

Data as a material for fashion

Fashion Research & Technology

Author(s)

Nachtigall, Troy

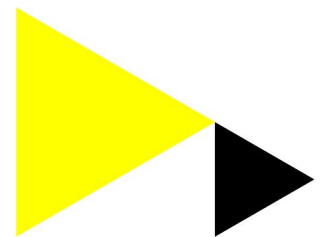
Publication date

2021

[Link to publication](#)

Citation for published version (APA):

Nachtigall, T. (2021). *Data as a material for fashion: Fashion Research & Technology*. Hogeschool van Amsterdam.

**General rights**

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations

If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please contact the library: <https://www.amsterdamuas.com/library/contact>, or send a letter to: University Library (Library of the University of Amsterdam and Amsterdam University of Applied Sciences), Secretariat, P.O. Box 19185, 1000 GD Amsterdam, The Netherlands. You will be contacted as soon as possible.

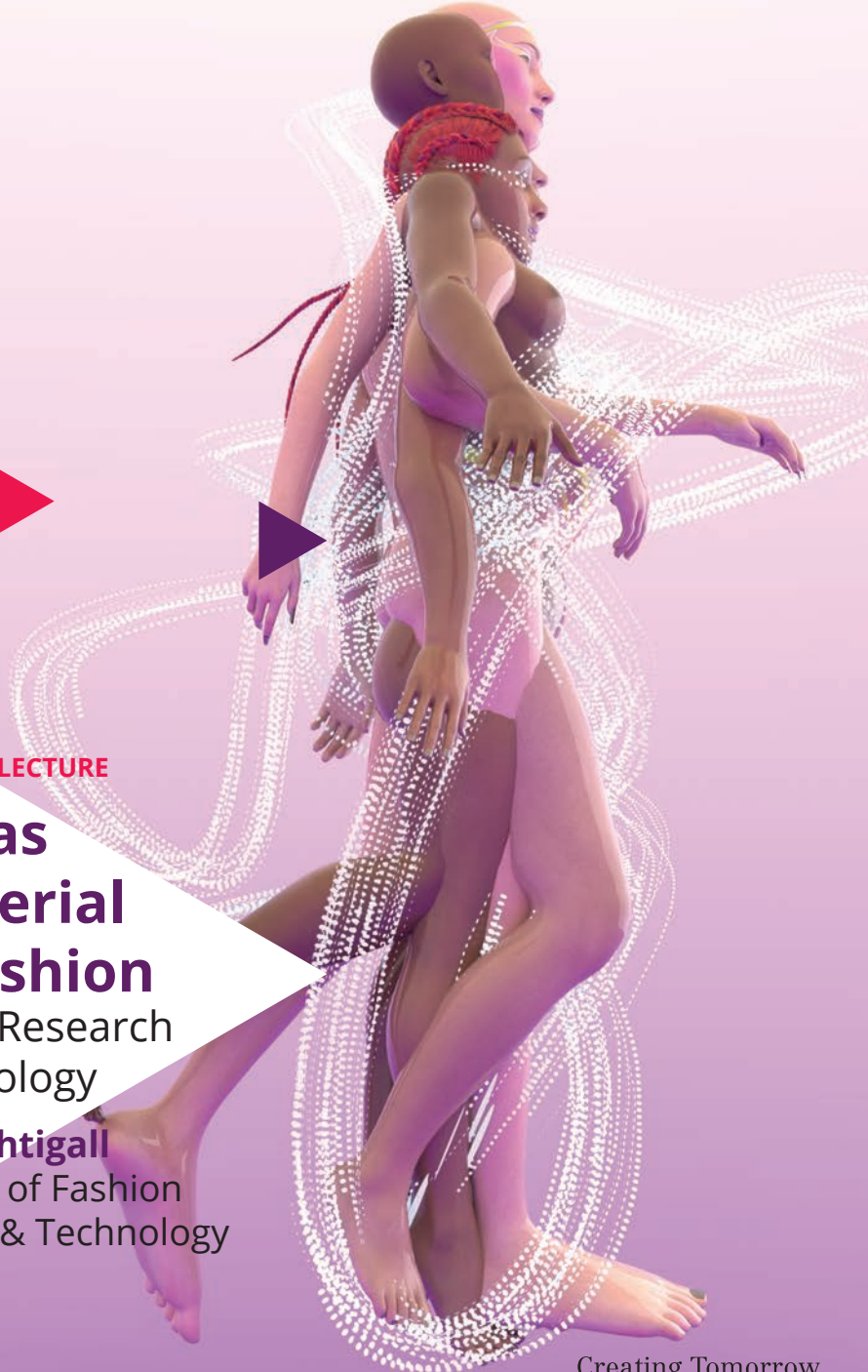


INAUGURAL LECTURE

Data as a Material for Fashion

Fashion Research
& Technology

Troy Nachtigall
Professor of Fashion
Research & Technology



Data as a material for fashion

Data as a material for fashion

Fashion Research & Technology

Inaugural Lecture

Delivered on Tuesday, September 14, 2021

by

Dr.ir. Troy Nachtigall

Professor of Fashion Research & Technology

At the Amsterdam University of Applied Sciences

ISBN 978-94-6301-369-7

Eburon Academic Publishers, Utrecht
www.eburon.nl

Cover image by Lili Eva Bartha, This image was developed in the Beyond Vision Project as part of the FDMCI Artist in Residency program. The image was developed into research into personalization and what it means to create fashion for all.

Cover design:: Textcetera, The Hague

Typesetting: Studio Iris, Leende

© 2021 Troy Nachtigall/Amsterdam University of Applied Sciences. All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission in writing from the proprietor.

A brief note of thanks

Prof. Ron Wakkary once pointed out that I thanked at least 350,000,156 people in my PhD Thesis. To start this lecture I would like to thank the people of the Netherlands and Europe for supporting my research. Thank you for the funding to complete my PhD research at TU/Eindhoven, my postdoc at Aarhus University, and for my position here at the HvA as Lector in Fashion Research & Technology. I think my research is important for creating new ways of making and new ways of wearing; I hope you will as well. I have several acknowledgments at the end of this lecture but there are two very important people to mention here.

Fiore Basile and I became friends when we founded the Fablab Firenze together. We developed many projects together for museums, companies and the maker community; we founded a few more Fablabs along the way. Fiore was my guru in the Fab Academy course. When I left to complete my PhD Research, Fiore, with the Fab Foundation, created the Textile Academy, an international FabLab network and training course dedicated to the fabrication of textile technologies. Fiore was a force of nature that encouraged all around him to find a space needed in open source culture and then make it a reality. We collaborated in the textile academy and Fiore created the spirit of "W2Fd3?" (What would Fiore do, drink, design?). His unexpected death shortly after returning from China, where he had just built another Fablab was far too early for all who knew and loved him.

Valérie Lamontagne was my immediate predecessor as professor of fashion research and technology at the AUAS. Valérie was an accomplished academic, artist and mentor based in Montreal. Valérie was also a friend who helped me write an early draft of my PhD thesis. I wasn't the only one who Valérie supported; Valérie was the heart of wearable technology via her 3lectromode blog and talks around the world including V2 iRotterdam. She made so much of what fashion technology research today. Valérie became ill and died shortly after becoming professor at AUAS; she left big shoes to fill. In her memory, an Artist in Residency has been created. Despite COVID-19, we hosted a virtual residency in virtual fashion with the support of the faculty of Digital Media and Creative Industries. Valérie would have loved the results of the residency: we plan on more residencies. I hope you see Valérie's vision and flair in our ongoing work.

Background

This lecture forms the vision, mission and research program of the Fashion Research and Technology Group. A brief description of my personal practice as a designer and researcher helps to frame these ideas. I make things. I understand the world by making and using things. I like to make with others, it gives access to their consciousness and intentions. Together we often make artifacts, prototypes, exemplars, demonstrators, material samples; sometimes times we make services (i.e. interfaces, experiences, or software) and every once in a while we make systems (i.e. tools, toolkits, card games, interpretive frameworks, guidelines, software, techniques, and standards). All of these things are made critically because “the thing being made is not a forerunner of the future product, but a vehicle for observation, reflection, interpretation, discussion and expression” (Sanders and Stappers 2014).

A hybrid form of fashion and technology has held my fascination for as long as I can remember. This early-in-life hybridization seems to be unique to technology researchers. Like many authors who have hybridized ideas like journalism with technology (Broussard 2017) or art with technology (Hertz 2021), I begin with some personal background. I grew up in the high plains of Wyoming in the United States. Wyoming is more than six times larger than the Netherlands, but with one-thirtieth of its population. I grew up with an interest in sewing and electronics. The deep connections between computational technology and textile technology seemed obvious to me. It still surprises me how society often sees fashion and technology as different disciplines. In my professional and academic practice I have continued to do both, often together, and have been delighted to be a part of this small but passionate worldwide community (Hertenberger et al. 2013) who does this as well.

My professional practice started when I left university early to join the first internet bubble in New York City. I worked as an ICT engineer at a company providing technology to some of the key players of the age. When that bubble burst, I returned to the State University of New York to study fashion at the Fashion Institute of Technology (FIT). Through the International Fashion Design study program I moved to Florence, Italy and soon began working as fashion designer in the studio system of Empoli. I designed for brands such as Calvin Klein, Hugo Boss, Jean Paul Gaultier Jeans. I then went to work for my favorite, Emilio Cavallini, as head designer. My flair for technology had not gone unnoticed by the fashion industry and in 2008 I formed Troykyo Design that combined fashion and technology.

As a fashion technologist (a term I learned recently from AMFI director Dirk Reynders) I was a “Special Forces” creative who worked on everything technological from classic fashion design (e.g. technical flats, look-books, look-videos, touch-books, illustration, and prototyping) to the more specialized forms of design like material explorations (Hertenberger et al. 2013), 3D printing, 3D modeling (Nachtigall et al. 2018), exhibition design, jewelry design, shoe design, branding, exhibition design and graphic design. This led to teaching courses on design, fashion and technology at IUAV of Venice, Sapienza of Rome, IED and ISIA.

My interest in wearable technology then took me to research. I attended Ars Electronica and the International Symposium on Wearable Computing (ISWC) in 2009. I created artistic explorations best seen in the projects “Fatto a Mano for the Future”¹ with Fendi and “Time and Space, A Tribute to Galileo Galilei”² for Panerai Watches. At the same time I was working with Plug and Wear, a knitted wearable technology company. I then joined the E-textiles summer camp³, a collective of worldwide fashion technology practitioners. In 2014 curated an exhibition with ISWC for Microsoft Research Studio 99, then became a PhD as a Marie Curie Research Fellow at TU Eindhoven and Post-doctoral research in Socio-Technical Design at Aarhus University.

At the same time, the ideas of Research through Design (Zimmerman et al. 2007) and Critical Design (Ratto and Hertz 2013) created space for practitioners to return to PhD programs to understand that “value of material production itself as a site for critical reflection” (ibid). These ideas gave birth to the ArcinTexETN Marie Curie European Training Program⁴ that brought together fashion designers, interior designers, architects, chemists and material engineers to strengthen the foundations of design in preparation for more sustainable forms of living. Since then I have been finding more ways to share learning from making, crafting and critical reflection with others by including them in the process.

1 <https://www.vogue.it/en/talents/news/2011/06/ied-at-pitti-immagine-uom>

2 http://www.agds.it/portfolio/panerai-time-and-space_shangai/

3 <http://etextile-summercamp.org/>

4 <http://www.arcintextetn.eu/>

Introduction

Fashion is broken. Covid has bankrupt hundreds of brands.⁵ But Covid was just the end of more than a decade of instability.⁶ Fashion design tends to see technology in a way that only the Amish would understand and appreciate. The Amish selectively allow certain technologies like roller skates and phones in the barn. Buttons on clothes are just fine but zippers, patented in 1913 are not. This is ironic in that fashion was on rapid technological innovation by the Medici's of Florence in the Renaissance (Schwarz et al. 2015) in a way that only Apple has grasped in our current age.

The digital transformation of the fashion industry is in its infancy while industries like publishing have given birth to behemoths like Amazon (who now have their own space programs). Ironically, a vast amount of the technology developed by publishing has been abandoned. (remember Adobe DPS?). Along the way these master of technology the actors in the field took over retail. Fashion remains behind, except for a few exceptions. Amazon now has a series of private-label fashion brands and Zalando which has adopted AI-driven personal shopping. The companies that are surviving made a digital transformation in the last two decades. Most of the others are bankrupt, leaving us an opportunity to rebuild fashion in a way that is empowering and enabling: sustainable, smart and digital.

If there was ever a moment to change fashion, it is now. The industry is in financial trouble while social movements have exposed the inherent inequalities in the fashion system. The resources required to make the fibers, yarn, textiles, dyes, coatings and metal pieces that create clothing have a large impact on the sustainability of our planet. Fashion may not be one of the largest polluters,⁷ but it does have a serious impact.

In order to change fashion we will need to change some assumptions about what fashion is. Three assumptions can help us understand fashion in a new way:

1. Fashion is any technology that envelops the body.
2. Fashion is made and worn with data as a material.
3. Fashion is the craftsmanship of dress.

5 <https://wwd.com/fashion-news/fashion-scoops/coronavirus-impact-fashion-retail-bankruptcies-1203693347/>

6 <https://www.nytimes.com/interactive/2020/08/06/magazine/fashion-sweatpants.html>

7 <https://www.nytimes.com/2018/12/18/fashion/fashion-second-biggest-polluter-fake-news.html>

Fashion

Fashion has always stood apart from other creative industries. This is most apparent in the language used. For example, industrial designers say “artifacts,” but fashion designers say “looks.” The same is true for “prototypes” vs. “samples,” “drops” vs. “deliveries,” “DTC” vs. “B2C,” “tech pack” vs. “design specs,” “Lab Dip” vs. “CMF.” There is no shortage of examples. This difference irritates many, often ending with many people considering fashion elitist. We tend to embrace this difference as an interesting phenomenon where fashion uses a different lens to describe what is going on. Many fields have their own jargon but making fashion practice often relates to the stakeholders’ relationship to the moment of sale. Ironically, much of the innovation found in fashion terminology goes unnoticed as fashion scholars tend to look at the cultural theory, cultural history, marketing or textile science. This is changing as the Netherlands has started to produce PhDs with backgrounds in fashion design, most of them coming from what fashion scholar Bradly Quinn calls “techno-fashion.”

Quinn describes techno-fashion as “real enough to revolutionize the meaning and function of fashion” (Quinn 2002). We see this idea of fashion well argued in Toussaint’s thesis “Wearing Technology: When Fashion and Technology Entwine (Toussaint 2019).” Toussaint cites the work of Smelik, “[w]e have now entered an age in which technology is not only an extension, but also an improvement, enhancement, and expression of the body. We use technology with the idea that we can control, improve and enhance our life and even our own body” (Smelik 2017). It is from here that I adopt an encompassing view: Fashion is any technology that envelops the body.

***Fashion is any
technology that
envelops the body.***

Technology isn’t only electronic, but also biologic, textile or mechanical. Koert van Mensvoort captures this idea in *Next Nature* (2012) where every kind of tool is considered a technology, naturalized through human use. The Greek word *praxis*, meaning putting an idea or theory into practice, is what is intended here. Praxis encompasses technology and aesthetics, which gives way to a semiotic understanding, but for now technology is the focus.

This lens of technology (as praxis) enveloping the body also works in other ways. Electronic technologies worn on the body are fashion: a cell phone in a pocket, a watch on the wrist, eyeglasses on the face (Zeagler 2017). Kristina Andersen and I look at this idea of wearing data in “Making Secret Pockets” (Andersen and Nachtigall 2018) where the pocket becomes an encryption device securely obscuring the data we put inside it from others. This gives

fashion a unique perspective on technology, and human computer interaction (HCI) as seen from the rich background of fashion instead of the problem-solving nature of computing technology. Convincing HCI of this has its own challenges that the members of this research group are happy to accept. Anouk Wipprecht's⁸ 3D printer spider dress is a great example of technology in fashion design. Anouk designs computational dresses that incorporate digital and non-digital technologies that change the meaning of fashion as a functional and aesthetic medium

Data

In the fable "The Emperor's New Clothes" by Hans Christen Andersen (1837) an emperor parades through the street naked because he had been told that the fabric was so fine that it was invisible to most people. Some see this as a morality tale about gullibility; others see it as a lesson about the personal courage of convictions. But what if it is a story about wearing data? Is data visible data? Is it tangible? We think so.

A few examples are needed here. Francis Bitonti⁹ used data as an element of dress. In the dress made for Dita van Teese, Francis architected the data of the body and 3D printed interlocking pieces to form a complex yet elegant dress (figure x). Francis is a designer and a programmer who has created more than one iconic look. In order to create the intricate features of the designs, Francis and team had to write new software to describe data-driven physical forms that comprise his materialized designs. Francis summarizes this well in *3D Printing Design: Additive Manufacturing and the Materials Revolution* (Bitonti 2019):

3D printers are capable of producing so much variety because they run on a discrete additive logic. It is a generic non-specific tool, capable of self-replication. 3D printers present us with a methodology for thinking about materials and assemblies as a set of discretized operations that inform a manipulation of matter that is much closer to how we manipulate software; and as a result, assembly of physical form and material differentiation no longer fall on the tool but on the manipulation of a codified language. This is a paradigm shift. This means materials are now shaped by linguistic constructs (Bitonti 2019).

8 <http://www.anoukwipprecht.nl/gallery>

9 <http://studiobitonti.com/>



Figure 1. 4D printed shoes made with data from a 3D body scan implemented as aesthetic, mechanical, and thermal design considerations worn by Jet Bussemaker at Prinsjesdag 2015.

Another example is Project J¹⁰ a parametric hat, dress, and shoes made for Minister of Education, Science and Innovation Jet Bussemaker for Prinsjesdag 2015 by Pauline van Dongen, Leonie Tenthoff van Norten and me. As depicted in our video,¹¹ Project J used parametric design software (Rhino Grasshopper), 3D body scanning, flexible 4D printing (see figure 1), shrinking textile coatings, and classic fashion craftsmanship to create a personalized look that Jet herself helped design thanks to the parametric interfaces. Foot scans and walking data were used to create custom high heels, 4D printed and documented in “Towards Ultra Personalized 4D Printed Shoes” (Nachtigall et al. 2018). Since 2015, Project J has inspired me to enable fashion designers with generative software (Nachtigall et al 2016), data-gathering techniques (Nachtigall 2017), models (Nachtigall et al. 2019b), interpretive frameworks (Nachtigall et al. 2019a) wholistic systems (Amorim et al. 2019), failures (Nachtigall 2018) collaborative modes (Andersen et al. 2019) models (Nachtigall et al. 2020) and the doctoral thesis “Materializing data: craftsmanship and technology for ultra-personalization” (Nachtigall 2019).

10 <https://www.paulinevandongen.nl/portfolio/be-tween/>

11 <https://vimeo.com/143614849>

A driver of change in design is that data (along with the algorithmic tools that manipulate it) allows design to grow well beyond an activity of making a thing by sketching technical drawings and sending it off to a China for a developer to fabricate. (I speculate this has led to the disconnect in fashion between the conceptual semantic and tangible direct approach (Koskinen et al. 2011)). Tools like 3D modeling (Frens et al. 2017), digital fabrication (Baudisch and Mueller

Fashion is made and worn with data as a material.

2017), and material exploration (Karana et al. 2016) have transformed that process. Data in design is empowering the individual and people near them to make specific things for specific situations. As data becomes a key part of the design process, a new possibility arises: Fashion is made and worn with data as a material.

Design ideas from HCI are not easy to bring to fashion as fashion tends to use the least common denominator of technology (Zhang et al 2019). This means that instead of teaching fashion practitioners to be data scientists, we make tools for fashion designers using the materials that they already know intimately. Treating data as a material allows us to meet fashion practitioners where they are. It is vital to the ideas of diversity and sustainability that fashion have the tools to create for smaller groups of specific people rather than the large demographic groupings. We aim to see if data can enable this at scale. Fashion must design for all parts of society, not just the small group of rich and famous that it holds most dear. H&M, Zara and Primark need as much data innovation as Iris van Herpen, Viktor & Ralph and Mark Jacobs.

AMFI wants to change fashion, AUAS wants to change fashion, and so does our research group. The idea of design has changed dramatically with the idea of participatory co-design and design thinking. Yet fashion (especially fashion design) remains a bastion of an idea formed in the 1980s.

Craftsmanship

When I came to the Netherlands in 2015 I finally understood design research. I was thrilled by the idea that design research could be done by a designer embedded in the context of the work (Sanders and Stappers 2014). The fast cycles of fashion left little room to reflect upon the questions surrounding the things we made. Like many other designers, I have traveled the world to investigate from the inside how fashion is designed, made, worn and analyzed. I especially like to see how things are made by making them myself. Craftsmanship is one way of expressing that idea.



Figure 2. An rendering from the *Beyond Vision* project, part of the Artist in Residency program of the fashion research and technology group. Resident Lili Eva Bartha used mathematics and Virtual Reality to create interactive experiences around the idea of self-identity.

Making leads to practice, practice results in craftsmanship. In other words, “Craftsmanship embodies the embodied practice of the craftsperson” (Nachtigall 2019). Craftsmanship is the combined practice of everything someone has ever made. Craftsmanship is internal. Craftsmanship is personal. In contrast, fashion is social, engaging and reportedly fickle. Everyone engages in fashion every day as they select and wear clothing (or not, which is also fashion). The craftsmanship of fashion is challenging and thrilling. Fashion is hard to explain, its meanings are most often implicit and ambiguous. It’s a good thing ambiguity is a highly valued resource in design (Gaver et al. 2003) that allows the user to find their own meaning in everyday use.

***“Craftsmanship
embodies
the embodied
practice
of the craftsperson.”***

So what is fashion? According to fashion designer Marc Jacobs, “Clothes mean nothing until someone lives in them.”¹² The clothing, accessories and footwear that we put on through the act of dressing are an embodied practice. Every time we dress we are adding to that embodied practice of wearing

12 <https://www.independent.co.uk/life-style/fashion/features/marc-jacobs-fashion-force-be-reckoned-834246.html>

clothing. If craftsmanship embodies embodied practice, fashion is the craftsmanship of wearing clothing (dress). But if we are to data as a material, a new craftsmanship is needed as well.

We see this happening in the work of The Fabricant¹³ and in the work of Lili Eva Bartha, the first artist in residency of the research group, see fig 2. The Fabricant is making exclusively virtual fashion. They are allowed to break the rules of the physical universe as they are not making a physical garment. Instead they are dressing the virtual self using experience based virtual environments. Interestingly enough, many of the practitioners who have taken this direction in design refuse to be called “fashion designer,” preferring “experience designer” or “digital aesthetics designer.”

Making a new craftsmanship of fashion

How has the craftsmanship of fashion changed in the digital age? Most people wear clothing that people 300 years ago would recognize (much of it as pajamas). Fashion continues to be made the way it is because that is the way practitioners have always done it. Where is the disruption? We see great technological changes in the craftsmanship of architecture (generative design), computation (handheld digital devices), and transportation (driverless cars). Where is the fashion that demonstrates the transition to a digitally enabled society?

Fashion is the craftsmanship of wearing clothing (dress).

We see an opportunity to create a new form of fashion that empowers and enables the user (as wearer). We want to make fashion that actually represents our time: a time that is smart, digital, sustainable, inclusive and diverse. We want to use cutting-edge theories in critical making and research through design to understand the making and craft of fashion on an informed and visionary level.

Transitioning fashion requires a reframing of the idea of craft. The word “craft” connotes things that are “traditional” and “old.” While this is true and valuable, there is also a craft to emerging technologies like digital. There is much work into new forms of craft, especially in the field of textiles. This is laid out well in “Understanding Craft-Based Inquiry in HCI” (Frankjaer and Dalsgaard 2018) or in the practice of Maggie Orth (2009), the critical analysis

13 <https://www.thefabricant.com/>

of “I don’t want to wear a screen” (Devendorf et al. 2016), commercial products like “Project Jacquard” (Poupyrev et al. 2016), in the ideas of crafting technology (Buechley, and Perner-Wilson 2012) and most recently in “Digital Crafts-machine-ship: Creative Collaborations with Machines” (Andersen et al. 2019). The idea of what craft can be has expanded greatly and continues to be supported by the EU in the New European Bauhaus¹⁴ initiative. In “On Craftsmanship: Towards a New Bauhaus,” Frayling begins to identify what this new craftsmanship looks like (Frayling 2011):

Crafts can be made with machines and maybe even by them, if numerically-controlled technology goes on improving;
Crafts can be made with synthetic materials, in all colours of the rainbow;
Crafts can be non-functional;
Crafts can be made in limited production;
Crafts can be designed by one person and made by another;
Crafts can provide designed prototypes for industry;
Crafts can be made in towns, and usually are;
Crafts can be high fashion, and still be well made, although they needn’t be;
Crafts can use ideas borrowed from the fine arts of painting and sculpture; they can even inhabit the avant-garde;
Crafts can be transient;
Crafts can be very expensive indeed (again, like most of William Morris’s work; the late Victorians were prepared to pay for quality);
Above all, crafts needn’t provide a solace –; their role is rather to provide a challenge, often by means of an ironic statement about traditional notions of “the crafts.”

Over the next years the Fashion Research and Technology Group intends to explore making and crafting with data to create new craftsmanship of fashion.

Data as a material

Data is conceptual. Some would argue that data has no physical form, yet we see many examples of data being an integral part of materiality. Wiberg argues that the human experience of things holds a materiality (see fig. 3), that is not only materials but also includes details, textures and wholeness with examples of interactive materiality driven by data (Wiberg 2014). If data has a materiality, is it also a material? Can we blend it with wool and cotton to

14 https://europa.eu/new-european-bauhaus/index_en

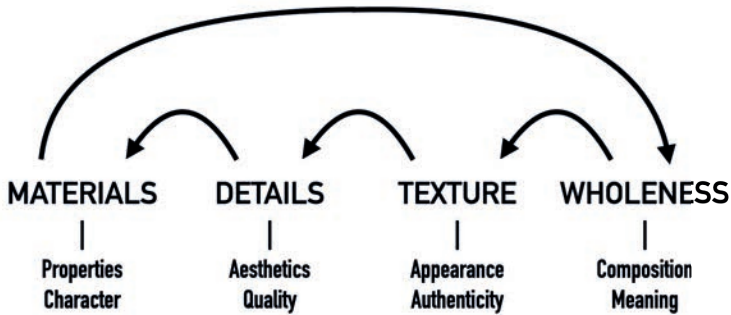


Figure 3. *The Wiberg model of materiality in which data can play a role in composition and meaning implying data is also a material. Extracted from (Wiberg 2014).*

make something with new design properties? Can we dust mycelium spores with it to make new kinds of leather? Can we find it in materials like vegetable tanned leather and use the data properties to make computational fashion? Can we wear data itself, or is this a new form of the emperor's new clothes? If we have that data, can we change how we brand, develop and build business out of fashion?

This requires new tools and toolkits that allow the stakeholders of fashion to excel in their role while bringing the material of data to their practice. So I invite industry, academia, society and education, to join us as we make data an into a material for fashion just as much as wool, cotton, polyester, nylon, silk, linen stainless steel, tencel, viscose, elastane, leather, algynyl currently compose the attire that together constitute fashion.

Fashion needs a larger design space; a set of all the possible outcomes that allow for the emergence of unique garments, looks, accessories and collections. Höök and Löwgren might describe this as a place of intermediate-level knowledge where concepts and theories become instances (Höök and Löwgren 2012). Frauenberger (2020) would say "Humans and their tools mutually define themselves and co-evolve over time." Behind each practice is a series of people, technologies and materials that as a constituency form a design space. If we invent new technology and enable people to use that technology, we change the design space of fashion.

Vision

Practitioners of fashion have long dreamed of a past age where everyone wore tailored clothing, designer handbags and handmade shoes. Fashion holds this as this vision of what fashion should be and tends to portray it as young, white and feminine. But what if these are both lies told to sell clothing with its fashion narrative? What if ancient Romans had mass manufacturing and distribution of shoes (Greene 2019)? We like to talk about vanity sizing and size inflation in fashion, but what if sizing has always been off due to the impossibility of a single number representing the diversity of human body shapes and sizes? We don't believe that this mythical past ever existed, or was only available to the rich, famous and powerful. But could we make it true for everyone? To quote one of fashion's favorite singers, George Michael, "All we have to do now is take these lies and make them true, somehow."¹⁵

In our vision of fashion, the fashion fits the individual. This is a fit of more than the anthropometric shape of a person, but also their movement, their personality, their social position, their stage of life, aspirations and self-image. We see a future where our social media, personal biometric and contextual life data are compared to those around us to present us with personalized clothing. We want to understand what data sources are being used to generate their personalized fashion by showing them alternatives that include and exclude that data. Just like shopping for shoes online, you see a series of shoes on a page that are all designed the moment you load the page and show you what data sources are used. We know that this is technically challenging, but that is why we like to do it.

We want to empower fashion practitioners to parametrically combine the form language (Djajadiningrat et al. 2004) of their designs with the form language of the body that is wearing that design. We want to enable wearers to buy fewer clothes because the things fit the shape and composition (muscles, flesh and bone) of their bodies, their self image and their social needs to fit in or differentiate. We ask, what does fashion do? This question has many answers, some scientific (e.g., protecting the body from the elements) (McLuhan 1964), some artistic (e.g., individual expression) (Simmel 1957) argues for a social function of fashion to align and differentiate us from our social peers. We know this to be a complicated challenge (Nachtigall et al. 2019c). It is a complex and adaptive system that drives computational couture, but data science and emergent fabrication technologies (Andersen et al.

15 <https://www.youtube.com/watch?v=diYAc7gB-0A>

2019) enable the dreams of tailoring and personalization fashion has always held as important.

The Fashion Research & Technology group asks two questions, which it answers with a third question:

1. How can creativity, technology and innovation foster fashion products, services and systems that use data to empower stakeholders to create critical smart attire and enable circularity for sustainability?
2. How can the things we make in fashion provide perspective on technology and design to interact, affect, empower and engage our constituency including ourselves, wearers, designers, entrepreneurs, advertisers, society, education?

In order to realize our vision and respond to these wicked problems, we look through a lens of data by asking: How do we use data as a material for fashion?

Fashion practitioners are not often great at data science, but they are great at blending materials as noted before. How do we as fashion practitioners use data as a material? How can we encourage others to do so? What does developing these new technologies tell us about design and computer human interaction? These are not easy questions to answer, but we intend to look at them from designerly, artistic, and scientific perspectives to

How do we use data as a material for fashion?

understand how we can make data accessible to fashion. How do we make clothes, accessories, footwear and other forms of attire with data? What does it mean to wear data on the body? How does a person embody data? What does it mean to interact with data on the body? How does our attire make data? How does that data as part of a worn product (thing) become part of a systemic ecosystem? How do we use only the data needed so that people are not wearing data that can be used for nefarious reasons? How do we make that data in the clothes we create safely personal, systemically distributed and knowingly explicit in circular ecosystems? To answer these questions as a large group, a manifesto is needed.

FR&T Manifesto

1. We are here to innovate fashion

We are practice based researchers. We define our time by critically crafting meaningful tools, products, services and systems to shape the space of technology, sustainability and making.

2. Data is a material

Data is the most important material of our digital age. Fashion is a rich resource for data science. Understanding data allows us to critically create ecologies inside of the complex adaptive system that is fashion. With data we will find new ways to analyze, design, make, and wear fashion.

3. Our constituency is diverse

We embrace the diversity of the people, places and resources involved in wearing, making, designing and analyzing fashion. We respect our constituency; ourselves, community, city and world. We encourage our constituency to be change-makers; technologists, disruptors, and guardians who design, develop, direct, instigate, influence, innovate, brand, market, manage and do things we have no terminology for yet. We respect our constituency as co-makers, co-authors and co-designers.

4. Future means of making

We develop smart new means of crafting emergent technologies to enable our constituency with tools, toolkits, software, exemplars, canvases and code to critically make.

5. Future ways of wearing

We look deeply into the daily practice of fashion to find new ways of wearing clothing, accessories and technology that lead to systemic change and distributed circular systems.

6. Think while you make, Make while you think We actively seek to make “things” to represent our thoughts and provide spaces (conceptual and physical) to make those things with our constituency.

7. We stand at the intersection of physics and metaphysics

We understand fashion critically and holistically as Designertly, Artistic, and Scientific impacting in ways that are Socio-Technical and Socio-Aesthetic.

Figure 4. Manifesto of the Fashion Research and Technology group to set a course for our mission of making fashion that enables and empowers our constituency by making and wear data as a material.

A Manifesto as our mission

To transform this vision into reality, we composed a manifesto out of love for the Bauhaus and design. We started this work in the middle of the Covid-19 crisis, which was in many ways a hindrance, but did enable the co-design of the research group. Many stakeholders were available to talk in Zoom and Teams, many for the first time in decades as they had been furloughed from large fashion companies like LVMH. We reached out to many stakeholders in Amsterdam, in the Netherlands and around the world to co-design our impact on fashion and technology. Thank you to all who gave me time to discuss how to make this work. The co-design process clarified the motives and intentions of this research program that we expressed in the FR&T manifesto, see fig. 4.

As a foundation, the research program of the Fashion Research and Technology group is situated in practice-based research. This has been solidified by the work of the last two professors in the group, Dr. Valerie Lamontange (Lamontange 2013) and Dr. Hein Daanen (Daanen and vn 2013). We come from a tradition of constructivist phenomenology (Koskinen et al. 2011) where things are made to test-prove theories. We are the applied physicists of the design world. We use Research through Design (Zimmerman et al. 2010) methods to bring forth new practices via Everyday Design (Wakkary and Maestri 2007), Critical Materiality (Berzowska et al. 2019), Slow Technology (Odum et al. 2007), and Post-Phenomenology (Hauser et al, 2018).

We want to show our students, teachers, fellow researchers, industry and society how fashion can be done differently. This is not an easy task as in the Netherlands, fashion has few university programs to draw from, especially in design. In Applied Science we are expected to implement theory in what is often called Technology Readiness Level (TRL) 4-8, but where do we find our basic principles, formulated technology concepts and experimental proof of concepts that form TRL 1-3 (https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf)? We often look to the arts, hard sciences, social sciences, marketing and medicine and programs like the Swedish School of Textiles and the State University of New York Fashion Institute of Technology.

While our foundation is in design, this manifesto was developed from a co-design process with education, academic, industrial and societal partners (table 1). We will use this manifesto in the research group to generate our ideas, guide our process and evaluate our results.

We are here to innovate fashion

We are practice-based researchers. We define our time by crafting meaningful tools, toolkits, products, services and systems to shape the space of technology, sustainability and making. In the research group we use data-driven design, humans and post-human centered design, research products, iterative ecosystems, ultra-personalized design, co-manufacturing, ubiquitous design and situated design techniques for demonstrating new ways to create products, services and systems that inform not only fashion, but also design and technology.

We understand that fashion is a complex system full of peculiarities, and averse to certain technologies. Fashion is struggling to make the digital transformation. Fashion is disconnected from the wearer. Many see these as insurmountable challenges, but we see it as a unique opportunity for co-design, co-manufacturing, co-use and co-analysis. We want to change fashion inherently and disruptively from the inside. We see ways of making fashion more personalized and sustainable through the smart and the digital.

Many fashion practitioners and educators still believe that fashion has not changed since the 1980s. This was a time when people spent a large part of their disposable income on fashion and supermodels were as popular as rock stars. One might think that as hundreds of fashion brands have closed¹⁶ and others have been devastated financially,¹⁷ fashion would embrace this moment to change. Yet fashion icons Tim Gunn and Heidi Klum through their seminal fashion television shows *Project Runway*¹⁸ and *Making the Cut*¹⁹ represent the difficulties of fashion all too well. In their latest season, Tim and Heidi recognize that fashion is collapsing, and yet have doubled down on the egotistic vision of the designer. Where is the collaboration that most brands wholeheartedly engage in? Where are the craftsmanship and materiality? So much of the how and why of fashion goes unanswered. Where is the epistemology of fashion?

The business strategist Wouter Stokkel cynically remarked, "It's art if it can't be explained. It's fashion if no one asks for an explanation. It's design if it doesn't need explanation." If this is the case, then the data-rich age that we live in demands that fashion become more like design. It's time to introduce

16 <https://www.buro247.my/fashion/news/fashion-brands-closures-bankruptcies-covid-19.html>

17 <https://wwd.com/fashion-news/fashion-scoops/coronavirus-impact-fashion-retail-bankruptcies-1203693347>

18 <https://www.bravotv.com/project-runway>

19 <https://www.amazon.com/Making-The-Cut-Season-2/dp/B096MZ26GY>

friction and provocation in fashion and to start raising questions about fashion.

Design is not just performed by designers, but also by those in business, development, branding, manufacturing retail and wearing. “The act of making here is not just a performative act of reproduction, but a creative act which involves construction and transformation of meaning” (Sanders and Stappers 2014). The role and definition of what is design is changing and expanding in amazing ways that require fashion to reevaluate itself. Branding, business, development and all the other parts of fashion need to embrace their generative output as designerly acts, and own their contribution to the process.

Data as a Material

Is data a material? Scholars like Paul Dourish in “The Stuff of Bits” (Dourish 2017) have shown how data might be considered a material by way of materiality. My previous work is very interested in this emerging field (Amorim et al. 2019; Nachtigall 2017; Nachtigall et al. 2019c).

By way of ideas like meta-materials (Ion et al. 2016, 2018, 2019) we not only use data to design objects like shoes; we can also make physical objects record data and perform calculations. Parametric, computational, generative and algorithmic design, most often found in architecture, are rapidly changing the landscape and are ripe for changing the practice of fashion entirely. In the form of genetic algorithms a designer could be presented with hundreds of variations of their design in simulation software like Clo 3D,²⁰ turning fashion from a slow additive practice to a rapid subtractive practice, in which the techno craftsperson need only select the model that is most aesthetically pleasing from hundreds of possibilities. The algorithmic nature allows for additional generations of the garment to be grown that allow for ever-increasing precision of the selected aesthetic. This can be applied to silhouette, line, color, pattern, texture and drape.

The same is true for cellular automata, as we have already seen in the examples of Loe Feijs and Marina Toeters (2015, 2018). What emerges is the idea that there is craftsmanship to emerging technologies (Nachtigall 2020). We intend to look into the craftsmanship of data science as applied in fashion, a field known for being very selective in the technologies it adopts.

Moreover, visual methodologies for analyzing the vast quantities of data available on Instagram can track the impact of a trend or design over use and

²⁰ <https://www.clo3d.com/>



Figure 5. *The digital-physical transformation of an artifact when data is used as a material. Objects such as shoes are sometimes physical, sometimes digital transitioning between states in a series of phases. (Extracted from Nachtigall et al. 2019c)*

time. At Hugo Boss I learned that menswear trends run at an eight-year cycle because most garments tend to last seven years in the man's wardrobe. Larger systems of fashion business and branding are needed that implement this technological ability to see what people are wearing into every aspect of analysis, design and manufacturing.

In the preliminary year of the research group we built a Style AI with students of the Applied AI minor. Users can upload a picture to the app and have three different AIs tell them what style they are wearing. We are excited by the early results as users have already reported that enjoy getting several opinions. The differences help the end user understand that AI is not always right; rather, AI is an aggregated opinion that depends on a training set. This semester we will work with students in the AMFI Dimension of fashion business and development to create their own training set and add their own AI to the app to understand changing trends.

Finally, data is ephemeral. As data scientists (of which we loosely consider ourselves) we have had to invent thousands of complex techniques to record

data through millions of hours creating sensors, software and other computational techniques to create understanding. Fashion is also ephemeral. Practitioners of fashion quickly learn to work with the transient nature of fashion and ride its complex trends and tendencies. What remains to be done is consider how the ephemeral nature of data and fashion inform each other. The methods of data science should tell us something about fashion. The feelings of fashion should tell us something about data science.

In this we see fashion as a digital and physical material (see fig. 5). A thing can exist in a physical form or as a digital form, throughout its lifecycle it transfers back and forth, informing future generations (Nachtigall et al. 2019c). The practitioners of tomorrow are both Digital Natives and also Physical Natives (Michahelles and Mayer 2021). We imagine a world where the wearer (client, user, everyday practitioner) buys the digital NFT version of the garment and a physical version arrives at their house as well. Much like a Gucci bag, both the digital and physical garment are guaranteed for life and there are entire factories (as with Gucci in Florence) dedicated to repairing decades-old bags.

We see our work as not only showing that this crossover of domains is possible. We also want to make the tools with our different constituencies (people, places, things, resources), providing them with the toolkits, software, design patterns and critical reflections that are tailored to their HCI interaction, design and wearing style.

Future Means of Making

With data as a material, we set our sights on understanding how data changes the way we make fashion. This requires a new craft and craftsmanship which makes a new fashion. We see this generative process as designerly, making branding, business, development and product all part. But we realize that fashion itself has a different interpretation of design deeply rooted in the semantic approach (Koskinen et al. 2011).

The word *design* in fashion is associated with a particular set of activities that primarily involve product development. But as I noted in the introduction, design has changed. Design has come to mean service (as in brand) and system (as in marketing), not just product. We see this in the fields of design such as everyday design, service design, social design, embodied interaction, experience design, design trajectories, speculative design and design fiction. Just look at how many people who are not designers deploy design thinking processes in their jobs. Design is everywhere. I am excited that our closest Educational Program AMFI has embraced a Dimensions system that sees the crucial role of design across all of the classic disciplines.

What are we going to make?

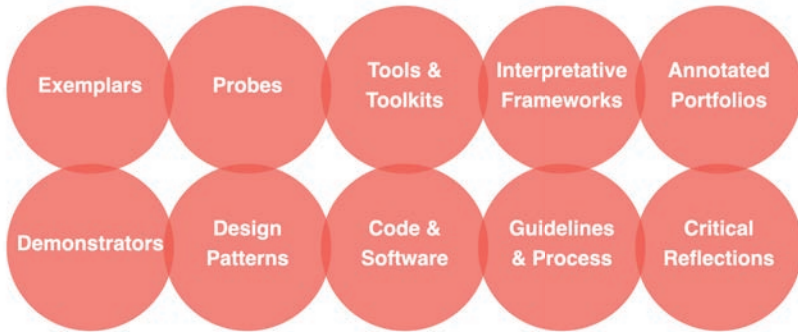


Figure 6. As a research group founded in practice we intend to make tools, things, services and systems that embed knowledge inside the artifact so that our constituency (including students, teachers, industry and society) can learn directly from what is critically made..

Future means of making goes beyond design; it means making new ways of analyzing, designing, manufacturing, selling, wearing, and recycling fashion as well. It asks for new forms of crafts and craftsmanship. Our research looks at holistic changes to systems of fashion that can make fashion more personal, equitable, sustainable, circular and local. It also means looking for past technologies in systems that are ancestral, indigenous and archaic. Future doesn't only mean novel. Maaïke Feitsma, PhD is joining the research group to do a PhD on historic practices that may be more sustainable than current practices. At the same time, we look at novel methods of generating data from various practices to enable data science to quantify the systems, services, products and materials we are using to deepen our understanding of our impact on our constituency.

The way that practitioners work is rapidly changing thanks to smart technologies. Nearly eight billion people on the planet wear clothes. Each person needs to be empowered with fashion that represents them. Fashion happens at many levels: haute couture, fast fashion, and anti-fashion (For example, Mathematicians and computers scientist are expected to look completely out of fashion because they think that their ideas are so good that they don't have to hide behind clothing.) We need all kinds of designers for all kinds of people. Ron Wakkary expresses this idea well in his article "Nomadic Practices: A Posthuman Theory for Knowing Design" (2020). Nomadic practices are described by Wakkary as having three key features: *multiplicity of intentionalities* (different stakeholders do different things with a design),

situated knowing (design is understood in the specific moment of use), and *nomadism* (there is a plurality of ways of using, none of them proper or correct). Take one look at the fashion influences on social media who are showing all kinds of ways to style today's clothing and you will know that this is true in fashion.

We see our work as not only showing that novelty is possible in many areas of fashion, but also as a critical process to make the tools with our constituencies (designers, branders, developers, engineers, programmers, instigators, technologists and guardians), giving them the toolkits, software, design patterns and critical reflections (see fig. 6) that are tailored to their emerging craftsmanship of new craft. At the same time we take learning from fashion that inform design and human computer interaction to add our unique way of creating technology to the discussion.

Future Ways of Wearing

The design of fashion doesn't stop once the collection is sold. We see the everyday practice (Wakkary and Maestri 2007) of choosing an outfit to be a designerly act engaging the wearer in fashion, consciously or otherwise.

We see fashion as a designed system. This system has responsibilities to the future of the planet, its resources, and all of its inhabitants. It is important to our research that we find sustainable, circular and resilient ways to fulfill the functional, aesthetic and social functions of fashion. There are great possibilities for using data to understand the lifetimes of a piece of attire and bring that data back to create a better fit for the wearer of fashion. We use the term *wearer* because as we generate data from a garment all of the involved stakeholders in the fashion system become co-users of the garment, if only in its digital form. We don't assume that this means electronic. Past research has shown that we can record data in mechanical ways using the complex structures that create our clothing, footwear, and accessories. We can also use existing technologies; we have applied for funding that will allow us to see if the LIDAR scanning technologies found in today's cell phones are capable of transmitting detailed 3D maps allowing us to understand how the attire is being worn. Moreover, we see this idea of fit not just applying to the 3D form of the body, but to the movement, behavior, aesthetic and social fit of the wearer as well.

This requires a new form of digital twinning that we presented with the Digital Society School of the AUAS. Fashion primarily (and almost exclusively) uses demographic data, but the tools of today allow us to gather so much

Lifecycle Ecosystem of Fashion

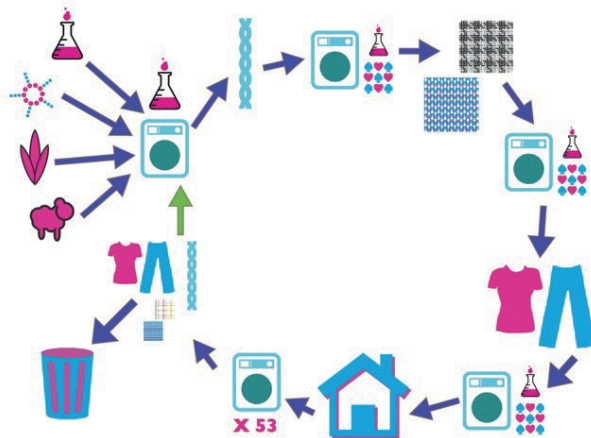


Figure 7. Illustration of the lifecycle of a garment from the lens of the physical material. We intend to look at the whole life-cycle and ecosystem of things we make to understand the everyday context of our research.

more data about our users. Our partner Pptrns.ai²¹ has shown that fashion can use demographic, technographic, psychographic, contextual, sociographic data as well. Understanding specifically who a person is, who they aspire to be, how they see themselves and how society sees the individual opens up vast new areas for fashion. We look to understand the lifecycle of a fashion artifact, including how long was it used, how many people used it, how did it wear out, where did it end up (see fig. 7). Our abilities to rapidly analyze social media data along with the vast amounts of data online allows us to build a situated profile for every person. The nascent field of situated design is opening up the possibility of making the myth of personal tailored clothing an actual reality for all.

But this possibility comes with great responsibility. The General Data Protection Regulation (GDPR) law demands that we be explicit as to the data we collect and how we are using it. We are asked as to collect as little data as is needed to accomplish our explicit task. In the preliminary year we have worked with the students of ICT Blockchain minor to create tools to help not only track the garment through its many stakeholders, but to all create a sort of bottle recycling fee that incentivize the reuse and recycling of the item. As a constituency we see our work as not making things to sell to clients. We look at the lifetimes of wear to see how fashion lives with us, enabling those

21 <https://www.pptrns.ai/>

who create fashion to understand the long tail of its impact, in order to inspire new and robust ways of wearing fashion.

Our Constituency Is Diverse

Fashion is far more than a financial relationship between a designer and a client.

As society moves towards circular economy and extended producer responsibility, the parameters of the fashion system have to change. In 2007, Levi's took a large step in this direction as they completed a full life cycle analysis (LCA) on its 501 jeans (Levi Strauss & Co. 2015). In this LCA they presented all of the materials, energy and water needed to make and use one pair of jeans. This was the first time a fashion company had studied the lifetime of a garment. Using LCA to understand all the people resources and energy involved in a thing has led Post-Human Design (Robbins et al. 2020) to the idea of constituency. In *The Things We Could Design*, Ron Wakkary (2021) defines constituency as:

the assembly of humans and nonhumans from which designers of things are gathered to go on to design things and form biographies. It can be seen as an expansive version of what is called design practice. To imagine a structure that is similar to a constituency is to think of bringing together the socio-material interdependencies and commitments of designing that include human actors of design (e.g., speaking subjects, stakeholders, audiences, families, partners, sponsors, clients) as well as nonhuman actors of design (e.g., locale, materials, tools, methods, techniques, organizations, institutions, policies, companion species, and other entities that can also be understood more fluidly as cross-assemblies of matters and forces).

Industrial design has an advantage over the fashion system in the sense that they adopted Human Centered Design after 2000 and now Post-Human Design has conquered business and marketing with critical design and design thinking thanks to companies like IDEO.²² How do we in fashion create a constituency that is inclusive? Can we bring the wearer, designer, developer, manufacturer, brander, marketer, analyzer, technologist, programmer, guardian, instigator, influencer and trend setter together with the non-human actors like cotton, water and knitting machine to design an ecosystem of fashion? Probably. What happens when we start to see human and non-human actors as constituency is that we start to understand who is not at the

²² <https://designthinking.ideo.com/>

An Iterative Circular Model of Fashion

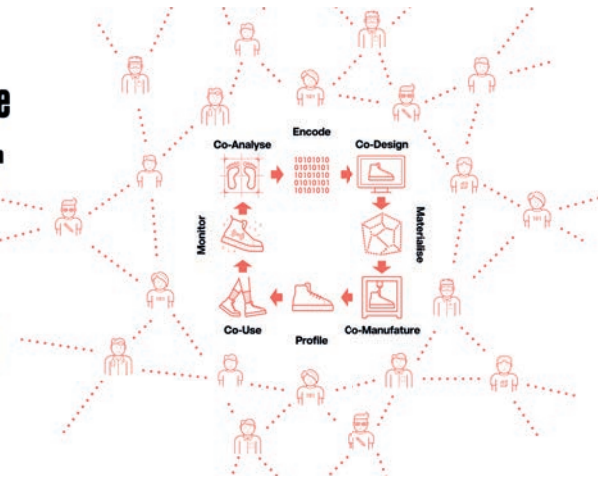


Figure 8. An interpretive model of a circular and iterative system that included data as a material developed as part of research into ultra-personalized product service systems (Nachtigall et al. 2020)

table? Who are we not giving a voice in the process of co-analyse (trending), co-design, co-manufacturing and co-wearing?

Preliminary results from working with fashion innovators like ByBorre²³ indicate that many of us who have worked in this field a long time are ready to see it done differently. We look to all the parts of a fashion process as agents, partners and stakeholders to develop new understandings of fashion (see fig. 8). Fashion as an open and transparent system goes against the decades of secrecy, yet early results (Nachtigall et al. 2019d) indicate that a new way of executing fashion mixing the roles of stakeholders is at least possible.

“Think While You Make, Make While You Think”

This quote was printed on the wall in the second FabLab I made with Fiore. The words have been attributed to William Owen of Made by Many, but the phrase is now owned by the maker community. This idea embraces the sentiment shared by many creatives such as myself: “I love to make things.” A thing can transmit as much understanding as an article or a book. I like to live with difficult things, the friction and ambiguity (Gaver et al. 2003) help me understand and appreciate the intention of a designer. I find this especially

²³ <https://byborre.com/>

true in fashion. We spend so much of our time learning how to make things by making them. Fashion is an artistic practice in that its methods of learning 3D forms and their 2D flat pattern analogs are done by making and making again. My critical side, though, wonders if we are starting to have a mathematical understanding that will soon allow much of that process to be done by software.

Imagine what it would mean to a designer of ten small variations could be shown on a screen at the same time to allow for the selection of the most aesthetically pleasing. Now imagine if the same software allowed that designer to see that on ten different body sizes, shapes and colors so that the optimal solutions were personalized. Then imagine if knowledge could be stored and translated to a body scan of an individual to translate the vision of the designed object to that individual. The metaphoric DNA of the object is joined to the metaphoric DNA of the individual to create something that personal tailoring has always dreamed of (and purported to be true, but happens only in the highest and most expensive forms of soft weft tailoring).

The research group is closely tied with Textile Academy of the Fab Academy found locally at the Waag Society. Many of the members of the group have completed and/or taught in the course. The Textile Academy is a worldwide course that allows us to influence and understand a group of creatives developing textile ideas worldwide. In the preliminary year, our publication “Making Sustainability Work” (Bogers et al. 2021) documents a group of students, teachers, artists and designers of AUAS and the Center of Expertise for Creative Innovation thanks to our collaboration with the Learning Community of Critical Making Research through Design led by researcher Loes Bogers. The book documents the journey undertaken by six creatives in the Textile Academy course and how they came to some fascinating results, all documented in an annotated portfolio.

We Stand at the Intersection of Physics and Metaphysics

Fashion is a designerly, artistic, and scientific practice. I borrow this idea from *Physics and Metaphysics of Art* by fashion academic Clemens Thornquist of the Swedish School of Textiles. In the book, Clemens presents more than 130 philosophical strategies for art and fashion. As Clemens puts it, “The point is simply to demonstrate a series of possibilities that, even at this stage, demonstrate the potential for alternative modes of knowing that form a more open and cogent science of art and design.” Fashion has become a multiverse of possibilities, but how do we create young professionals who are capable of

the collaboration and connection that is required to empower and enable people tomorrow?

The answer may lie in the idea of “Drifting” offered by Krogh and Koskinen (2020). In the paper “Ways of Drifting – 5 Methods of Experimentation in Research through Design” (Krogh et al. 2015) categorized research through design as accumulative, comparative, serial, expansive, and probing. These five are all designerly methods that range from scientific to artistic in the making of things (products) services or systems of things. Research through Design (Frayling 1993) is seen as a subset of constructivist phenomenology (we make stuff to prove things) (Koskinen et al. 2011) or constructivist post-phenomenology (We make things to see how they affect humans and non humans) (van Dongen 2019, Wakkary et al. 2018, Desjardins et al. 2016). Moreover we see artistic practices becoming important to design in papers like “From HCI to HCI Amusement” (Devendorf et al. 2019) or “Disruptive Improvisations: Making Use of Non-deterministic Art Practices in HCI” (Andersen et al. 2018). I am a proponent of expansive drifting (Nachtigall 2019) which I see as a natural fit for current fashion practice, but a question emerges: How can fashion use the idea drifting with data to expand its horizons?

The answer lies somewhere near the design idea of the role of a prototype (proto or look). Matthews and Wensveen (2014) provide some input that I find important for fashion. They find four roles of a prototype:

1. Experimental Component. Test of specific hypotheses. Does this work in blue? Provide systematic variations of prototype or context of use. Tools like Clo 3D are accelerating our possibility to do this. But do we look at the diversity of wearers in fashion?
2. Means of Inquiry. Open-ended exploration. This is an artistic instrument to collect, record and measure phenomena. How do I feel about this for next season? This is a sense that is often developed in fashion studies.
3. Research Archetype. Illustration or demonstration. A physical embodiment of research concept, understanding or design research space. We can all think of pieces by Iris van Herpen, Martin Margella or Viktor and Rolf that do this.
4. Vehicle for Inquiry. Driver for the research direction. Research contribution is tied to the process of crafting the artifacts. We gain craftsmanship when making an artifact and that experience is invaluable.

In the later book, *Drifting by Intention*, Krogh and Koskinen (2020) show that design benefits greatly when multiple methods (ways of drifting) are used on the same subject. There is a deeper understanding created when the designer can describe and evaluate simultaneously. When we combine methods, we create ways of knowing that embrace crafting, aesthetics, function, expression and experience all at the same time. Fashion has known this implicitly for a long time, but it is now that we need to make this explicit and share it with others.

This is a hard thing to accomplish, but we are happy to report that preliminary results include an Artist in Residency looking at experience design of clothing in VR alongside the textile science PhD of long time AMFI teacher Sandra Kuijpers within the FR&T research group. Moreover, we are grateful to be in a faculty where research combines for example artistic methods like those of Sabine Niederer with data science like those of Nanda Piersma. A strong connection with the other talented lecturers and teachers in our education programs promises to make this possible.

How we work

Bringing our manifesto together into a research program means looking at fashion through three sets of lenses.

The Smart Lens

How can we as a constituency make fashion in a way that explores the technological shift that is fundamental to our age? We look to change fashion by looking at it as smart. Smart doesn't necessarily mean electronic, nor does it take on the more fashion meaning of clean, neat, and well dressed. We interpret smart here to mean "showing intelligence." Our work is a first-person making of things, services and systems that shows the intelligence of the constituency that made them. We intend to make critically to realize fashion that is smart, but also transmits its intelligence to others as to inspire, inform, and add a reference as an archetype.

The Sustainable Lens

The same is true with the lens of sustainable where the focus of Future Ways of Wearing. This lens looks at the everyday practice of fashion to understand how impact is found in the socio-aesthetic realm that is society and its interactions. Building upon past work into research products and wardrobes by Dr. Irene Maldini, we look deeply into how the products, services and

systems can be used by people in the everyday. Our goal is to bring the things we make into circular systems that go well beyond the point of sale. We look to make in ways that led to iterative generations, much like software app design. We see fashion not only as a system of seasons, but also as a constantly renewed system that changes with the user. How do we make things that last longer? How do we make fashion that is more recyclable? How do we deal with the current mountains of fashion that now must be recycled?

The Digital Lens

The final research vein of the Fashion Research & Technology group takes a holistic look through a digital lens. How can we practically apply the idea of physical/digital relationships to the products, services and systems that we create in fashion? How can we use digital fabrication technologies along with 3D scanning technologies (LIDAR) found in many cell phones to build new models of fashion? The Digital lens enables us to look at smart and sustainable in new ways that allow us to move to a circular, localized and distributed ecosystem. By ecosystem we not only mean value chain and supply chain, but the cycles of use that construct our wardrobes over a lifetime. In that lifetime we look to the digital/physical relationship (Nachtigall et al. 2019c) that enables co-design, co-manufacturing, co-use and co-analysis of a circular ecosystem. We have already found the emergence of new roles in that system (encoding, materialization, profiling and monitoring) and we intend to work closely with AMFI and other education programs at the AUAS to create new profiles of fashion professionals who can lead through the digital transformation of the industry.

In practice

As researchers we work together in the Fashion Technology Studio to critically make the products, services and systems that serve as demonstrators, archetypes and exemplars. We do this in three research veins that are intimately related by data to form a research program (see fig. 9). While this has not been easy during the Covid crisis, we have embraced this moment as an opportunity to consider alternative futures for fashion. The group is organized around the three research veins presented in the previous chapters. Each research vein has a primary researcher along with a PhD or postdoc supporting a lab. Additionally, we are supported by two learning communities: critical making research through design and urban interaction design. We also intend to have an artist in residence or a significant artistically

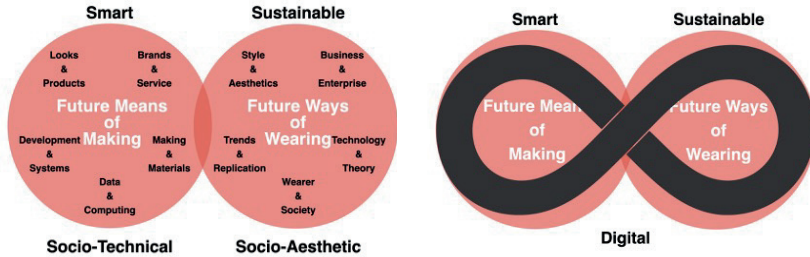


Figure 9. An illustration of how the three research veins, Smart, Sustainable and Digital, come together as in the research program of the Fashion Research and Technology group.

driven project attached to each of the learning communities. Thanks to the Center of Expertise for Creative Innovation (CoECI) and the Faculty of Digital Media and Creative Industries this has become a reality.

Future Means of Making

Future means of making is researching how systems of knitting can make the fashion system more personalized, inclusive and open. We are part of the World of Textile Opportunities project with the highly innovative company ByBorre.²⁴ We are working with project partners from all over the world to make parts of the fashion system more open and transparent. We are also working with the Textile Academy²⁵ located at the Waag Society²⁶ in Amsterdam and in Fablabs all over the world to find new ways to make fashion. Future Means of Making is also the home of the 3D Knit Fieldlab²⁷ coordinated by Mikki Engelsbel, run by the talented programmer and designer Hanneke Lunning, and supported by ClickNL. Inside this Fieldlab we perform industrial research on a Shima Seiki full garment knit machine, see fig. 10. We work with great partners such as New Industrial Order,²⁸ Knitwear Lab,²⁹ Ministry of Knits³⁰ and the Fashion Tech Farm³¹ to create new ways to make. This includes the four themes of the Fieldlab: sustainably distributed, practically parametric, entirely personal, and technologically emergent.

24 <https://byborre.com/>

25 <https://textile-academy.org/>

26 <https://waag.org/en/home>

27 <https://www.hva.nl/kc-fdmc/gedeelde-content/lectoraten/lectoraat-fashion-research-technology/fieldlab-3d-knit/over-het-fieldlab.html>

28 <https://new-industrial-order.com/>

29 <https://knitwearlab.nl/>

30 <https://ministryofknits.nl/>

31 <https://fashiontechfarm.com/>

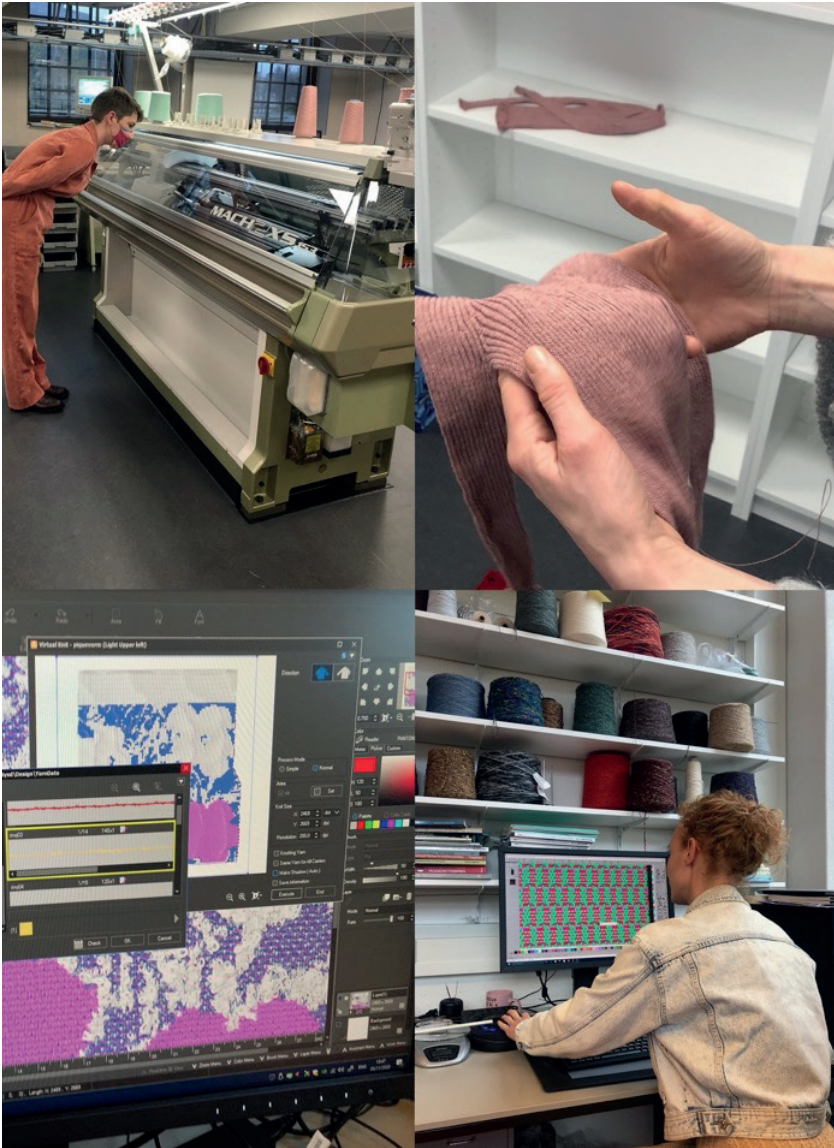


Figure 10. Images of the 3D Knit Fieldlab supported by ClickNL. In the Fieldlab we use data as a material to create complete garments that allow us to critically understand new ways of making fashion that we can then wear.

Future Ways of Wearing

Future way of wearing is researching how to create a new fashion system from the ashes of the Covid crisis in the "Solidarity in Fashion"³² project with ArtEZ funded by SIA and is also investigating clothing usage in the "Change: Environmental System Shift in clothing consumption"³³ funded by The Research Council of Norway. It is also home to the 3D Body scanning lab funded by AMFI and HBO-ICT. In the lab we can 3D scan full bodies to understand the actual garment in use and compare it over time and with the digitally simulated version of the same clothing. The lab hopes to bring greater understanding on how attire changes with use and how we can extend that use or enable better recycling/reuse. Future ways of wearing also includes the postdoc of Maaïke Fietsma who is investigating sustainability found in Ancestral, Indigenous and Archaic technologies. Moreover, we are working closely with the Center of Expertise for Urban Transformation and with the professors of Collaborative Innovation and Entrepreneurship to fund research that supports the transition to circular economy.

Data as a Material

Data as a material is researching the physical and digital properties of the materials and textiles that fashion is made from. This includes the PhD of Sandra Kuijpers funded by the Faculty of Digital Media and Creative Industries. Together with the Robot lab in the Faculty of Technique (Engineering) Urban Technology we have a project funded by the Center of Expertise for Creative Innovation and the Vegetable Tanned Leather Consortium. Artists and designers work along with engineers using the Printing on a Cloud technology³⁴ developed by the team of Dr. Marta Malé-Alemaný. With Printing on a Cloud an object like a shoe last is 3D scanned and then modified using 3D printing and milling technology. This allows for rapid personalization as the base object can be adapted to the size, style and behavior of the individual. Designers, artists, and artisans then use the personalized form to create a unique piece of attire made from a leather that is not only long lasting but made with a leather that uses natural dyes and tannins in a closed cycle water process, making it very sustainable.

32 <https://www.hva.nl/subsites/en/kc-fdmci/projects/fashion-projects/solidarity-in-fashion.html?origin=ruiotwDNRJqRNUdN1kmcPQ>

33 <https://www.oslomet.no/en/research/research-projects/change>

34 <https://www.hva.nl/urban-technology/gedeelde-content/projecten/digital-production-research-group/printing-on-a-cloud.html>

Conclusion

Fashion stands at a crossroads where a tendency to adopt technology slowly has left it behind similar disciplines like product design and architecture. The Covid-19 crises has left hundreds of fashion brands in bankruptcy creating an opportunity to build fashion back in a new way. The vision of the Fashion Research and Technology group is to realize an age-old idea of fashion that clothes are tailored for individuals, personalized to individual style, in materials that fit behavior and expression. We doubt that nostalgia for a tailored past was ever true for anyone but the elite, but we intend to make it real by enabling practitioners and wearers. We will adapt design methods like participatory co-design, critical design and design thinking to empower our constituency in a way that enable inclusion and diversity. As we create tools for fashion, we will share our findings not only to fashion, but to with related fields like human computer interaction. It is our mission to create tools to change fashion in a way that promotes smart, digital, and circular. To do that we look at fashion in three unique ways:

1. Fashion is made and worn with data as a material.
2. Fashion is any technology that envelops the body.
3. Fashion is the craftsmanship of dress.

We see data as the most important material for which fashion. Fashion, in terms of data, has far too few tools, toolkits, examples, demonstrators, code bases, interpretive frameworks and annotated portfolios to lean upon. We see it as our mission to create these tools and examples with all involved in fashion to enable our constituency to co-use data as a material. We make these tools smart, sustainable and digital while at the same time making sure our constituency is diverse and inclusive to ensure that the things we make are for all of fashion. In making new tools with fashion, we will seek a new craftsmanship of fashion practice.

In the Fashion Research and Technology group we look to see how fashion can be different from a participatory co-design methodology where the classic roles of users, designers and researchers are merged and blurred. We will continue to learn by making and learn by wearing the things we have made. We will create alternative realities of fashion by making and experiencing them. We will be critical and honest about the products, services, and systems that we make. We will include our constituency in all we do; this includes not only students, teachers, companies, government, and society, but also the

machines, resources and materials like wool, cotton, nylon and data. We will embed our ideas into products, services, and tools to empower and enable as many people as possible. As a constituency, will live with the products, services and systems in order to describe them better to others and critically describe to others as to why they should be adopted into everyday use.

We will look beyond the status quo of fashion and ask; What is enabled when we treat data as a material? How does data change the fashion product? How does data change fashion as a service? How does data change fashion as a system? How does data change the meaning of a wardrobe? What is data in the lifetime and lifecycle of a garment, a wearer, a trend, a manufacturing technology? How can we design with data for those lifetimes as circular ecosystems and make them more personal? How can we use data to create fashion for all? We will do this from perspectives that are applied and first person. We will look at fashion as the craftsmanship of the technology dress to find insights that inform fashion, design, and human computer interaction as well.

Acknowledgments

This inaugural lecture is the product of years of research and practice. Focusing a vision and mission for a research program and research group may seem like a personal process. In practice, the vision, mission and research program laid out here is the result of hundreds of conversations and thousands of hours creating projects by many talented people around the world. I am grateful to the many people along the way who helped understand what design and fashion are but moreover, what they could be.

I want to start by extending my deep gratitude to the Amsterdam University of Applied Science Executive Board of Trustees for the trust they have placed in me to lead this research. In practice this thanks goes to Rector Geleyn Meijer for the belief in the vision, and support, especially when it came to amazing knitting machines. This special thanks is also extended to the Faculty of Digital Media and Creative Industries Dean Frank Kresin's unwavering support in making this vision a reality and the hours spent discussing this field and research.

It is important to honor the memory of my predecessor Valérie Lamontagne whose flair and ingenuity will be forever remembered. I must also thank Hein Daanen, former professor of the research group, for all of the support and collaboration in rebooting it. Just as important are the other lecturers of the Faculty of Digital Media and Creative Industries: Sabine Niederer, Tamara Witschge, Nanda Piersma, Somaya Ben Allouch, Martijn de Waal, and Geert Lovink. While we may seem far apart in our research, the combined passion of this faculty was nothing short of magical. Thanks also to Professor Emeritus Ben Schouten, who laid a solid foundation with a TU/Eindhoven style. It is an honor to be among you.

I am also grateful to the education managers at the Faculty. Working with students and teachers in research is vital to creating a future of fashion research that includes making. The ideas, collaborations and encouragement is what makes AUAS such an amazing place for practice based research, thanks to the efforts of all the teachers and students lead by Stephanie Beckers, Eelco Brancart, Andre Neumann, Dirk Reynders, Jord Schaap, Jorien Schreuder, Albert Sikkema, Irene Sparreboom, and Harry Zengerink.

It is equally important to thank to the collaborative members of the Fashion Research and Technology group. Your diverse backgrounds and approaches make the group dynamic and engaging with incredible research outputs that speak to academia and society: Thank you Lisette Vonk, Irene Maldini, Mikki Engelsbel, Sandra Kuijpers, Loes Bogers, Marjolijn Ruijg, Maaik

Feitsma, Angella Mackey, Marco Mossinkoff, Hanneke Lunning, Charlotte Wassmer and Lili Eva Bartha.

Thanks to my advisors and collaborators who constantly find fresh approaches that inspire and delight. I am especially appreciative of the mathematics and style of Professor Loe Feijs. I am also very grateful to Professor Ron Wakkary for reminding me that we make things, great wonderful complex things. My gratitude to Professor Peter Krogh for showing me more ways to research. I would also love to thank Kristina Andersen, Oscar Tomico, Professor Stephan Weensven, Laura Devendorf, Professor Bill Gaver, Anna Vallgård, Professor Lorenzo Imbesi, Professor Maria Luisa Frisa, and Professor Regina Bernhadt.

Applied science cannot exist without external partners. My gratitude goes to Borre Akkersdijk and Arnoud Haverlag of ByBorre, Diane Becker and Barbara Manucci at the Genuine Italian Vegetable-Tanned Leather Consortium. Also, thank you to the many collaborators in the Knitwear Fieldlab, Ministry of Knits, Knitlab, Fashion Tech Farm and New Industrial Order. I would like to extend my gratitude to the Professors of the other Applied Sciences Universities with who we do research projects, such as Solidarity in Fashion with Artez, thanks to Professor Danielle Bruggeman, Professor Jan Mahy, Professor Theresia Grevinga and the researchers of their lectoraats. Thank also to the industrial organizations Modint and Netfas for their support in coordinating and writing white papers for Industry, this includes Rens Tap, Lucie Huiskens and Miriam Geelhoed.

My deep appreciation to the outstanding members of the ArcInTexETN Research Project, The Wearable Senses Lab, The Socio-Technical Design Group, The d\search Lab, the Everyday Design Studio, the Fab Academy and the Textile Academy. Your collaborations and support are invaluable. Additionally, there are many people worldwide whom I have had the pleasure of organizing conferences with worldwide. Your quality and care calls for my gratitude to all volunteer committee members of the CHI (Computer Human Interaction), ISWC (International Symposium on Wearable Computers), TEI (Tangible Embedded Embodied Interaction) and Ubicomp (Ubiquitous and Pervasive Computing).

Thank you to all the readers of the many drafts of this lecture, your time and care was very generous.

My love and thanks to my children Aurelio, Arturo and Adriano for constantly showing me new things, my parents Lynn and Nina for nurturing my bliss, my sister Tara and her husband Randy for keeping me sharp and the

large extended family all over the world for keeping me insightful about this planet as a whole.

Deepest thanks of all to my partner Annaluisa Franco for always being well-reasoned and willing to consider any idea about fashion.

References

- Amorim, D. J. N., Nachtigall, T., & Alonso, M. B. (2019). Exploring mechanical meta-material structures through personalised shoe sole design. *Proceedings of the ACM Symposium on Computational Fabrication - SCF '19*, 1–8. <https://doi.org/10.1145/3328939.3329001>
- Andersen, K., Devendorf, L., Pierce, J., Wakkary, R., & Rosner, D. K. (2018). Disruptive improvisations: Making use of non-deterministic art practices in HCI. *Conference on Human Factors in Computing Systems - Proceedings*. <https://doi.org/10.1145/3170427.3170630>
- Andersen, K., Goveia, B., Tomico, O., Toeters, M., Mackey, A., & Nachtigall, T. (2019). Digital craftsmanship in the wearable senses lab. *ISWC '19: Proceedings of the 23rd International Symposium on Wearable Computers*. <https://doi.org/10.1145/3341163.3346943>
- Andersen, K., Wakkary, R., Devendorf, L., & Alex McLean. (2017). Digital Crafts-machine-ship: Creative Collaborations with Machines. *Interactions*, 30(3), 305–319. <https://doi.org/10.1007/s13347-016-0240-4>
- Berzowska, J., Kelliher, A., Rosner, D. K., Ratto, M., & Kite, S. (2019). Critical Materiality. *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction - TEI '19*, 691–694. <https://doi.org/10.1145/3294109.3295656>
- Bitonti, F. (2019). *3D Printing Design: Additive Manufacturing and the Materials Revolution*. Bloomsbury.
- Bogers, L., Nachtigall, T. R., Maldini, I., de Gaetano, C. A. M., & Niederer, S. M. C. (2021). *Making Sustainability Work: Critical Making in Collaboration with Nature*. Hogeschool van Amsterdam.
- Bogers, L., & Chiappini, L. (2019). *The Critical Makers Reader:(Un) learning Technology*. Institute of Network Cultures.
- Bogers, S., van Kollenburg, J., Deckers, E., Frens, J., & Hummels, C. (2018). A Situated Exploration of Designing for Personal Health Ecosystems through Data-enabled Design. *Proceedings of the 2018 on Designing Interactive Systems Conference 2018 - DIS '18*, 109–120. <https://doi.org/10.1145/3196709.3196769>
- Buechley, L., & Perner-Wilson, H. (2012). Crafting technology: Reimagining the processes, materials, and cultures of electronics. *ACM Transactions on Computer-Human Interaction*, 19(3), 1–21. <https://doi.org/10.1145/2362364.2362369>
- Daanen, H. A. M., Levels, K., Vonk, L., Bosman, W., Schnepper, Y., & ter Haar, F. B. (2016). *Changes in the Volume and Circumference of the Torso, Leg and Arm after Cycling in the Heat Determined Using 3D Whole Body Scanners*. 45–53. <https://doi.org/10.15221/16.045>

- Desjardins, A., & Wakkary, R. (2016). Living In A Prototype. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*, 5274–5285. <https://doi.org/10.1145/2858036.2858261>
- Devendorf, L., Andersen, K., Rosner, D. K., Wakkary, R., & Pierce, J. (2019). From HCI to HCI-Amusement. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI '19*, 1–12. <https://doi.org/10.1145/3290605.3300265>
- Devendorf, L., De Kosnik, A., Mattingly, K., & Ryokai, K. (2016). Probing the potential of post-anthropocentric 3D printing. *DIS 2016 - Proceedings of the 2016 ACM Conference on Designing Interactive Systems: Fuse*, 170–181. <https://doi.org/10.1145/2901790.2901879>
- Devendorf, L., Lo, J., Howell, N., Lee, J. L., Gong, N., Karagozler, M. E., Fukuhara, S., Poupyrev, I., Paulos, E., Ryokai, K., & Berkeley, U. C. (2016). “I don’t want to wear a screen”: Probing perceptions of and possibilities for dynamic displays on clothing. *Chi '16*. <https://doi.org/10.1145/2858036.2858192>
- Djajadiningrat, T., Wensveen, S., Frens, J., & Overbeeke, K. (2004). Tangible products: redressing the balance between appearance and action. *Personal and Ubiquitous Computing*, 8(5), 294–309. <https://doi.org/10.1007/s00779-004-0293-8>
- Dongen, P. Van. (2019). *A Designer’s Material Aesthetics Reflections on Fashion and Technology*. Technical University of Eindhoven.
- Dourish, P. (2017). The Stuff of Bits: An Essay on the Materialities of Information. In *The Stuff of Bits: An Essay on the Materialities of Information*. The MIT Press.
- Feijs, L., Nachtigall, T. R., & Tomico, O. (2016). Sole Maker: Towards Ultra-Personalised Shoe Design Using Voronoi Diagrams and 3D Printing. *Proceedings of the 2016 Fabrication and Sculpting Event - FASE of the International Geometry Summit - IGS'16*.
- Feijs, L., & Toeters, M. (2018). Cellular Automata-Based Generative Design of Pied-de-poule Patterns using Emergent Behavior: Case Study of how Fashion Pieces can Help to Understand Modern Complexity. *International Journal of Design*, 12(3), 127–144. www.ijdesign.org
- Feijs, L., & Toeters, M. (2015). Drapely-o-lightment: An algorithmic approach to designing for drapability in an e-textile garment. *Leonardo*, 48(3), 226–234. https://doi.org/10.1162/LEON_a_00913
- Frankjaer, R., & Dalsgaard, P. (2018). Understanding Craft-Based Inquiry in HCI. *Proceedings of the 2018 on Designing Interactive Systems Conference 2018 - DIS '18*, 473–484. <https://doi.org/10.1145/3196709.3196750>
- Frauenberger, C. (2019). Entanglement HCI the next wave? *ACM Transactions on Computer-Human Interaction*, 27(1), 1–27. <https://doi.org/10.1145/3364998>
- Frayling, C. (1993). Research in Art and Design. *Royal College of Art Research Papers*.
- Frayling, C. (2011). *On Craftsmanship: Towards a new Bauhaus*, Oberon Masters.

- Frens, J., Forlizzi, J., & Zimmerman, J. (2017). New Challenges when Teaching UX Students to Sketch and Prototype. *Proceedings of the International Association of Societies of Design Research - ISADR*.
- Gaver, W. W., Beaver, J., & Benford, S. (2003). Ambiguity as a Resource for Design. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 233–240. <https://doi.org/10.1145/642611.642653>
- Greene, E. (2019). Metal Fittings on the Vindolanda Shoes: Footwear and Evidence for Podiatric Knowledge in the Roman World. In *Shoes, Slippers and Sandals: Feet and Footwear in Classical Antiquity* (pp. 328–342). Routledge. <https://doi.org/10.4324/9780429487699-29>
- Halskov, K., & Petersen, M. G. (2010). DIS 2010 - Proceedings of the 8th ACM Conference on Designing Interactive Systems: Foreword. *DIS 2010 - Proceedings of the 8th ACM Conference on Designing Interactive Systems*, 310–319.
- Hauser, S., Oogjes, D., Wakkary, R., & Verbeek, P.-P. (2018). An Annotated Portfolio on Doing Postphenomenology Through Research Products. *Proceedings of the 2018 on Designing Interactive Systems Conference 2018 - DIS '18*. <https://doi.org/10.1145/3196709.3196745>
- Hertenberger, A., Scholz, B., Stewart, B., Kurbak, E., Perner-Wilson, H., Posch, I., Cabral, I., Qi, J., Childs, K., Kuusk, K., & others. (2014). 2013 e-textile swatchbook exchange: the importance of sharing physical work. *Proceedings of the 2014 ACM International Symposium on Wearable Computers: Adjunct Program*, 77–81.
- Ion, A., Frohnhofen, J., Wall, L., Kovacs, R., Alistar, M., Lindsay, J., Lopes, P., Chen, H.-T., & Baudisch, P. (2016). Metamaterial Mechanisms. *Proc. of UIST '16*, 529–539. <https://doi.org/10.1145/2984511.2984540>
- Ion, A., Kovacs, R., Schneider, O. S., Lopes, P., & Baudisch, P. (2018). Metamaterial Textures. *Chi '18*, 1–12. <https://doi.org/10.1145/3173574.3173910>
- Ion, A., Kovacs, R., Schneider, O. S., Lopes, P., & Baudisch, P. (2018). A Demonstration of Metamaterial Textures. *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems*, D403. <https://doi.org/10.1145/3170427.3186525>
- Ion, A., Lindlbauer, D., Herholz, P., Alexa, M., & Baudisch, P. (2019). Understanding Metamaterial Mechanisms. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI '19*, 1–14. <https://doi.org/10.1145/3290605.3300877>
- Ion, A., Wall, L., Kovacs, R., & Baudisch, P. (2017). Digital Mechanical Metamaterials. *Proc. of CHI '17*, 977–988. <https://doi.org/10.1145/3025453.3025624>
- Karana, E., Giaccardi, E., Stamhuis, N., & Goossensen, J. (2016). The Tuning of Materials. *Proceedings of the 2016 ACM Conference on Designing Interactive Systems - DIS '16*, 619–631. <https://doi.org/10.1145/2901790.2901909>
- Koskinen, I., Zimmerman, J., Binder, T., Redstrom, J., & Wensveen, S. (2011). *Design research through practice: From the lab, field, and showroom*. Elsevier.

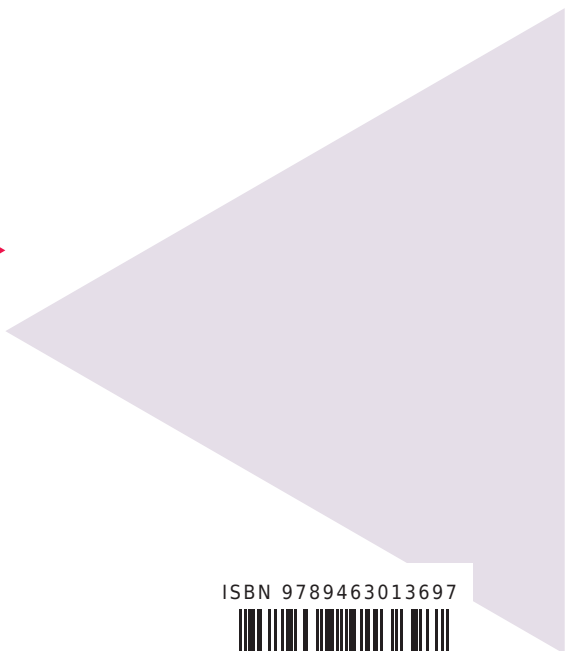
- Krogh, P. G., & Koskinen, I. (2020). *Drifting by Intention*. Springer Nature Switzerland. <https://doi.org/10.1007/978-3-030-37896-7>
- Krogh, P. G., Markussen, T., & Bang, A. L. (2015). Ways of drifting—Five methods of experimentation in research through design. *Smart Innovation, Systems and Technologies*. https://doi.org/10.1007/978-81-322-2232-3_4
- Krogh, P. G., Markussen, T., & Bang, A. L. (2015). Ways of Drifting-Five Methods of Experimentation in Research Through Design. *Systems and Technologies, 1*. https://doi.org/10.1007/978-81-322-2232-3_4
- Lamontagne, V. (2013). Fashioning embodied interfaces: Open wearables crafting. *International Conference of Design, User Experience, and Usability*, 296–305.
- Levi Strauss & Co. (2015). The Life Cycle Of A Jean. Understanding the environmental impact of a pair of Levi's 501 jeans. *Levi Strauss & Co.*, 16–50. <http://levistrauss.com/wp-content/uploads/2015/03/Full-LCA-Results-Deck-FINAL.pdf>
- Matthews, B., & Wensveen, S. (2014). Prototypes and prototyping in design research. In Paul A. & Rodgers and Joyce Yee (Eds.), *Routledge Companion to Design Research* (pp. 262–276). <https://www.researchgate.net/publication/270511639>
- McLuhan, M. (1964). *Understanding Media: The Extensions of Man*. Routledge.
- Mensvoort, K. (2012). *Next Nature: Nature Changes Along With Us*.
- Michaëlles, F., & Mayer, S. (2021). Personal Fabrication: Patrick Baudisch and Stefanie Mueller Talk About Physical Natives. *IEEE Pervasive Computing*, 20(1), 28–34. <https://doi.org/10.1109/MPRV.2020.3045822>
- Nachtigall, T., Tomico, O., & Wakkary, R. (2019). Oneday shoes: A maker toolkit to understand the role of co-manufacturing in personalization. *TEI 2019 - Proceedings of the 13th International Conference on Tangible, Embedded, and Embodied Interaction*. <https://doi.org/10.1145/3294109.3295637>
- Nachtigall, T. (2017). EVA Moccasin: Creating a research archetype to explore shoe use. *Proceedings of the 2017 ACM International Symposium on Wearable Computers - ISWC '17, Part F1305*, 197–202. <https://doi.org/10.1145/3123021.3123077>
- Nachtigall, T. (2018). The Box of Glorious Failures. *Disruptive Improvisation: Making Use of Non-Deterministic Art Practices in HCI Workshop at the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*. https://disruptiveimprovisation.files.wordpress.com/2018/04/nachtigall_cr_040118.pdf
- Nachtigall, T. R., & Andersen, K. (2018). Making Secret Pockets. *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, 1–6. <https://doi.org/10.1145/3170427.3188611>
- Nachtigall, T. R., Tomico, O., Wakkary, R., Wensveen, S., van Dongen, P., & Tentoff van Norten, L. (2018). Towards Ultra Personalized 4D Printed Shoes. *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, 1–9. <https://doi.org/10.1145/3170427.3174369>

- Nachtigall, T. R., Tomico, O., Wensveen, S., & Wakkary, R. (2019). Unpacking Solemaker into a Model for UPPSS. *Proceedings of the Conference on Research Through Design. 2019 RtD'19*, 1–16. <https://doi.org/https://doi.org/10.6084/m9.figshare.7855817.v2>
- Nachtigall, T., Mironcika, S., Feijs, L., & Tomico, O. (n.d.). *From Personal to Ultra-Personalized*.
- Nachtigall, T., Mironcika, S., Tomico, O., & Feijs, L. (2020). Designing ultra-personalized product service systems. *CoDesign*, 16(4), 274–292. <https://doi.org/10.1080/15710882.2020.1842454>
- Nachtigall, T., Tetteroo, D., & Markopoulos, P. (2018). A Five-Year Review of Methods, Purposes and Domains of the International Symposium on Wearable Computing. *Proceedings of the 2018 ACM International Symposium on Wearable Computers - ISWC '18*, 48–55. <https://doi.org/10.1145/3267242.3267272>
- Nachtigall, T., Tomico, O., & Wakkary, R. (2019). ONEDAY Shoes : A Maker Toolkit to Understand the Role of Co-Manufacturing in Personalization. *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction - TEI '19*, 1–11. <https://doi.org/https://doi.org/10.1145/3294109.3295637>
- Nachtigall, T., Tomico, O., Wakkary, R., & Dongen, P. Van. (2019). Encoding Materials and Data for Iterative Personalization. *Proceedings of the 2019 Conference on Human Factors in Computing Systems - CHI '19*. <https://doi.org/https://doi.org/10.1145/3290605.3300749>
- Norman, D. (2013). *The Design of Everyday Things: Revised and Expanded Edition*. Basic Books.
- Odom, W., Banks, R., Durrant, A., Kirk, D., & Pierce, J. (2012). Slow technology: critical reflection and future directions. *Proceedings of the Designing Interactive Systems Conference on - DIS '12*. <https://doi.org/10.1145/2317956.2318088>
- Orth, M. (2009). *100 Electronic Art Years*. http://www.maggiearth.com/art_100EAYears.html
- Poupyrev, I., Gong, N., Fukuhara, S., Karagozler, M. E., Schwesig, C., & Robinson, K. E. (2016). Project Jacquard : Interactive Digital Textiles at Scale. *In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*, 4216–4227.
- Robbins, H., Frens, J., Kuijter, L., & Wakkary, R. (2020). *Speculative Energy Futures*. 1–3. <https://doi.org/10.1145/3419249.3420073>
- Schwarz, M., Rublack, U., Schwarz, V. K., Hayward, M., & Tiramani, J. (2015). *The First Book of Fashion: The Book of Clothes of Matthaeus and Veit Konrad Schwarz of Augsburg*. Bloomsbury Academic.
- Simmel, G. (1957). Fashion. *The American Journal of Sociology*.
- Wakkary, R. (2021). *Things We Could Design*. MIT Press.
- Wakkary, R., & Maestri, L. (2007). The Resourcefulness of Everyday Design. *Proc. of C&C '07*, 163–172. <https://doi.org/10.1145/1254960.1254984>

- Wakkary, R., Oogjes, D., Lin, H. W. J., & Hauser, S. (2018). Philosophers Living with the Tilting Bowl. *Proc. of CHI '18*, 94. <https://doi.org/10.1145/3173574.3173668>
- Zeagler, C. (2017). Where to Wear It. *Proc. of ISWC '17*, 150–157. <https://doi.org/10.1145/3123021.3123042>
- Zhang, M., Sas, C., Lambert, Z., & Ahmad, M. (2019). *Designing for the Infrastructure of the Supply Chain of Malay Handwoven Songket in Terengganu*. 486, 14. <https://doi.org/10.1145/3290605.3300716>
- Zimmerman, J., Forlizzi, J., & Evenson, S. (2007). *Research through design as a method for interaction design research in HCI*. <https://doi.org/10.1145/1240624.1240704>

By making fashion with data as a material, we believe that we can critically create for everyone; no matter what shape, size or color. Data is the key to personalized fashion as it empowers and enables individuality yet retains the social potential of fashion. Fashion has believed for centuries that clothes used to be personally tailored, we intend to make that true for all.

This is an important moment for fashion. Much of the industry is bankrupt, creating opportunities to rebuild with new ideas surrounding technology and sustainability. Data is key to the digital transformation of fashion, meaning new craftsmanship is also required. Furthermore, the unique qualities of fashion allow for our research to inform technology and data science.



ISBN 9789463013697



9 789463 013697 >