# Application of soft robotics for shape-changing fashions: a speculative study

Application of soft robotics for shape-changing fashions: a speculative study

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This is a speculative project investigating the potential of using soft robotics technology to augment the field of interactive fashion design. We envision a collection of wearable dresses made of fabric that drapes naturally with gravity, but upon activation of pneumatic actuators strategically situated around the dresses, the structures of the dresses will inflate to form defined, semi-rigid forms. Origami techniques will be used in the construction of this collection due to their shape-changing and generative potential. Reactive systems of microcontrollers and sensors will be implemented to enable users to animate the dresses instinctively and intuitively. Through this project, we ask questions on the nature of future fashion, such as the potential utility shape-changing wearables will bring in aspects of communication, assistive augmentation, and aesthetics. Furthermore, we aim to formulate methodologies to bridge the knowledge gap between fashion designers and the field of soft robotics, in terms of applications of such technologies to the gamut of the designer's craft, as well as reconciling technical considerations of materials used in soft robotics with traditional garment making textiles and thread.

CCS CONCEPTS • Human-centered computing → Human computer interaction (HCI) →HCI design and evaluation methods

**Additional Keywords and Phrases:** design methodology, interactive fashion, wearable technology

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## 1 INTRODUCTION & OVERVIEW

This speculative project is an ongoing exploration on how soft robotic technologies can be applied in the development of interactive, shape-changing wearable fashions. Adopting a constructive design research methodology [4], we seek to explore the definitions of design and making in the context of digital fabrication and technological fashion ('tech-fashion').

Fashion and clothing are necessary aspects of daily living, not just to be worn for the wearer's protection but also to enhance their appearance and improve their self-image and confidence. Fashion designers and practitioners are skilled in the drafting of patterns and manipulation of textiles to formulate three-dimensional forms to enclothed the human body. Fabric-based fashion design methods are mature and have been used since times of antiquity.

However, we are observing new paradigms being developed that presents increasingly viable alternatives to fashion production, as well as implanting new spectrum of capabilities and features into once-static clothing artefacts.

### 1.1 Rise of Digital Fabrication

Processes other than those used in the manipulation of fabric, as well as alternative materials, are increasingly adopted by designers and their collaborators in the development of wearable fashion. Examples include laser cutting, the various techniques known under the category of 3D printing, and the use of computation to execute various design tasks such as 3D modelling and pattern generation. The growing relevance of this field of digital fabrication, where assets are built digitally to be fabricated physically through automated systems, has called for traditional designers to augment their skillsets with knowledge to handle these new modalities.

### 1.2 Development of Tech-Fashion

The fashion industry has often looked to the latest technologies to inspire and empower the development of the latest products. Material innovations including high performance textiles (i.e. Gore-Tex and Kevlar) [1] and manufacturing developments such as computational knitting (i.e. Shima Seiki Wholegarment system [12], Stoll knitting machines [6]) are common. These advances are concerned with how fashion is fabricated, but we observe more designers emphasizing on innovating the worn experience. Fashion designer Hussein Chalayan created a garment known as the 'airplane dress' in 2000, which consisted of an outer shell made of fibreglass and resin which opened up in response to a remote-control signal, to reveal a secret pink tulle blossom underneath. He followed up with a series of 6 dresses in 2007 that transform mechanically, autonomously, into different looks inspired by different eras of fashion history [2]. More recently, designer Anouk Wipprecht merged robotic actuators, sensors and microcontrollers with 3D printed structures to create her tech-fashion collections. These range from garments that react to others in close proximity by actuating a set of spider leg-like appendages on the shoulders or releasing clouds of smoke [13]. Although wearable, early examples of tech-fashion garments are not deemed suitable for daily wear due to their material limitations or constraints from the robotic technologies used.

### 1.3 Inaccessible technologies & materials

Moreover, even though there is steadfast development in the areas of digital fabrication for fashion and of interactive wearable fashions, these advances remain available only to niche communities, being mostly inaccessible to the majority of designers due to the latter's lack of resources or knowledge. Even though there are efforts to democratise and reduce barriers to adoption of new technologies, for example, the proliferation of 'personal fabrication devices' such as fused deposition modelling (FDM) printers in academia and the consumer market to allow larger number of practitioners to create, they are unsuitable for most fashion applications. The most advanced 3D printing techniques are restricted to complex applications requiring resources not readily available to the masses [14]. As for shape-changing technologies with potential fashion applications, they reserved for applications best suited for their expense, such as in medicine [1], medical devices and advanced robotics.

The various technologies (of varying accessibility) that can be used on shape-changing tech-fashions can include Nitinol wires, shape memory materials, pneumatic soft materials and heat-sealed inflatables [11].

## 2 AIMS & OBJECTIVES

The fields of actuation and soft robotics, and access to their esoteric techniques, materials and equipment, are presently restricted to select academic communities, industry experts and representatives. Designing interactive garments presents unique challenges to researchers and designers because collaboration in these fields is still relatively new and not part of traditional fashion design training [11].

This research calls for an active push to encourage the development of applications, methods and techniques of these fields by practitioners in the fashion industry. By bridging the knowledge and technological gap faced by designers in creating tech-fashion, the pace of development of novel, shape-changing garments can be accelerated.

### 2.1 Why shape changing fashion?

Shape changing mechanism have proven useful for many engineering applications, such as in self-assembled architecture [10] and leaf-inspired, shape deformable wind turbine blades [7]. By utilising the morphing qualities of materials, engineering designs can adaptable to different conditions, possess improved mechanical qualities, autonomy and energy saving capabilities.

Berzowska writes that the act of integrating electronics into wearables transforms them into 'functional' items with utilitarian purpose [1]. As a reflection of that statement, many recent developments in the field of tech-fashion can be described as pragmatic. Vahid, Maziz and Berzowska list out several such applications, such as improving clothing fit, displaying emotions and sensory aspects [11], augmentative and bodily assistive functions [5], and to manipulate the social fabric [1].

Furthermore, designers such as Chalayan have shown that shape changing capabilities in fashion garments are useful in portraying narratives, communicating ideas. In his work, the novelty of the designs serves no perceptible utility, except perhaps to astonish and impress his audiences. Albeit this can still be a justifiable reason to adopt such technologies into fashion design.

### 2.2 Embodiment & augmentation of Self

Researcher Pauline van Dogen writes that fashion involves "material processes and embodied practices" [11]. There is great potential in imbuing dress with levels of autonomy and actuation, integrating with the human body to augment their abilities or uncover new methods of bodily expression. The multi-modal interactive nature of shape changing fashion presents additional dimensions of designs that fashion practitioners can work with, and it is imperative that developmental roadmaps are prepared to guide this transition to the new mediums. Designers without experience using actuated e-textiles or visualization media are limited in their ability to develop shape-changing wearable fashions [11].

## 3 MOTIVATION

As the field of tech-fashion further develops, we anticipate researchers to uncover more novel applications of these technologies. This research proposal intends to build on that body of knowledge by bridging the knowledge gap through the execution of a research-through-design project. We seek to investigate whether skills of design and form making can be transferable to science, and spur development of novel applications of wearable soft robotics, by attempting to answer the following questions:

1. Which fabrication methods are readily available to HCI researchers and hobbyists?
2. How can we lower the entry barrier for people from technical and non-technical backgrounds to start incorporating programmable materials and soft robotics strategies into their projects?

## 4 RESEARCH METHODS

Koskinen describes “constructive design research,” as design research in which construction — be it product, system, space, or media — takes centre place and becomes the key means in constructing knowledge [4]. In that vein we propose to develop a usable methodology for designing and fabricating a collection of inflatable, interactive dress designs that possess the potential for utility and/or for meaning, through the weaving together of aesthetics, narrative and function into the forms and mechanisms of the resultant design assets.

Due to the exploratory nature of this project and the need for a feasible framework for us to conduct our design experimentations, we take reference from Parsons and Campbell for their own digital apparel design process in 2005 [8], where they theorized that designers must first approach the problem in a more experimental fashion due to the lack of effective design methods at early stages of technology implementation, which aptly describes the state of this project. They described explorative designers, or “practice-based designers” / “p-designers” as defined by Günther and Ehrlenspiel [3], focusing on individual “sub-problems” and resolving them throughout each phase of the design process. Only after resolving one will designers move on to the next “sub-problem”, and they were observed to move back and forth design phases instead of approaching the task in a linear fashion. As designers become more experienced with the technology, they will eventually revert back to a methodological, linear mode of design and documentation. Parsons and Campbell adapted the four-stage design process from Günther and Ehrlenspiel, which in turn we intend to harness for this project. Each stage is labelled as such (Table 1):

Table 1: 4-stage Design Process

| Stage | Relevant Activity |
|---|---|
| Problem Identification | Pinpointing issues to resolve, either technical or design-based. |
| Conceptualization | Design tasks such as sketching, 3D modelling, pattern generation. |
| Prototype | fabrication and sewing of tactile swatches and design prototypes. Incorporation of actuators, programming of control electronics. |
| Solution | Assembly and testing of garments. Wearing and evaluation. |

Taking these abovementioned design stages as guides to our own process, we will in turn evaluate our design actions and outcomes to validate what was observed in [3] and [8], that we will transition from a problem solving methodology to a linear design methodology upon familiarization with these novel shape-changing technologies.

Shape changing dresses are not static but possess many configurations. Through the use of data collection devices and network connectivity, interactive garments no longer merely take on the shape of their wearers but they can be data driven, altering their forms based on data input and in response to programmed conditions.

For this project, we will take our cue from [11] to harness the effectiveness of combining origami structures with inflatable actuators to define the form of the design outcomes due to their demonstrated benefits in fabric-based fashion design and computational modelling methods.

Thus, even though we have mentioned several actuation options described in [11], we chose to adopt pneumatic actuators as the main mechanism, as it allows the folded origami structures to shape-change most naturally through the inflation of internal bladders as compared to other mechanisms. The alternating inflating and deflating deformations cause folded structures to progressively unfold and refold back, thus preserving the integrity of the dress structure.

The design and fabrication processes are briefly as follows:

### 4.1 Problem Identification Phase

Initial research will be done to source relevant materials and components. This process is crucial for us as we need to establish the level of difficulty in obtaining needed resources, not only for us but for fellow designers. We will consider both geographically dependent distributors (brick and mortar suppliers) as well as online merchants to consolidate a comprehensive overview of resources.

Once we have the materials, inflatable swatches akin to those created by [11] will be built and tested by the research team to gain tactile familiarity with the medium and folding mechanisms. Each swatch variation will be evaluated for their physical and aesthetic feasibility for use on various areas of the human body.

Additionally, the size and weight requirements of pneumatic components will be accounted for to establish constraints for the design process.

### 4.2 Conceptualization Phase

Using 3D modelling software such as Rhinoceros3D, three-dimensional digital rendition of the dresses will be prepared (Figure 1) and visually evaluated for aesthetics and narrative value. This is followed by separating the design into parts and unfolding them (Figure 2) using a custom-written software plug-in or similar application (such as Pepakura - https://tamasoft.co.jp/pepakura-en/).

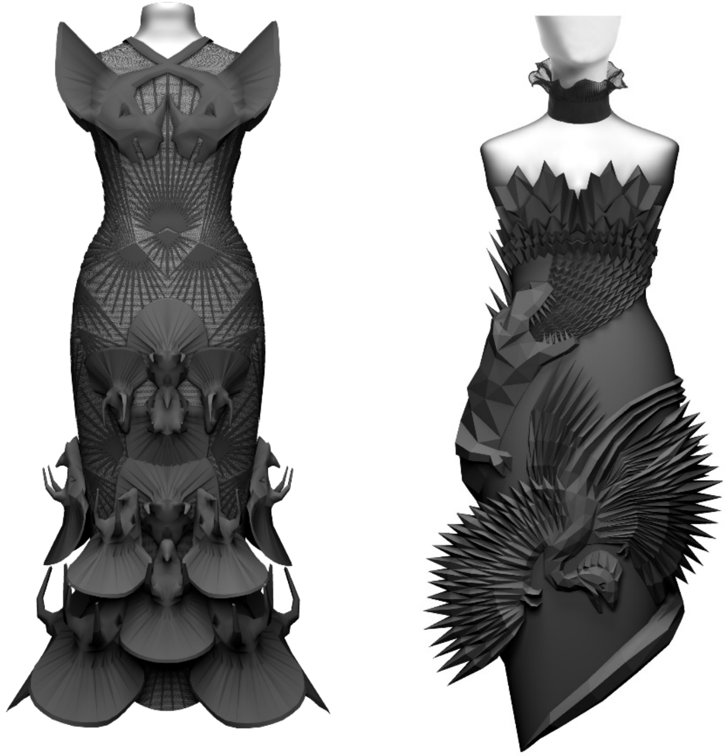

Figure 1: Some potential designs modelled on Rhinoceros3D software.

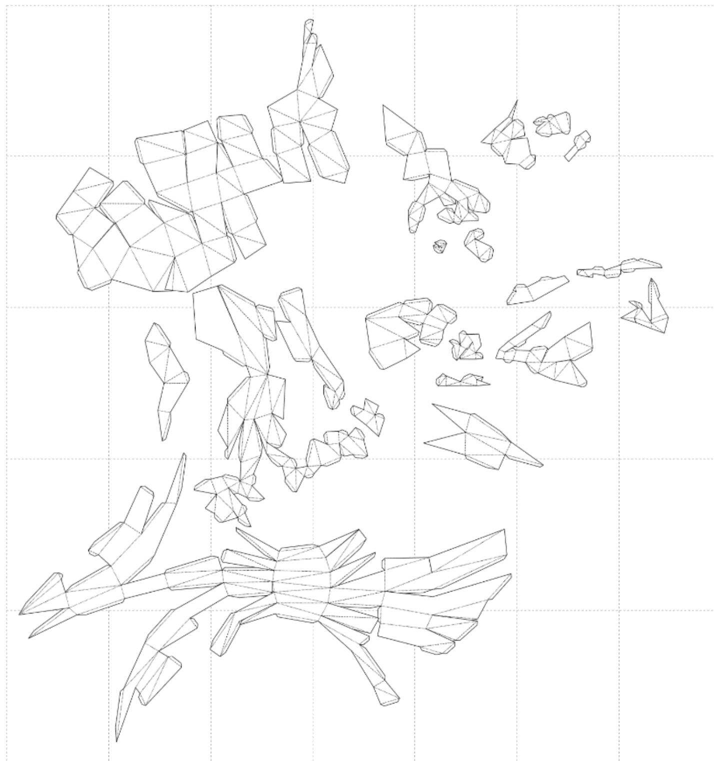

Figure 2: A 3D design unfolded into multiple 2D patterns using Pepakura software.

### 4.3 Prototype phase

The unfolded patterns will be transposed in proper scale onto fabric, where the fabrics will be cut, creased and sewn according to the prescribed design plan. For installation of the actuators, they will be attached to the relevant locations of the assembled dress while the microcontrollers are programmed and connected to both actuators and sensors (or data feeds). In regards to which areas are most relevant for installation of mechanisms, this is dependent on the particulars of every individual design, but our general assumption is to embed the bulk of these components within more voluminous areas of the garments to ensure their presence will not detract from our designed silhouettes. In the example shown in Figure 1, actuators will most likely be hidden within the larger volumes at the bottom of the skirt. These areas are not computationally decided, but are derived through designer intuition and experimentation.

Additional post-processing work will be carried out to camouflage mechanism and electronic components within the structure of the dress for their protection and maintenance of design aesthetic.

### 4.4 Solution phase

Through a mixed-mode evaluative approach, we will invite participants to try on the dresses and provide feedback. Their reactions will be recorded via a quantitative survey their physiological experience in wearing the dress, and a qualitative interview to garner their emotive response to the worn experience. It is crucial to not only evaluate aspects of the static worn experience, such as dress comfort and wearability, but also on the shape changing performance of the garment and how that aspect influences wearability. With the triangulation of data afforded by this mixed-mode approach, the researchers hope to consolidate holistic feedback for the improvement of dress design outcomes.

Furthermore, this methodology can be further evaluated by inviting designers to try the techniques themselves and garnering their reactions as well as their design outcomes.

## 5 EXPECTED RESULTS AND DISCUSSION

Through this act of construction, we anticipate the design outcomes and experienced methodology of this exercise to contribute to the ever growing body of literature for shape-changing fashion design. With this growing resource, the greater understanding on the use of such novel technology will aid in lowering barriers to entry for lay designers to take on and experiment in this field. The lack of documentation in regards to suitable tools, materials and other resources is expected to lessen with every contribution to expertise, as researchers build up a library of recommendations and vendor lists for designers to consult.

Furthermore, our contribution will be in establishing a robust methodology to applying the swatches shown in [11] onto the human body as a feasible wearable, using feedback from test wearers to validate our explorations.

This study is limited to applying pneumatic actuators and inflatable mechanisms as recommended by [11], and applications of other actuator types on shape-changing fashions will warrant future study.

Lastly, publishing a resource list to allow designers to conveniently source and obtain relevant materials, tools and components for shape-changing fashion will be a step to allow this field to be more accessible to practitioners.

## 6 CONCLUSION

This project proposal intends to be one of many steps for building a mature field of interactive fashion design. The researchers aim to do so through the construction of a feasible design methodology that enables designers to produce robust, shape-changing, tech-fashion garments. The promising development of the described techniques may also find potential use in alternative contexts such as in healthcare, architectural and product design fields that see the need for transformative soft mechanisms.

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