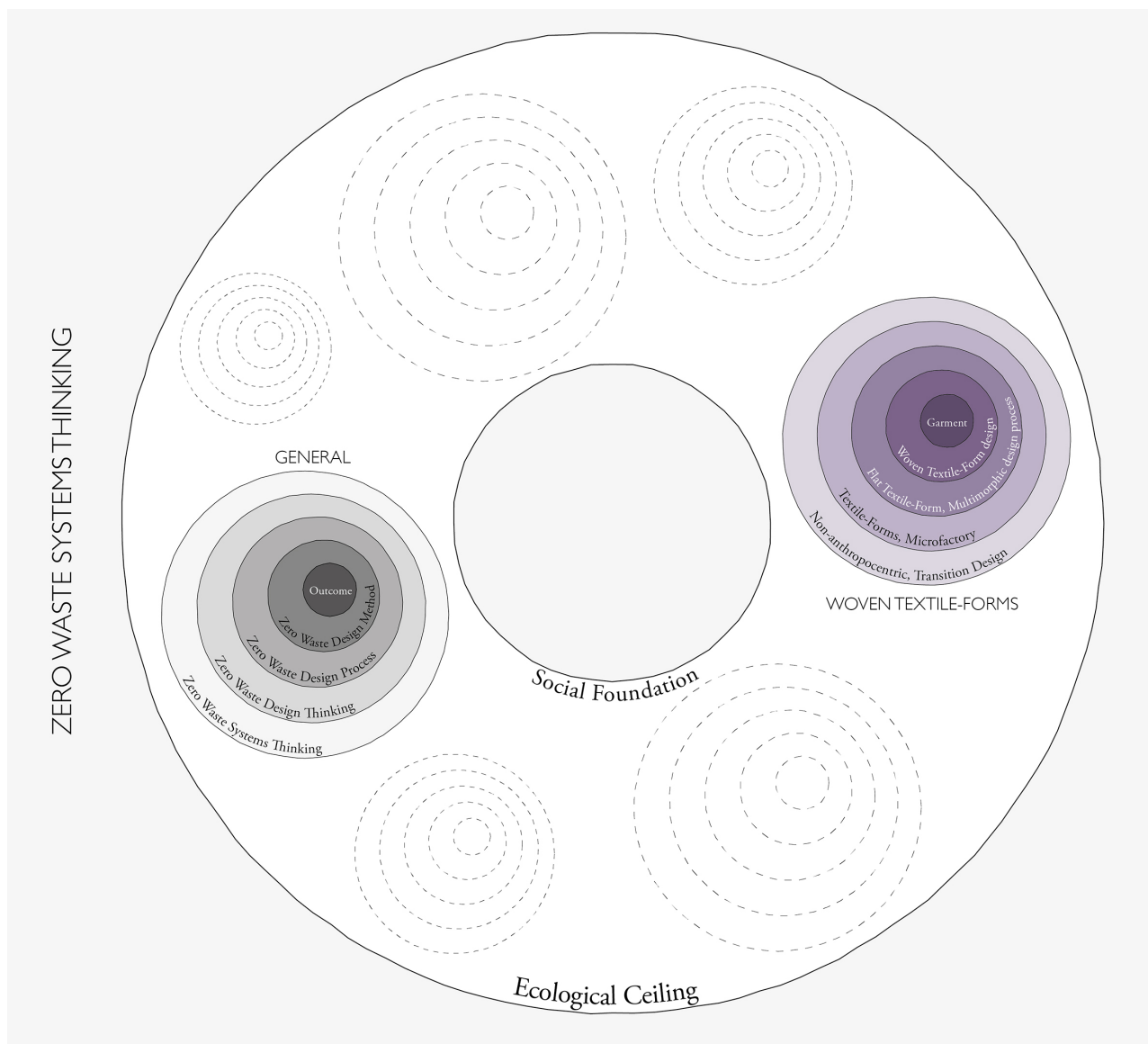


Figure 1

Methodology

This research is developed under an umbrella of the research program which builds on transition design and posthumanism in the context of zero waste system thinking. The research as a whole looks at a variety of flatbed construction methods in this context; however, this paper focuses on woven textile-forms. Utilising an experimental design methodology, the research asks what new methods and aesthetics are possible in this context and what implications they have for the

development of new systems of design and production for textile-based forms.

Experimental design research

Experimental design research shares features with transition design, particularly regarding the opposition to 'imposing pre-planned and fully resolved solutions upon a situation'. Hans-Jorg Rheinberger wrote that experimental research needs to be stable enough to withstand the destabilising forces of the experiments and 'sufficiently loosely woven so that in principle something unpredictable can [and must] happen.' This research undertook a series of experiments which aimed to expand the design methods available for woven Textile-forms in the context of zero waste system design. This paper presents a variety of prototyping methods used to deepen understanding of the complex 'reverse origami', or 'flattening' methods required. These explorations of form-making for whole garment weaving then lead to more resolved Objects of Design intended to test the processes in a specific context.

This paper will focus on the three experiments undertaken so far relating to the trouser form, beginning with a discussion of methods for the visualisation of 'flattening' as a tool to develop designs in this field, a variety of prototyping methods are explored, both analogue and digital. The outcomes of the experiments take the form of both 'Figures of Thought', which include everything from 'dynamic research sketches' to unrefined digital and analogue prototypes as a result of the experimental process and Objects of Design which are more refined and outward facing. These 'Figures of Thought' are similar to Schmidt and Wagner's 'in-the-process-of-becoming' things and are prototypes that materialise and further comprehend figments of ideas or theory, and to articulate or solve physical, digital and technological problems or experiences. In this case, they are notes, paper metamorphic sketches or models, digital experiments, photographs, and more conventional textile and cloth-based samples.

Multimorphic Flat Textile-forms

The ZWST (figure 3) diagram discussed earlier encompasses multiple perspectives simultaneously, and while it is possible to read and analyse as discrete sections for clarity, comprehension of the whole is necessary. The same is true of the textile-form, which results from the application of this way of thinking. To develop the objects, the designer is required to understand the many contributing limitations and inputs from machinery and technology, as well as the broader social and economic inputs, impacts and outgoings (if seeking to be an aware, ethical designer). Additionally, the designer is required to delve into and isolate at the near-field scale of matter (fibre and yarn), into the context of its interaction with weave structure, and digital and textile layers at a variety of axes, and to the far-field human scale of how these flattened layers allow for form-making upon expansion and how this form is desirable and needed in the social context of designed objects. To design in this transdisciplinary way requires multimorphic thinking and methods. In the multimorphic objects and design processes used in this research, the relationship between cloth and form is approached from different perspectives simultaneously and constantly interacts and forms the other, like a web where the reverberations of one strand are felt throughout. It requires a broad and holistic approach to design. Multiple perspectives (visual, material, and theoretical) each feed into and respond; however, the designed object provides a tangible 'thing' that focuses the lens we use to view the system

it emerges from and functions within. The textile-form is the intersection of complex inputs and materials from multiple perspectives, which is made so that form emerges from it. Form, technology, and social context are both embedded in and made from it. The outcomes express theory around the making and thinking through the design practice undertaken, but also the wider social and environmental context they exist within because they are a result of applying a particular way of thinking – zero waste system thinking.

Flattening

In order to rethink the process by which we design and make textile-based forms such as garments, this research delves further into the processes of garment production to the weaving of the textile itself. Since all woven textiles are of a planar construction, to weave form we have to be able to flatten the 3D form of a garment into the 2D cloth, so new design methods are required. To design a flat textile-form is to design the 3D form (garment) potential into an apparently 2D structure (cloth). Basic understanding of design methodologies was developed through the design of t-shirt forms, and utilising the multimorphic understanding of flat textile-form design gained from those experiments, other garment types were explored. This research has explored garment types and their associated flat-form technical/aesthetic challenges including the t-shirt, trouser, tunic, coat, gown, and shoe. The series of experiments revealed several distinct design methodologies that enable textile-based forms to be produced on a flatbed (such as weaving).

Experiments

Next, a series of experiments are discussed which aimed to expand the design methods available for these systems with a focus on whole garment weaving in the context of zero waste design. These are often developed parallel to each other, even though they are presented sequentially, that is not actually how the design process evolves, and usually, many elements are interconnected and developed simultaneously.

Trouser Experiment 1: Flattening a trouser

The process of flattening often involves the use of methods that enable the visualisation of a potential axis of flattening. In this case, the trouser began with the commonly used method to fold trousers for hanging (Figure 2). There are many ways a trouser can be folded, here the trouser is folded from the profile or side axis, with centre front and back waistband folding inward toward the centre line of the body and the leg folding near the centre of the leg.

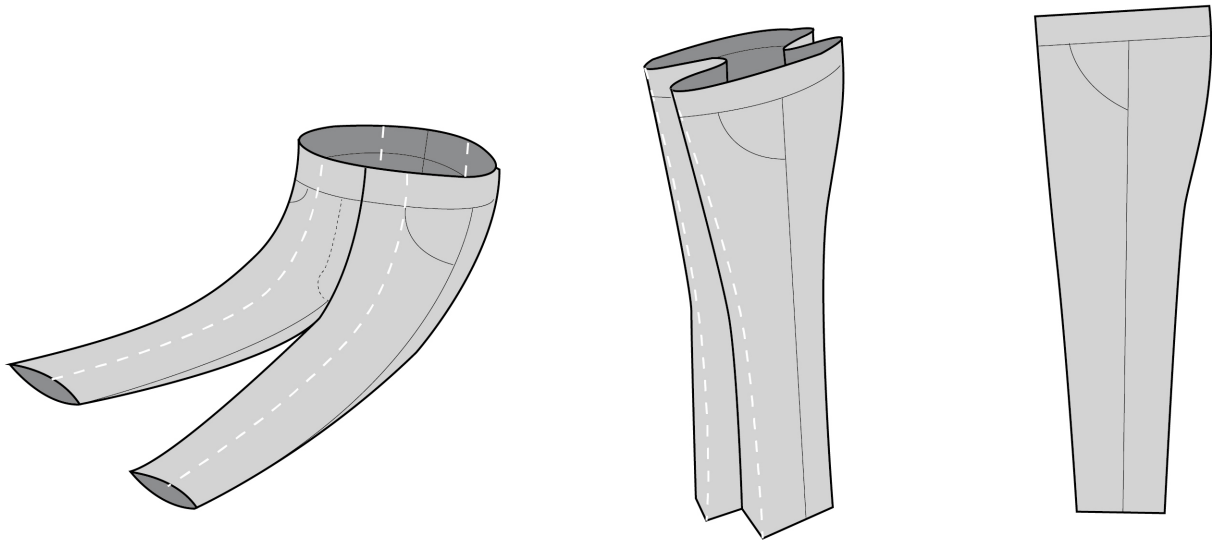


Figure 2

Placing garments on a lightbox enables an understanding of the layers that are the result of flattening to occur as the light transmission is reduced the more layers it has to travel through (Figure 3). This stage allows for the beginning of the relationship between layer construction and form to be determined. These images could be turned into weave-able files almost exactly as they are, or their details and form manipulated further to allow the methodology and technology used to influence their expression.



Figure 3

New forms and expressions are also explored through the use of paper models. These figures of thought are like 2D/3D sketches that experiment with an element of, or the entirety of a form. The paper models begin to demonstrate that an action (from form to flat and flat to form) is a 'material' of design of these textile-forms – the models are metamorphic sketches or objects that facilitate the experience of transformation from two dimensions to three, and back again. The desired form determines the number of layers through the cross-section of the design at this point of the design process. If it is known how the form will be constructed, then it is determined by an intersection of desired form and construction specifications (such as loom warp density if woven). The paper models exist as physical things and also as videos of them transforming – as is shown in the stills in Figure 4. Videoing of the transformation both documents the transformation while also allowing for new ways of seeing the action and becomes part of the design process itself. Additionally, paper models allow effective communication between collaborators as they physically manifest the flat to form relationship by being able to exist as flat and formed as well as every state in-between.

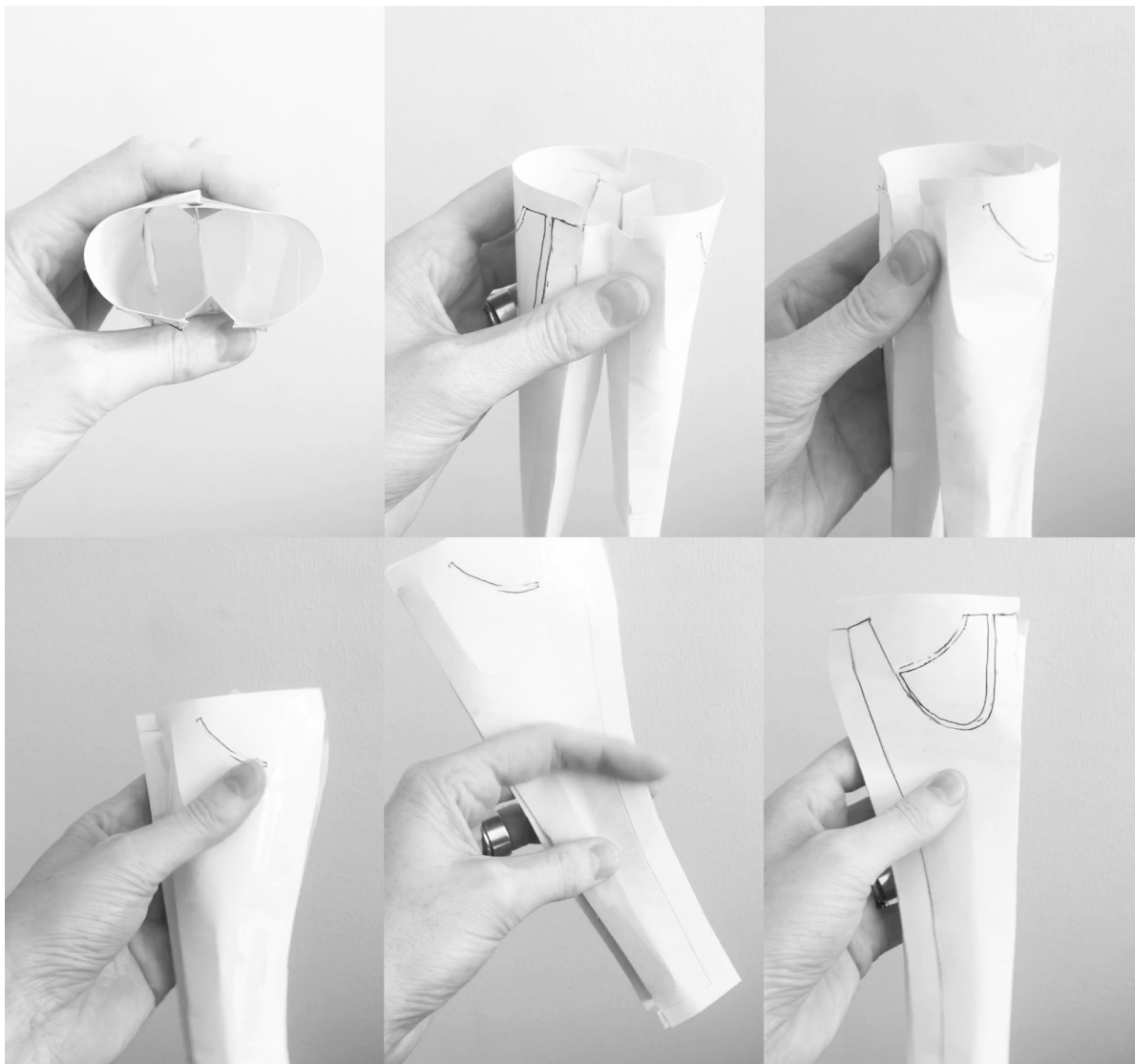


Figure 4

The basic form explored in the paper model as derived from the folded trouser was then explored in digital form using CLO3D (Figure 5). Here the relationship between body and form begins to be manifested. The number of layers required in the flat textile-form is finalised (four), but exact design details are not resolved. This design shows the negative space created by the crotch seam in the middle two layers enables a pocket to be built in the form. The digital model at this stage is like a template of a basic flat textile-form design that can be manipulated further and detailed to explore a range of possible resulting expressions depending on the construction method intended to be used.



Figure 5

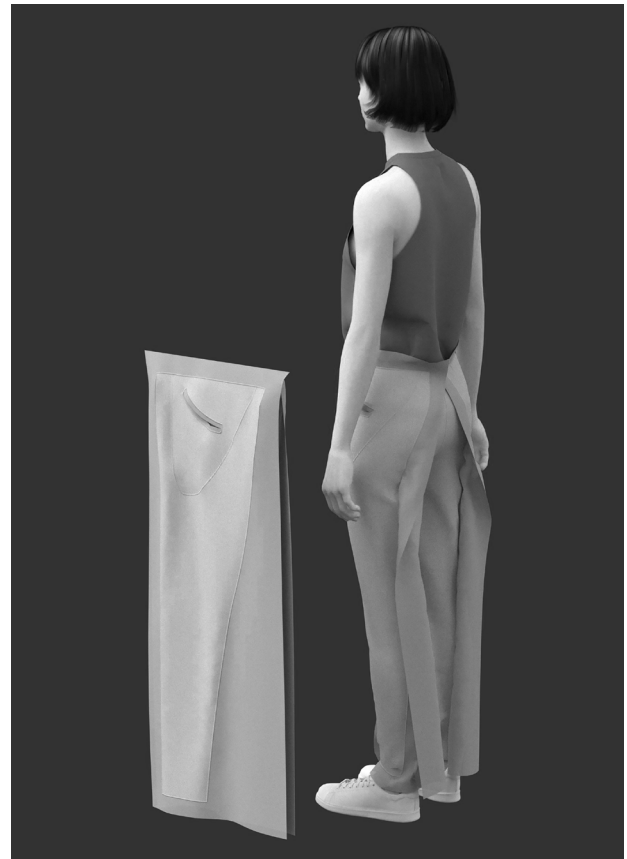


Figure 6

The final stage of this experiment was developed initially to a digital prototype (Figure 6). In this stage, the construction method was chosen (weaving) but only applied to the point of the width of loom repeat (40cm). As a result, an interim map of bindings was constrained by this 40cm width and the ensuing form potential was explored. The aesthetic possibilities of draping fabric from the front and back leg seams were developed, and considerations of fit, and edge details were resolved.

Trouser Experiment 2: Weaving a Trouser

In Trouser Experiment 2, the critical experimental element to explore was to resolve and code the Map of Bindings so that the flat textile-form from Trouser Experiment 1 could be woven. The relationship between 3D form woven into the layers of the cloth and the map

The diagram illustrates the cross-section of book bindings with varying numbers of layers, from 1 to 5. Each layer is color-coded and labeled with a sequence of numbers representing the binding structure.

- Single Layer:** Labeled '1'. The cross-section shows a single grey layer.
- Double Weave:** Labeled '12' and '1/2'. The cross-section shows two layers: a grey layer on top and a red layer on the bottom.
- Triple Weave:** Labeled '123', '12/3', '1/2/3', and '1/23'. The cross-section shows three layers: grey, red, and blue.
- Four Layers:** Labeled '1234', '123/4', '12/3/4', '1/2/3/4', '1/2/34', '1/23/4', and '12/34'. The cross-section shows four layers: grey, red, blue, and yellow.
- Five Layer:** Labeled '12345', '1234/5', '123/4/5', '12/3/4/5', '1/2/3/4/5', '1/2/345', '1/2345', '1234/5', '123/4/5', '12/3/4/5', '1/2/3/4/5', '123/45', and '12/345'. The cross-section shows five layers: grey, red, blue, yellow, and purple.

The labels indicate the sequence of layers from left to right, showing how the binding structure evolves as more layers are added.

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This experiment was a remote collaboration with weaver Milou Voorwinden who worked with the author to develop the final map of bindings and then used the video in Figure 4 and a simplified layer coding system (Figure 8) to understand the intended relationship between layers to assign weave bindings. The final woven outcome (Figure 9) used contrasting colours to illustrate the layers of the weave. The rigidity of the resulting cloth (which is 100% polyester) was not adequately accounted for and will be developed in future testing.



Figure 9

Trouser Experiment 3: Planet City Trouser

This experiment was a collaboration with Karin Peterson and Kathryn Walters for the speculative film Planet City directed by Liam Young and costume direction from Anne Crabtree. This trouser experiment took the basic form developed in experiment 1 and 2 and combined it with surface pattern and embedded emergent behaviour formed on a mould.

In the Planet City Woven Trouser experiment, the form was determined in part by a scanned 3D mould made by Peterson, which when input into CLO3D helped drive the design development of the trouser textile-form. The trouser was designed to work for either men or women, with adjustable sizing depending on the degree of shrinking applied. These factors, in combination with the loom width, determined we could fit three trousers across the width of the loom.



Figure 10

The initial Map of Bindings (Figure 11, top) was a balance between the width of the loom, the minimum size of each trouser, and the flexibility offered by the moulding process. Three trousers fit well across the full width which allowed for a small amount of texture to appear at the widest point of the mould while shrinking enough to reduce to its smallest (the hem).

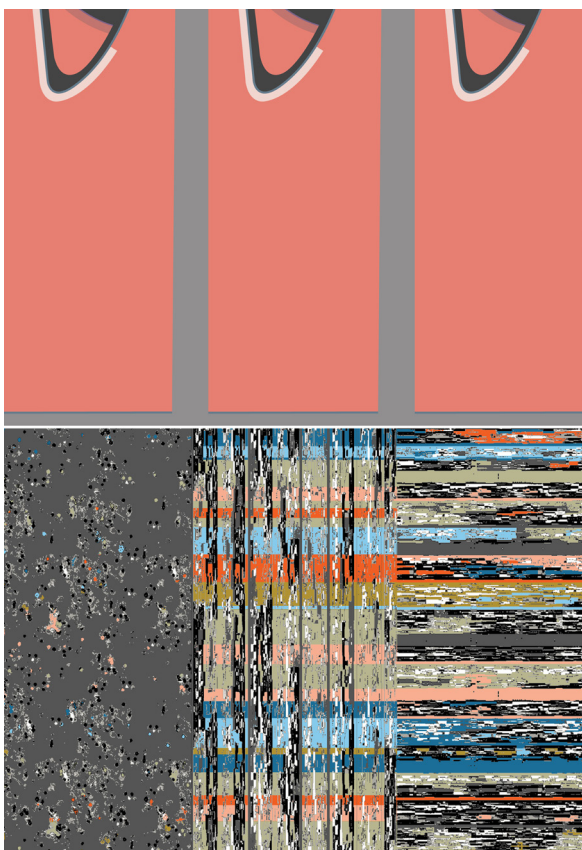


Figure 11



Figure 12

Young and Crabtree of Planet City partially determined the surface pattern (Figure 11, bottom). For the purposes of research in this experiment, it was a variable with unknown effect in terms of how the additional bindings required for the surface pattern would impact on the bindings required for the form. In combining all of the previous elements – body, 3D mould, map of bindings and surface pattern, a digital approximation can be produced to communicate to within the collaborative team and to the client what the outcome might look like (Figure 12). It is important to note (and was communicated to the directors of Planet City) that due to limitations of technology, this digital prototype cannot be entirely accurate.

While the moulding process itself is open in that where and when heat is applied can affect the outcome – in contrast to cut and sew – in this process almost all of the expression of the trouser is determined before the cloth is woven. Peterson calls this reversal 'Reverse Crafting' and means there is still craft embedded in the outcome – it is just in another place. The construction of the trousers is a matter of the weave technicians loading the appropriate weft yarns and pushing a button. The textile form arrives at the user almost fully formed, with only a few cuts required to release the 3D form from the 2D textile, and one seam sewn for the zipper (Figure 13). Beyond that, if fitting is required, or the form possible through moulding, then the heavy application of a hairdryer can transform the textile-form further. In all, it seems a process well suited to micro-factories or makerspaces.

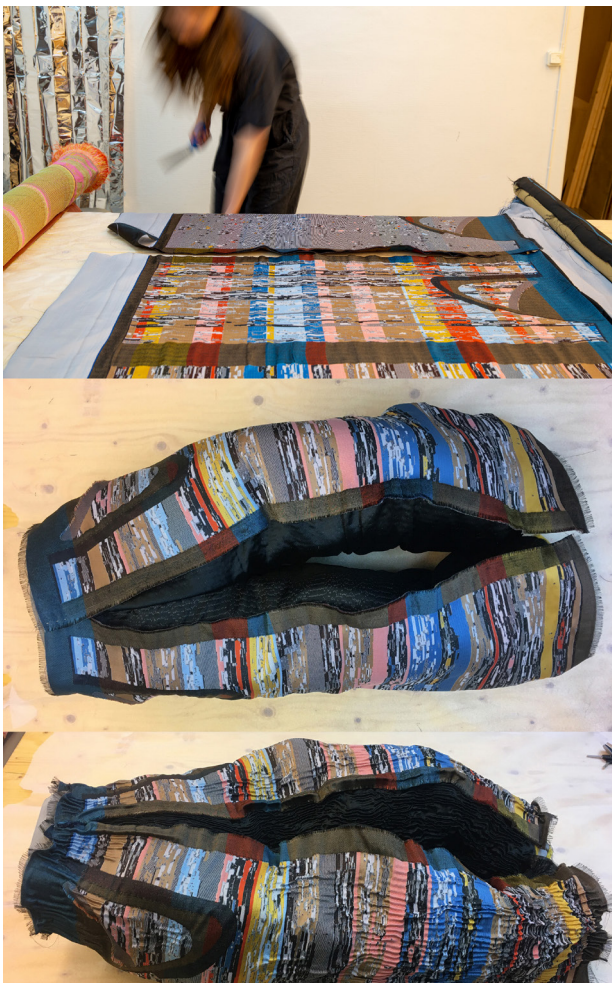


Figure 13



Figure 14

Reflection on experiments

This research identifies three stages of transition from existing industry ways of working to the kind of holistic, regenerative industry we need. In Stage 1 (for more on this see McQuillan, 2019) we move from bad to better, utilising industry 4.0 in existing industrial contexts to reach for a low waste fashion ecosystem supported by Industry 4.0. In Stage 2, the industry is reimagined in multiple centres with semi-automated, zero waste micro-factories supported by regional waste collection systems and the development of the circular economy. Stage 3 builds on practices of regenerative agriculture, and encompasses the entire production, design, and use chain in Regenerative Micro-systems moving away from synthetic fibres (unless we can solve issues of microfibre pollution). This proposed Regenerative Micro-system can be articulated as a cycle of Farm – Form – Wear – Worm (and back to Farm), where sites of cultivation of fibre (Farm), production of form (Form), use of outcome (Wear) and decomposition (Worm) occur in hyper-local systems. Further reduction in production and consumption is achieved by addressing both the systems of manufacture and attitudes towards use, resulting in a plurality of production approaches, sites, and aesthetics, all which seek to eliminate the concept of waste as we currently conceive it. The first two experiments of this paper primarily address stage 2 and propose 'Form' (design and production) methods for stage 3. The Planet City experiment is situated primarily in Stage 3; however, it approaches the cycle outlines from an alternative perspective provided by the film context. Planet City proposed that all resources come from the reuse and re-mining of late capitalism and so the process would instead start with re-mining the leftover plastics and polyester of our contemporary society: a Mine, then Form – Wear – Reuse cycle. In this context, a circular economy use of polyester was assessed as most relevant, and in Planet City's speculative future, it is assumed the problem of microplastics is solved, though it would not be regenerative, only cyclical.

Transition design asks that this research consider the implications of automation on the fashion industry and how a 'just' transition can be designed to manage the transition from the dominant manual high human input that exists now, to a mostly automated system in this imagine 'preferred' future. Another layer of analysis that Transition Design theory would add is the consideration of location. How might the system discussed operate in Sweden, New Zealand, Nigeria, India, China – urban or rural settings? Irwin states that transition visions 'propose the reconception of entire lifestyles where basic needs are met locally or regionally, and the economy is designed to meet those needs, rather than grow for its own sake', therefore these broader structural notions would need to be considered in both the development and analysis of the outcomes of this research.

A key reflection of Experiment 2 occurred when estimating the wholesale cost of constructing trousers on the loom. The cost of the (Europe based) weaving mill time, length of the trouser and number of trousers across the loom width per metre results in a production cost of about €26 per unit for five pairs of trousers. Larger sizes will be more expensive as they use more yarn; however, economies of scale will drop that cost to €10.40 per unit if making more than 500 trousers at a time. This illustrates a potential unintended consequence of this method of design and production. It could conceivably be desirable to develop for large scale garment manufacture as it might enable a massive reduction of their workforce through automating the production of garments utilising technology that already exists.

Covid-19 has had and will continue to have an impact on the globalised supply chain of the fashion and textile industry. As well as driving a reduction in overall consumption, the sudden disruption, and in many cases destruction, of existing supply chains has increased the appetite for localised, automated supply chains. However, as neither localisation and automation of production necessarily ensure material waste reduction, they run the risk of exacerbating the global issues we face unless we holistically approach its development and implementation. The tendency to want to scale-up efficient production methods in any post-Covid world needs to be tempered with this understanding – instead, this research seeks to explore the potential to scale-out to multiple centres of production which are responsive to the individual needs of the community and resources of the environment.

The role of the outcomes of these experiments, or artefacts, in this research, is a complex one. It is a physical manifestation of a range of holistic theoretical, methodological, and physical inputs. The design process explores how we can utilise existing technology in the making of new forms and new futures. A key aspect is the translation from 2D to 3D, which occurs as a kind of reverse origami, allowing for more complex forms than those usually possible with whole garment weaving, and without waste creation. Its multimorphic and analogue-digital craft practice develops new understandings of conventional textile design and manufacturing elements, such as jacquard looms and weave structures, for use in micro-manufacturing contexts. The form-making processes developed in this research can be utilised in a range of processes. Primarily it is jacquard weaving that has been explored, but there is potential for these methods to be applied in the context of the biological textiles of Diana Scherer, and Kate Goldsworthy's work with Laserline, both of which require flatbeds for production. This will inform some future explorations of this research.

Conclusion

The work presented in this paper aims to develop methods and processes which are viable in the context of digitally distributed manufacture and local micro-factories, utilising existing technology in alternative ways and suggesting new methods with the potential to transition the form and nature of the industry to one that works for all. We need multiple visions of a future in which a just, safe and fulfilling life for all is bound by the social foundation and the ecological ceiling articulated by Kate Raworth.

We lack the methods to implement the automated, local micro-factory production of woven garments. By designing the interstitial spaces of textiles and not only the surface, we reimagine the 2D textile as 3D potential – enabling complex 3D forms to be constructed from an apparently 2D material. The boundaries between textile and garment are blurred. Operating in this blurred space enables new methods to emerge and the making of alternative futures. These design methods apply to any production method that requires a flatbed and allows for complex 3D form to emerge from that with minimal and in many cases, no stitching at all. New design tools are needed to be developed to automate the translation from 3D to 2D; new materials and processes are needed in production. This holistic and disruptive reshaping of form-making has the potential to future-make the industry, our cities, and our social fabric.

So, imagine a circular micro-factory or regenerative micro-system in every community. What would micro-factories producing on-demand in every community mean for the textile and

garment industries? Currently, it has one of the most globally distributed, complex supply chains of any industry, utilising the bodies of the largest workforce in the world. We need to consider the flow-on effect of what in some cases will cause the reshoring of production – models such as these would put many out of work. However, the CO2 emissions associated with the transportation of materials and goods for the current fashion and textile systems are massive. Garments made-to-order locally, utilising local materials needs to become a commonplace reality, and to do that we need to reduce transportation and transform the relationship between design and production, which suggests redistribution and automation – how should we ensure a just transition? The so-called global north currently exports the negative impacts of garment production to countries in the global south with more relaxed laws relating to labour laws and environmental impacts. If we redistribute production, we risk merely redistributing the environmental problems associated instead of addressing them. Perhaps this will force the development of materials, recycling, production, and waste management processes which previously were far easier to ignore. Radical change is coming, either it happens to us, or we design the transition ourselves.

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