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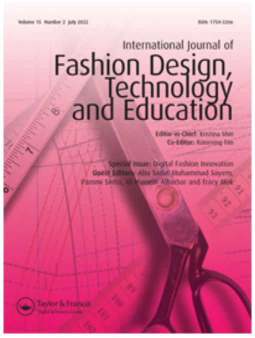


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# 'Just hit a button!' – fashion 4.0 designers as cyborgs, experimenting and designing with generative algorithms

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**ABSTRACT**
This article investigates algorithmic fashion design approaches in order to explore the ongoing digital transformations in fashion designership. The article asks how the automation of design processes and collaboration with machines affect the authorship and professional boundaries of fashion designers. The article analyses two case studies, the Finnish designer Matti Liimatainen and the Dutch 'digital-only' fashion house The Fabricant, to demonstrate how different ways of combining fashion designers' expertise, creativity and tacit knowledge with programming and/or computer-generated content alter the design process. The article also uses Donna Haraway's metaphor of the 'cyborg' (1985) to explain how digitalisation of the process intertwines designers with digital infrastructures. Two approaches to algorithmic fashion design are identified: generative clothing development and AI-aided digital fashion sketching. It is argued that both approaches involve the characteristics of computerisation/hominisation, re-professionalisation and 'cyborg designer 4.0'.

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Algorithmic design; fashion designer; digital fashion; cyborg; professionalism

## 1. Introduction

In 2017, Amazon declared that they would start using an 'AI fashion designer' with the aim to 'replace' designers with artificial intelligence (Knight, 2017). While Amazon believes that algorithms may outperform humans in responding to customer desires, some smaller players experiment with algorithms for conceptual, creative and ethical reasons (Pownall, 2019; Valle-Noronha, 2015). This article examines how the increasing use of AI in fashion design and the digital automation tools of fashion design processes – herein referred to as 'algorithmic fashion design' – transforms the profession of the fashion designer.

Fashion is a collective and institutionalised, yet designer-driven system (Kawamura, 2018). Traditionally, a designer's strong author myth, aesthetic and management skills, as well as their tacit technical knowledge, play a significant role in professional legitimisation and jurisdiction (Abbott, 1988; McRobbie, 1998; Särmäkari, 2020; Sinha, 2002). Professional legitimisation defines the status of designers within their field and in relation to other professional fields (Kawamura, 2018), whereas jurisdiction refers to a socially recognised authority over a certain set of tasks and expertise (Abbott, 1988). The social dimension of professionalism is accompanied by designers' embodied knowledge of designing physical clothes (Ræbild, 2015) that possess the required functional, aesthetic, temporal, discursive and economic qualities (Eckert & Stacey, 2001; Kawamura, 2018; Sinha, 2002).

The fashion designer's profession co-evolves alongside technological and societal changes. Using digital tools and experimenting with algorithms is part of the so-called 'fourth industrial revolution' (Bertola & Teunissen, 2018). The emerging 'cyber-physical system' of 'fashion 4.0' entails the use of smart technologies and networks, as well as the convergence of physical and digital (ibid.). These expand and complicate the role of the designer, who is also expected to develop a mutual language with engineers, improve their technical skills and master different types of new software, such as three-dimensional (3D) computer-aided design (CAD) (Sun & Zhao, 2018, p. 362). Conversely, technology permits non-designers and even machines to enter the field of fashion design, and this arguably leads to de-professionalisation (Kawamura, 2018).

To discuss these professional changes, this article explores the embodied nature of design work and compares the expertise of the human fashion designer with algorithmic design methods. The starting point is the pragmatist notion that the body is always a part of

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relational interaction networks (Määttänen, 2015, p. 18). The fashion designer is always more-than-human: a cyborg (Haraway, 1985). This article asks how, why and to what extent designers use generative algorithms in fashion design processes, and how these methods contest the traditional figure of the fashion designer. The notion of 'algorithmic fashion design' unfolds through literature and two case studies, where designers use generative algorithms in their design processes: the Helsinki-based designer Matti Liimatainen and the Amsterdam-based 'digital-only' fashion house The Fabricant. Both redefine the bodily and social dimensions of fashion design by creating alternative, more-than-human fashion design methods using digital technologies. The article provides novel empirical knowledge on algorithmic fashion design practices, which have previously attracted little to no attention in fashion studies and design research.

## 2. Relevant literature

### 2.1. The embodied nature of the fashion designer's profession

From the day we are born, clothes interact closely with and define the boundaries of our bodies. They are part of our everyday sensory-motor experience, for example through our sense of tightness or softness (Lakoff & Johnson, 1999). Clothes are also important means of social communication through which we define, express, construct and negotiate our social and cultural identities (Entwistle, 2000). The ability to express the *zeitgeist* – the trends and spirit of the times – is one of the key skills of the fashion designer (Vinken, 2005). Another is to understand that fashion is a 'situated embodied practice' (Entwistle, 2000): it manifests through the clothed body. Bodies, together with visually and haptically experienced mental schemes of 'clothing archives', are the starting point for many designers (Eckert & Stacey, 2001, p. 4; Ræbild, 2015, p. 185). Designers use their own and others' bodies when examining drawings and patterns, handling materials, and evaluating end results during fittings, as well as for 'indicative drawing' to communicate with their teams (Ræbild, 2015). Fittings are an essential part of design, although typically only the creative side of the work – research, ideation, sketching, concept and product development – is considered the designer's remit (McKelvey & Munslow, 2012). Sometimes patternmaking is integrated into the design process and is, in fact, a defining element of it, for example when draping on a mannequin or pursuing zero-waste design (McQuillan, 2020). Designing merges thinking and doing, and it is hard for designers to explicate their tacit knowledge (Polanyi, 1969; Ræbild, 2015). To create clothing for presumed situations, embodied experiences and emotions, fashion designers draw not only from data and trend reports but from their tacit knowledge, both as situated human beings and as fashion professionals.

New generations of designers have adopted technologies such as 3D CAD software, digital co-creation platforms, code and rapid manufacturing to modernise the profession and dismantle designer-centred ideals (Särmäkari & Vänskä, 2020). This has been accelerated by ethical awareness, e-commerce and real-time communication among globally dispersed networks; in other words, the fashion industry is exploring digitally enhanced practices, including the possibilities of AI (BoF & McKinsey, 2020).

### 2.2. Algorithmic fashion design

In 2019, the 'AI fashion designer' DeepVogue, created in China by DeepBlue Technology, won a prize at an international fashion competition in Shanghai (Jain, 2019), thus legitimising the non-human AI designer as a proper fashion designer. Further possibilities of AI in assisting the work of fashion designers have been explored by researchers and the industry (e.g. Kang, Fang, Wang, & McAuley, 2017; Yildirim, Seward, & Bergmann, 2018). AI can be applied to manufacturing, retailing, supply chain management and design (Guo, Wong, Leung, & Li, 2011; Luce, 2019). Most research on algorithmic fashion design is conducted in computer sciences. Uses for AI have been identified in apparel CAD systems, fabric and colour issues, fitting and design optimisation, image generation, and evaluation of virtual 3D designs (Guo et al., 2011; Thomassey & Zeng, 2018). Data mining helps in analysing consumer desires, and can replace sales data reports and top-down trend guides (Luce, 2019, pp. 141–2). The most common AI methodologies in algorithmic clothing design are neural networks, genetic algorithms, fuzzy logic and expert knowledge systems, as well as hybrids and models of these (Guo et al., 2011, p. 1881). They enable prediction, classification, identification, generation, optimisation, evaluation and partial design automation.

Algorithmic models typically assist fashion design through machine learning, using large datasets as input to generate new output (Luce, 2019, p. 125). The input comprises professional or user-generated images from social media, platforms, editorials or runways, company websites and databases, and textual garment or style descriptions commissioned from fashion experts (Cui, Liu, Gao, & Su, 2018; Luce, 2019; Yildirim et al., 2018), among others. The output is whatever the algorithms create based on the input and a machine learning system, from texts and vague sketches to photorealistic visualisations (Sbai, Elhoseiny, Bordes, LeCun, & Couprie, 2018; Yildirim et al., 2018).

In terms of design, generative adversarial networks (GANs) are mostly favoured (Luce, 2019, p. 130). The GAN model is a set of two duelling neural networks: the generative (G) network generates content, and the discriminative (D) network determines whether this content is machine-generated or from a 'real' dataset, as if they were playing counterfeiter and police, finetuning each other's skills (Goodfellow et al., 2014). GANs are used, for example, as 'trend consultants' to analyse demand before production (Kato, Osone, Oomori, Ooi, & Ochiai, 2019, p. 3). They integrate trends and personalisation with brand identity and familiar clothing archetypes, balancing between heterogeneity and homogeneity (Hyun & Lee, 2018; Kang et al., 2017). GANs can also focus on particular garment attributes (Yildirim et al., 2018).

Genetic algorithms are another way to generate optimised and data-driven garment attributes (Mok et al., 2013). Inspired by the evolutionary processes of living organisms, the technique employs the principles of struggle for survival in generating iteratively evolving populations (Khajeh, Payvandy, & Derakhshan, 2016). Academic research on genetic algorithms and expert systems was the earliest field of AI fashion design (Inui, 1996; Kim & Cho, 2000). While neural networks typically tackle the *fashion* imagery aspects of design, genetic algorithms are used in *product development*, including optimisation of patterns, generation of complex 3D models and searching for novel or random shapes. Two main approaches to algorithmic fashion design were identified in literature: *generative clothing design* and *AI-aided digital fashion sketching*. Both approaches are closely related to generative design, emphasising 'form-finding' over 'form-making' (Alcaide-Marzal, Diego-Mas, & Acosta-Zazueta, 2020). The designer becomes a conductor, 'orchestrating the decision-making process of the computer' (Gross, Bohnacker, Laub, & Lazzeroni, 2018, pp. 3–4). All algorithmic fashion design practices entangle data, algorithms and the fashion designer's tacit professional knowledge.

**Figure 1.** Panels and assembled coat with Liimatainen's special seam. Photo: Author 1.

## 3. Methods

This research used the qualitative case study strategy to examine the complexity of the 'fashion 4.0 designer' in a real-world setting (Yin, 2018). The cases of this study represent the two different approaches to algorithmic fashion design: generative clothing design (Matti Liimatainen) and AI-aided digital fashion sketching (The Fabricant). Although the case studies are representative of developments in the field, they are regarded as experimental because they operate on a small scale.

Data on Matti Liimatainen were collected in 2018–2020 at his studio, through semi-structured interviews and four days of observation. Additionally, media publications, the designer's own writings, lectures, website, videos and exhibition materials were used as research material. The Fabricant's work was observed at their studio for two days in 2019. All four members who were present at the studio were interviewed. During 2018–2021, data from many media publications, talks, the website, the Leela virtual platform, press releases, blog posts, social media and streamed design sessions were also collected. In both cases, ethnographic field notes and photos were taken, and the interviews were recorded and transcribed by Author 1, with the full informed consent of all participants. None of the participants requested anonymity. Data collection followed the institutional ethical guidelines of the Finnish National Board on Research Integrity (TENK).

Textual research materials were analysed using reflexive thematic analysis, which emphasises the situated role of the researcher in actively generating themes (Braun & Clarke, 2019, p. 594). Steered by the research questions, the analysis began with familiarisation with the research materials (transcription, reading through the texts, examining the photos). The analysis proceeded to manual and ATLAS.ti assisted coding, after which the materials were interpreted abductively and the themes were generated iteratively and reflexively.

## 4. Generative clothing design: Matti Liimatainen case study

Matti Liimatainen is one of the pioneers of *generative clothing design*. Before becoming a fashion designer, he studied mechanical engineering. He combines fashion design and patternmaking with mathematics and computer science. He teaches the machine to design physical clothes, drawing from generative design, genetic algorithms and expert knowledge systems, where the designer transparently sets the parameters (Alcaide-Marzal et al., 2020; Guo et al., 2011). Liimatainen designs for the international fashion industry and runs three projects: Self-Assembly, ITSE and Syntax of Clothing.

Self-Assembly and ITSE provide ready-to-assemble (vs. ready-to-wear) garment kits. Both projects are based on a special loop-and-hole seam developed by Liimatainen, which allows the garments to be assembled without sewing (Figure 1). While Self-Assembly provides fixed kits (as the 'IKEA' of fashion), ITSE (as the 'Lego' of fashion) offers open-ended kits that invite 'anyone to design and make their own clothes' by combining panels (Liimatainen, 2019, p. 2).

Liimatainen's third project-in-progress is Syntax of Clothing, an algorithmic grammar and language of different stages of fashion design and production. Liimatainen aims for an autonomous, entirely automated and 'posthuman' process, requiring no human involvement. He aims to teach a computer that which cannot be explained, translating tacit knowledge and what is known in Finnish as *näppituntuma* (literally 'finger feeling', i.e. 'gut feeling') into numerical form. Liimatainen believes that fashion design is compatible with algorithmic methods because clothes are constrained by the human body, two-dimensional materials, patterns and Western clothing archetypes (cf. Eckert & Stacey, 2001; Kang et al., 2017). Algorithmic design can augment human creativity and problem-solving capacity, and eliminate repetitive tasks (cf. Alcaide-Marzal et al., 2020). Liimatainen's automated system can also be chopped into small parts for specific purposes: it could, for instance, serve a patternmaker who needs machine-generated designs (Figure 2).

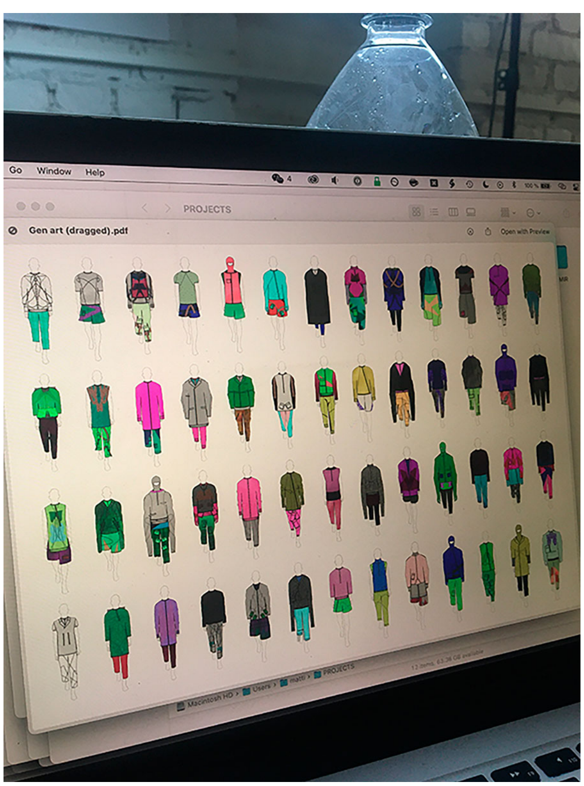


**Figure 2.** First experimentations of generating designs. Photo: Author 1.

Liimatainen contrasts his fashion-specific methods with more typical generative design processes, where interactive genetic algorithms produce a large number of designs for designers/users to choose from and to refine the evolutionary system (e.g. Agkathidis, 2016; Khajeh et al., 2016; Kim & Cho, 2000; Mok et al., 2013). Liimatainen envisions, that '[…] the system would need to generate only one product, and it would immediately be the right one'. Liimatainen divides design creativity into two types: human creativity (mimicking) and evolutional creativity (morphogenesis) (cf. Agkathidis, 2016; Gross et al., 2018). He believes that generative algorithmic design should be contextual rather than random, starting from the wholeness of the garment and evolving into a product as an embryo: 'There is no existing ready-made hand which is slammed into the body, but the hand is developed from a small blank that grows into a hand, and it is always suitable for the organism where it grows' (M. Liimatainen, interview, December 5, 2020).

Liimatainen has divided the automation process (Figure 3) into six steps: *brief, design, interpreter, description, fabrication* and *use*. As the development of the automated system implies a constant iteration between bottom-up programming and physical prototyping, he started with the most concrete steps: *use* and *fabrication*. Liimatainen has also included a digital 3D simulation for visually testing generated designs (Cui et al., 2018; Yildirim et al., 2018). The project progresses towards the *brief*, which stands for something that a planner, product manager and/or creative director would do. The *design* encompasses the geometry of the garments, comparable with traditional sketches, flat drawings and patterns. The *interpreter* ensures that all components fit with each other aesthetically and functionally, calculates the lay plan and can even aim at zero-waste design if the *brief* demands it. *Description* is a *graph* of the garment, based on *seams* instead of surfaces (Figure 4). Liimatainen developed a planar graph he calls GIM (garment information modelling)

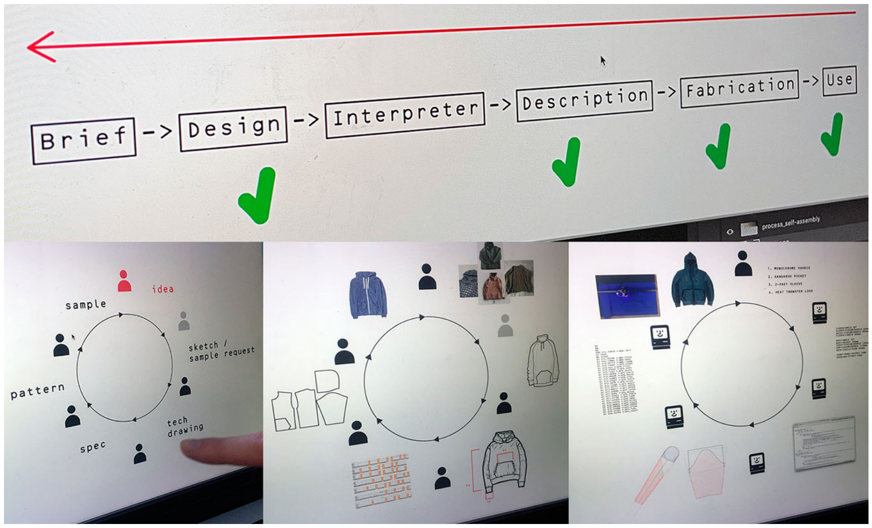


**Figure 3.** Plan of automation: Matti Liimatainen. Photos: Author 1.

to solve the problem of ambiguous communication between different professionals and cultures. Inspired by graph theory and BIM (building information modelling) from the field of architecture, GIM is an integrated hub for all operations and a light format that can be read and modified by different professionals and any software. For example, if a patternmaker modifies the graph in their software, the design changes for the whole team. This exact data representation of the garment can be sent directly to the automated (or traditional) *fabrication*.

GIMs can become databases of designs, preserving the DNA of a company. The designers would only need to modify the graphs according to trends or their creative visions. Regarded by Liimatainen as a compromise between human and computer, GIM can be used in human–human, human–machine and machine–machine interaction. At all stages, he tries to empathise with the computer, asking 'How would a computer do this?' Instead of hominising the computer, Liimatainen respects its vitality (cf. Valle-Noronha, 2015; Vänskä, 2018), using a numerical computer logic and communication style. On a conceptual level, Liimatainen questions the role of the designer and the myth of fashion (Särmäkari & Vänskä, 2020) and asks what value human involvement adds to a garment. Replacing a fashion designer is no end in itself; its purpose is to advance fashion design. The aim of AI is to further understanding of how humans think (Cross, 2001, p. 49).

## 5. AI-aided digital fashion sketching: The Fabricant case study

The case of The Fabricant contributes to the area of *AI for digital fashion sketching*, i.e. a conceptual approach in which the fashion designer builds on machine-generated images.

The Fabricant is a digital-only fashion house that designs digital couture for virtual worlds, avatars and on-screen bodies. Digital fashion is a new field of fashion design that relies on designer-specific 3D software and produces hyper-realistic, data-intensive digital 3D garment simulations that are digital-only products or digital models for physical products (Lyst & The Fabricant, 2021; Särmäkari & Vänskä, 2020). Digital fashion is both a tool and an alternative fashion culture, contesting the traditional profession of the fashion designer.

The founders of The Fabricant describe their company as a paradigm shift in the fashion industry, which they perceive as conservative, resource-depleting, secretive and exploitative. Their wish is that people would use durable clothing in their physical lives, and nurture the expressive, imaginative and conspicuous layer of fashion by buying, wearing and customising digital clothes. The Fabricant collaborates with blockchain companies, resulting e.g. in the auctioning of the digital-only Iridescence dress for cryptocurrency worth $9,500, with which the brand made its name (The Fabricant, n.d.). Blockchain technology – especially non-fungible tokens (NFTs) – enables the authentication and tokenisation of digital assets, turning digital-only garments into rare collectibles and investments (Hernandez, Vogelsteller, & Sieler, 2019). The Fabricant also shares digital garments as 'FFROPs' (free file drops) and streams their design sessions to promote a co-creational open-source philosophy.

The Fabricant believes that digital 3D representation and quick testing with AI-enabled 3D software (CLO3D

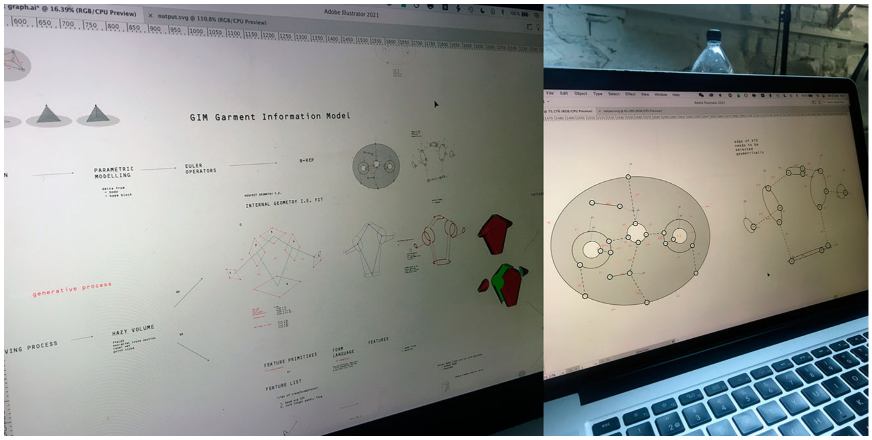


**Figure 4.** GIM graph on Liimatainen's screen. Photos: Author 1.

in their case) fuels the design process (cf. Cui et al., 2018; Yildirim et al., 2018). The core of their practice is in a human team creating fashion experiences, merging fashion with technology, animation, filmmaking and storytelling. The Fabricant collaborates with a global network of clients and remotely employed freelance designers. They call their practice 'thought couture', which is 'no longer tied to physical space' (Larosse, 2019a), and their audience are 'digi-sapiens' (Larosse, 2019b) – a new species of cyborgs enmeshed and evolving with technology (cf. Haraway, 1985; Hayles, 2012). Believing that '[o]ur bodies are becoming fluid […]', The Fabricant finds digital fashion liberating, not bound to social, material, anthropocentric or physical constraints or cultural and gender norms (The Fabricant, n.d.).

In 2016, two years before The Fabricant was founded, Amber Jae Slooten – fashion designer, creative director and co-founder of the company – explored the possibilities of a connection with a computer. Slooten had just graduated from the Amsterdam Fashion Institute with a combination of a traditional fashion design skillset and the first-ever digital-only graduation collection. She decided to experiment with algorithms with a software developer. They used a dataset of thousands of Paris Fashion Week pictures as input for a GAN model that generated pixelated output images. This 'image-to-image translation' created styles, shapes and colourways that could be developed into designs by human designers (Kato et al., 2019; Sbai et al., 2018). The Deep Collection was eventually launched in 2018 (see Figure 5 and https://www.thefabricant.com/deep).

**Figure 5.** Generated GAN images and Deep Collection outfits by A. J. Slooten. Photos from a Fashion Channel video at https://youtu.be/dylHxlTn32g, collage by Author 1.

Slooten thinks that she would never have come up with these designs without the help of AI. In other projects, Slooten also uses the Google Deep Dream tool to generate prints for digital garments. She questions the importance of a human designer's authorship and defines her role as *curator,* as if she purely made choices from an existing pool of possibilities: […] did I design this print? I don't know! Is this important? […] the funny thing is there is always going to be my signature, because I'm the one curating it (A. J. Slooten, interview, November 19, 2019).

Slooten almost hominises computers, describing them as companions. She also believes that combining human and machine creativity is ideal. Comparing the digital fashion design process with physical craftsmanship, she empathises with virtual garments through her own body and emotions, as though with tangible artifacts. Slooten designs intuitively by throwing and draping fabric directly on the avatar's body. AI technology, such as fuzzy algorithms, finetunes the fashion design-specific 3D software to create fabric simulations with real 'feeling' (Chen, Tao, Zeng, Koehl, & Boulenguez-Phippen, 2015).

The Fabricant has used AI for inspiration and sketching, yet they also investigate the potential of automating as many tasks as possible, to scale their practice. The Fabricant scrutinises their workflows (cf. Cross, 2001) and consults technological experts to find optimal automation solutions. As Kerry Murphy, the visual effects specialist and co-founder of The Fabricant, states:

> We need to automate everything. Our process is now digital body, digital movement on the body, 3D draping and fitting on the body, putting the digital clothing on the body, clothing simulation, the movement of the clothing, the virtual photo studio, video, environment lighting and rendering. So how do we make that final image? The whole process should be completely automated. It takes us six weeks at the moment, and we should do this in five days. (K. Murphy, interview, November 19, 2019)

## 6. Cyborg fashion designership

Sections 6.1–6.3 exemplify in detail the expansion of the bodily and social dimension of fashion designership. Considering the case studies, this article proposes applying Haraway's (1985) concept of the cyborg to explain the fluid and enmeshed nature of fashion design professionalism. Informed by the theoretical underpinnings, three themes were generated during the analysis: *computerisation/hominisation*, *re-professionalisation*, and *cyborg designer 4.0.*

### 6.1. Algorithmic fashion design and the bodily dimension: computerisation/hominisation

One of the central questions in digital fashion is whether the embodied, lifelong human experience of wearing clothes, inhabiting a society and culture, and intuitively expressing the zeitgeist through fashion can be meaningfully mathematised. As pragmatists and posthumanists alike have noted, our consciousness, thoughts and minds are embodied, formed by the innumerable particulars of behaviour (Haraway, 1985; Hayles, 2012; Määttänen, 2015; Polanyi, 1969). Computers do not have fleshy bodies (yet) but they can either learn someone's tacit knowledge or extract it from big data to a certain extent. However, fashion design and computers are complex, open-ended systems. Machines can gradually adopt human behaviour and further develop it – even developing knowledge of their own. The human designer's body may also have learned the ontological principles of being a machine, as in the case of Liimatainen, who computerises himself rather than hominising (ascribing human qualities) to the computer (Vänskä, 2018). In contrast, The Fabricant utilises algorithms created by others. In doing so, they simulate the designers' fleshiness and hominise the computer. Both cases arguably inhabit *technogenesis*, co-evolving with technology on a cognitive and unconscious, as well as embodied, physical level, where computers become an extension of their cognition – parts of their bodies rather than mere tools (Hayles, 2012, p. 3). In algorithmic fashion design practices, technology is a companion, a prosthesis, a material and a medium.

### 6.2. Algorithmic fashion design and the social dimension: re-professionalisation

In the media discourse, 'AI fashion designers' are addressed as if they were real designers (e.g. Jain, 2019; Knight, 2017). This reveals that the fashion designer is traditionally seen purely as someone who sketches, even though the designer's work in reality is much more complex, social and technical. As the discussion on professional work automation shows, a distinction must be made between *work* and *tasks* (Newman & Blanchard, 2019). Like human designers, computers can only be legitimised and authorised as fashion designers by the humans in the fashion system. However, machine designers may eventually develop into new designer figures with new ways of meeting people's needs and desires. Likewise, their creators – mathematicians, computer scientists or fashion designers with programming skills – are also becoming new players in fashion design, challenging and expanding the professional field. In a digitalised and decentralised fashion system, the old players should update their technological skills and deepen their knowledge of garment construction to be able to work seamlessly with the new players, technologies, manufacturers and consumers (cf. Sun & Zhao, 2018).

Automation of fashion design might propel fashion designers' work towards ostensive data-driven 'objectivity', contradicting the situated knowledges of fashion practice (Entwistle, 2000; Haraway, 1988). Designers cannot compete with computational effectivity, but they can give value to the design process by emphasising the 'blood, sweat and tears' behind the work. This article argues that, far from de-professionalising fashion design, all these transformations re-professionalise it. Re-professionalisation involves the accentuation of the embodied qualities of fashion design and intellectualisation of design processes, interoperating with varying networks of people and technologies, supporting artistic activities with automation, and developing a flexible technical and technological skillset.

Both Liimatainen and The Fabricant make the design process visible and intellectualise it through a minute analysis of their own professional knowledge and workflows. They also lay foundations for algorithmic and digital fashion design practices that combine pre-industrial craft skills with post-industrial workflows. The Fabricant's modus operandi is a flexible network of freelancers, whereas Liimatainen aims at replacing them with an automated system. Automation could arguably be a chance for survival for small companies, since it allows for more artistic integrity than the traditional practices that require heavy production systems and investments (McRobbie, 1998). In this sense, automation and digitalisation flatten the hierarchies of the traditional fashion system.

### *6.3. Cyborg designer 4.0*

Based on the literature and case study analysis, this article proposes the concept of 'cyborg designer 4.0': a physical and digital craftsperson, who translates their tacit knowledge into algorithms or digital garment construction and learns computerly ways of knowing and doing. Cyborg designer 4.0 moves between the physical and virtual worlds, between closed and open-ended products and systems, and communicates through visual-numerical representations.

Both case studies show how fashion designers who develop generative algorithms or co-create with existing ones can use their own human and professional, fleshy, situated and embodied knowledge of garment construction when working with virtual and/or physical materials and bodies. Together, they form the cyborg designer, or the fashion designer 4.0, with fluid boundaries between the human body and the machine, the material and the virtual world, creativity and computational data, the author and non-author, the professional and non-professional designer, fashion and mathematics, and so on.

## 7. Conclusion and further research

The umbrella term *algorithmic fashion design* was used for a design approach that uses algorithms to process data and generate images, structures, digital models, and entire design processes in the context of fashion design. This article proposes that this approach be defined as the 'cyborg designer', a contemporary figure of the fashion designer 4.0 that is enmeshed with technologies and complex human networks. Algorithmic fashion design entails hominisation of computers and computerisation of humans. This forces designers analytically and critically to evaluate how fashion designers actually work, which ultimately contributes to the knowledge and epistemology of fashion designership and the re-professionalisation of the profession. Until now, machines have mostly mimicked the existing creative works that they are fed and performed tasks they are assigned. Designers who experiment with deauthorisation of their work still inject their embodied knowledge into the creation and realisation of processes and artefacts. Machines have not yet assimilated the whole spectrum of a designer's work and professional jurisdiction. One of the challenges of constructive research on algorithmic fashion is its oversimplification of the complexity of fashion design work and the lack of critical examination.

This study is limited to a qualitative analysis and to the researchers' interpretation of two specific niche case studies pertaining to small teams. Other types of AI-aided fashion practices and processes in different design environments are yet to be studied. Further empirical research on algorithmic design processes that rely on big data and pursue large profits is needed to understand the implications of AI-aided design culture, beyond the experimental stage of the current state of the art. Contemporary technologies are increasingly complex and contain a high risk of design flaws, unpredicted uses and unintended biases. Therefore, future research ought to consider what *should* be done instead of what *could* be done. Alongside the ethical and aesthetic questions of algorithmic fashion design, the status of computer-generated works as 'real' fashion should be addressed. Who will authorise the possible virtual designers; humans or computers? Or will this legitimisation system disappear?

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## Disclosure statement

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