‘Soft Embodied Architectures’

Towards a hybrid embodied design ideation method for soft embodied architectural design

Marina Castán Cabrero I Royal College of Art

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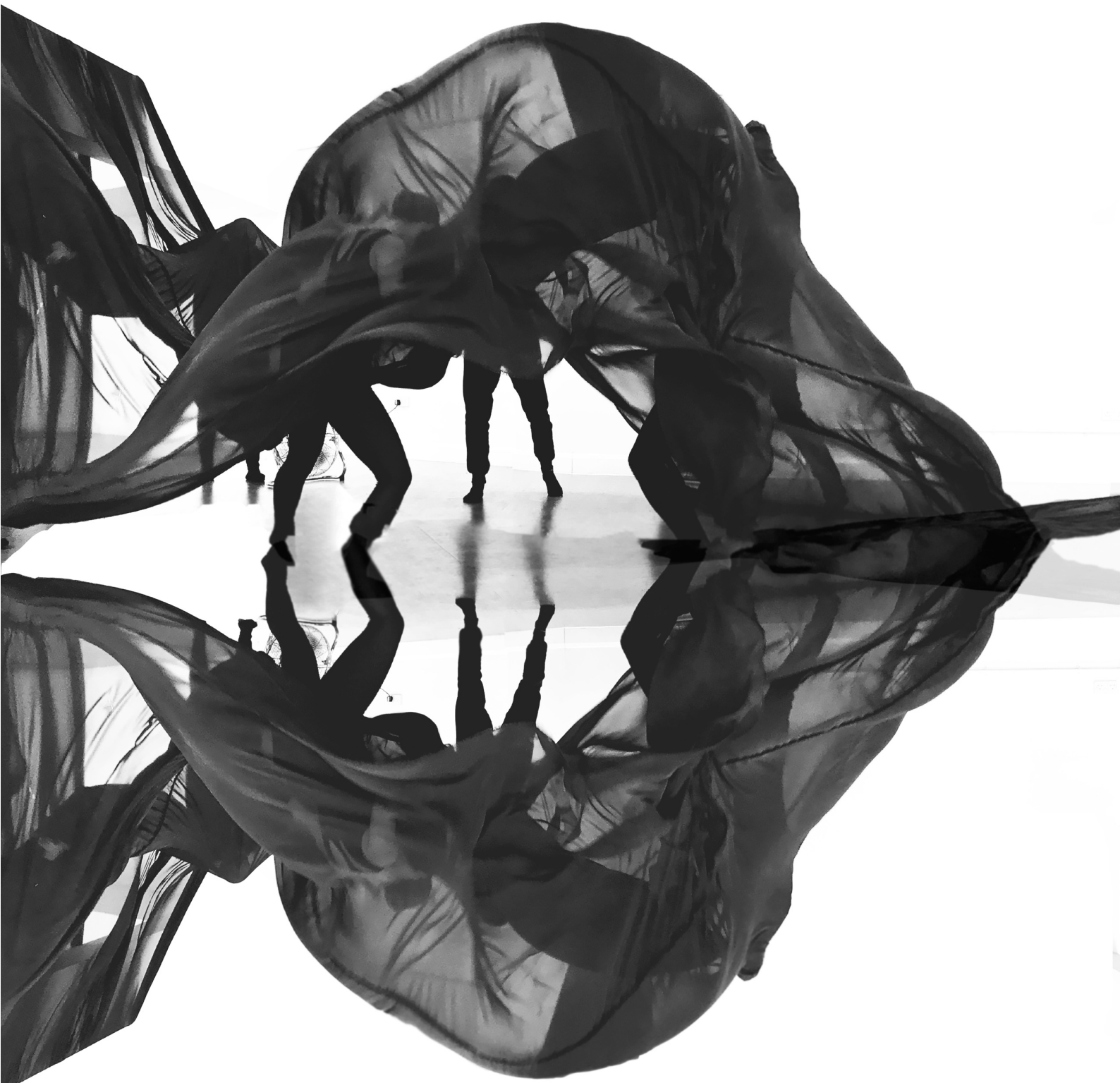

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List of Publications

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- Castán, M. and Tomico, O., 2018. Layering Up Soft Materiality: a Hybrid Embodied Design Ideation Method for Soft Architectural Design. In: *NordiCHI'18*, Oslo. New York, NY: ACM Press.

Author's Declaration

This thesis represents partial submission for the degree of Doctor of Philosophy at the Royal College of Art. I confirm that the work presented here is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

During the period of registered study in which this thesis was prepared the author has not been registered for any other academic award or qualification. The material included in this thesis has not been submitted wholly or in part for any academic award or qualification other than that for which it is now submitted.

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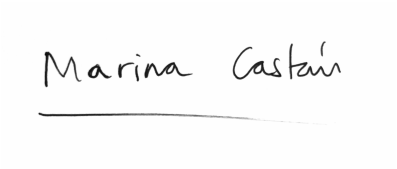

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ABSTRACT

'Soft Embodied Architectures' is a practice-based investigation that explores the use of embodied design ideation (EDI) methods within the context of textile architecture. The expression 'textile architecture' comprises a wide and varied range of projects that make use of textile materials for architectural design in various ways. EDI methods have proved to be successful in eliciting meaningful knowledge during the early phases of the design process. While EDI methods have been widely used in other fields such as interaction design, fashion design, and product design, there are fewer examples of these within the context of textile architecture. Consequently, this investigation sought to find out how EDI methods could contribute to creating new ways of ideating textile architecture. Through four collaborative experiments, the spatial potential of textiles was explored by means of body-material interactions and mapped out into the digital realm. By collaborating with dancers, choreographers, embodied interaction designers and architects, the notions of embodiment, materiality, and choreography were explored in relation to the creation of nuanced spatial expressions such as dynamic soft volumes, elastic spaces and soft envelopes.

This investigation acknowledges the agency of the material, the body and the context, and develops a hybrid EDI process that combines embodied explorations with motion capture technology. The findings show that by exploring spatial opportunities through body-material interactions, soft body-space entities emerged. Such entities offer a nuanced understanding of space, in which the material, the bodies and the context co-shape the architectural form through the experience. By digitally capturing this co-shaping process, raw geometries were obtained and explored to expand the design possibilities of a soft and embodied architecture. A hybrid EDI process such as this offers a new way of ideating soft embodied architecture by collectively folding, deforming and 'layering up' soft material on and around human bodies, providing embodied and digital outputs that can be combined and used as insights for designing soft embodied architecture.

Glossary of terms

Actor-network-theory (ANT): a philosophical theory developed by Michel Callon and Bruno Latour within the field of Science and Technology studies (STS).

Adaptability (textile material): the capacity of a fabric to adjust to surfaces and volumes.

Affordance: an object's property of showing possibilities for action

Agency: the capacity to influence.

Auxetic: a material structure that becomes thicker when it is stretched.

Body-material interactions / Embodied explorations: physical explorations that combine body movement and material interaction.

Brekel: a mo-cap software that allows communication with the Kinect camera to capture an environment and objects in motion.

Digital toolset: a group of tools to work with specific software and hardware.

Dynamic: it is the word used to name the qualities that emerge out of the interaction between the body and the textile material, e.g. thresholds of elasticity and transparency.

Elasticity: a material's ability to elongate.

Embodiment: a way of being in the world through the body and its senses.

Embodied: it is the knowledge that arises from the first-hand experience and allows the participant to make sense of a lived event by means of the body.

Embodied Interaction: a research field within HCI that focuses on the relationship with artefacts to design its interaction.

Embodied design ideation (EDI) methods: a group of design methods for the early phases of a design process that involve the use of the body in different ways.

Enabler / Disabler: the ability of an object to facilitate or reject certain actions.

Foldability (textile material): the capacity of a fabric to bend upon itself.

Formal expression: the aspect and particularities of a thing's form.

Form-giving process: a process to lend form to a material.

Geometry: a system that operates under the relationships of points, lines, angles and shapes in space.

Grasshopper: an application for Rhino 3D software that allows the programming of generative algorithms in a visual way.

Human agency: the capacity of humans to exert influence or power.

Hybrid: it refers to the combination of analogue and digital processes. In the present investigation, an analogue process is a body-material interaction and a digital process is the digital capture of this body-material interaction**.**

Interface: a medium to communicate between two or more things.

Kinect: a depth sensor camera that allows the tracking of environments and objects.

'Layering up': the act of overlapping layers of material.

Materiality: physical properties of artefacts and technologies that affect the way we interact with objects.

Mesh: a digital technique to define a three-dimensional form, often using polygons such as triangles or quadrilaterals.

Mesh parametrisation: a digital function that allows the definition of parameters of a surface or volume.

Mesh reconstruction: to build part of an incomplete mesh through numerical approximation.

Morphology: the process of evolution of a form.

Motion capture: the process of recording environments and objects or bodies in movement.

Near-field volumes: in a morphology, the data that operates close to its volumetric limits.

Network: as in ANT, an agent that makes visible the set of connections between humans and non-humans.

Non-human agency: the capacity of objects to exert influence or power.

NURBS: acronym for non-uniform rational B-spline. A mathematical model to create curves and surfaces.

Pliability (textile material): the capacity of a fabric to be flexible.

Point Cloud: data set in the form of points in space

Point Cloud Decimation: a process of selecting and erasing data based on a specific percentage.

Polymesh: a mesh composed of polygons.

Procedural pipeline: a set of data instructions connected in series, creating an automatic process.

Real-time capture: a record of data processed and available as it is being recorded.

Retopology: a function to optimise the geometry of a surface.

Rhino 3D: a computer-aided design software for modelling 3D objects based on NURBS

Scattered points: a new distribution of the points of a mesh.

Script: as in ANT, refers to the programmatic instructions embedded in an object.

SideFX Houdini: an animation software that allows the creation of 3D animation and visual effects.

Shell structure: a structure that behaves far from the body.

Skin structure: a structure that behaves close to the body.

Soft: a quality that highlights an adaptive behaviour of a textile material as opposed to the rigid behaviour showed by the textile-reinforced structural composites, commonly used in architectural applications.

Soft embodied architecture: an architecture that acknowledges and makes use of the dynamic qualities that emerge out of the interaction between the body and the textile material.

Soft entity: something that exists, in the sense of 'being' made out of adaptive and flexible materials.

Spatial entity: a tangible thing that has spatial qualities.

Soft form vocabulary: a collection of soft formal expressions.

Spatial experience: a physical encounter with space.

Spatiality of textiles: the spatial qualities of fabrics (textile materials) such as dimension, form, proportion, scale, light and sound.

360-degree capture: a recording of view from every direction of an environment.

Triangulation: to define a distance between the vertices of a triangle.

Topology: refers to the spatial properties of a geometry.

Workflow: a systematic and repeatable process.

TABLE OF CONTENTS

Introduction

Soft Embodied Architectures

'Soft Embodied Architectures' emerged from my continuing interest in investigating the role of the body within the design process. In earlier research projects (Tomico and Wilde, 2015; Castan, Rubio and Gonzalez, 2016), I collaborated with embodied interaction designers and dancers in the design of wearables and smart textiles by means of Embodied Design Ideation (EDI) methods. EDI methods are design methods that make use of the body and its senses to support the early phases of a design process. The body can play different roles depending on the designer's motivation, e.g. to prototype with materials, to analyse body movements or to communicate concepts or ideas (Wilde, Vallgårda and Tomico, 2017). These collaborations made me aware of the potential of involving the body within the design process. The use of the body within the design process helped to open up new possibilities for designing wearables. Moreover, by focusing on first-hand experiences (Tomico, Winthagen and Heist, 2012), I could engage at a more detailed level with the materials and dynamically shape the interaction with the prototype through different iterations supported by processes of reflection (Schön, 1983). The motivation behind this thesis was to find out how a soft and embodied design approach could bring innovative design processes to architectural design.

This thesis proposes a soft, dynamic and embodied understanding of architecture to make a difference to the way textile materials are explored within the ideation design phase of architectural design. Soft embodied architectures differs from traditional ways of using textiles in architecture as tensile membranes or composite textiles, whose behaviour is closer to hard materials (Ramsgaard Thomsen and Bech, 2011). From my perspective as an embodied textile designer, the adaptive nature of textile materials to fold, expand and shrink affects the way I engage with such materials. This engagement between the textile material and the body constrains or facilitates certain actions. To highlight such embodied engagement, I have developed the term 'soft embodied architectures' to define a type of architecture that relies on the interaction between the body and the textile material to explore subsequent dynamic qualities such as gradients of transparency, elasticity thresholds and material foldability. Soft embodied architectures invites a dynamic interaction between users and spaces (Pišteková, 2017; Schillig, 2009).

This thesis borrows from Embodied Design and EDI methods and combines them with motion capture technology to propose a hybrid EDI process for ideating soft embodied architecture. Ideating is a common part of the design process, and is also known as the conceptual phase, sketching or brainstorming (Lindwell, Holden and Butler, 2003). The idea of combining motion capture technology with the use of EDI methods emerged out of the collaboration with architect Daniel Suárez during the secondment we spent at Vilnius Art Academy as part of the ArcInTex ETN.[1] Motion capture technology allows architects and designers from different backgrounds to map out environments providing digital geometries that can be further explored using procedural modelling software. By combining EDI methods with motion capture tools, a hybrid EDI process emerged. This process enabled the combination of embodied and digital outputs, connecting temporary soft spaces with their equivalent digital geometries, helping to generate insights to inform the design of soft embodied architecture.

The hybrid EDI process this thesis introduces uses a version of the 'choreography of interaction' method (Klooster and Overbeeke, 2005) to explore the spatiality of textiles through the body. Such interaction between the body and the textile materials creates temporary soft spaces that are captured by Kinect sensors to support a particular ideation process. Choreography of interaction is an EDI method inspired by improvised dance techniques and interaction with a focus on product design. It uses body movement as a tool for design, enabling designers to shape both the interaction and the outcome of the product that is being designed. Motion capture technology has been proved useful to capture environments and body gestures in order to mapped them out into the digital domain and use them as material for design (Hirschberg et al., 2006; Salazar Sutil, 2015). Motion capture tools such Kinect cameras are affordable sensors that are compatible with different digital modelling software. These sensors provide raw data that can be explored in many ways, depending on the designer's motivation (Kyan et al., 2015; Pacher, 2014).

Using the choreography of interaction method, an iterative ideation process consisting of several body-material interactions was developed across four collaborative experiments. This iterative ideation process allowed the envisioning of

[1] Further information regarding ArcInTex ETN can be consulted at the Appendix section.

a ‘becoming’ space as it unfolds, helping to identify material transitions concerning the creation of a soft embodied space. By co-shaping the space, participants in the experiments could explore not only dynamic and spatial qualities but also opportunities for interacting with others through these qualities.

Collaboration is a common activity within design practice and the value of involving experts in varied fields in research activities has been studied and acknowledged by the research community (Sanders and Stappers, 2008; Bowen et al., 2016). Collaboration was an important aspect of this investigation in order to articulate a hybrid EDI process for soft embodied architectural design. Dancers, choreographers, embodied interaction designers and architects were involved during the four practice-based experiments.

Dancers and choreographers are experts in expressing with their bodies and performing improvised body movements. Several projects have taken place that acknowledge such expertise and include collaboration with dancers and choreographers to ideate, analyse and communicate research outputs (Varna, 2013; Ross and Wensveen, 2010; Kirsh, 2013). The roles of the dancers and choreographers within this investigation were as experts on body movement and as facilitators to support the development of the body-material interactions. These will now be referred to in the research as ‘embodied explorations’.

The collaboration with embodied interaction designer Sietske Klooster (Eindhoven University of Technology, TU/e) contributed to the exploration of the potential of an embodied approach to the field of textile architecture. Klooster’s research focuses on the use of movement-based embodied methodologies to bring change and innovation to products or systems through multi-disciplinary interaction.

The collaboration with architect Daniel Suárez contributed by introducing an architectural language through a digital toolset to articulate the hybrid EDI process that this investigation proposes. Suárez was my colleague within the ArcInTex network. Suárez’s research interests are similar to mine. His research focuses on textile augmentation for architectural design, and he was interested in combining analogical textile processes with digital techniques. We saw an opportunity to

combine the embodied explorations with the design of a digital toolset to expand the design possibilities for soft and embodied architectural design.

Motion capture technology devices such as the Kinect camera were an affordable and suitable option. Kinect camera does not require a complex process to set it up, and it provides an easy and straightforward way of capturing body gestures and environments. By connecting the embodied explorations with their digital equivalent, I was able to articulate a bridge between an embodied exploration and the generation of digital geometries, which are the main tools that architects use to communicate their concepts (Szalapaj, 2005). The way architects work with materials differs significantly from approaches in other design disciplines. In fashion and product design material engagement within the design process is direct, allowing designers to experiment fully with their prototypes with their whole bodies (Blaisse, 2013; Karana et al., 2015; Bugg, 2009); however, in architecture the relationship with materials is often relegated to the scale of the model, making it difficult for architects to acquire knowledge from first-hand experiences with materials at one-to-one scale. Sattrup points out that architects are 'rarely [...] directly building their own work, and much of the analytical and projective design process is executed via the symbolic representations of space through geometry' (Beim and Thomsen, 2012, p.105).

Although the experience represents the core element within the process of embodied design, architecture relies very much on technological processes such as modelling software and geometry optimisation. Therefore, geometry becomes the main tool with which architects can communicate with engineers, contractors and environmental experts in order to materialise an architectural project (Szalapaj, 2005). In this sense, the motion capture technology introduced in this thesis aims to bring together the two domains in an accessible way for architects to implement within their practice.

According to Picon, the widely adopted computational approach to design practice allows the architect to control every single aspect of the process, from the generation of a digital form to the fabrication of the final prototype (Picon, 2004). Picon suggests that as result of this approach, the majority of contemporary architectural projects offer a rather homogeneous, digitally crafted aesthetic that abandons the materiality of architecture (Picon, 2004). Picon points out how the use of digital tools neglect the physical dimension of architecture:

> What does digital architecture, even in its present state of incomplete development, suggest regarding the changing categories of physical experience? If materiality is not endangered, how is its definition nevertheless evolving? (Picon, 2004, p.115)

I suggest that the hybrid EDI process this thesis presents could help to enhance the material and experiential aspects of architecture. Although architecture has now clearly made significant progress regarding this subject by integrating material qualities into the digital workflow and creating hybrid design processes (Ahlquist and Menges, 2011; Gannon, 2014; Thomsen and Karmon, 2011), there is still scope to further explore the complex relationship between materials and space by including the first-hand experience as a source for ideating soft embodied architecture. While the experimentation with soft materials, such as fabrics, in the creation of artefacts is a common practice within the architectural design field (Wærsted, Lenau and Brandt, 2014), the use of EDI methods that allow knowledge to be gained through first-hand experience is rarely addressed.[2]

Recently emerging theories associated with what is known as 'the material turn' in social sciences and the humanities (Van der Tuin and Dolphijn, 2012) have become popular in design and architecture research, shifting the way architects address matters of design. An example of this is the research developed by architects Achim Menges and Sean Ahlquist on computational design (Ahlquist and Menges, 2011), in which they acknowledge the importance of material agency by drawing on DeLanda's approach to materiality (DeLanda, 2015). Similarly, Latour and Yaneva highlight the lack of theory that considers aspects of this materiality and agency in architecture:

> 'Matter is much too multidimensional, much too active, complex, surprising, and counter-intuitive to be simply what is represented in the ghost-like rendering of CAD screen shots. Architectural design embraces a complex conglomerate of many surprising agencies that are rarely taken into account by architectural theory' (Latour, B., Yaneva, 2008, pp.80–89).

Acknowledging the multidimensionality of matter, and drawing on the notions of human and non-human agency, this investigation proposes a collaborative hybrid EDI

[2] Text partially adapted from Castan and Tomico, (2017)

process in which the relationships between the material, the bodies and the context produce new soft body-space entities. These entities enable participants to ideate and experience temporary soft embodied spaces in a dynamic and situated way.

The failure to take consideration the material and embodied dimension of architecture may result in a reduced spatial experience, since such experience gets relegated to the visual category (Pallasmaa, 2012). 'Soft Embodied Architectures' calls for a more dynamic interaction within space, one that bodily ideates and explores a soft embodied space through folds and layers of soft materials, creating bonds between people and space and helping to re-connect the experiential, *the body*, with space, *the architecture* (Marble, 1988).

By applying a soft and embodied approach to architectural design, the present research aims to open up new ways of ideating architecture. An embodied approach such as this one comes with a challenge: that of the change of scale. Whereas the EDI methods mentioned above have been used to design from the body to the body (Wilde, Vallgårda and Tomico, 2017), the present inquiry addresses the challenge of ideating soft embodied architecture from the body to the *building.*

ArcInTex European Training Network

The present investigation is framed within the ArcInTex European Training Network that aims to deepen the connection between architecture, textiles and interaction design by focusing on design expressions for new sustainable forms of living. The consortium comprises the Eindhoven University of Technology, the Swedish School of Textiles at Borås University, Vilnius Art Academy, Berlin University of Arts, the Royal College of Art and two companies: Philips (The Netherlands) and ab Ludvig Svensson companies (Sweden). Partner organisations are Audejas Uab in Lithuania, Heatherwick Studio and Haworth Tompkins in the United Kingdom.

The overall focus of the programme's network is on investigating new sustainable ways of living through textile thinking and collaborative research. The project started in September 2015 and comprised three years of intense research activities, including two secondments of four months each. In my case the first of these took place at Vilnius Art Academy and the second one at Heatherwick Studio in London. A more detailed description of the ArcInTex programme can be found in the Appendix section

of this thesis, under 'ArcInTexETN'. Collaborative research activities were an important aspect of the ArcInTex network. The four practice-based experiments presented in this thesis have a strong focus on collaboration. In addition to the collaboration with Sietske Klooster and Daniel Suárez, the collaboration with dancers Petras Lisauskas, Judita Šečkutė, Julija Mintautė and Viktorija Bobinaitė from Lithuanian Academy of Music and Theatre (Vilnius); London-based freelance dancers Gwen Nelson and Hae Yeon Lim, Ellen Finlay and Katerina Chaida, Berlin-based Siciliano's ballet company dancers Rachel Tack, Marika Giannoccari and Berit Einemo Frøysland, and the choreographer Salvatore Siciliano was key in bringing expressive movement qualities to the embodied explorations. Dancers Gwen Nelson and Hae Yeon Lim also performed as facilitators, helping the other participants to engage more actively with the embodied explorations.

Research Question and Aims

The main research question of this thesis is: How can a soft embodied architecture be ideated by means of EDI methods? It aims to explore the potential of a dynamic engagement with soft materials through the body to ideate soft embodied architecture. This aim relates to the lack of design methods in the field of textile architecture that consider an embodied perspective during the early phases of the design process. As designers engage with materials through their bodies in context, they enter the realm of experience. The first-hand experience is a physical encounter with materials, other participants and the environment. Bringing this perspective into the context of textile architectural design has potential benefit, as it would allow architects to explore new ways of ideating a soft embodied architecture in which the experience operates as a link between the ideation process and the future use of such soft embodied architecture. Such an embodied approach would, eventually, allow architects to gain an awareness of the potential future uses of the spaces they ideate.

Sub-questions

The four sub-questions aim to find out how to implement the use of EDI methods in the context of soft embodied architectural design. Each sub-question is answered through a practical exploration that leads to the following one. The first sub-question looks at the transition between textile and space, and aims to identify the dynamic and spatial qualities that may emerge when there is bodily interaction with a textile

material. The second interrogates ways of expanding the design possibilities of soft embodied architecture into the digital realm. The third aims to explore the design of a hybrid EDI process in collaboration with a group of architects. Finally, the fourth sub-question focuses on the definition of a hybrid EDI process suitable for soft embodied architectural design.

Sq1. When does a textile become space?

To explore the spatiality of textiles from an embodied perspective.

Sq2. How can the design possibilities of a soft embodied architecture be expanded into the digital realm?

To explore the potential of motion capture technology to support the ideation of soft embodied architecture.

Sq3. How can a hybrid EDI process for soft embodied architectural design be created?

To explore with architects the opportunities and limitations of a hybrid EDI process.

Sq4. How could the hybrid EDI process be implemented within an architectural design methodology?

To design a hybrid EDI process suitable for soft embodied architectural design.

Contribution

This investigation helps to expand the understanding of textile architecture towards a concept of soft embodied architecture by exploring textile materials in a bodily and situated way. Figure 0 shows a sequence of an embodied exploration with a Lycra Spandex fabric in which the dynamic quality of elasticity emerges out of the interaction between the bodies, the material and the elements of the context such as the beams. The resulting elasticity allows participants to create and expand a soft space around their bodies. This quality contributes to the exploration of emergent spatial opportunities when the bodies interact with the material and the context, offering temporary soft spatial compositions.

The main contribution of this thesis is the articulation of a hybrid EDI process towards a new method for soft embodied architectural design. This kind of process consists of four phases that would allow architects to generate insights for designing soft embodied architecture by combining embodied and digital outputs. The use of motion capture technology connects temporary soft embodied spaces with their equivalent geometries, contributing to the development of a digital process that can be utilised

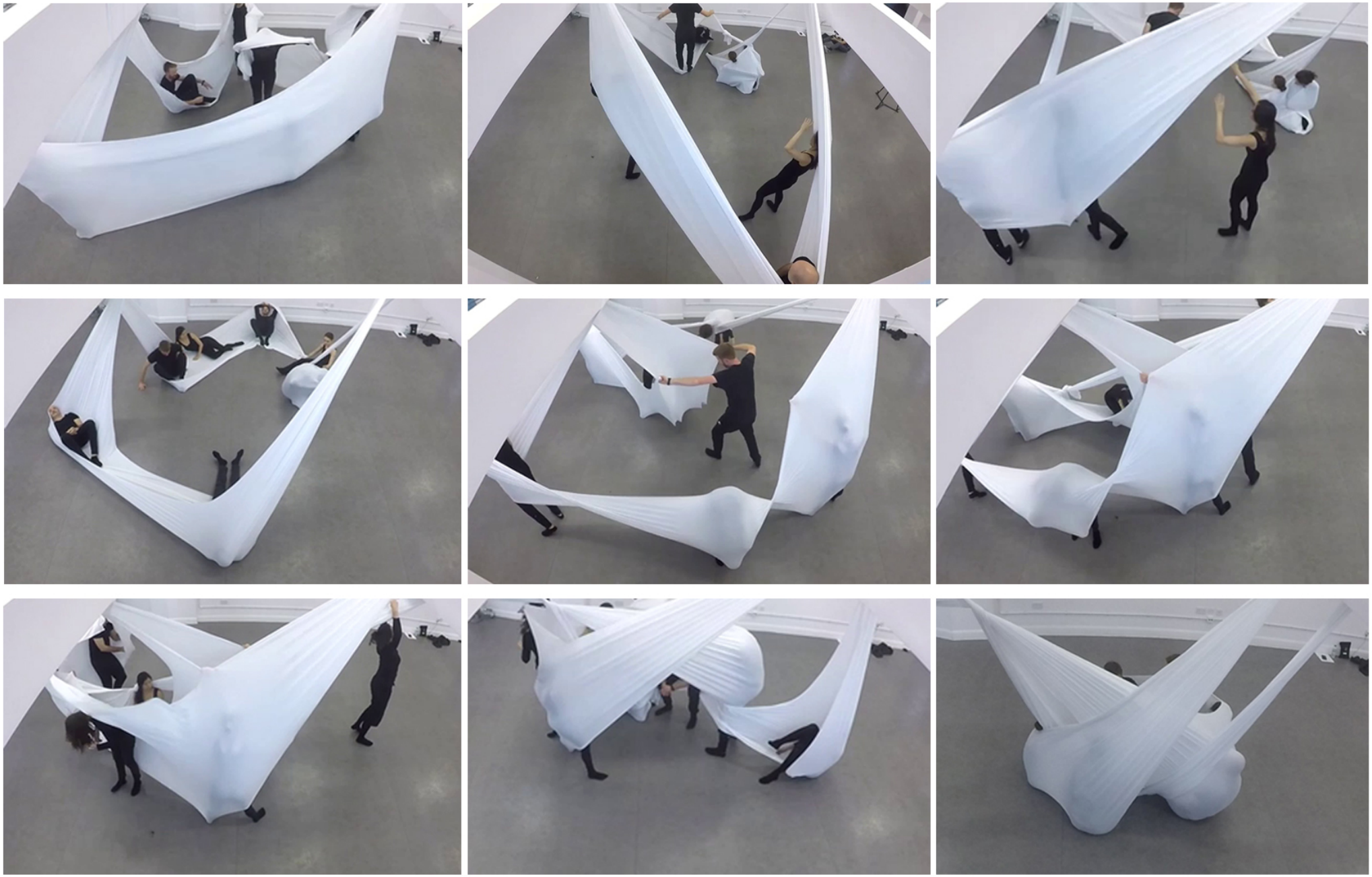


Figure 0. A sequence of an embodied exploration with a Lycra spandex fabric.

by architects. The hybrid EDI process would help to open up new ways of ideating soft embodied architecture by:

1) Allowing architects to engage with textile materials more experientially, by involving their bodies and their full range of senses to discover dynamic and spatial qualities through the agency of the material, the body, and the elements of the context.

2) Connecting body-material interactions with their digital geometries through a motion capture digital toolset.

3) Collaborating with textile designers, interaction designers, dancers and choreographers to ideate soft embodied architecture through collective experience.

This thesis is organised into six chapters. Chapter One addresses the methodology of the thesis with a focus on the choreography of interaction EDI method (Klooster and Overbeeke, 2005).

Chapter Two offers a literature review of published work on textile architecture, embodied design and EDI methods. It considers actor-network theory (ANT) and the influence of human and non-human agencies within the design process.

Chapter Three, 'The Spatiality of Textiles from an Embodied Perspective', details the first experiment conducted in collaboration with embodied interaction designer Sietske Klooster. The aim was to explore the spatiality of three different fabrics in an embodied way. The collaboration focused on exploring the transitional state between textiles as flat materials worn on the body to textiles as a soft embodied space. This chapter considers the dynamic and spatial qualities that emerge from the interaction between the textiles, the body and the context.

Chapter Four, 'Soft Embodied Geometries: Bridging Physical and Digital Realms', describes the first collaboration with architect Daniel Suárez. It explored the potential of using motion capture technology to map out a series of body-material interactions with the aim of expanding the design possibilities of a soft and embodied approach to architectural design.

Chapter Five, ‘Layering Up Soft Materiality: Exploring the Design of a Hybrid EDI Process for Soft Embodied Architectural Design’, discusses the workshop I co-organised with embodied interaction designer Sietske Klooster in which we involved architects from Heatherwick Studio and freelance dancers in exploring the ideation of a soft courtyard. The aim of this collaborative project was two-fold: on one hand to help to address the question of how to design a spatial experience with textiles that

Heatherwick Studio was investigating, and on the other hand to explore with the architects the design of a suitable hybrid EDI process for soft embodied architectural design.

Finally, Chapter Six, ‘Soft Embodied Architectures: Towards a Hybrid EDI method for Soft Embodied Architectural Design’, explores the design of a Multi Kinect toolset and an elastic interface to articulate a hybrid EDI process suitable for implementation within an architectural design methodology.

Chapter One

Methodology

1.1 Research through Design (RtD)

This practice-based investigation follows a Research through Design (RtD) approach and focuses on the creation of knowledge that emerges from practice (Jonas, 2007b; Findeli, 1998). RtD was first described by Frayling as a way of conducting research that is 'less straightforward, but still identifiable and visible' through 'material research [...] development work [...] and action research' in comparison to 'research into' (research into theory of art and design) and 'research for' (the development of a design product and its visual or iconic communication) (Frayling, 1993, p.5). Although it is not very clear what Frayling means by RtD, it seems to suggest that RtD is the development of a design project in which research output is the design process itself, suggesting that RtD is a way of doing research. Both Findeli and Jonas differ from Frayling's categorisation and argue for a RtD definition that puts more emphasis on reflection processes and theory building (Findeli, 1998; Jonas, 2007a).

Findeli defined RtD as follows: 'such research helps build a genuine theory of design by adopting an epistemological posture more consonant with what is specific to design: the project' (Findeli, 1998, p.108). Jonas follows Findeli's definition and refers to it as follows: 'research through design is based upon a generic structure of learning/designing, which has been derived from practice' (Jonas, 2007b, p.1377). Both acknowledge that RtD is a way of conducting research that produces knowledge from practice. Similarly, a more recent account of this practice with a focus on human-computer interaction (HCI) puts emphasis on the creation of knowledge:

> In the practice of RtD, design researchers focus on how design actions produce new and valuable knowledge. This knowledge can take many different forms including: novel perspectives that advances understanding of a problematic situation; insights and implications with respect to how specific theory can best be operationalized in a thing; new design methods that advance the ability of designers to handle new types of challenges; and artefacts that both sensitize the community and broaden the space for design action. (Zimmerman and Forlizzi, 2014, p.168)

Zimmerman and colleagues see value in using a RtD approach for conducting research into HCI as a way to create a paradigm shift (Zimmerman, Forlizzi and Evenson, 2007). More than two decades ago, HCI was operating under a technology-

driven paradigm, in which technology shaped the way research was conducted. In order to shift the focus towards a more theoretical approach, the HCI community started to look at other ways of conducting research. RtD offered a way to expand the research field of HCI. RtD enabled HCI researchers to develop knowledge and elaborate theoretical concepts based on explorative design processes that operate in the present with the aim of having an impact in the future, instead of the traditional problem-solving approach (Zimmerman and Forlizzi, 2014). Zimmerman et al. describe RtD as 'an approach to conducting scholarly research that employs the methods, practices and processes of design practice with the intention of generating new knowledge' (Zimmerman and Forlizzi, 2014, p.167). Therefore, RtD acknowledges the embedded meaning of design processes and artefacts, opening up new design spaces and theories (Cross, 2006).

In undertaking RtD, the prototype gains relevance in the creation of knowledge. In relation to this, Stappers argues that 'the designing act of creating prototypes is in itself a potential generator of knowledge (if only its insights do not disappear into the prototype, but are fed back into the disciplinary and cross-disciplinary platforms that can fit these insights into the growth of theory)' (Stappers, 2007, p.87). According to this perspective, the role of the prototype in RtD becomes key, contributing to the discussion and to the questioning of the topics of the research matter at stake.

Zimmerman and colleagues discuss the difference between RtD and design practice and argue that design researchers who follow a RtD approach 'focus on how design actions produce new and valuable knowledge' (Zimmerman and Forlizzi, 2014, p.168) whether this is new frameworks, perspectives, guidelines or design methods. In contrast, the aim of design practice is to be successful in designing a commercial product (Zimmerman and Forlizzi, 2014). A RtD approach contributes, then, to the generation of research outputs that emerge from practice, and is therefore a way of producing knowledge.

However, some concerns have been raised regarding the articulation of knowledge in RtD and how it remains a challenge (Höök and Löwgren, 2012; Löwgren, 2013; Zimmerman and Forlizzi, 2014; Stappers, 2007). In an effort to address such concerns, Gaver emphasises the diverse nature of RtD and argues that 'theory produced by RtD tends to be provisional, contingent and aspirational', as opposed to

'extensible and verifiable', which is a common description of scientific research (Gaver, 2012, p.938). He further questions the role for theory in RtD and, drawing on Stolterman's definition of design as the 'ultimate particular' – which equals the truth concept in science – he suggests that 'design theory is best considered a form of *annotation*, serving to explain and point to features of 'ultimate particulars', the truths of design' (Gaver, 2012, p.944). Such annotations are written text that accompanies a design outcome, enabling the linking of different features of the design outcome and their relation to the broader design field under discussion. A collection of several design outcomes and their annotations would result in an annotated portfolio, which determines a specific design space.

Annotated Portfolios (Gaver and Bowers, 2012) were used to interpret and communicate the findings of this thesis. This methodological tool for intermediate-level knowledge allows the researcher to communicate the relevant aspects of design artefacts (Löwgren, 2013). Annotated portfolios can take many forms, such as framework analysis (Lorenz Schilling, Wakkary and Odom, 2018), an artefacts portfolio (Sauerwein, Bakker and Balkenende, 2018) or a photo essay (Jarvis, Cameron and Boucher, 2012). They usually combine visual material with written text, enabling 'family resemblances to be reasoned about, rather than theoretical deductions to be made' (Gaver and Bowers, 2012, p.48). Building on Gaver's approach, Hook and colleagues propose the idea of 'strong concepts', which are 'a particular form of generative intermediate-level knowledge', the knowledge determinant in the creation of new designs (Höök and Löwgren, 2012, p.23:2). Other examples of intermediate-level knowledge in the context of interaction design research are single design solutions (Stolterman, 2008), criticism (Bardzell et al., 2012) and operationalisations of general theory (Lindwell, Holden and Butler, 2003).

Making use of annotated portfolios (Lorenz Schilling, Wakkary and Odom, 2018; Isbister, Márquez Segura and Melcer, 2018; Dykes et al., 2016) when conducting explorative research could be beneficial, as it allows the researcher to make explicit connections between images and text, supporting the creation of theoretical notions and the discussion of possible implications within the design field that is addressed.

Annotated portfolios allow researchers to present the visual and the written outputs, as equal, supporting the construction of design narratives and theories. Images are

essential elements of the design process, widely used by design researchers to communicate relevant aspects such as material details and product behaviour. Annotated portfolios are very aligned to this way of working, thus, facilitating the communication of design research outputs. This thesis uses annotated portfolios to create a series of diagrams that combine key visuals and concepts derived from the results of the four practice-based experiments. Such diagrams support the development of qualitative analysis and the generation of theoretical concepts.

1.2 Choreography of Interaction for soft embodied architectural design

This thesis uses the choreography of interaction method (Klooster and Overbeeke, 2005) as the main EDI method to explore new ways of ideating soft embodied architecture. Under the RtD paradigm, the choreography of interaction method is an embodied mode of enquiry that uses movement as a tool for design. The method involves the exploration of improvised body movements with previously selected materials and context to examine the design ideation phase of an artefact. Klooster's ideation method draws on Laban Movement Analysis (LMA), which is used to describe, analyse and visualise body movements. Klooster's method integrates Laban's notions of movement within the design process based on three key aspects: physical involvement, dynamic quality and expressed meaning. Physical involvement relates to all the agents that take part in it: materials, people, objects and context, and the relationships among them. It also implies the characteristics and qualities of each. Dynamic quality is key to the understanding of the choreography of interaction, and comprises the notions of spatiality, time and the play of forces, where the first relates to the aspect of direction or path, the second refers to rhythm, and the last is about body characteristics such as weight, balance and control. Expressed meaning is a notion related to the field of dance, and it refers to the meaning that is found in the interaction in each of the roles performed by different agents. Focusing on the meaning that emerges out of the interaction between the material, the body and the context, this thesis developed four collaborative practice-based experiments in which a series of body-material interactions were carried out in order to explore alternative ways of ideating soft embodied architecture.

The use of motion capture technology was introduced in Experiment 2 as a result of the collaboration with architect Daniel Suárez. The aim of this collaboration was to expand the design possibilities of a soft and embodied approach to architectural

design. A more detailed account of motion capture technology is provided in section 2.3 of this thesis.

The four experiments presented in this thesis combined action and reflection processes, as in Dewey's and Schön's concept of reflection-on-action (Dewey, 1934; Schön, 1983). Video and voice recording were used to gather the data. The reflections from the participants were used to inform the analysis of the experiments. The main findings were underpinned by actor-network theory (ANT) notions of network, human and non-human agency. The term 'actor-network theory' was coined by Michel Callon and Bruno Latour (Latour, 2005). This theory places humans and non-humans at the same level, giving agency to objects. It poses an understanding of the world through a set of relationships (networks) between humans and non-humans, the latter having an influence on human actions.

Chapter Two

Literature Review

This chapter provides a review of research in the field of textile architecture, focusing on the concept of soft embodied architecture. It considers the embodied design domain with a focus on EDI methods. Finally, the chapter introduces the notions of network, human and non-human agency from an embodied design perspective.

2.1 Textile Architecture

What is textile architecture?

Traditionally, textile design and architectural design have operated as two distinct disciplines that perform at several scales (Semper, 1989). Textiles operate from the micro scale of the fibre and the yarn, the construction of knitted, woven and non-woven fabrics for garment-making to large pieces of textiles such as carpets or curtains, and even on macro scales, if considering industrial applications such as geotextiles or scaffolding fabrics (Jefferies, Conroy and Clark, 2016). Architecture has traditionally performed at the scale of the built environment, handling more complex design processes as it involves a larger group of stakeholders such as contractors, policymakers or environmental experts (Ramsgaard Thomsen and Bech, 2011).

Textiles and architecture had come together well before Frei Otto advanced the field of architecture towards a novel textile approach. An example of this new approach is Otto's wood grid shell, made out of wood slats that were intertwined, mimicking a flat lattice structure that allowing for a certain flexibility, making it possible to shape it by lifting it up in a controlled way (Ramsgaard Thomsen and Bech, 2011). Architecture and textiles have been connected through history. From the primitive hut as the idea of a basic human need for shelter – in contrast to the existing Baroque style of that period (Laugier, 1755) – to the several kinds of tents such as the black tent, the yurt or the tipi typical of nomadic societies. Borrowing from the fields of textiles and fashion design, textiles have been widely used by architects as a shelter, as interior architecture to humanise a building and more recently as woven and knitted structures (Underwood et al., 2009; Sabin, 2017; Prado et al., 2017).

Architect Mette Ramsgaard Thomsen discusses early examples of textile architecture from the 1900s in which the use of textiles was not based not on the material itself but as a textile metaphor (Ramsgaard Thomsen and Bech, 2011, p.14). Such

examples use textile principles to project them into a new textile logic for architecture, often using metal, glass and wood as tensile structures. It seems that the first development considered as textile architecture was the work of Vladimir Shukhov, who experimented with tensile lightweight structures made out of thin steel sheets as a roof covering (Ramsgaard Thomsen, M; Kuusisto).

The first notable examples of textile architecture employing textiles as construction materials were the Music Pavilion (1955) in Kassel and the Tanzbrunnen (1957) in Cologne (Nerdinger, 2005). Both were made out of cotton fabric that was tensioned into a cable-supported structure. Later on, pneumatic architecture made use of textile to create air-domes in which the air supports the fabric secured by a set of cables (American Pavilion, Osaka Expo '70). During the 1970s, 1980s and 1990s, textiles were used mainly as façade elements. An example of this is the British Pavilion for the Seville Expo '92 (Kuusisto; Grimshaw Architects 2010) in which the textile membrane was tensed into the structure of the building.

In 2006 Garcia proposed the term 'architextiles' to define the union of architecture and textiles, materialised in a variety of projects and ways of thinking (Garcia, 2006). This hybrid term, architextiles, results from combining textile thinking and architectural thinking through the 'architecturalisation of textiles' and 'the textilisation of architecture' (Garcia, 2006). An example of the architecturalisation of textiles, or rather, the architecturalisation of fashion, the work of fashion designer Iris van Herpen in collaboration with architect Philip Beesley (Beesley, 2013) could be defined as a micro-architecture on the body. On a more significant scale, the work of Lars Spuybroek exemplifies the concept of the *textilisation* of architecture. Spuybroek's work is influenced in turn by the work of architect Gottfried Semper and his classification of the 'four elements of architecture: earth for foundation, wood for construction, textile for enclosure and fire for climate' (Garcia, 2006, p. 53). Semper connected textiles with architecture through the symbolic in *Stoffwecheseltheorie*, which draws on the idea of the transposition of one material (textile) into another (stone) (Garcia, 2006). Later, Spuybroek took this idea further and developed what he defines as textiles tectonics, the design of a structure whose appearance is soft but it is made out of hard materials (Spuybroek, 2011). Because of their adaptive nature, textiles as materials offer a variety of functionalities and aesthetics that enable them to adapt to different scales, from objects and clothing to interior design and

architecture. Otto's tensile structures and Fuller's geodesic tensegrity domes advanced the architectural field towards a textile perspective (Aldinger, 2016; Fuller, 1952) that has been updated with computational design thinking by Menges (Ahlquist and Menges, 2011). More recent examples of textile architecture include investigations into knitting technology for hybrid structures (Ahlquist, 2015; Deleuran et al., 2015). Projects such as these merges computational design thinking with textile thinking, making use of the design possibilities that CNC knitting machines offer in order to engineer the fabric according to structural requirements. As a result, a hybrid textile structure is created by tailoring the design of a knitted fabric to adapt to an architectonic system.

Several scholarly accounts of the field of textile architecture exist. Table 1 offers a condensed view of those identified through the literature review process.

TEXTILE ARCHITECTURE OVERVIEW			
Kuusisto (2010)	**Garcia** (2011)	**Heimdal and Anker** (2011)	**Quinn** (2015)
- Textiles *in* architecture - Textiles *for* architecture	- Textile metaphor - Architecture borrows a textile form - Textiles as composite - Concepts and theories	- Textiles as Add-ons - Textiles as metaphors - Textiles as building materials - Textiles as Media	- Pneumatic Architecture - Fabric Formwork - Architectural textiles - Geotextiles

Table 1. Textile architecture overview.

Garcia describes four ways in which architecture and textiles come together (Garcia, 2006). The first, textile metaphor, refers to the idea of embedding a textile logic into an architectural process. It does not necessarily mean that the final outcome is soft, but that its appearance engages with certain textile thinking instead (Spuybroek, 2011; Gehry, 2015). The second way is when architecture borrows a textile form, such as a skirt, veils or curtains, to design a space. The work of architect Petra Blaisse is an example of how textiles are used to clad spaces (Blaisse, 2009). The third way is the use of textiles as composite materials for architecture: that is, the development of technical textiles for architectural design. Companies such as Sefar Architecture and Ferrari Textiles specialise in the production of textile composites and smart fabrics such as conductive, heating or lighting fabrics (Sefar, 2018; Ferrari Textiles, 2018). The fourth way, concepts and theories, comprises conceptual writing and theoretical notions that connect architecture with textiles. Examples of these would be Deleuze's concept of the fold in relation to space, understood as a temporal unity

in which matter and form come together, in continuous transformation (Deleuze, 1992) and Serres' soft thinking that uses textile metaphors to criticise the rigid and rigorous thinking in favour of a fluid and elastic theoretical approach (Serres and Latour, 1995).

A more general classification of textile architecture in comparison to Garcia´s categories is the one provided by Kuusisto (Kuusisto, 2010). Kuusisto differentiates between textiles *in* architecture and textiles *for* architecture. Textiles in architecture refers to the use of existing textile materials to build structures, and emphasises the potential of textile to be embedded into self-supporting structures to facilitate portability. These uses of textile materials range from the origins of textile architecture, the tent, to contemporary textile architecture, focusing on lightweight tensile structures and pneumatic structures. In contrast, textiles for architecture focuses on composite fabrics and smart materials for construction. Textiles in architecture and textiles for architecture differ in the way textiles are used. The first uses existing materials to build a self-supporting structure, while the second implies the development of technical textiles (composites) that are a structural part of the construction. Kuusisto highlights the potential of smart textiles such as conductive, thermochromic and fibre-optic fabrics to explore new uses and applications. More relevant to this investigation is Kuusisto's suggestion of exploring the 'dynamic nature of the textile in relation to shape' as textiles can adapt to different surfaces and structures. (Kuusisto, 2010, p. 86). This suggestion is in line with the exploration in this thesis, as it seeks to harness the potential of the dynamic qualities that emerge from a co-shaping process between the body and the textile material.

Heimdal and colleagues distinguish four categories, including textiles as add-ons, referring to the use of textiles as an additional element to affect the spatial experience; textiles as metaphors, that relates to Semper's concept of material transposition; textiles as building materials are textile composites and textiles as media refer to the creation of textile models to gain inspiration from the material properties and apply them to other materials for architectural design (Wærsted, Lenau and Brandt, 2014). Textiles as media connects with Kuusisto's suggestion of making use of the dynamic qualities of textiles as it implies the manipulation of textile materials to understand and discover behaviours that can be applied to an architectural design.

From a more functional approach, Quinn differentiates between pneumatic architecture, fabric formwork (the use of textiles to as a recipient for cast concrete), architectural textiles (the equivalent of textile composites mentioned above), and finally geotextiles, typically used in the built environment as underground reinforcement, to pave a landscape or as filters for soil (Quinn, 2015). Quinn's distinction between types of textile architecture responds to a more functional perspective, based on the material properties and their uses in architecture. Quinn's categorisation brings to the light the hidden role that technical textiles such as geotextiles play as structural elements in the construction of the built environment.

Kuusisto, Heimdal et al. and Quinn offer a more practical perspective on textile architecture, whereas Garcia acknowledges the philosophical dimension of architextiles by drawing on postmodern theories of space (Deleuze, 1992; Rashid, 2018; Kas Oosterhuis, 2018; Novak, 1991; Prestinenza Puglisi, 1999; Gorny and van den Heuvel, 2017):

> [...] Architectural space should reorientate itself, both metaphorically and literally, from a model based on the solid to one based on liquid and gaseous energy-states of matter. In the transition stage from the solid to the liquid, the material and energetic state of textiles, with their common properties of surface continuities, lightness, softness, flexibility, thinness and fluid-like dynamism, make them an apt material group for the expression and realisation of this new spatiotheoretical paradigm (Garcia, 2006, p.8).

The new spatiotheoretical paradigm that Garcia describes acknowledges the adaptive quality of textiles and their capacity to transform the spatial experience, from soft to hard, from opaque to transparent, from flexible to rigid. The experiments carried out in this investigation support the concept of space proposed by Garcia and advocate for the ideation of a soft embodied architecture based on temporary, dynamic and spatial qualities that arise by folding, deforming and stretching the soft materials through the body.

The four reviews of textile architecture described in this section show the richness of the relationship between textiles and architecture. Despite the challenge that using non-structural materials such as textiles within architectural design practice represents, it is clear that there has been keen interest from architects in using these materials, whether in a more metaphorical way (Spuybroek, 2011), a technical way

(Quinn, 2015; Kuusisto, 2010; Wærsted, Lenau and Brandt, 2014) or from a more philosophical standpoint (Garcia, 2006). However, there are fewer examples of textile architecture that acknowledge and use the dynamic and behavioural qualities that arise from a body-material interaction. It is in the field of fine art that we find more examples in which textiles have been contextualised within the boundaries of architectural design, and that posit a soft and embodied understanding of space, one that acknowledges the dynamic and behavioural spatial qualities of an embodied exploration with textiles (Filipovic and Walther, 2014; Allamoda, 2017; Candela et al., 2017). An example of a soft understanding within the architecture domain is the 'Slow Furl' project (Choi et al., 2002). The project proposes a behavioural and soft approach to architecture that relates to the one pursued in this thesis. 'Slow Furl' acknowledges the dynamic and pliable qualities of textiles and uses them for designing a soft robotic architecture (Ramsgaard Thomsen and Bech, 2011). Ramsgaard argues that early examples, created at the beginning of the1900s, that used construction techniques of textiles as a starting point do not consider textiles as materials that are flexible and pliable. According to Ramsgaard Thomsen and Bech, the adaptive qualities of textiles posit challenging questions for architectural design: 'how could architecture make use of the motile and the soft? How could it be to live in a soft space?' (Ramsgaard Thomsen and Bech, 2011, p.15). The soft and flexible nature of textiles contrast with the hard and rectilinear geometries predominant in architecture. Until the 1990s, textile architecture was achieved by means of tensile and pneumatic structures in which the textile was applied in roofs and façades in such a way (tensioned and inflated) that it became almost as stiff as hard materials.

One of the earliest examples of textile architecture in which the textile was not presented as a stiff material is the Curtain Wall House (Ban, 1995). Two storeys of fabric hang from the top of the building across its two facades, breaking up with the concept of curtain wall typically made out of glass (Murray, 2009, p.26). The fabric moves dynamically as the wind blows, allowing the material to express its qualities in relationship with the environment, mediating the relationship between inside and outside. This example offers a dynamic understanding of textile architecture by making use of the adaptive qualities of textiles, such as foldability, elasticity or pliability. Some recent examples of architecture exist that pose a similar dynamic understanding of soft materials. Beesley's (Beesley, 2013) textile lattices installation offers a contemplative soft and kinetic understanding of space; similarly, Mossé's

responsive structures aim to raise awareness of the temporary and dynamic qualities of the exterior environment within the domestic space (Mossé, Gauthier and Kofod, 2012) whereas Neto's organic installations invite a direct interaction with a soft space, enabling a closer relationship between people and spaces (Neto, 2009), a shared aim of this doctoral research investigation.

As pointed out by Ramsgaard, 'architectural design often operates within a paradigm of optimisation looking for minimal material use and structural support. When looking to textiles a very different approach is developed constructing complex structures through a redundancy of very weak material' (Ramsgaard Thomsen and Bech, 2011, p.22). According to Ramsgaard, while architecture has traditionally relied on the representation and abstraction of hard materials, the majority of textile materials are soft, behavioural materials. Thus, the design of a soft architecture implies qualities of dynamism, movement and behaviour that are not usually present in hard materials (Ramsgaard, 2011). In a similar way, Dumitrescu et al. acknowledge the dynamic behaviour of textile materials and reflect on the notion of textile hangings to describe the 'sense of lived-in space' emphasised by the temporal and changeable expressions of textiles (Dumitrescu, Landin and Vallgårda, 2012). I argue that hard architecture is capable of achieving similar dynamic and motile qualities by means of the visual, through the transposition of one material into another, as in the case of the recently built UTS building in Sydney (Gehry, 2015). Gehry takes inspiration from a paper bag to design a building that resembles the folds and the wrinkles of paper. However, the soft, behavioural aspects of textile materials often remain unexplored, both in the design process and in the later use of the space.

Ramsgaard's early projects using knitting technology (2011) offer a soft and behavioural approach to architecture in which the fabric is conceptualised through computational design, resulting in a robotic wall membrane. 'Slow Furl' investigates the behavioural nature of a textile installation. It uses knitting technology to develop a dynamic skin supported by a scaffold that is programmed to move autonomously, producing a behavioural architecture that leverages the ability of textiles to fold and adapt to a structure that is in motion. The dynamic skin is made out of conductive yarns that create a circuit with multiple soft switches across the fabric. The switches are triggered individually according to the actions of the inner scaffold, creating a behavioural self-actuated soft landscape (Ramsgaard, 2011). 'Slow Furl' enhances

the transitional and dynamic aspects of a soft space through technology. A soft space that moves necessarily brings a different spatial experience from that of a rigid space. ‘Slow Furl’ focuses on the relationship between a robotic structure and a responsive skin, and does not elaborate further on the particularities that the robotic wall membrane offers in terms of spatial experience and interaction with others. However, it is relevant for this investigation as it acknowledges the transformative behaviour of textiles and uses it as material for designing a soft architecture.

Closer to the design space in which this investigation is framed (soft and embodied architectural design) are the works of Pišteková and Schillig. Pišteková proposes approaching the ‘in-between’ spaces of dress and architecture, using the body as a point of reference for the design process and drawing metaphorical parallels between fashion and architecture (Pišteková, 2017). Similarly, in the ‘Public Receptors’ project, Schillig explores the connections between ‘body, clothing architecture and the built environment’ (Schillig, 2009, p.45). ‘Public Receptors’ is a series of transformable felt structures defined by Schillig as ‘wearable spatial structures’ that are designed to mediate the relationship between users and the built environment (Schillig, 2009, p.45).

Schillig draws mainly upon the work of the artists Lygia Clark and Lygia Pape to elaborate on her understanding of soft space in which textiles play a mediating role between the body and the world, creating ‘a second skin, able to mediate realities within relational spaces’ (Schillig, 2015, p.58). The concept of a second skin proposed by Schillig understands space as a continuous experience, as opposed to space as a form. Schillig thinks of embodied textile structures as an influential element for creating new spatial logics. This kind of understanding can be also identified in the work of Walther (Filipovic and Walther, 2014), in which large pieces of textiles connect several people, creating soft spatial structures. Such structures require physical involvement, and therefore affect the way we perceive both a space and others around us.

Drawing on the writing of Merleau-Ponty, Schillig describes a phenomenological concept of space, introducing movement as a disruptive element in architecture that ‘generates a non-determined concept of space where spatial and bodily boundaries are constantly blurring’ (Agkathidis et al., 2010, p.9). As Schillig suggests, introducing

movement in architecture breaks with the idea of architecture understood as something static and rigid, offering instead a more dynamic understanding of space. Schillig uses movement to activate a soft structure that has been previously designed according to a shape or a pattern, often borrowing from fashion and textile techniques (Agkathidis et al., 2010). In contrast, this investigation uses movement as material for design. Thus, the movement becomes an important aspect of the design process and introduces new dynamics by involving the behaviour of both the material and the body in relation to the particularities of the context (exterior or interior spaces, or a lab).

Schillig articulates a 'soft space' approach within the boundaries of fashion design and architectural design. However, while she reflects on the materiality of the felt as a material that enables the creation of volumes and depths and a form-defining process that is adaptive and transformative, it is not clear how these physical models could be further developed within architectural design practice. She states that the goal of this project is to 'expand the imagination' and 'systemize a technique as form-defining device' (Schillig, 2009, p.157) but does not explicitly states how this form-defining device could be implemented within a broader architectural design methodology.

Earlier work that capitalises on the combination of movement and the ability of textile materials to behave spatially include Maria Blaisse and Jessica Bugg's work. Blaisse's foam costumes for dance, 'Kuma Guna' (1999) and 'Spheres' (1989) explore the relationship between materials, body and form to design costumes and objects that sit between fashion, sculpture and body architecture (Blaisse, 2013). Bugg's fashion designs for performance explore innovative pattern-making that becomes sculptural when activated by the wearer's movement. Schillig's, Blaisse's and Bugg's work resemble the dresses worn by the earlier twentieth-century dancer, choreographer and inventor Loie Fuller (1862-1928). In Fuller's performances she created soft sculptures by performing energetic and circular movements while wearing a long layered silk dress (Salter, 2010). All these works show that certain spatial qualities can be achieved by interacting with textiles in a bodily way. These works emphasise the dynamic and spatial qualities that emerge from the interaction between the material and the body in movement, offering temporary soft and embodied spaces.

Concluding remarks

The projects outlined in this section show the diversity of the uses of textiles within architectural design. Some of the projects are designed from a more material and structural performance perspective (Choi et al., 2002; Ahlquist, 2015; Deleuran et al., 2015), while others take a more soft and dynamic approach to textile architecture (Ban, 1995; Choi et al., 2002). More relevant to this investigation is work that explores the spatiality of textiles from a bodily perspective (Schillig, 2009; Agkathidis et al., 2010; Pišteková, 2017). However, there is still one aspect that remains unexplored. I refer to the richness of interaction afforded by the use of movement as material for design in a bodily and situated way, not only during the use of the resulting soft embodied spaces, but more importantly within the design process. As stated by Hummels and colleagues, the idea that '"interaction creates meaning"' not only holds for users during interaction but also for designers when generating ideas and developing concepts' (Hummels, Overbeeke and Klooster, 2007, p.677). Examples that use the relationship between material, body and context to inform a design or research project, in the way that this occurs in embodied design (Wilde, Vallgårda and Tomico, 2017) are rarely found in textile architectural design.

By applying an embodied design approach (Wilde, Schiphorst and Klooster, 2011b; Van Rompay and Ludden, 2015; Schleicher, Jones and Kachur, 2010), architects could benefit from first-hand experience to find new ways of ideating soft embodied architecture, thus allowing architects to grasp the subtleties and details that happen when interacting with a soft material at the scale of the body in a situated way.

2.2 Embodied Design and EDI Methods

Embodied design is an emergent design space that allows designers to make use of their senses. This design space includes ideation, speculation, engagement, analysis and embodied interaction processes (Wilde, Vallgårda and Tomico, 2017). Theoretically, embodied design borrows from phenomenology, 'pragmatist aesthetics, embodied cognition and embodied, embedded and enacted minds' (Wilde, Vallgårda and Tomico, 2017, p.5159).

Within the embodied design field, EDI methods (Wilde, Vallgårda and Tomico, 2017) and embodied ideation activities (Turmo Vidal and Márquez Segura, 2018) have gained popularity among researchers, especially within the field of human-computer

interaction (HCI) and embodied interaction (Iacucci and Kuutti, 2002; Wilde, Schiphorst and Klooster, 2011a; Loke and Robertson, 2013; Segura, Vidal and Rostami, 2016; Márquez Segura et al., 2016). EDI methods are characterised by involvement with the body within the early stages of the design process. These methods connect the material, the context and the body to draw relationships between them that are used to inform a design. Table 2 shows an overview of the theories, approaches and EDI methods identified through the literature review process.

EMBODIED DESIGN METHODS , THEORIES AND APPROACHES OVERVIEW		
Loke & Robertson (2011)	The 'Lived body' in interactive technologies	1) Philosophical perspectives 2) Concepts of the body: - as anatomy and physiology - as expression; as knowledge - as physical skill - as a felt experience - as social, cultural 3) Design approaches and methods
Several authors	Movement-based interaction	- Bodystorming (Burns et al. 1994) - Embodied Sketching (Márquez segura et al., 2016) - Moving and Making Strange (Loke and Robertson, 2013)
Van Rompay (2015)	Embodiment in Product Design	1) Anthropomorphism, familiarity and literal resemblances 2) Relational properties: image schemas and symbolic meaning 3) Meaningful sensorial experiences 4) Embodiment in product movement and action
Wilde, Vallgårda and Tomico (2017)	EDI methods landscape	- Phenomenology - Feldenkrais - Mindfulness and Somaesthetics - Performance practices - Movement skills - Representations of movement

Table 2. EDI methods, theories and, approaches overview.

While EDI methods relate to physical involvement within the design process to analyse, ideate or communicate, in architectural design a more cognitive approach to embodied design, which relates to symbolism and visual imagination, predominates. Examples of these are the 'Architecture of Embodiment' project (Arteaga, 2014) which derives from an enactivist perspective, drawing on Varela, Thompson and

Rosch's approach to embodied cognition (Thompson et al., 1992) and the enactive framework for architectural experience (Jelić et al., 2016). Other works propose alternative frameworks to analyse how the built environment is perceived (Peri Bader, 2015); to develop conceptual frameworks inspired by perception and embodiment through participants' experience in responsive architecture environments (Faleh, 2014); to elaborate theories and approaches to architecture acknowledging the embodied dimension of architecture (Pallasmaa, 2012; Marble, 1988; Albright et al., 2015) and the everyday experience of this (Rasmussen, 2000; Bloomer and Moore, 1977).

EDI methods often draw on other fields and body-related activities such as dance, yoga and performance. Wilde and colleagues distinguish between methods that use Feldenkrais,[3] mindfulness and Somaesthetics,[4] performance practices, movement skills and representations of movement (Wilde, Vallgårda and Tomico, 2017). Van Rompay and colleagues (Van Rompay and Ludden, 2015) highlight how researchers have used dance techniques to explore movement qualities and patterns for product interaction (Ross and Wensveen, 2010; Hummels, Overbeeke and Klooster, 2007). In this way 'designers can create an envisioned expression through movement characteristics' (Van Rompay and Ludden, 2015, p.8). I argue that Ross et al. and Hummels et al. not only envisioned expressions through movement qualities but more importantly shaped and designed such an experience. Embodied interaction designer Sietske Klooster proposes the choreography of interaction (Klooster and Overbeeke, 2005), an EDI method inspired by dance techniques framed within the 'design movement' approach, which explores the relation between movement and design (Klooster and Overbeeke, 2005). Design movement is a framework that understands movement as a material for design. The choreography of interaction method combines the design of a product with dance improvisation and choreography. As a result, the choreography of interaction is both the design process and the design outcome.

[3] Feldenkrais is a method that aims to expand the bodily knowledge by practising different body movements that help to raise awareness of sensations and body feelings (Feldenkrais, 1972)

[4] According to Shusterman, Somaesthetics 'is an interdisciplinary research project devoted to the critical study and meliorative cultivation of the experience and use of the living body (or soma) as a site of sensory appreciation (aesthesis) and creative self-stylization' (Shusterman, n.d.). It draws on pragmatist aesthetics (Dewey, 1934) to develop an interaction design perspective that focuses on the qualities of the interaction between user and objects (Lee, Lim and Shusterman, 2014).

Drawing on Shusterman's theory of pragmatist aesthetics, Ross and colleagues (Ross and Wensveen, 2010) propose a design approach known as 'designing for aesthetic interaction through aesthetic interaction', in which experience is used as a mechanism for designing an interactive lamp. According to Ross and colleagues, pragmatist aesthetics understands aesthetics not only as pleasant or beautiful but also as something that serves a purpose. Pragmatist aesthetics is a situated experience in the sense that it belongs to a socio-cultural context in which form becomes inseparable from the aesthetic experience (Ross and Wensveen, 2010). Based on the four principles derived from pragmatist aesthetics – (1) the aesthetic serves a purpose; (2) the socio-cultural context influences the aesthetic experience (3) form and aesthetic experience are linked; (4) aesthetic experience involves both the intellect and the body – Ross and colleagues propose a three-step approach to aesthetics for designing interactive products: 'creating behaviours through acting out choreographies', 'specifying behaviour in dynamic form language' and 'implementing dynamic form in experiential prototypes' (Ross and Wensveen, 2010, p. 6). To illustrate how their approach could be translated into design practice, they present a design case study of an intelligent lamp. The first step of Ross and Wensveen's approach explains the role of the dancers and participants within their approach. Ross and Wensveen used a version of the choreography of interaction method (Klooster and Overbeeke, 2005) and invited professional dancers to create movement strategies with the aim of designing through experience. The dancers acted out several movements for a group of participants creating a new entity, the dancer-lamp. This new entity held and moved the lamp in different directions and positions in order to assist and adapt to participants' needs when reading.

According to Ross and Wensveen, within this process of acting out movements, the dancers made use of their 'perceptual-motor, emotional, cognitive and social skills in their creative process' (Ross and Wensveen, 2010, p.6). As highlighted by Ross and Wensveen, the process of acting out movement strategies to design through experience differs significantly from other traditional design processes in which the social context and bodily involvement is much less present.

However, the reason for using dancers in this investigation was not a response to the need to map out behavioural patterns that would later inform an interactive product. Instead, on one hand dancers helped to unpack the spatial qualities of textiles

expressively through dance improvisation, and on the other hand they became facilitators by helping out other participants to engage actively with the body-material interactions. For instance, during the explorations described in Chapter 5, architects would mimic some of the dancers' movements. However, there is a common aspect that is shared in both cases – the use of the body and the exploration in context as a source for ideating the design of a product or space. Tomico and Wilde highlight the importance of working in context when designing from an embodied perspective, as it helps to situate the action 'to engage with the constraints that come from the context, the performing body, material properties and functionality, enabling designers to frame "meaningful" design opportunities' (Tomico and Wilde, 2015, p.1182). By working in context, both designers and materials are situated and influenced by the specific context (lab, social setting, outdoor, etc...), bringing them closer to the final user experience of the product or space. This allows designers to acquire a deeper understanding of the relationships between the material, the participants and the context while providing formal insights to inform the final design outcome.

Another example of an EDI method that acknowledges the importance of situating the actions in context is the aforementioned 'Embodied Sketching' (Márquez Segura et al., 2016). This EDI method proposes the designing of bodily experiences in social settings, connecting the design activities to the final design.

Within the domain of movement-based interaction design, which includes a variety of areas for application such as dance, game design or physical exercises (Höök et al., 2017), bodystorming has been widely used by researchers as an embodied ideation technique. Coined by Burns (Burns et al., 1994), and described as 're-enacting everyday people' (Oulasvirta, Kurvinen and Kankainen, 2003, p.126), bodystorming is a context-aware and situated activity that makes use of first-hand experiences as an ideation process to enhance design ideas (Oulasvirta, Kurvinen and Kankainen, 2003). Bodystorming often involves working with 'data in embodied ways' and uses a creative, problem-solving, on-site approach in order to become familiar with the unfamiliar (Oulasvirta, Kurvinen and Kankainen, 2003, p.133). In exploring the benefits of using bodystorming as an embodied method, Oulasvirta and colleagues report that according to participants' feedback, their method – focusing on acting out a role in a staged office – did not bring the expected results, design ideas sensitive

to interaction and social aspects. (Oulasvirta, Kurvinen and Kankainen, 2003, p.133). In response to this limitation, Marquez et al. (2016) argue that engaging with a physical activity during the ideation processes becomes more difficult if such activity is not directly related to the design goal (such as acting out a role) and the final design outcome. They further argue that their 'embodied sketching' EDI method contributes to bringing more effective ways of engaging with participants, as the main activity relates directly to the final design outcome (Márquez Segura et al., 2016).

The underlying knowledge that emerges from the relationship between the material, the context and the body is of an emergent nature. EDI methods are difficult to transmit because of their tacit nature, making it difficult for other researchers to make use of them. To solve such challenge, Wilde, Vallgårda and Tomico (2017) propose a framework to enable designers to understand and appropriate the existing methods to ultimately design their own. Whilst they note that some efforts have been made in order to address this gap (Loke and Robertson, 2013, Lyons et al, 2012) there is a lack of a common understanding or more explicit insight that might support designers in developing their own methods. This claim is also supported by Marquez and colleagues (Turmo Vidal and Márquez Segura, 2018), who suggest that in the context of embodied interaction, 'HCI researchers have not yet established a set of design practices, methods and tools that are readily accessible and acceptable to the research community' (Segura, Vidal and Rostami, 2016, p.194).

Schön and Cross highlighted the importance of acknowledging the way designers make and know (Cross, 2001; Schön, 1983). Donald Schön (Schön, 1983) introduced the concept of reflection-on-action, drawing on Dewey's writing on exploring experience, interaction and reflection. Reflection-on-action refers to the ability to be aware of our everyday practice and re-frame our experiences as practitioners by reflecting on them. In this way, designers can communicate their practice and their thinking in a way that is understood by others. This investigation aims to articulate a hybrid EDI process by defining a series of ideation phases to make it accessible to other researchers.

Concluding remarks

The examples outlined in this section (Table 2) show the variety of approaches and methods that have been developed by designers and researchers in recent years.

EDI methods shape the way designers work, analyse experiences or communicate results. Increasingly, approaches and perspectives are employed in which the digital realm becomes more prominent as technology progresses. As pointed out by Wilde and colleagues (Wilde, Vallgårda and Tomico, 2017), within this context of technology-mediated design, the use of EDI methods become more relevant, as they contribute to a more seamless design process in which the connection between what it is designed and how it is experienced by its future users becomes closer.

In the next section I reflect on EDI processes drawing from actor-network theory (ANT) and explain how the concepts of human and non-human agency can be meaningful in articulating a soft embodied approach to architecture.

2.3 The concepts of network, human and non-human agency in actor-network Theory (ANT) from the perspective of soft embodied architecture

ANT is one of the predominant theories within science and technology studies (STS) that has been applied to different research fields such as biology, computing science, medicine, architecture and design as a way to open up new possibilities in the way researchers conceptualise and frame their investigations. In the last decade it has gained a certain popularity among designers and architects as an approach to support the development of theoretical concepts, design frameworks and methods (Fallan, 2008; Storni, 2015; Storni et al., 2015).

ANT is concerned with the set of associations between humans and non-humans and does not distinguish between them, lending them both agency (Latour 2006). According to Latour, no concept of 'the social' as a separate entity exists; instead the social becomes visible through the interactions between human and non-human actors. This set of associations is called a network, which is considered as an actor itself. As stated by Fallan, 'networks are made up by associations and constituted by the effects of the enrolled actors'. (Fallan, 2008, p.83).

This flat ontology that put humans and objects at the same level, with no hierarchy, is concerned with the way in which both humans and non-humans come into being, attending to the whys and hows of such a process. Therefore, action is a requirement for an actor-network to emerge. As explained by Fallan, in the process of planning, designing and constructing a building, networks are created and materials and

meanings evolve (Fallan, 2008, p.88). Latour's example of the gunman helps to clarify the logic behind the concept of human and non-human agency in ANT (Latour, 2005). The gun, defined as an actor, influences and transforms another actor, the man, creating a third entity, the gun-man entity. According to Latour, it is at that point that the possibility of killing someone emerges. According to this understanding, how an object behaves only becomes visible in use, in the interaction with other agents.

Latour uses the concept of 'scripts', borrowed from the film and theatre world, to describe the influence of an artefact on human actions (Latour, 1992). For example, a glass made out of crystal has the script to wash it after used, whereas a plastic glass has the script to throw it away. In that sense, 'products enable and invite certain behaviours and inhibit others' (Overbeeke, Kees C. J.; Hummels, 2011). Yaneva elaborates further on the concept of scripts and focuses on the design field (Yaneva, 2009). She states that design practice is accountable to how these associations take place, as design shapes the relationship between objects and humans. Following the concept of 'scripts', she refers to them as directions of use that unfold a specific vision of the world through the object. She argues that objects shape the way humans and non-humans interact, and that design, therefore, shapes the social by activating certain behaviours, 're-assembling the social' (Yaneva, 2009, p.276). To her, design is a medium through which social ties are created, a way to bind humans and objects.

I argue that considering the concepts of human and non-human agencies during an EDI process could lead to the articulation of new theoretical notions informed by the relationships between the agencies of the material, the context and the designer. Traditional ways of designing include the generation of new material, drawings, prototypes and digital simulations that do not normally consider the agency of the material, the context and the designer. Reflecting on ANT within the context of traditional design research, Storni states:

> Entities do not pre-exist the design process as fixed and separated actors with predefined roles and qualities but rather emerge, shift and fuse together in an open-ended assemblages of humans and non-humans (Storni, 2015, p.169).

When applying an embodied design ideation method, the roles of the material, the body and the context become active elements of the design process, whose

relationships are re-defined through the engagement with the material, the context and the body. As a result, design outputs or entities, to put it in ANT vocabulary, emerge out of an explorative process that continues when users engage with such entities in an open-ended process that creates multiple bonds between humans and objects. Thus, I argue that taking an ANT approach to soft and embodied architectural design allows the researcher to think in terms of human and non-human actors and brings a relational perspective that helps to emphasise the value of involving the body, the material, and the context within an EDI process.

Concluding remarks

In this section I have described the ANT concepts of network, human and non-human and related them to an EDI process. Both Latour and Yaneva argue for a relational understanding of the interaction between humans and objects, emphasising how objects affect human choices and how such interactions create and re-configure social ties between human and objects. As discussed, EDI processes are activities in which the body-material interactions are explored in context, focusing on the relationships that emerge between them. Thus different actors, humans and non-humans, come together through a set of associations. I suggest that an ANT perspective to soft embodied architectural design would support the analysis of the research outputs and the articulation of theoretical concepts.

Chapter Three

The spatiality of textiles from an embodied design perspective

This chapter addresses the first research sub-question of this investigation: when does a textile become space? It describes, analyses and discusses the exploration of three textile materials by means of the choreography of interaction. Several body-material interactions were rehearsed with the aim of exploring the spatiality of a nylon fabric, a spandex Lycra fabric and a mesh netting fabric. As a result, three soft body-space entities were identified.

3.1 When does a textile become space?[5]

In order to answer this first research sub-question, I organised a collaborative experiment with embodied interaction designer Sietske Klooster (SK) and the support of design researcher Oscar Tomico (OT) at the University of Technology in Eindhoven (TU/e). The aim of the experiment was to explore how the choreography of interaction method could provide a soft and embodied approach for ideating architecture. The experiment explored notions of embodiment, materiality and space in relation to the creation of nuanced soft embodied spatial expressions. Focusing on the expressed meaning[6] of the choreography of interaction, the spatiality of textiles was explored through a series of body-material interactions.

Set-up of the experimental work

The experiment consisted of a series of individual and group improvised embodied explorations with three different fabrics. The three fabrics differed in their texture, density, weight, elasticity and colour in order to explore different material qualities: a 3x3m 100% woven nylon parachute kite fabric in olive colour; a 2x1.5m spandex Lycra fabric in black and a 4x2m high density knitted polyethylene mesh netting, commonly called scaffolding fabric, in blue. The nylon fabric is characterised by its lightness, while the spandex Lycra fabric is highly stretchy and translucent. The main characteristic of the netting fabric is its open structure, which gives it transparency.

The individual explorations were carried out by SK, OT and me, and the group explorations were supported by two students (S1, S2) and a professor (P) from the

[5] Text partially adapted from Castan and Tomico, (2017)

[6] A notion related to the field of dance. It refers to the meaning that is found in the interaction between the different agents of a given activity (see the methodology chapter for further information).

TU/e. The roles of S1, S2 and P within the group explorations were merely as facilitators, helping us to explore the interaction with others and use several pieces of fabrics at the same time. The experiment took place in a park, to explore how non-human actors could affect the embodied explorations. The embodied explorations were video-recorded for their later use in the analysis of the results. Video recordings would allow me to see the transitions between movements, and therefore to identify potential dynamic and spatial qualities.

Individual and group explorations

The individual explorations started by trying out each of the materials intuitively, as a cover for our bodies, letting the body and the textiles interact with and eventually challenge each other. The arrangements of the textiles on the body evolved as we explored them with our bodies. The interaction between the body and the material consisted of very simple movements, holding the textile with the hands and understanding the behaviour of the material in relation to body movement. After observing the different interactions of the participants with the materials and experiencing them myself, I decided to add certain elements to allow other parts of the body to be more active. For instance, the nylon fabric blew quickly just by holding it with the hand. To allow for more richness of movement, four elastic straps were attached to each edge of the fabric. This enabled more options in terms of interaction with the material, as we could engage with our full bodies by taking the straps with our feet, hands, knees and waists. For example, we moved faster and could attach the material to more than one body at a time. In the case of the spandex Lycra fabric I observed that stretching the fabric with our bodies was necessary in order to relate spatially. To facilitate the interaction with this material, I added one elastic strap to each of the edges of the fabric. Regarding the mesh netting fabric, I realised that the material was rather heavy on the body and I suggested using wooden sticks to support the bodily interaction with the material.

The group explorations started first with an introduction to the three new participants, S1, S2 and P1. We explained the purpose of the embodied explorations and how the textile became space, and asked them to join us in intuitively exploring improvised body movements while interacting with the fabrics.

To interpret the findings of the experiment, the embodied outputs and participants' reflections were organised, combining visuals and concepts as in an annotated portfolio (Gaver and Bowers, 2012). Only SK, OT and I reflected on the results of the experiment, as the other participants were facilitators of the embodied explorations. Annotated portfolios focus on the relationship between artefacts and their descriptions to produce meaning. According to their authors, 'designs need to be annotated if they are to make clear and accountable contributions to research' (Gaver and Bowers, 2012, p.43).

Figures 3a, 3b, 7, 10, 15, 18, 22 and 26 show the annotations of the embodied explorations of the three materials: 1) The spatiality of a nylon fabric, 2) The spatiality of a netting fabric and 3) The spatiality of a spandex Lycra fabric.

3.2 The spatiality of a nylon fabric

The individual explorations with the nylon fabric revealed a spatial quality that is expressed in the moment the body mobilises the textile by walking towards the direction of the wind. A fluid shape emerges out of the body-material interaction afforded by the flow of air generated by the body in movement and the wind. As a result, a dynamic volume expands around the body (Figures 1 and 2). In reflecting on the experience of interacting with the nylon fabric, I observed: 'it is a space in motion that comes into you and gives you a feeling of fluidity'. SK pointed out: 'the movement and the wind help to build space around the body'. I added: 'the perception of the space from the inside offered a concave appearance that moved less in comparison with the outside, which showed a spherical convex volume that was constantly moving'. As seen in Figure 1, and according to participants' reflections, I argue that the nylon fabric became space afforded by the agency of both the body and wind agencies, shaping the spatial form and creating concave and convex volumes in motion. The shape of the volumes in motion was determined by the position of the textile on the body, attached to the wrists and the ankles, and the body moving backwards and taking advantage of the wind direction (Figure 3a). The wind, in relation to the lightweight materiality of the nylon fabric and the body movement, yielded the possibility of enacting a temporary soft space that is always in motion (Figure 3b). The wind, the nylon fabric and the body offered a new entity, the *billowing body-space entity*, as in Latour's example of the gunman (Latour, 2005). This new entity only emerged when all the actors were in action, or rather in interaction.

Figure 1. Front view of the textile designer exploring the nylon fabric.

Figure 2. Back view of the textile designer exploring the nylon fabric.

Figure 3a. Annotations of the spatiality of the nylon fabric: individual explorations.

Figure 3b. Annotations of the sequence of the nylon fabric: individual exploration.

As explained by Storni, ‘ANT acknowledges the ability to act (to provoke change or make a difference) to both humans (H) and non-humans (NH)’ (Storni, 2015, p.169). OT suggested an idea for applying this material based on its temporary spatial qualities: ‘This fabric could be interesting for things that move, like cars, because it creates space when it moves, and when it does not, it disappears. Also, for houses, as they do not need to be full if you are not there. It could be an attachment to houses, as an extra space that inflates when the wind blows.’ OT’s suggestion of applying the nylon fabric to things that move resonates with the Aeolian project (2004) by artist Jessica Ling Findley, an artistic initiative that gathers people together to cycle around cities with a sort of lightweight garment that inflates when cyclists move, creating inflated sculptures. ST saw the potential for choreographing the entrance of a store, where the street door is situated, as a way to create a temporary, soft, pop-up space.

For future explorations, I suggested that exploring with larger pieces of textiles collectively would allow the soft embodied spaces to grow in scale. Finally, OT argued that ‘if architecture is designed for many, the action of exploring the possibilities for textile architecture on the body should equally be explored collectively’. The participants’ reflections show that thinking through the material and the body – that is, letting the material and the body guide your thinking and being aware of non-human agencies such as the wind – fosters a spatial experience from which to think of potential applications for soft embodied architectural design.

Following this, S1, S2 and P1 joined us to carry out a group exploration with the nylon fabric. More layers of the nylon fabric were used to create a larger textile to interact with; some of us attached the material to our ankles through the elastic strips while others held them with their hands. The results, as Figures 4, 5 and 6 shows, offered a less defined soft space when compared to the individual explorations, as there were more people involved in the activity, acting intuitively at the same time. This shows how the collaborative engagement with the material established a process of negotiation between us and the material, offering a set of entities that also shows how the set of relationships was distributed across the bodies, the lightweight materiality and how wind shaped the resulting soft embodied spatial expressions. Concave and convex volumes emerged as we walked together, similar to the ones identified in the individual explorations of the nylon fabric.

Figure 4. Participants exploring several layers of the nylon fabric.

Figure 5. Participants exploring several layers of the nylon fabric.

Figure 6. Participants exploring several layers of the nylon fabric.

Figure 7. Annotations of the nylon fabric: group explorations.

The group exploration helped to increase the scale and to raise awareness of how the different arrangements of the fabric on the body would have an impact on the shapes of the temporary soft embodied space. A more symmetrical arrangement on the body would have produced a more regular outcome, as in the case of the individual explorations in which the material was attached almost symmetrically to both arms and legs.

The explorations with the nylon fabric resulted in a meaningful understanding of the relation between the material, the body and the context, connecting the creation of volumes to the body movement and the flow of air of the context. Each of the shapes of the nylon fabric contains traces of the body, as the movements of the hands, arms and legs influence how the textile moves, wrinkles or unfolds. At the same time the wind intervenes in this action by blowing the textile to different degrees. Experiencing the material in a bodily way allowed us to gain an immediate understanding of the qualities of the material in relation to the space that emerged from the interaction, thus helping to prompt creative ideas for possible future soft embodied architectural design applications.

3.3 The spatiality of a netting fabric

The explorations with the netting fabric revealed the possibility of devising a space based not only on the immediate space around the body but also on the context. In this case elements in the park, such as trees. As soon as I interacted with the mesh netting fabric, I realised that it was rather heavy, and I suggested using bamboo sticks to ease the interaction with this material. The transparency of the netting fabric mediated the relationship between the body and the context, helping the participant to ideate a space beyond the limits of the material. This mediation was afforded by connecting the directionality of the angles created by the body and the bamboo sticks with the line of trees. Figure 9 gives a sense of how that extended space is perceived from the inside of the textile, and how the level of transparency differs depending on the angle of the fabric. This difference in the transparency shows that the extended space is not always perceived while someone moves inside the fabric. The experience of interacting with the netting fabric is thus transitional, and affects the perception of interior and exterior participants. As pointed out by OT, the perception from the interior was influenced by the black lines (Figure 8) of the netting fabric: ‘they guide you into this mesh of transparency, when the lines go perpendicular or you try

THE SPATIALITY OF A NETTING FABRIC

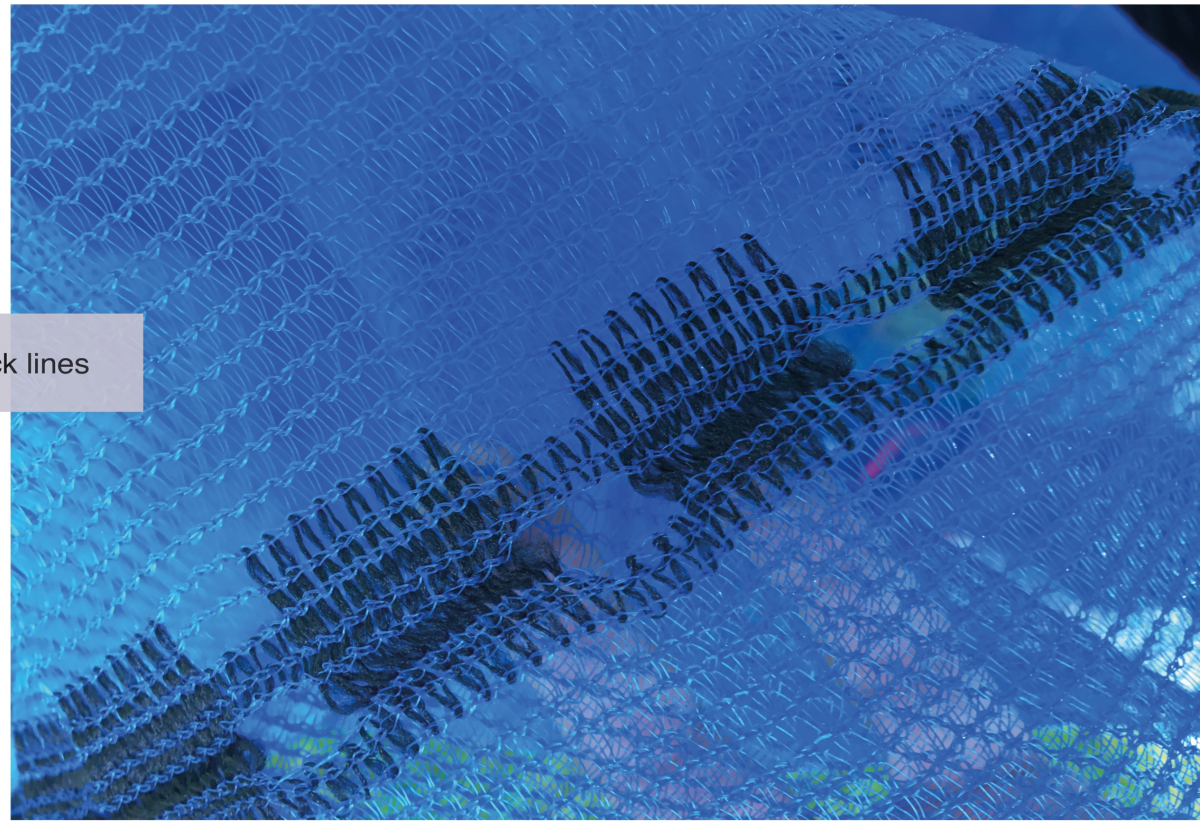


Figure 8. Detail of the netting fabric.

Figure 9. The transparency of the netting fabric.

Figure 10. Annotations of the nylon fabric: group explorations.

to create compositions with them. That is the moment when you feel that you are inside something'. This shifting sequence between one direction and another provides a sense of directional orientation as each layer of the fabric folds and unfolds (Figure 11). OT pointed out how the black lines also helped to create this sense of direction: 'from the inside, the layering process created a gradient of transparency, from very clear to almost opaque'. In contrast, from the outside, the action of opening and closing up the netting fabric resembles origami shapes (Figures 13 and 14). In Figure 12, ST explores how the pliability of the netting fabric allows the creation of opening and closing transitions. ST said: 'the fabric can be extremely opened; you can work with the pleats and folds of the fabric to make it closed'. Figure 12 shows how this opening-closing transition evokes a soft envelope shape.

The set of relationships distributed across all the actors – the netting fabric, the bamboo sticks and the body – offers a new entity, *the foldable body-space entity*. Such an entity unfolds the possibility of devising an extended space from the inside while creates origami-like from the outside. The agency of the netting fabric, manifested through its materiality, transparency, heaviness and pliability – the agency of the body and the sticks operating as an extension of the body, and the trees of the park – created a complex conglomerate of agencies (Yaneva, 2009) that allowed participants to shape their thinking and create meaning out of the embodied explorations (Tomico and Wilde, 2015; Hummels, Overbeeke and Klooster, 2007).

When we interacted in groups of two (Figure 16), the foldable body-space entity gained in scale. The directionality of the netting fabric's black lines and the angles created by the folded netting body-space entity created larger, origami-like expressions. As Figure 17 shows, ST and I intuitively established a bodily dialogue in order to interact both with the material and with each other. In doing so, we also extended the possibility of ideating a larger space. The transparency of the netting fabric, together with the space generated between ST and me, allowed us to envision a larger space as more trees appeared within the soft space around us.

3.4 The spatiality of a spandex Lycra fabric

The individual explorations with the spandex Lycra fabric revealed a transparent transitional quality mediated by the elasticity of the fabric. By pushing the elastic fabric outwards, the surface became gradually transparent. OT mentioned: 'just by putting

Figure 11. Interaction design researcher exploring the netting fabric.

Figure 12. Embodied interaction designer exploring the netting fabric.

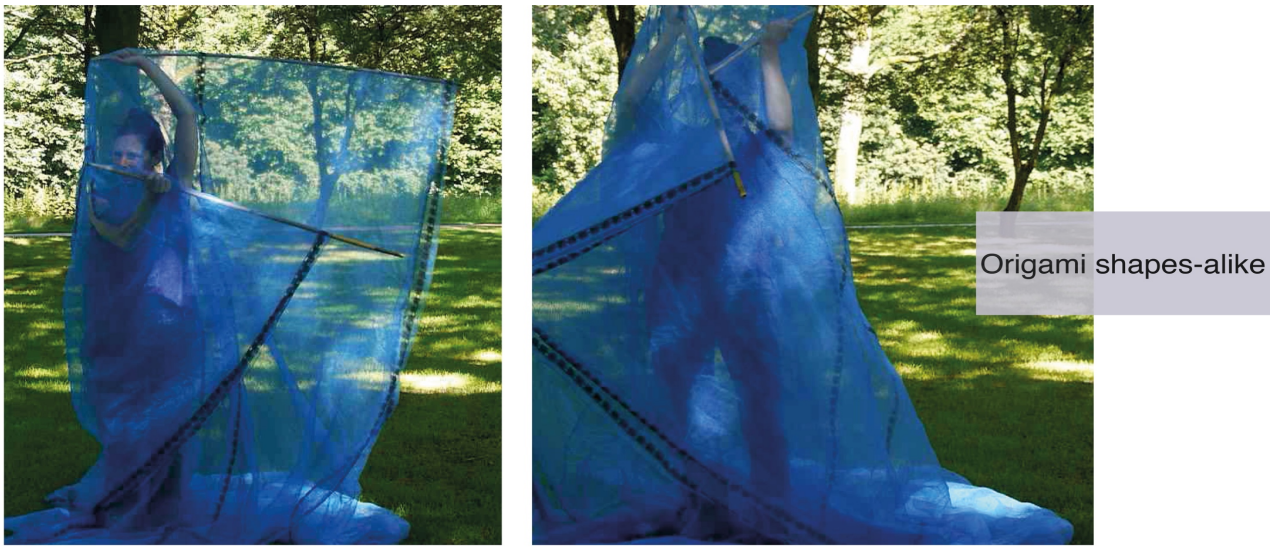


Figure 13 and 14. Embodied interaction designer exploring the netting fabric.

Figure 15. Annotations of the netting fabric: individual explorations.

Figure 16. Embodied interaction designer and textile designer exploring the netting fabric.

Figure 17. Embodied interaction designer and textile designer exploring the netting fabric.

Figure 18. Annotations of the netting fabric: group explorations.

your hands on it you create dark and light'. He further mentioned: 'It is like you are shaping the light of a space' (Figures 20 and 21). Close to this idea of shaping the light of a space, Wilde and colleagues explored the potential of relating the moving body to the creation of space. They did that through a wearable device that projected light beams, creating an extended visual space around the body. In this sense, both experiments allow participants to acquire a bodily and spatial sense through the light. (Wilde, Cassinelli and Zerroug, 2012).

In relation to the transitional state between the spandex Lycra fabric and the creation of space, ST pointed out: 'by opening my arms, I create a kind of a dome. The stretchiness and the tension of the material give that spatial experience' (Figure 19). In relation to OT's and ST's comments, I suggest that the relationship between the textile, the body and the context becomes graspable, as the elasticity of the elastic fabric operates as an enabler – as in the concept of the 'scripts' coined by Latour – for the body to push it, allowing the body, in turn, to personalise the outside. Such relational logic gave room to a new entity, the soft deformable body-space entity.

Figures 23 and 24 show a collaborative embodied exploration in which S1, S2 and ST interact inside the spandex Lycra textile. By pushing the textile upwards, they could explore the amount of light that passed through it and thus decide how much outside space they would like to see (Figure 24). OT suggested that 'this material could be interesting to create a soft, deformable roof or window, that could be personalised to control the amount of light or how much of the outside one would like to see.

Analysis of the results

Three soft body space entities emerged out of the embodied explorations that hold different spatial qualities. Each of these offers opportunities for ideating a soft space based on body-material interactions. The first enables the experience of what it is like to inhabit a soft volume in motion – how the textile behaves when interacting with the body and the context. The second shows how the subtlety of a transparent textile allows the person to devise an extended space that is inside and outside at the same time.

Figure 19. Embodied interaction designer exploring the spandex Lycra fabric.

Figure 20. Detail of the action of pushing the spandex Lycra fabric upwards.

Transitions of material transparency

Figure 21. Detail of the action of pushing the spandex Lycra fabric upwards.

Figure 22. Annotations of the spandex Lycra fabric: individual and group explorations.

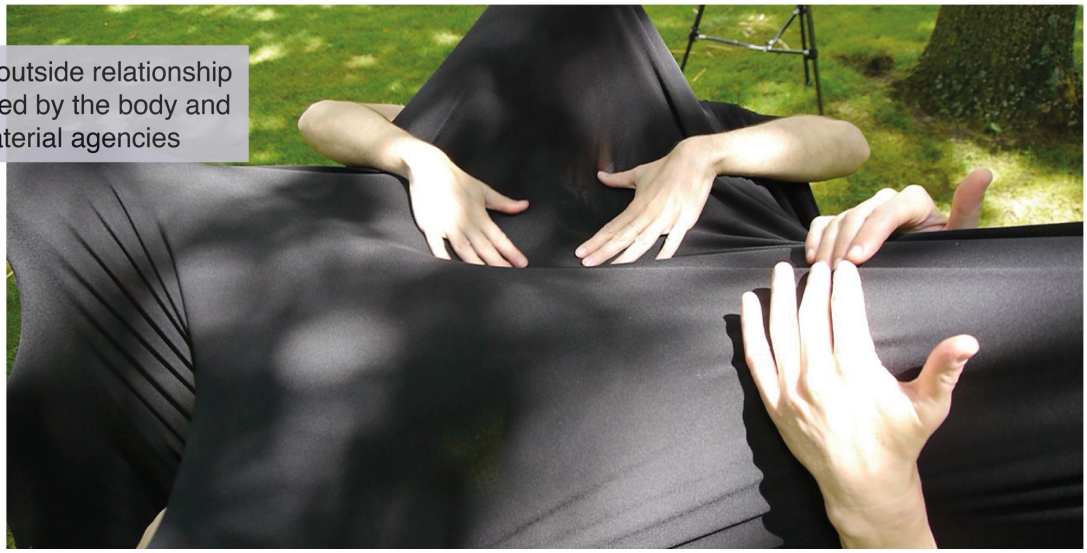


Figure 23. Top view of participants exploring the spandex Lycra fabric.

Figure 24. Inside view of participants exploring the spandex Lycra fabric.

Figure 25. Front view of participants exploring the spandex Lycra fabric.

Figure 26. Annotations of the spandex Lycra fabric: group explorations.

The last one relies on the concept of a transitory state in relation to the elasticity of the textile, allowing the participant to shape the amount of light and room taken up by stretching the textile. In a similar way, Wilde and colleagues proposed a bodily way of thinking about the relationship between body and space through laser beams. By means of three wearable light systems, the wearers could connect their body, imagination and the environment in an experiential way (Wilde, Cassinelli and Zerroug, 2012, p.987).

Three spatial qualities were identified for each of the body-space entities: the spatiality of billowing soft spaces, the spatiality of folding soft spaces and the spatiality of deformable soft spaces. Table 3 summarises the dynamic and spatial qualities of each of the three soft body-space entities:

EXPERIMENT 1: WHEN DOES A TEXTILE BECOME SPACE?			
Main findings	**THE SPATIALITY OF A NYLON FABRIC** It enables the experience of bodily enacting a soft volume in motion.	**THE SPATIALITY OF A NETTING FABRIC** It shows how the subtlety of a netting fabric allows the user to devise a space based on the context and its elements.	**THE SPATIALITY OF A SPANDEX LYCRA FABRIC** It allows the user to shape the light and personalise the space by stretching out the textile.
Dynamic Qualities	Lightweight > Volumes	Foldability > Inside-outside transitions	Stretchability > Gradient of transparency
Spatial Qualities	Soft space in motion	Extended space	Deformable space

Table 3. The spatiality of the soft body-space entities.

Three main findings were identified that are common to the three embodied outputs: the billowing body-space entity, the deformable body-space entity and the foldable body-space entity.

1) Form-space relationship

The relationship between form and space emerges from the interaction between the agencies of the body, the material and the elements of the context (wind, trees and light). Space and its form are simultaneously experienced and created. The form is not imposed by an abstract idea or concept but emerges as a consequence of ideating a soft space through the body. Form and experience go hand in hand, revealing distinct appearances and nuances. In the spatiality of billowing soft spaces, the relationship between form and space is more ephemeral than in the other two cases, the spatiality of deformable soft

spaces and the spatiality of foldable soft spaces. At the moment that the body stops moving, the lightweight polyester falls down. In contrast, in the spatiality of folding soft spaces and the spatiality of deforming soft spaces, the space remains steady, even if the body is not in movement.

2) Spatial transitions

The embodied explorations with the three materials offered a sequence of spatial transitions mediated by the agency of each of the fabrics. Such transitions – from flat fabric to volumes in motion, soft envelopes and deformable spaces, allowed a re-thinking of the concept of a soft and embodied space towards a more temporary and personalised one. Temporary because the soft space only becomes visible through the interaction between the body, the context and the material. Personalised, because the combination of the agency of the body, the material and the context unfold dynamic qualities such as volumes in motion, gradients of transparency or spatial directionalities that enable participants to shape the space according to their needs or desires.

3) Constraints and opportunities

In all three cases, the agency of the body, the agency of the material and the agency of the context offered new soft body-space entities that operate as enablers and disablers of certain actions (Latour, 2005; Yaneva, 2009; Storni, 2015) offering specific dynamic and spatial qualities. Thus the embodied explorations enabled participants to identify constraints and opportunities that would have been difficult to identify without interacting in a situated way with the body and the material (Tomico and Wilde, 2015).

The three-soft body-space entities described in this experiment provide a dynamic, embodied and temporary engagement with soft spaces, as identified in the works of Schillig (2015) and Pišteková (2017). The three body-space entities bring this engagement further by introducing the agencies of material, body and context as material for design. Approaching soft embodied architecture from an ANT perspective helps to make explicit the relationship between the actors and to frame meaningful connections that might be useful to inform the design of a soft embodied architecture (Table 2). Considering the embodied explorations with the nylon fabric, what would it mean from an ANT perspective to interact with a space that constantly moves? How would that shape our actions as users of that space? Maybe it would prompt us to circulate differently, to behave in a more contemplative way or interact with others in

a more personalised way; for instance, in the case of the netting fabric, the transparency of the netting fabric would allow us to bodily frame an extended space by the interaction with other users.

The three soft body-space entities that emerged from the body-material interactions showed that the relationship distributed across all the actors (material, body and context) as enablers and disablers, is relevant to provide insights for ideating a soft embodied architecture. The body plays an important role, as it becomes a tool to design and to reflect (Overbeeke, Kees C. J.; Hummels, 2011).

3.5 The transformative nature of a soft embodied approach to architectural design

Common to all of the three soft body-space entities is their temporary aspect. Vallgårda reflects on the temporary form of a responsive space and argues that this temporal aspect relates to the amount of time needed in order to 'experience its temporal patterns unfolding'. Such temporal patterns relate to the changes in shape of this responsive space. In a similar way, the three soft body-space entities described in this chapter hold these temporal qualities, updating the spatial perception of the participants through each of the volumes, folds and deformation of the fabrics.

The three soft body-space entities challenge the notion of architecture as something that is static and permanent. Latour and Yaneva (2008) move away from the definition of a building as a static Euclidian space that is reduced to a drawing, preferring instead the dynamics of a lived space that is in continuous transformation. According to them, in doing so architecture could move away from the dualistic approach of differentiating between subjects and objects and contribute to a theory of architecture in which the relationships between the material, the tools, the context and the architect are taken into consideration in the design of a building.

Concluding remarks

In this chapter I have investigated a textile becomes space from an embodied perspective. As a result, three different soft body-space entities emerged, offering three dynamic spatial qualities: the spatiality of billowing soft spaces, the spatiality of folding soft spaces and the spatiality of deformable soft spaces. Based on participants' reflections I analysed the main findings through annotated portfolios and

discussed them from an ANT perspective. The results suggest that a textile material becomes space when the body, the material and the elements of the context are interacting with each other, offering temporary soft embodied spatial entities. By taking an ANT perspective on the embodied ideation process, I was able to elaborate on the agency of the different actors and make explicit the set of associations that allow the spatial soft body-space entity to exist. The set of associations – like the elastic-transparency sequence that enabled participants to adjust the amount of light of the deformable soft body-space entity – not only contributes to the ideation of a temporary soft space but also fosters a relational thinking that arises from the experience and expands to other issues such as the relationship between form, space and the interaction between the participants. The soft body-space entities question the traditional concept of textile architecture depicted in the tensile membranes and, pave the way for a more relational, soft, embodied and dynamic understanding of this.

The following chapter describes the collaborative project with architect Daniel Suarez in which we investigated how the use of motion capture technology could connect the embodied explorations with the digital realm. The collaborative project focused on the design of a physical-digital toolset in order to expand the design possibilities of the previously identified soft body-space entities.

Chapter Four. Soft Embodied Geometries: bridging physical and digital realms[7]

This chapter describes the first of the two collaborative experiments I carried out with architect Daniel Suarez (Chapters 4 and 6). The experiment aimed to investigate how the soft embodied approach to architectural design introduced earlier could be developed further into the digital realm. Specifically, it focused on capturing the nuanced expressions of a new set of body-material interactions carried out in collaboration with dancers Petras Lisauskas, Judita Šečkutė, Julija Mintautė and Viktorija Bobinaitė from the Lithuanian Academy of Music and Theatre. The aim of the experiment was to explore the design of a digital tool set based on motion capture technology to expand the design possibilities for ideating a soft embodied architectural design.

4.1 How can the design possibilities of soft embodied architecture be expanded through motion capture technology?

Motion capture (mo-cap) technology enables the scanning of environments and their elements. This technology can be achieved by means of magnetic, acoustic and optical sensors (Hirschberg et al., 2006). From the optical tracking systems available, Microsoft's Kinect camera is commonly used by designers and architects because of its versatility in terms of connecting with different design software. The Kinect camera is a marker-less depth camera that operates via software capturing environments, objects and body gestures. It can be used as a real-time camera for interactive installations, as seen in *NO THING: analog digital world* (2015) by Milla & Partner communication agency, or *Fearful symmetry* (2012) by architect Ruairi Glynn. The Kinect camera can also be used as a 3D scanner for capturing architectural models (Bravo, Chaltiel and Carazas, 2018) or as a tool for supporting the design of augmented reality applications (Kyan et al., 2015).

Salazar defines mo-cap technology as a process of 'mapping, a passing from one domain of movement (live) to another (digital) via a process of codification' (Salazar Sutil, 2015, p.introduction). Salazar understands this technology as a language to represent movement in which the brain and the body are not two separate things. Salazar states that the process of moving 'digitally' combines abstract and concrete data:

[7] Text partially adapted from Castán and Suárez (2017).

> We move in thought and body, in software and hardware, and therefore the language machines we can come up with must generate new possibilities of movement representation that no longer carve up thought and body into separate domains. (Salazar Sutil, 2015, p.introduction)

This definition implies that the captured data is not a mere translation process from physical data into digital data but rather a new way to visualise movement, with its own particularities. Therefore, mo-cap technology is not only a way of capturing an action but a way of recording computationally, as new material is generated in the digital realm.

The use of mot-cap technologies in architectural design has attracted significant interest in recent decades. According to Hirschberg and colleagues, motion tracking technology has potential for three areas of architectural design: 'form generation, spatial analysis and gestural interaction with spatial environments' (Urs et al., n.d., p.115). Form generation refers to the act of freezing a captured movement to analyse its form; spatial analysis focuses on understanding how people move through spaces and use such knowledge to inform future architectural designs, and gestural interaction with spatial environments uses real time data to enhance people's interaction with spaces, becoming an interface that reacts to users' behaviour.

Architects and designers use mo-cap technology to capture body gestures for the purpose of generating architectural forms (Urs et al., n.d.; Stathopoulou, 2011), or to capture behavioural patterns such the circulation of the human body in space for its later analysis, form generation and fabrication process (Kalantari, Poustinchi and Ahmadi, 2016). The work of Pacher takes a performative approach to architecture and proposes the concept of working with our sense of movement and its ability to affect how space is perceived and enacted by actions of the body. Using Kinect sensors, Pacher developed a mobile application that allows the user to use his or her actions as inputs to influence the design of space in real time (Pacher, 2014). In a multidisciplinary design context, architects have collaborated extensively with dancers and choreographers to translate movement into notation systems through analogue-digital workflows. In doing so, the design of an architectural form or spatial arrangement is often materialised through rigid and static prototypes (Kato and Glynn, 2018). Architect and dancer Chryssa Varna uses dance notations to create a

choreography for designing kinetic architecture based on the use of robots and paper fans as responsive devices, offering a new spatial design language (Varna, 2013). This potential of the body to express and to sketch forms in space has been widely investigated by choreographers and architects respectively as a way to inform their design processes (Stathopoulou, 2011); Forsythe, Choreographic Objects, n.d.).

The works mentioned above shares the use of body gestures to inform the design of a space or an object, but it does not contemplate tracking other physical things such as materials. Elsewhere, in the field of fine art there are some examples of interactive art that make use of the Kinect camera to produce tangible interactive installations that combine different tools such as media projectors and sound devices with physical materials such as textile membranes. An example of this is the 'Firewall' project (Sherwood and Allison, 2012), a soft and elastic interface that reacts to body pressure by triggering sound and producing an alteration of the pattern that is projected onto the soft membrane. The Kinect camera was used to measure the depth of the textile membrane and send the data to the actuators. When users pushed it out, a change in the pattern and the sound was activated. Building on this idea of combining tangible materials with digital tools, this experiment used the Kinect camera to capture a series of body-material interactions in the physical realm and map them out in the digital. In this way, the textiles would expand the movement of the bodies and make their trajectory visible, capturing the resulting temporary soft body-space entities. The aim was to explore the spatial and formal implications of the captured soft body-space entities within the digital realm.

4.2 Bridging physical and digital realms: setup of the experiment

Two fabrics that are similar to the three previously used in Experiment 1 were selected for the second experiment of this thesis: a nylon fabric (Figure 27) and an elastic polyamide fabric (Figure 28). The nylon fabric differed in colour while the elastic polyamide was thicker, opaque and less elastic than the spandex Lycra fabric. The reason for choosing a different elastic fabric for this exploration was the constraints of the Kinect camera. Highly transparent materials were more difficult to capture, so we abandoned the use of the netting fabric for this second experiment. The context of this second experiment also differed from the first one. Although the most recent

Figure 27. Nylon fabric.

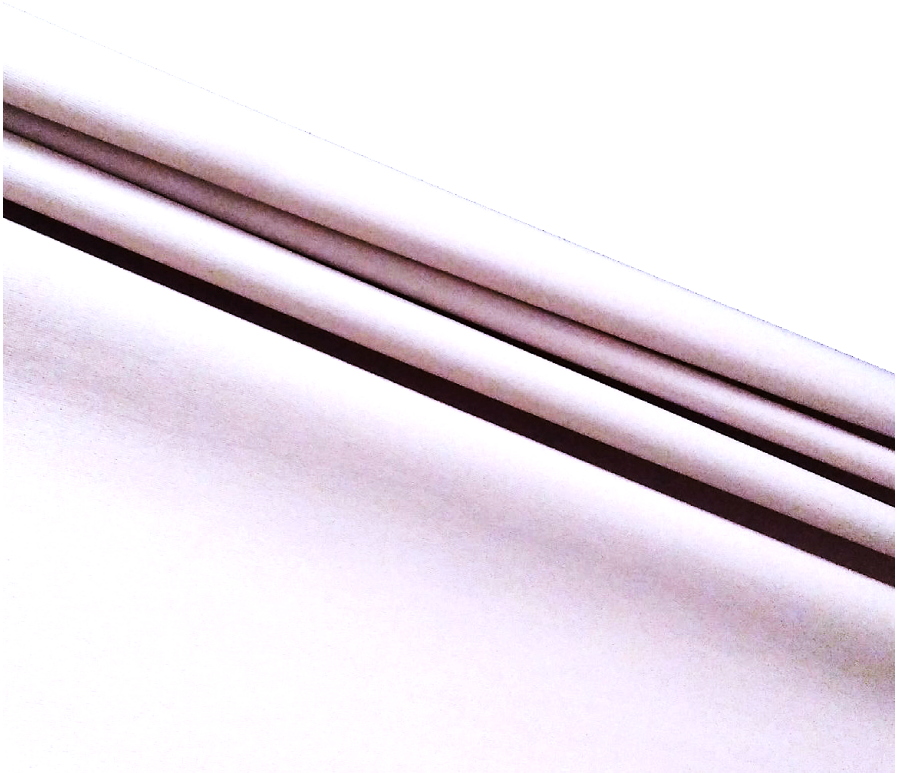


Figure 28. Polyamide fabric.

generation of Kinect cameras can perform outdoors, indoor conditions – where the amount of light can be controlled – worked best for capturing the texture of soft materials. Therefore, we placed a green screen in our studio at Vilnius Art Academy so that the Kinect camera could read the movements precisely. We set up a motion capture toolset that consisted of a Kinect camera, Brekel point cloud software[8] and a procedural animation software, SideFX Houdini[9]. Brekel software transforms the data captured by the Kinect into motion point cloud sequences and enables the viewing of the transitions between movements. Houdini software was used to explore and develop further the point cloud data obtained from the Brekel software. Both software programmes offered us an accessible and convenient environment in which to easily explore the dynamic data captured from the embodied explorations.

We first ran several tests to ensure the digital toolset was suitable for our purpose, and to understand its design possibilities. Since the goal of this second experiment was to come up with a suitable digital toolset to support the embodied explorations, we deliberately decided to focus on the functionality of the digital toolset. Therefore, basic body-material interactions were carried out to test the digital toolset and move forward into the next experiment (Chapter 5). I explored both the nylon fabric and the elastic polyamide by improvising simple movements (Figures 29 and 32 respectively). We tried out different distances and time durations of the body-material interactions to identify the best conditions for the later explorations with the dancers. We realised that the data we captured was too heavy in terms of information and we decided to focus on short sequences.

4.3 Mapping out soft embodied spatial expressions into digital geometries

Petras Lisauskas (PL), Judita Šečkutė (JS), Julija Mintautė (JM), Viktorija Bobinaitė (VB) were invited to perform intuitively with the nylon fabric and the elastic polyamide. We mapped out how the textile, as a formless material, was shaped by the interaction with the body in movement. As experts on body movement, they performed expressive movements that we captured and explored through the digital toolset. In this way, we could alternate between first person and second person perspectives to better support our reflections (Smeenk, Tomico and Turnhout, 2016).

[8] https://brekel.com/
[9] https://www.sidefx.com/

THE BILLOWING BODY-SPACE ENTITY

Figure 29. MC interacting with the nylon fabric.

Figure 30. JM interacting with the nylon fabric.

Figure 31a. Annotations of the billowing body-space entity.

We did not provide the dancers with any rules, except that they must move within the four-metre area required by the Kinect camera. Having previously experienced the elastic spandex Lycra fabric, as explained in Chapter 3, I realised it was hard to interact with its elastic qualities without having a more supported attachment to the body. Consequently, both edges of the elastic polyamide were folded and sewn, creating a pocket on each edge of the fabric so that the fabric could be fixed to the shoulders, elbows or heads of the dancers.

We agreed with the dancers on an introduction session and a mo-cap session. During the introduction session we showed them the materials and encouraged them to try out different movements and positions on the body. From the beginning, two of the dancers started to interact with each other through the elastic polyamide while the other two explored the nylon black fabric individually. In this way, the roles of each of the dancers with the material unfolded organically. After this first session, we met again to capture the final explorations with both fabrics. We recorded a total of five explorations, one with two of the dancers interacting with the elastic polyamide and two more explorations for each of the other two dancers who explored both the nylon fabric and the elastic polyamide individually. Dancers were not asked to perform individually or as a group. They decided not to perform as a group with the nylon fabric.

Figure 30 shows a moment of JM interacting with the nylon fabric. As mentioned in the previous chapter, the interaction between the body and this material expanded it to a soft volume around the body, producing a soft billowing body-space entity (Figure 31a). The agency of the nylon fabric was evident by being blown up when the interaction with the body shaped the way JM moved (Figure 31b). The context of the explorations with dancers PL, JS, JM, VB differed from those in the first experiment (Chapter 3). Although the wind was not present in this case, the dancers performed energetic movements with the nylon fabric, creating enough of a flow air for the fabric to billow up. PL mentioned that he noticed that each material's behaviour was different: when stretching out the nylon fabric it barely wrinkled, whereas the elastic polyamide tended to produce more wrinkled surfaces. The nylon fabric offered a smooth, flat surface while the elastic polyamide showed a more irregular, textured aspect. The dancers mentioned that performing with a textile attached to them made them move differently, as if they were not interacting with it.

Figure 31b. Annotations of the sequence of the dancers' exploration with the nylon fabric.

At the same time, the body activated the spatial qualities of textiles in a form-giving process that resulted in a new soft body-space entity. This interplay between the agency of the material and the agency of the bodies enabled the creation of dynamic soft spaces on and around the body. Figure 33 shows two of the dancers interacting with the elastic polyamide. A new soft spatial entity emerged as all the actors interacted with each other. From the outside a particular play of shapes unfolded as the dancers moved inside in a process of negotiation between the textile, the bodies and the space around them. While they were inside, the dancers observed that they could not see outside, reducing the spatial experience to the interaction between the two bodies, mediated through the textile. The agency of the elastic polyamide, demonstrated through the tension of the material when pulled out by the dancers, influenced their body movements, giving room to a soft deformable body-space entity.

Figures 31a, 31b, 34a, 34b, 41 and, 43 show the main annotations of both the billowing and deformable body-space entities and their explorative digital design process. Figure 35 shows the digital toolset set-up, comprising the Kinect camera and two laptops, to visualise two modes of the real-time digital capture. Figure 36 shows the raw point cloud of the deformable body-space entity captured by the Brekel software. We called this raw point cloud a *skin geometry*, since it shows a closer interaction between the material and the body. The digital skin geometry showed potential in exploring the formal aspects of its surface. Figure 36, 37, 38 and 39 show the process of transforming the raw point cloud of a tiny particle of the skin structure into a surface density retopology, which is an optimisation of the surface of a geometry. Once the volume of the surface was defined, we were able to explore different strategies in terms of surface organisation in order to achieve its optimal condition. We used several surface parameters, such hexagons (Figure 40) to gradually find a final geometry in which a mesh optimisation was achieved by means of circular distribution. A mesh is a digital technique that allows the definition of the parameters of a surface. By capturing the soft deformable body-space entity, we were able to visualise its digital equivalent, the skin geometry and explore their implications. In this way, the soft deformable body-space entity produced irregular, wrinkled textures that in the digital realm allowed us to explore its surface density. In contrast, the raw point cloud of the soft billowing body-space entity showed a more

THE DEFORMABLE BODY-SPACE ENTITY

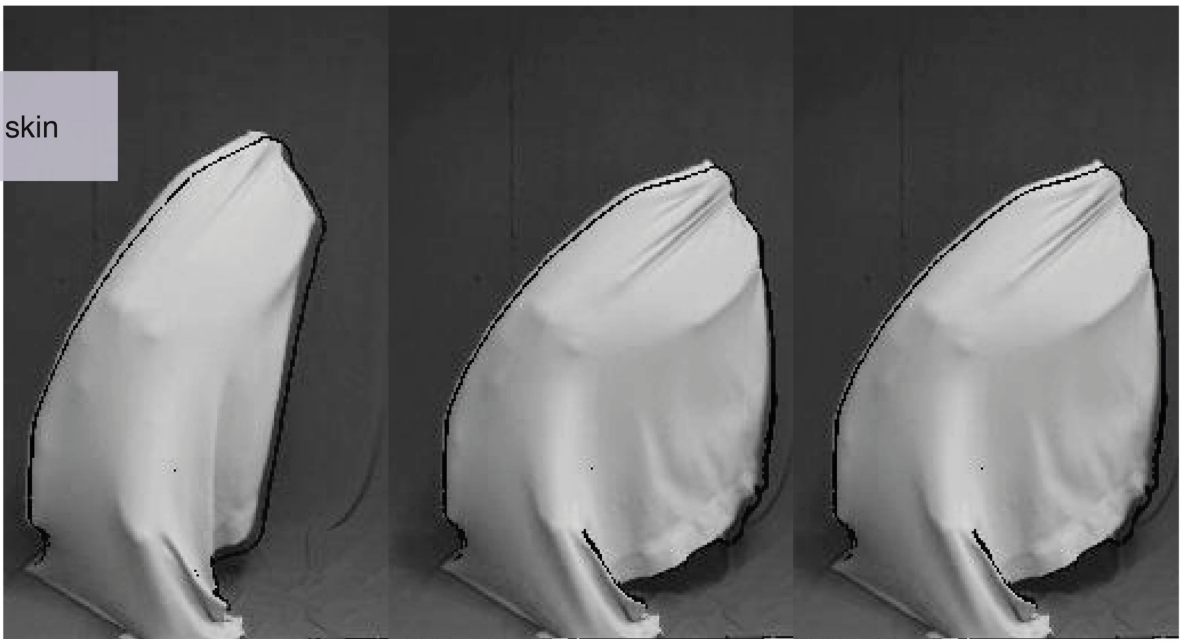


Figure 32. Me interacting with the elastic polyamide fabric.

Figure 33. Two dancers interacting with the elastic polyamide fabric.

Figure 34a. Annotations of the deformable body-space entity.

Figure 34b. Annotations of the sequence of the dancers' exploration with the Polyamide fabric.

Figure 35. Digital toolset, consisting of a Kinect camera and two computers.

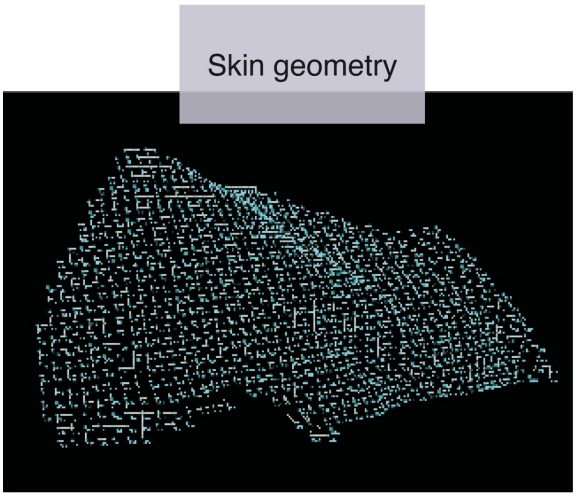


Figure 36. Point cloud mesh decimation.

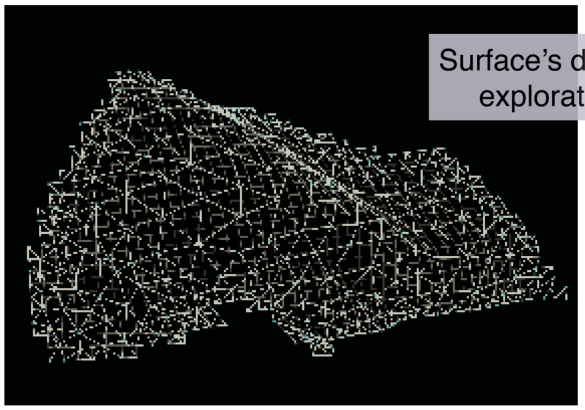


Figure 37. Parametrised mesh with new scattered points.

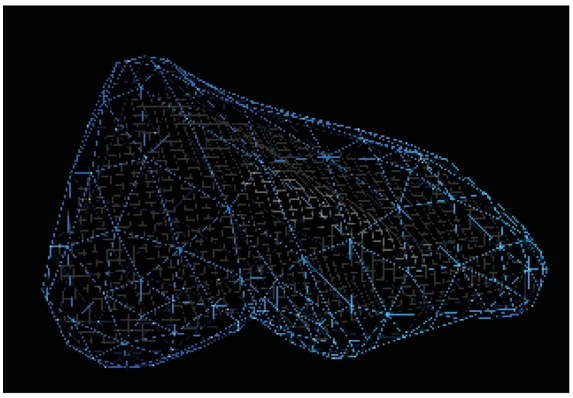


Figure 38. Volumetric modelling process.

Figure 39. Topology strategy using hexagons.

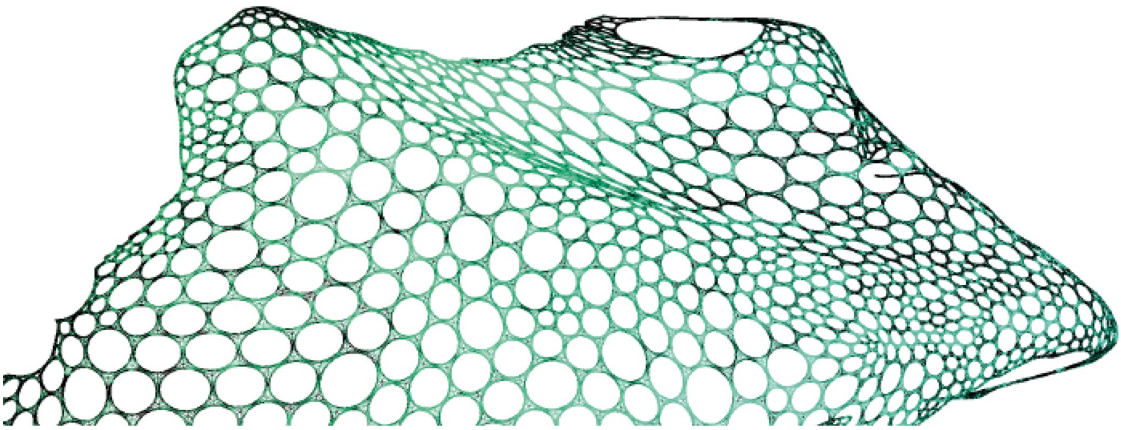


Figure 40.Surface retopology.

Figure 41. Annotations of the digital process of the skin geometry.

detached interaction between the material and the body, which we called *shell geometry*. The shell geometry offered the potential for exploring its volumetric qualities. In this way, we applied a different strategy to approach the explorative digital process. We first selected a tiny particle of the shell geometry and manipulated it at its near-field volumetric limits. This meant exploring the data that was closer to the limits of the shell geometry's volume. This led us to explore the volume of the geometry and arrive at an optimal volumetric synthesis. Figure 42 shows the evolution of the explorative process from the raw point cloud of the shell structure to its final mesh (top view and front view respectively). This explorative process produced a collection of digital morphologies (Figure 42). A digital morphology is the process of evolution of a form. In this way, we could visualise the optimal condition of the shell geometry.

4.4 Reflections on the explorative digital process

The proposed digital toolset allowed us to map out both the soft deformable and the soft billowing body-space entities and, understand and visualise their spatial particularities in the digital realm. The digital captures embodied the spatial and formal qualities of both entities, suggesting different explorative digital strategies for surface exploration and volume exploration respectively.

Other strategies could have been applied, as modelling software allows architects to explore digital material through different tools and criteria. Our decision regarding which strategy to follow was informed by the specificities of the captured data identified in each of both cases, the skin geometry and the shell geometry. In the same way that the soft deformable body-space entity offered a soft, wrinkled texture, its digital counterpart presented certain surface particularities that suggested exploring its surface in terms of density. This became clear to us as we realised some changes in the soft deformable body-space entity, alternating between a more tensed and less wrinkled and a less tensed and more wrinkled texture. This led us to explore the optimal density of the surface and create a retopology. In contrast, in the case of the soft billowing body-space entity, the resulting shell geometry enabled us to visualise its volume and further explore their volumetric qualities. Both the skin and the shell geometries operated as an extension of the two soft body-space entities, expanding their understanding into the digital realm by offering surface and volumetric insights (Figures 41 and 43). Although these digital insights are clearly

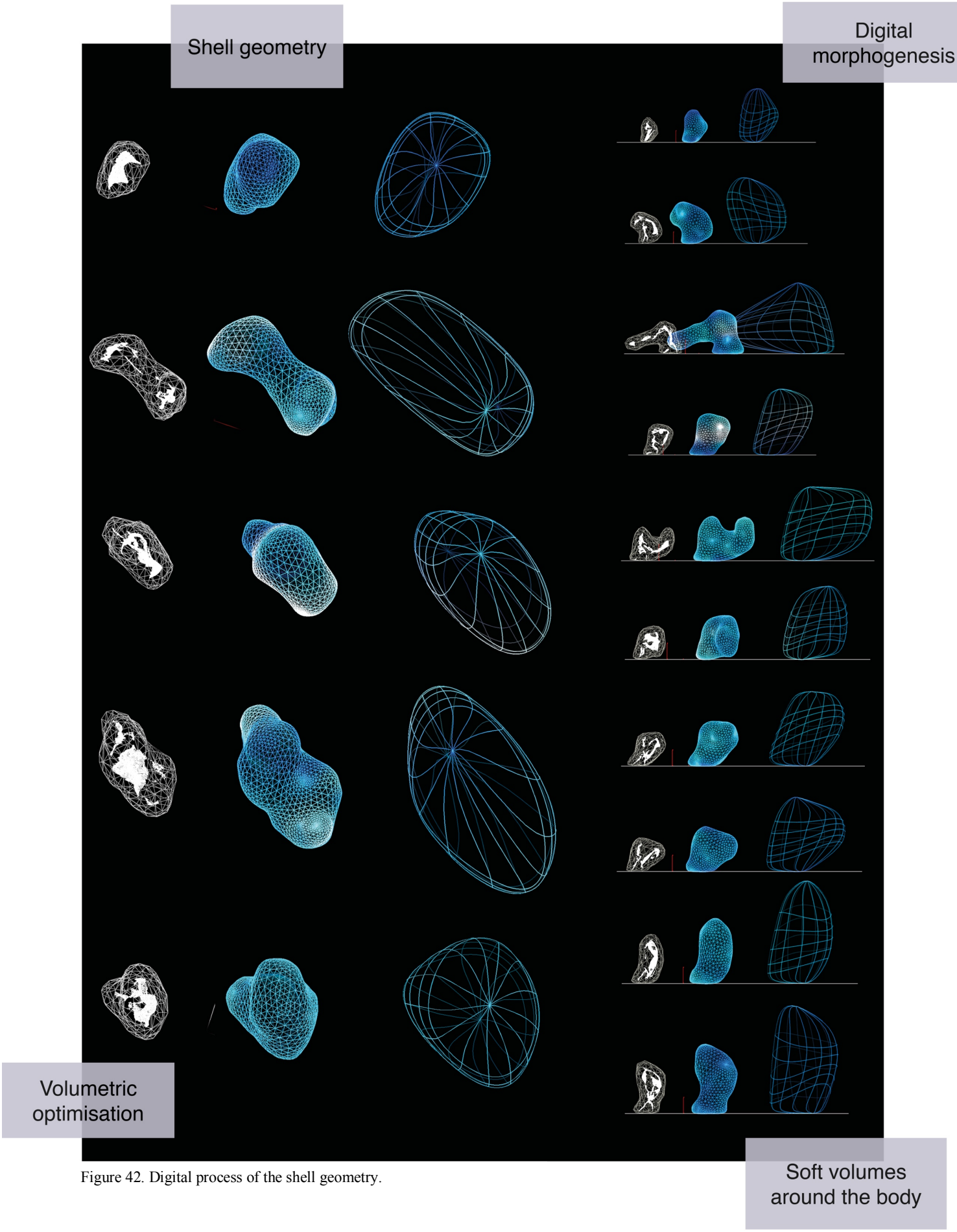


Figure 42. Digital process of the shell geometry.

Figure 43. Annotations of the digital process of the shell geometry.

incipient, and not robust enough to be considered suitable for informing the design of a soft embodied architecture, they show the potential of the digital toolset to connect embodied experiences with their digital equivalent.

4.5 Towards a hybrid EDI process

The resulting soft billowing and deformable body-space entities and their digital captures showed the potential for combining embodied and digital outputs to create a workflow for an organic experimentation between the physical realm and the digital form (Gannon, 2014). This workflow offered a hybrid design process that contributed to a direct experience with the material at the scale of the body and helped to digitally explore spatial and formal aspects that are fundamental to architectural design practice (Muslimin, 2010; Szalapaj, 2005). Projects that use similar hybrid design processes have proved to be successful for designing an architectural form (Stathopoulou, 2011) and to inform robotic fabrication processes (Kato and Glynn, 2018). However, the use of mo-cap technology to capture the dynamic and spatial qualities of soft body-space entities and further explore their design possibilities have received little attention. The hybrid EDI process brings the possibility of ideating temporary soft body-space entities and mapping out them out into the digital realm, offering the chance to explore the connections between embodied and digital outputs.

Concluding remarks

The aim of this chapter was to explore the design of a digital toolset that could expand the design possibilities of two of the three soft body-space entities explored in Chapter 3. In this chapter, I explored the use of mo-cap technology to capture the soft deformable and billowing body-space entities. The digital toolset introduced in this chapter enabled the capturing of such entities and produced two different types of geometries, skin geometry and shell geometry. The exploration of such geometries led to the achievement of optimal digital meshes that could be potentially used to inform a later stage of design development of both the soft deformable and billowing body-space entities. The results of Experiment 2 consisted of embodied and digital outputs, helping to outline a preliminary hybrid EDI process. In the next chapter, I explore with a group of architects the design of a hybrid EDI process suitable for soft architectural design.

Chapter Five

Layering up soft materiality: exploring the design of a hybrid EDI process for soft embodied architectural design'[10]

As part of my second secondment within the ArcInTex network, I spent three months at Heatherwick Studio in London. The purpose of the collaboration was to integrate my research topic into their professional practice in a way that was useful for both parties. We had several meetings before the secondment started to draft out what my role would be within the studio and how we could support each other in developing useful insights for each of our interests. I was assigned to work with one of the teams at the studio. The team was working on a major commission located in the Middle East to realise a public space made out of several courtyards. One of the courtyards was to be designed using textile materials.

The design team asked: how can we design a spatial experience with textiles? I proposed asking instead: how can we design a soft space with the body? I suggested organising a workshop to explore the design of the soft courtyard by applying the hybrid design process described in Chapter 4. The purpose of the workshop was on the one hand to generate design outputs that would inform the design of the courtyard, and on the other to explore with the architects the design of a hybrid EDI process suitable for soft embodied architectural design.

5.1 Embodied design ideation (EDI) workshop: exploring the design of a soft courtyard

The third research question of this investigation is: How can a hybrid EDI process for soft embodied architectural design be designed? To answer this question, I organised a workshop in collaboration with embodied interaction designer Sietske Klooster to explore the ideation of the courtyard alongside the team from Heatherwick Studio. Our dual role, as participants and observers, was to acquire a first-hand knowledge while being able to observe and reflect on what was taking place. As well as the group of architects, participants also included two freelance dancers. Dancers' training in how to interact through the body would bring expressive movements and help the architects to engage with the dynamics of the workshop in a more immediate way.

[10] Text partially adapted from Castan and Tomico (2018)

We first introduced the architects and dancers to the choreography of interaction method. We explained the aims of the dynamics of the workshop, which consisted of improvised interactions with the material and the other participants in an intuitive way; there were no rules about how to explore the different fabrics, except that it should involve their whole bodies. We also showed them a film of a previous workshop in which we used the choreography of interaction method to ideate the design of fashion wearables on the body (Tomico and Wilde, 2015). The reason for showing them a previous workshop example was to provide them with a more explicit understanding of the choreography of interaction method.

The goal of the workshop was to produce concrete embodied and digital outputs that could support the design process of the soft courtyard. We had in mind the particularities of the context of the project: an arid environment with high temperatures, wind and plenty of light. We also used three fans to simulate a windy atmosphere. To situate the action, we imagined the activities that were meant to happen within a courtyard of a high-end hotel. These activities include engaging in a conversation and having tea.

The digital toolset introduced in Chapter 4 was used to map the body-material interactions onto the digital realm. Video cameras were used to record the embodied explorations to be able to identify the transitions between movements. In this way I could select the images that illustrate best these transitions. The architects' reflections were recorded for later transcription and used for the analysis of the results.

Selecting, constructing and setting up the workshop materials

Three different fabrics were chosen to explore the design of the courtyard: a lightweight chiffon fabric, a thick neoprene and a spandex elastic fabric. Each fabric differed from the others in its properties, dimensions, densities and tactile and visual aspects. Sixty metres of chiffon fabric was sewn into a single piece, fifteen metres long and six metres wide (Figure 44).

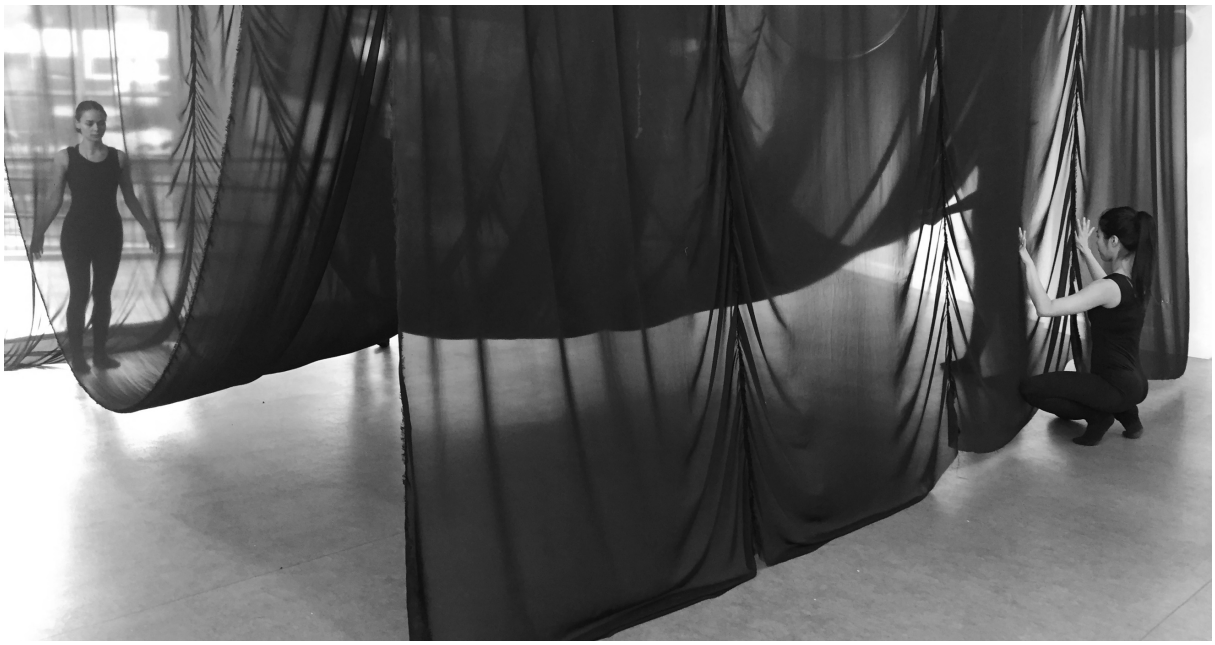


Figure 44. Chiffon fabric.

Figure 45. Neoprene fabric.

Figure 46. Spandex Lycra fabric.

The neoprene fabric was one and a half metres wide, which was very narrow for the collaborative explorations. I decided to sewn two pieces of the fabric into a single piece that was seven metres long and three metres wide (Figure 45). I laser-cut the central part of the neoprene fabric to connect the inside with the outside through auxetic cuts. The auxetic cuts enabled the material to become thicker when stretched. In this way, some of the openings would emerge, enabling participants to interact with the outside and with the other participants. In contrast, the spandex Lycra fabric was used in its standard size, thirty metres long and one metre wide (Figure 46). The spandex fabric is a highly elastic material that would expand significantly when stretched. For this reason, it was not necessary to sew two pieces of the material as it would expand through the interaction with it. The spandex Lycra fabric, when stretched, became semi-transparent, enabling participants to see through the material and to interact with the other participants and with the outside. When considering the material selection, I had in mind the context of the project. The black chiffon fabric was chosen because of its lightweight and elegant appearance, which seemed appropriate for a high-end hotel. The elastic spandex fabric was chosen for its elastic qualities. Based on the previous experiments, this type of material triggered a more active engagement with others. This was something that could be relevant for the soft courtyard as it was intended to be a space for socialising. Finally, the thick neoprene was chosen because its thickness and surface. The thick neoprene works well for creating laser-cut patterns, so I could create certain openings that would bring more possibilities for interaction between participants. This selection of material and sizes offered a wide range of soft materials in a variety of formats.

The workshop was held in a space that had plenty of light and was large enough to carry out the embodied explorations. We took advantage of the beams of the ceiling to arrange the fabrics across the space to facilitate interaction with them. The following section describes the embodied explorations, first with the architects and then with the architects and dancers together. Prior to that, we introduced the choreography of interaction method to the two dancers. The reason for starting the embodied explorations separately was because we considered it would help to achieve better results from the collaborative explorations if the participants were familiar with the choreography of interaction method. The choreography of interaction method consisted of a series of movement-based body-material interactions and reflections on the interactions. This process would eventually lead to the final

embodied design outcomes. Familiarity with the method would allow the participants to focus more on collaborating together during the explorations. The description of the embodied explorations only considers the exploration by the architects and the collaborative explorations by the architects and the dancers together. The outputs of the dancers' embodied explorations were not considered, since the architects were not involved. I deliberately decided not to consider dancers' feedback, as the purpose of this third experiment was to explore with the architects the design of a hybrid EDI process suitable for soft embodied architectural design. The role of the dancers was mainly as facilitators, not only helping to bring in expressive movements to the collaborative explorations but also to provide inspiration for the architects in terms of interacting with their bodies and the material.

5.2 Activating soft spaces through body-material interactions

The dynamics of the workshop were based on reflection-on-action processes (Schön, 1983) in which we asked participants to focus on three aspects:

1) To explore the qualities of the materials through their bodies.
2) To use these qualities to interact with others and the actual space.
3) To ideate a soft courtyard based on the two previous points.

The lightweight body-space entity

The first exploration by the architects with the chiffon fabric involved them in expanding the fabric to different points within the room. The architects started exploring the fabric from the outside, looking at the soft space that was being created, focusing on its dimension (Figure 47). Towards the end of the exploration, the architects gathered together by 'layering up' the material and wrapping it around their bodies (Figure 48). Figures 49 and 52 show the annotations of the embodied explorations with the chiffon fabric. The action of layering up afforded by the interaction between the material, the bodies and the beams made visible the relationships between human and non-human agencies. The beams supported the fabric, mediating the interaction between the fabric and the participants by helping to generate a certain tension. In turn, the chiffon fabric mediated participants' relationship between inside and outside as they navigated around layers of transparency. At the same time, the bodies influenced each other. For instance, during the exploration with the dancers the architects were keener on exploring the

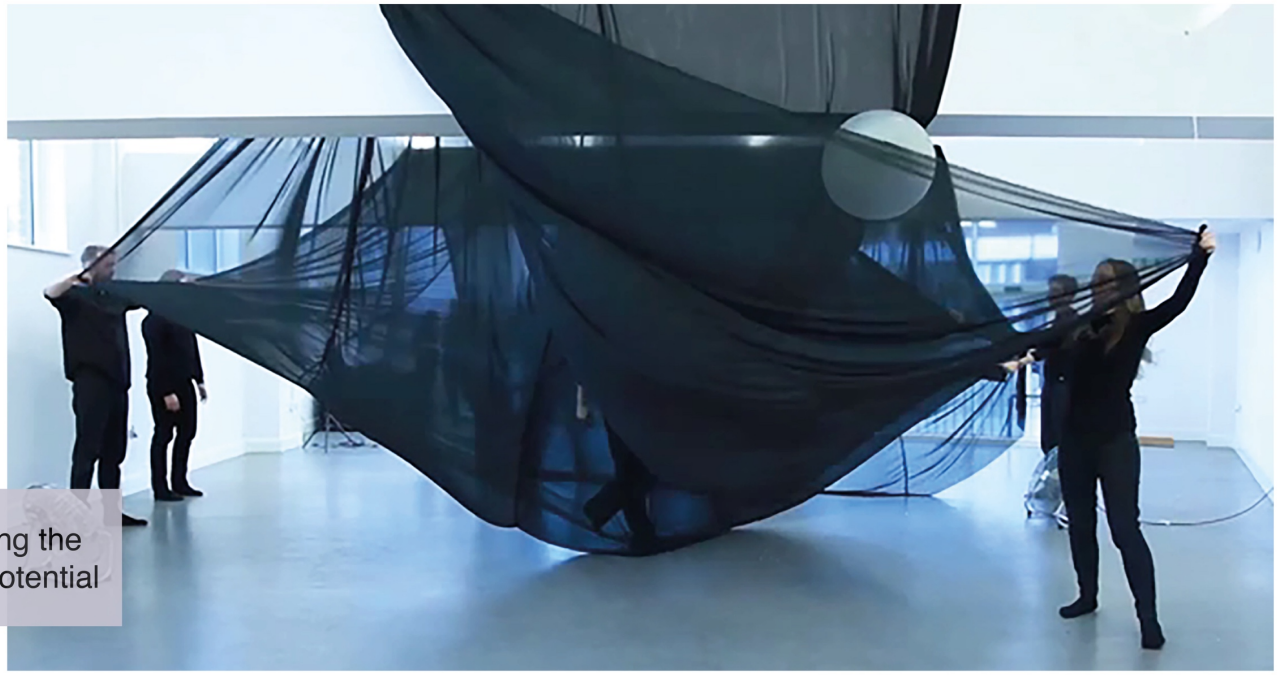


Figure 47. Architects exploring the chiffon fabric.

Figure 48. Architects layering up the chiffon fabric.

Figure 49. Annotations of the lightweight body-space entity.

Figure 50. Tunnel arrangement.

Figure 51. Architects billowing up the chiffon fabric.

Figure 52. Annotations of the lightweight body-space entity.

inside space of the chiffon fabric than expanding the fabric towards the walls of the space. The layering up of the chiffon fabric produced a soft lightweight body-space entity, creating tunnel arrangements, buoyant atmospheres and sequences of material transparency-opacity (Figures 50 and 51).

Architects' reflections

Architects' reflections on the chiffon fabric highlighted the texture and the expression of the material. A1 said: 'The grain of the material, it is a light material, it moves beautifully'. A2 commented: 'With the black fabric you can slide and, rolling out, there is more flexibility, you are more involved in the atmosphere'. A3 mentioned: 'You are more aware of the other people who were moving in the chiffon fabric'. A4 pointed out: 'Having a twisting motion immediately changed the tension of the fabric, felt quite a different environment'. A5 said: 'I was wrapping myself, I kind of felt the idea of going from big gestures to the smallest movements to appreciate the surface and other details'. A1, A2, A3, A4 and A5's reflections show how the embodied explorations enabled them to appreciate not only the texture, the touch and the appearance of the chiffon fabric but also how the material shaped the interaction with others and the space.

The foldable body-space entity

The first reaction of the architects when interacting with the neoprene fabric was to pull out its edges and try to expand the fabric across the room (Figure 53). Figures 55 and 58 show the annotations of the embodied explorations with the neoprene fabric. The agency of the beams in relation to the agency of the neoprene fabric helped to create tension in the fabric, holding the bodies in a certain way (Figure 53). Such a combination of agencies resulted in a soft expanded space, in which some of the bodies were suspended whereas others were pulling out the fabric (Figure 53). In a later exploration, Sietske Klooster and I joined the architects and dancers and I suggested moving inside of the neoprene fabric to explore other ways of interaction. More subtle movements resulted from this interior exploration in which folds and openings were generated across the fabric (Figure 54). In the first exploration with the neoprene fabric, the tension generated from the interaction between the beams, the fabric and the bodies held a soft space together, producing a soft body-space entity. In contrast, in the second exploration, the soft body-space entity was manifested through the creation of folds. These folds emerged as the agencies of

Figure 53. Architects exploring the neoprene fabric.

Figure 54. Architects and dancers interacting with the neoprene fabric.

Figure 55. Annotations of the foldable body-space entity.

Figure 56. Auxetic openings of the neoprene fabric.

Figure 57. Detail of the dancer interacting through the openings of the fabric.

Figure 58. Annotations of the foldable body-space entity.

each of the actors were distributed through multiple interactions, resulting in the creation of spaces inside spaces (Figures 56 and 57).

Architects' reflections

When reflecting on the neoprene fabric, the architects mentioned that the lack of material limited the possibility of exploring different configurations when interacting with the material. A1 said: The pink was more limited' [...] 'It was a more introvert experience'. A2 pointed out: 'It does not allow you to explore the material as well as in the black one'. From A2's reflection, I advise that when collectively ideating a soft space through the body using fabrics, it is important to ensure there is plenty of material so that the embodied explorations are not limited by this. A3 mentioned: 'you can put folds into the fabric and be away from the material to create a form that has more rigidity'. A4 said: I felt really enclosed and comforting, it is a kind of space within a space'. The interaction with the neoprene fabric offered the architects the possibility of creating and visualising shapes since the material revealed the quality of holding a shape. According to A1 and A4's comments, I suggest that the spatial perception that resulted from the interaction with the neoprene fabric became more intimate.

The stretchable body-space entity

The architects engaged immediately with the elastic qualities of the spandex Lycra fabric. Figures 61 and 63 show the annotations of the embodied explorations with this fabric. The relationship between the agency of the material, the bodies and the beams manifested in the tension of the material that varied depending on how much the material was stretched by participants. Multiple human and non-human agencies were evident through the interaction between the body, the material and the context: the tension of the beams; the slippery quality of the floor that enabled the architects and dancers to drag their bodies around; the weight of the bodies that operated as a counterbalance for the other bodies. These multiple agencies produced a playful interaction that resulted in a dynamic soft space (Figure 59), making a strong physical involvement of the architects and dancers visible (Figure 60). The set of relationships that emerged out of all the actors' agencies produced a stretchable body-space entity. This entity alternated between standing-up and sitting-down spatial configurations, creating cocoon shapes (Figure 62).

THE STRETCHABLE BODY-SPACE ENTITY

Figure 59. Architects and dancers exploring the spandex Lycra fabric.

Figure 60. Architects and dancers exploring the spandex Lycra fabric.

Figure 61. Annotations of the stretchable body-space entity.

Figure 62. Architects and dancers exploring the spandex Lycra fabric.

Figure 63. Annotations of the foldable body-space entity.

Architects' reflections

Architects highlighted the following specific aspects of the interaction that happened when bodily exploring the spandex Lycra fabric. A1 said: '[...] it is difficult to stretch, to put two bodies together so that kind of pushes you to a very individual move and again pushes you more towards the materiality and yourself but while feeling the tension of others'. A2 added: 'The elasticity is what it makes it interesting' [...] 'It invites you to many different activities. It is a playful material that allows you to invent new positions and risk a bit more than with the other textiles'. A5 said: 'Here you can play a little bit, trying to interfere in others'. According to the architects' feedback, the dynamic quality of the stretchable body-space entity to expand and tense would be suitable for creating a playful and dynamic relationship between users and the space.

Embodied outputs

The final explorations with the three fabrics resulted in three embodied outputs: the lightweight body-space entity, the foldable body-space entity and the stretchable body-space entity. These three entities showed how the interaction between all the actors' agencies was made explicit by the action of layering up soft materials around the bodies, the beams and through the floor. Figure 64 illustrates a soft enclosed space, mediating the relationship between inside and outside through layers of transparent material. Figure 65 shows a spatial configuration in which several layers of material are overlapped, giving room to one shared elastic space. Figure 66 reveals spaces inside spaces through folds of material. The three soft body-space entities resulted in specific spatial configurations as the agencies of all actors unfolded through a set of relationships (body-material, body-body, body-material-context) that held them together (Yaneva, 2009).

Digital Outputs

Figures 67a and 67b show the raw material captured with the Kinect camera (original mesh, right side) reconstructed as a processed Polymesh (left side). By capturing the three soft body-space entities, we obtained a raw geometry. As Figure 67a shows, the original mesh and processed Polymesh captured the texture of the material, displaying the folds of the fabric and its wavy texture. Different densities can be identified across the Polymesh, as shown in Figures 67a and 67b. The digital outputs obtained from this third experiment helped to visualise the particularities of the digital geometries and to open up the discussion of how to design a hybrid EDI process

Figure 64. ‘Layering up’ material transparency.

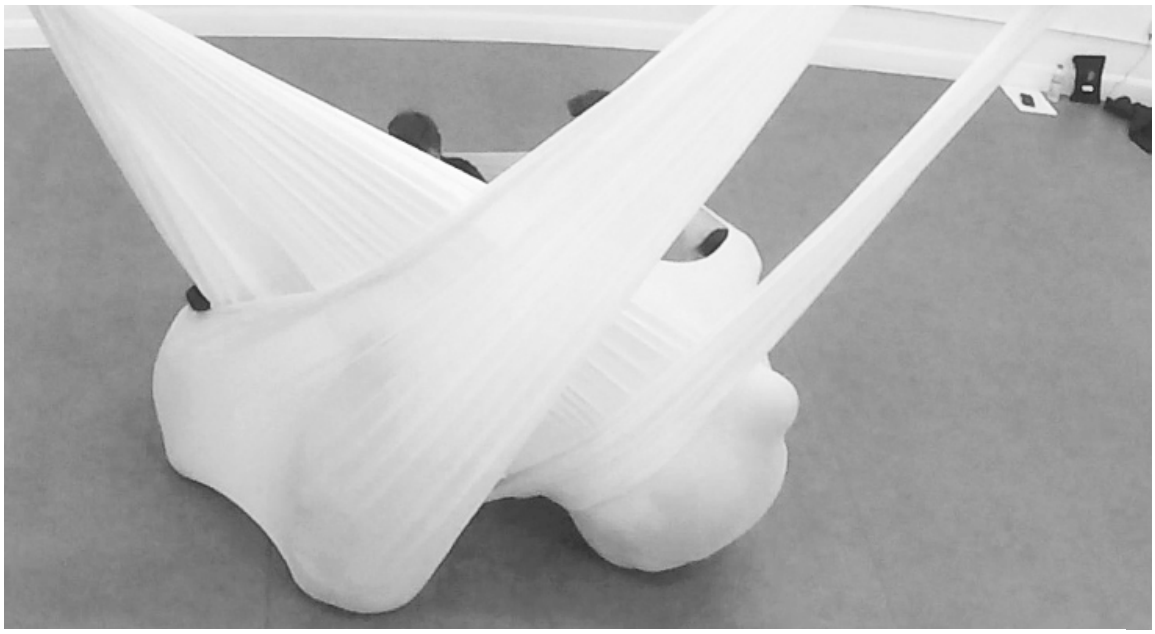


Figure 65. ‘Layering up’ material elasticity.

Figure 66. ‘Layering up’ material foldability.

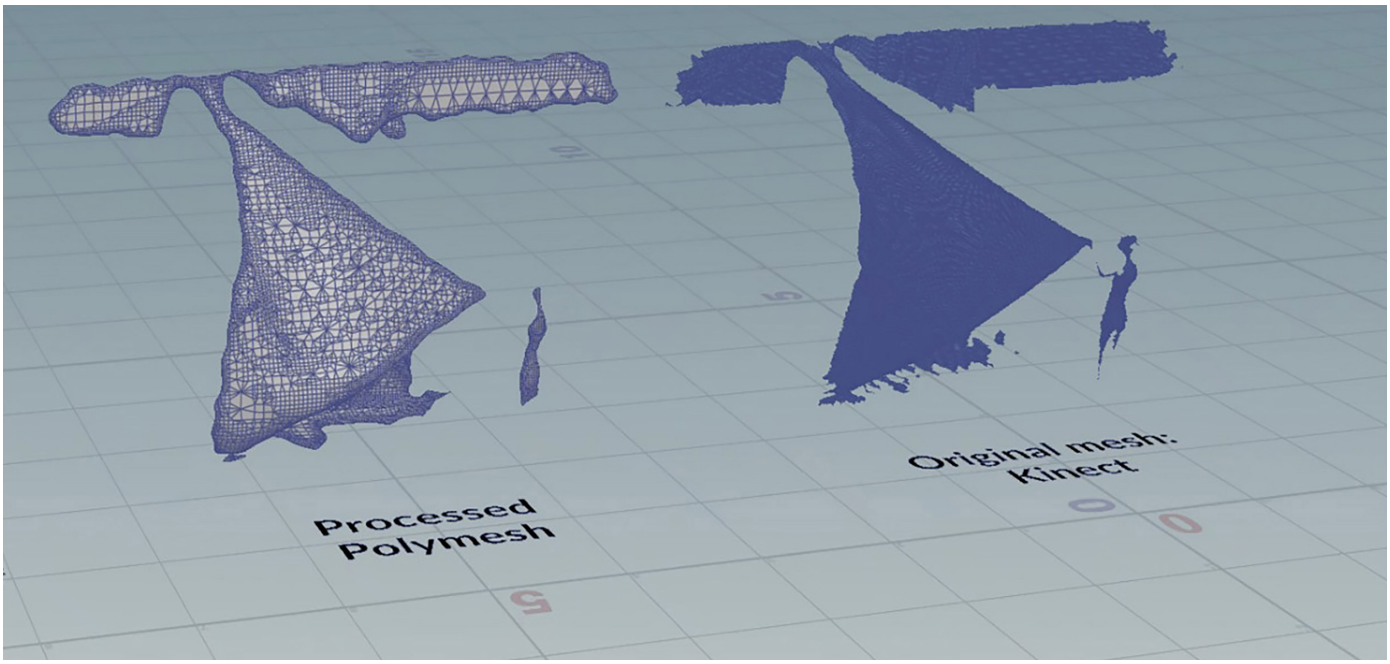


Figure 67a. Raw data captured by the Kinect camera.

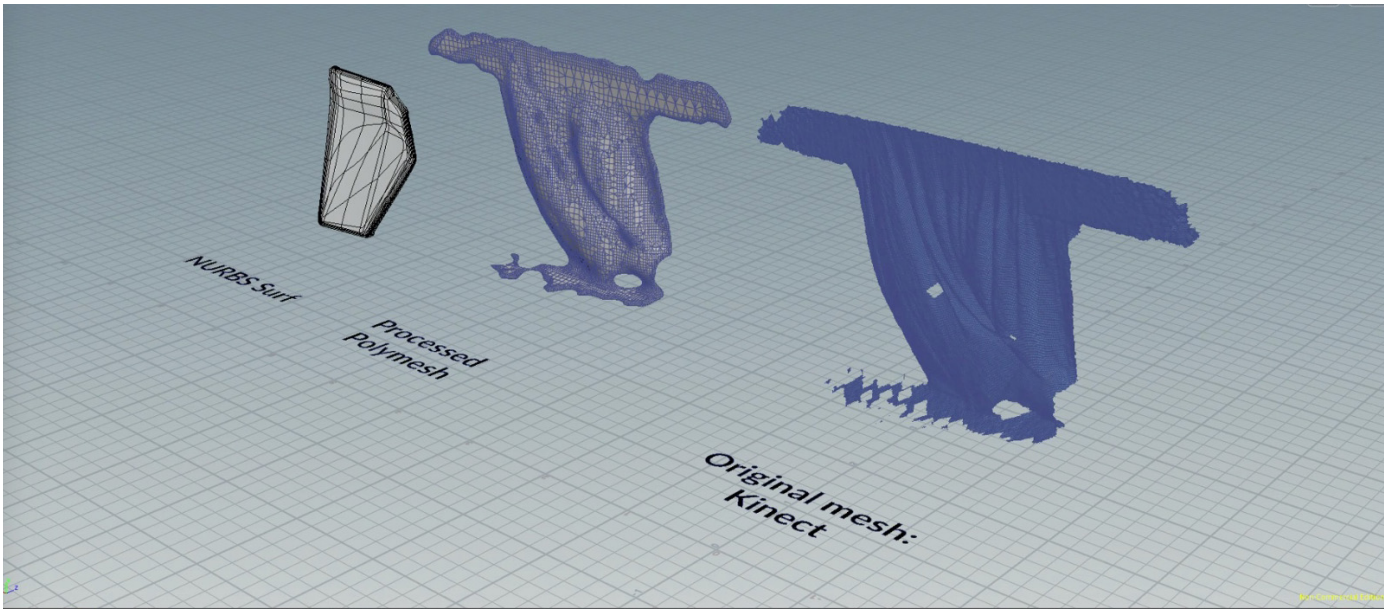


Figure 67b. Raw data captured by the Kinect camera.

suitable for soft embodied architectural design. When discussing the digital captures in order to find out how these could best support the design process of the courtyard, architect A1 said, in relation to the point cloud (Figures 67a and 67b): 'I think part of the interesting bit was the tension of the fabric that you can see in the point cloud. You actually extract the properties of the material in the point cloud'. I first showed A1 the sequences of movement that the Kinect captured, including the raw point cloud, the mesh and the NURBS, which are different 3D models of handling data[11]. Figures 67a and 67b enables an appreciation of the drape of the fabric and how the tension helped to shape the soft space that was being created. When asked about how he would use this material for the design of the courtyard, A1 answered: 'I would extract geometries, to see if there is some sort of relationship between the geometrical properties of the fabric and the experience'.

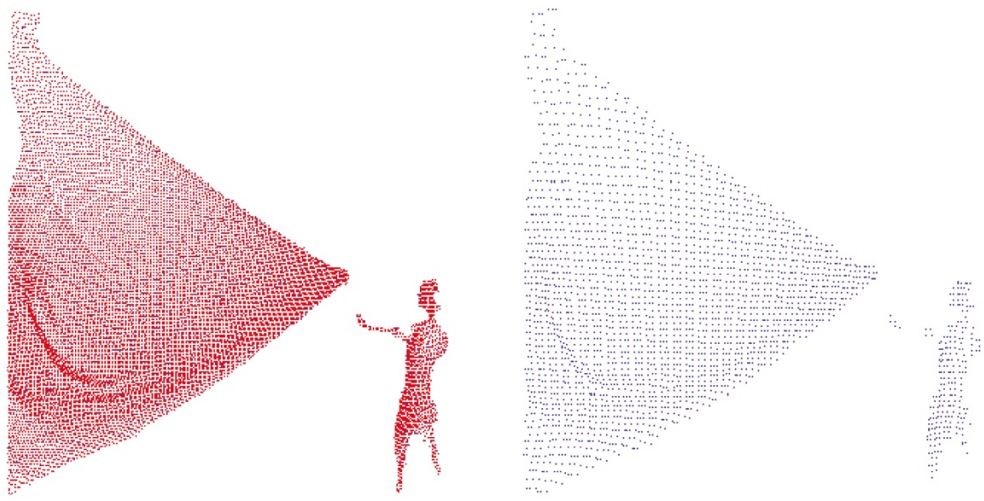
Based on A1's feedback, I would argue that asking the architects to reflect first during the embodied explorations and afterwards on the digital outputs enabled them to identify relevant connections between the two realms in a very intuitive yet concrete way. The feedback provided by A1 suggests an exploration of the potential of connecting embodied and digital outputs and paves the way for the articulation of a hybrid EDI process.

5.3 Combining embodied and digital outputs

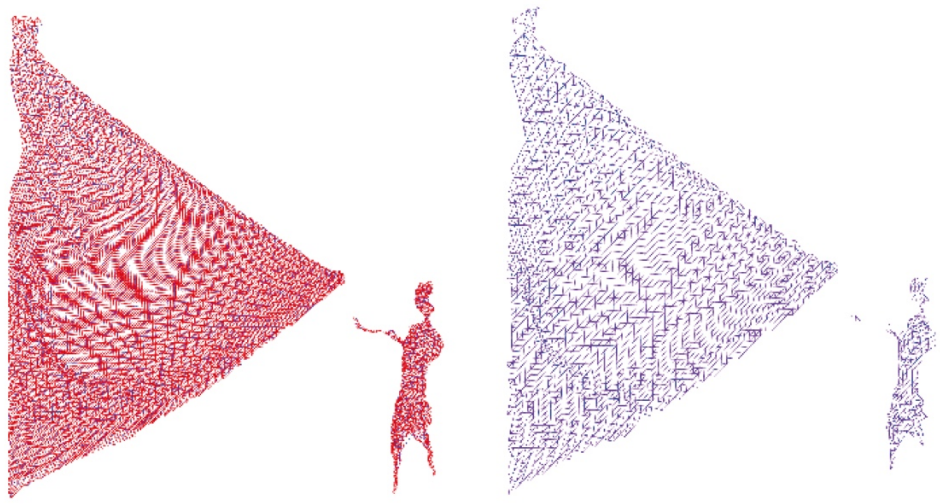
Following A1's suggestions, I aimed to connect the embodied experience with the digital geometry. I selected the sequences of the layering up of the chiffon fabric based on the architects' reflections and matched them with the meshes reconstructed from the captures. This information was organised in a diagram (Figure 68) to discuss the results. The diagram shows a selection of three key moments, Stills 1, 2 and 3, identified according to the architects' reflections. The diagram focuses on understanding how the tension and the drape of the fabric are mapped out into the geometry. In order to make explicit this relationship between experience, geometry and the architects' reflections, I broke down the geometry that corresponds to Stills 2 and 3 into three synthesised geometries through point cloud decimation and mesh reconstruction. The geometric sequences (point cloud and mesh) of Stills 2 and 3 show the change in the tension of the fabric.

[11] Further information can be found in the Appendix section (Glossary)

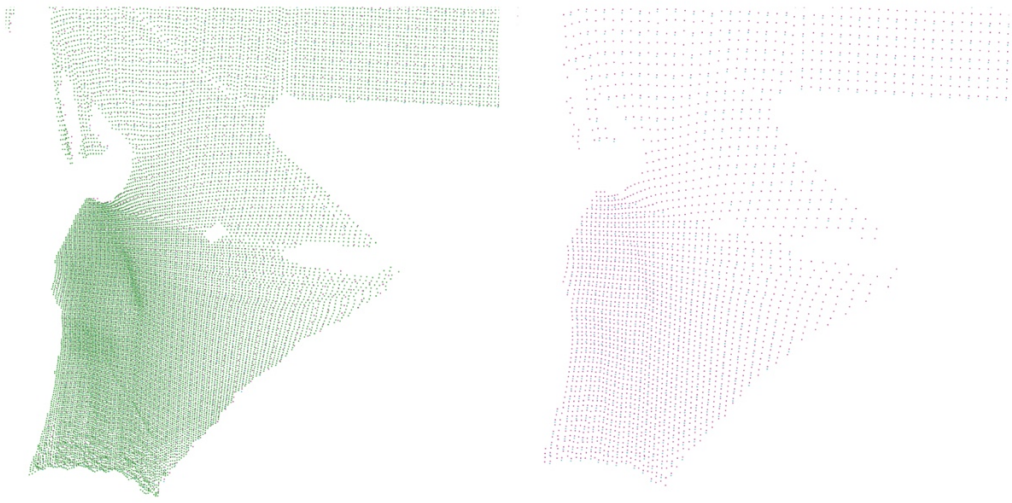
Point cloud decimation | Still 2



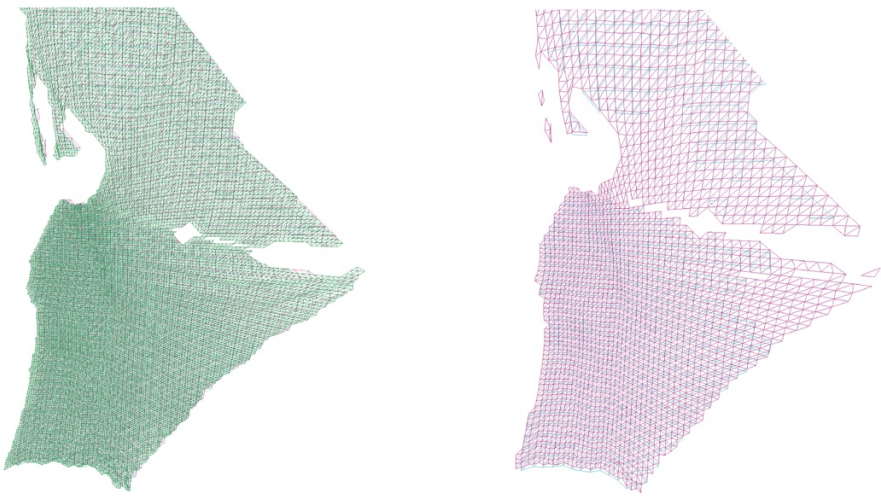
Mesh reconstruction | Still 2



Point cloud decimation | Still 3



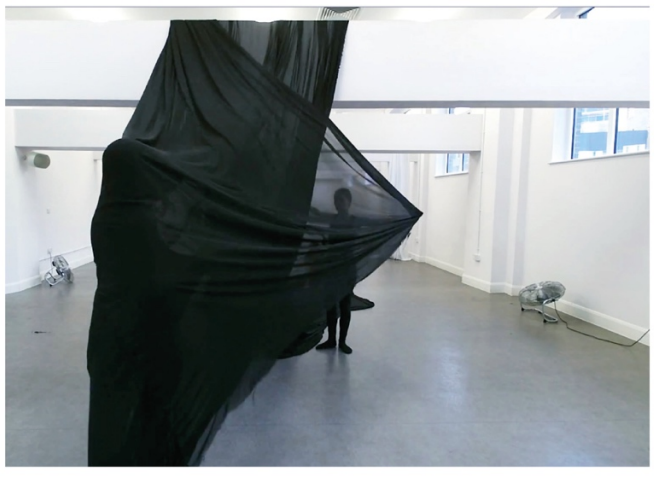
Mesh reconstruction | Still 3



Layering up material transparency

Still 1

Still 2



Still 3

Architects' reflections

Spatiality of textiles	- 'With the black fabric you can slide, and rolling out, there is more flexibility, you are more involved in the atmosphere'	- 'If you reduce the distance between the floor and your eyes the whole thing becomes like a tunnel, you're compressing the whole thing into a more intense experience'	- 'As the dancers were working rhythmically, I felt there was a nice balance, some people doing some things inside and others trying things from the exterior'
Embodied Experience	- 'We started with sitting down, which is a very simple rule and then we started breaking the rule, giving us a more defined role to start manipulating the fabric'	- 'Having a twisting motion immediately changed the tension of the fabric, felt quite different environment'	- 'I continuously felt that I have to step back and hold myself and reflect on the beauty that that was happening'. From the inside was quite messy'

Figure 68. Combining embodied and digital outputs.

The dancer pulled out the edge of the fabric and moved backwards, exerting more tension on the fabric as it was layered up. According to the architects, their experience of this exploration ranged from an atmosphere of involvement (Still 1) followed by a more intense experience as the fabric was compressed into a tunnel shape (Still 2) to a dynamically changing environment through the layering up of the fabric (Still 3). A4 mentioned that the environment changed as a consequence of the shift in the tension of the fabric: 'Having a twisting motion immediately changed the tension of the fabric, felt quite a different environment'.

The different directions of the tension of the fabric modified its drape and texture, alternating between flat and wrinkled surfaces. The more the fabric was layered up, the higher the tension of the fabric became, and the environment shifted into a more intense experience mediated by the number of transparent layers of the fabric. The diagram (Figure 68) connects the shift in the tension of the fabric with the participants' interaction with the material and the context and the architects' feedback. By visualising in one single document the lightweight body-space entity, the architects' feedback and, the geometry, the architects would be able to explore the potential of connecting embodied explorations to the geometry of a temporary soft space.

5.4 Architectural implications

In this section, quotes from the final discussion with the architects during the workshop are used to outline the limitations and opportunities of the hybrid EDI process.

A1 reflected on the exploration with the spandex Lycra fabric, during the which the spandex lycra fabric was intertwined through the beams, supporting the weight of the bodies while participants interacted with it: 'I cannot imagine designing a spatial arrangement just from the fact that the fabric works in tension and not in compression: what will hold the fabric? A1 highlighted the importance of the role of the body as a structure that holds the fabric: 'If you do not have people in the room all the time to hold this, it will fall apart'. A1 also emphasised the architectural limitations that come into play when ideating a soft space through the body*:* 'From the experience we had, there is a lot of information about human interaction but there is very little in terms of how the material works, because it is very limited. You can say one material is stretchier than the others but it depends on a supra structure that actually activates

it'. A1 also added: 'The beams and the smooth floor play a big role'. I suggest that making use of the elements of the context such as the beams and the floor brings in new agencies to the embodied explorations. From a broader perspective, I argue that ideating a space by means of the body helps to quickly identify the limitations and opportunities of the space that is being created and use them to inform future prototyping phases of a soft embodied architectural design.

The most important quality of the textile for architects was its dimensions, as, according to them, it determines how much space the textile can take up. A1 mentioned: 'The most important quality of the fabric for me it is dimension. It is already constraining the way the fabric can span from one side to the other, the way it occupies the space'. This sort of perception of the quality of the fabric determined their later engagement with the material. A1 added: 'The proportion of the fabric determines a lot of things. It is difficult to stretch and put two bodies together so that kind of pushes you to very individual moves and again pushes you more towards the materiality and yourself but while feeling the tension of others'. The dimensions of the fabric, together with the material engagement described by the architects, mediated the resulting embodied experience. A1 said: 'We managed to find a way through a collective setting while being aware of and coordinated by the properties of the material, the stretching and trying to keep it in. That engaged very interesting moments like the one we are in'. In contrast, I, as a textile designer, tended to be drawn first to the tactile and textural qualities of the textile rather than its dimensions. This demonstrates how architects' first reaction to materials is focused more on spatial features than on the particularities of the material itself.

In relation to the opportunities offered, the architects found several aspects of the hybrid EDI process that could bring a new layer of knowledge to architectural design methodology. The embodied interactions with the spandex Lycra fabric prompted ideas for the architects about future applications for soft embodied architectural design. As one A1 said: 'Because of the elasticity I think of a potential scenario in which you have two-storey fabric you pulled in and out, resulting in a morphing space. You use so much space with very little material. You feel the material and you want to stretch it'.

Exploring the spandex Lycra fabric collaboratively at one-to-one scale allowed participants to explore the agency of the material, the context and the bodies in a single, collective experience. This way of exploring with textile materials is very different from the way in which architects usually engage with materials, as A1 pointed out: 'We tend to articulate it in a more structural way. We would make diagrams about the stretchy qualities, how much variation there is, because you are only performing in tension and, you start making diagrams and variables and then you combine these. That is far from experiencing the material directly'. I suggest that the EDI process can help to bring the relationship between architecture and people closer by identifying nuanced and experiential aspects from the bodily interaction with the material.

I argue that in the same way that we need to try on a piece of clothing to understand and decide whether it fits us, we should be able to experience how it feels to interact with a space that is soft, deformable and dynamic. As suggested by A1, experiencing the materiality of textiles becomes relevant for designing a soft embodied space: 'I think the value of this is in the experiential properties we discovered, the transparency, elasticity, also form, all these properties as abstract things could be very rich. It is very interesting how the designer gains an awareness by touching things, you find senses of awareness and this brings another layer to design methodology, I guess'. A1's feedback suggests that the soft embodied explorations offered both experiential and formal insights that are relevant to architectural design. Thus, A1 acknowledges the contribution that the EDI process makes within the broader design methodology.

5.5 Analysis: process, results and opportunities for designing a hybrid EDI process for soft embodied architectural design

To find out how the hybrid EDI process could be suitable for soft embodied architectural design, I interviewed separately each of the architects who took part in the EDI workshop separately. Each architect had a different role within the studio and the project. A1 was the project leader; A2 was one of the architects of the team, working closely with A1. A3 was part of the model-making team for the project. Finally, A5 was the principal technical designer for the project, and he had a more general role within the project rather than actively participating in the design process. A4 was approached, but it was not possible to interview him. Each interview lasted 40 minutes approximately and was conducted face to face.

Set up of the interview

These interviews were carried out one week after the workshop was held, and included a selection of the videos that were recorded during it. The choice of the visual material was reduced to the chiffon fabric and the spandex elastic fabric, as these were the most relevant materials according to the architect's reflections analysed in the previous section. The questions only considered the embodied outcomes, as the digital outcomes were evaluated in a separate interview that will be addressed in section 5.9. Questions 1 to 5 focus on the results of the workshop whereas questions 6 and 7 address the potential of the hybrid EDI process within the broad field of architectural design:

1) What was the main finding of the workshop?
2) Which material was more appropriate in terms of the design of the soft courtyard?
3) What was the main quality that you identified while interacting with the chiffon fabric?
4) How could this quality be used for the design of the soft courtyard?
5) What aspects of the set-up and material selection worked and what did not?
6) How is this approach valuable for architectural design, as opposed to designing with the computer?
7) How did this approach work for you?

Embodied outputs analysis

Voice recording was used during the interviews that were later transcribed. Based on participants' experiences and reflections, the data was analysed to identify the main commonalities and establish the strengths and the shortcomings of the hybrid EDI process (Jones, 1992).

Questions related to the EDI workshop

The answers to the following questions contain a selection of the information provided by the architects.[12] The content that directly answers the question was the one considered and presented here as a direct quote. For the sake of being precise, only these quotes were taken into consideration for conducting the qualitative analysis.

[12] The complete transcription of the interviews with the architects can be consulted in the Appendix section.

1) What was the main finding of the workshop?

A1: 'the spatial expressivity of the fabric, its versatility, the number of things you can do with a piece of fabric just relying on the material properties of a specific textile'.

A2: 'touching the material and creating shapes was quite a very interesting way of form finding'.

A3: 'how amazingly manipulated the fabric was and how quickly the spaces were generated'.

A5: '[...] a kind of change in granularity of understanding perception, the kind of small scale of the fabric worked to the individual enabled to start to make these big movements, we begin to engage with others but not at the size of the whole group, and then we had to step back again'.

For A1, A2 and A3 the most relevant finding was the possibility of quickly creating space and expressive forms by bodily interacting with the soft materials. The workshop offered a fast and adaptable way of prototyping. The fabric's spatial expressivity captured the attention of A3 in a similar way that A5 found small-scale details such as the granularity of the fabric a driver to influence their movements.

2) Which material was more appropriate in terms of the design of the soft courtyard?

A1: 'The black chiffon. It was quite tied to the local culture we are working in [...], it is a very different social landscape and human relations have a lot of transitions and that has to be reflected in the space. The fabric mediated and managed to express this'.

A2: '[...] for a courtyard that is going to express luxury and elegance and sophistication, probably the black chiffon is the most suitable'.

A3: 'The black chiffon. I think the fact the fabric is semi-transparent is crucial because without that you don't see the forms. I think it is absolutely necessary'.

A5: 'For me the black one. And that was to do with scale, so in a room of that size we were able to do a lot more because we could hold it more easily, twisted more easily'.

All architects agreed that the black chiffon was the most appropriate for the design of the courtyard within the cultural context of a high-end hotel. The chiffon fabric brought qualities of transparency, lightness and colour that were more suitable for a space for social interaction within the hotel courtyard. The lightweight body-space entity offered

a more relaxed and contemplative experience, resulting in a better match to the type of activities that were envisaged for the soft courtyard, such as having tea and engaging in conversation with others. A1 and A2 based their answer on the context of the project and the design of the courtyard. Both A1 and A2 acknowledged the local context's particularities. In contrast, A3 and A5 focused on material aspects that could best support the embodied exploration. A3 and A5 identified the transparency and the dimension of the chiffon fabric as the prominent aspects when ideating a soft space by means of the body. A1, A2, A3 and A5 described design values through the chiffon fabric qualities that were relevant during the design process and, according to them, were also suitable for future users of the soft courtyard.

3) What was the main quality that you identified while interacting with the chiffon fabric?

A1: 'It's a combination of things: the transparency, the layering, the drape of the fabric was quite beautiful and really expressive [...] the fact these properties produce layers of transparency... It felt very airy, very easy-going, inviting you to transform it and move it around and stretch it [...] dimension was a very important fact'.

A2: 'I think the material was very permeable, this permeability allowed us to start making all these different configurations and see what was behind and interact with other people. I think this was putting everyone together in a shared way [...] I think that was quite relevant, working with this permeability, putting more layers or less around people'.

A3: 'I think when we were all working together, you suddenly saw the fabric layered up. During the whole process, you noticed when the fabric clusters massively in the middle, you don't necessarily appreciate it, I think it is when we move, when it's really close together it doesn't feel like much – but then suddenly we moved apart again and I think it is those moments when you appreciate it [...] I guess with any other fabric that isn't transparent you wouldn't get that experience'.

A5: 'Flexibility. I was able to stretch legs and arms and there was enough material to expand it. It has to do with thickness as well'.

The transparency of the chiffon fabric in relation to the action of layering up was the main quality identified by A1, A2 and A3. A3 specified a moment in which the transition of the layering up of the chiffon fabric made her aware of the change in the perception of the space. Figures 69 and 70 exemplify such transition. By layering up

the chiffon fabric around their bodies, architects identified a sense of togetherness that relates to the experiential quality of the interaction. This suggests that the agency of the chiffon fabric, manifested in the transparency and lightweight qualities of the fabric, triggered the action of layering up the material by the architects, becoming a lightweight body-space entity.

4) How could this quality be used for the design of the soft courtyard?

A1. 'Possibility of making a very flexible space' [...] 'a flat piece of fabric: it is a very simple principle but it can get really complex: spatial experience, material richness, programmatic and actual use of the space' [...] It pushes you to re-think on a one-to-one scale the possibilities of space, also the limits of the fabric and of the space'. A2. 'I guess it depends on how literal the translation is so you can extract values and qualities of the textiles and then apply them to architecture in an abstract way...or you can take it literally and take the textile itself and create a courtyard with that textile'.

A3. '...it could be in many different ways. If you are looking for patterns, purely for facade details, just pattern generation [...] It is not about 3D generating; it is about the details that you could take as a flat static image and used that to then inform a design process or the beginnings of a design'.

A5. 'I am thinking more of a series of actions that become drivers [...] I am thinking of building a particular vocabulary for a particular design task [...] Not knowing what the results would be, again, you have to engage with the verbs to see what comes out of the other way around rather than doing abstract spatial explorations.

Architects differed in their views of how to use the layering up quality to inform the design of the soft courtyard. Formal, experiential and conceptual insights were identified by all the architects. A3 suggested focusing on formal patterns as a starting point of a design. A2 suggested translating the formal arrangement of the fabric, or alternatively, working on a more abstract way to inform an architectural design. A1 and A5 focused more on the experience and the action of interacting with the material to inspire a vocabulary.

The architects suggested different options for applying the embodied outputs of the workshop into a design methodology. This shows that the workshop was a rich source

Figure 69. Architects creating a cluster with the chiffon fabric.

Figure 70. The cluster fabric being unraveled by the architects.

of inspiration for the architects but it also shows that it was too open to provide a final outcome for the design of the soft courtyard.

5) What aspects of the setup and material selection worked and what did not?

A1. 'The beams played a quite important role [...] many layers that are interacting with each other, mechanical issues, air conditioning, humidity sensors, that will eventually inform the fabric and vice versa [...] say the fabric is the most flexible device to cope with all these differences. In that sense the exercise is quite rich'.

A2. 'I think the 3 setups were quite relevant. They were very different from each other, that allowed us to test different experiences. Probably the black one was the one that I would find more suitable for the case: there are some connotations, it is the one that is more open and relevant to the context'.

A3. 'I think the beams were ideal, having the ability to support a structure. Regarding the second option (the neoprene fabric) it would be nice to have an abundance of fabric as in the black chiffon set-up because I would be interested to see what happens if you have even more'.

A5. 'I was really intrigued about the fan effect, wind generation, coming from the fan, air flow of a particular location [...] the next step would be to go to the Middle East to the hotel rooftop having the natural air flow of a particular location [...] as there are different environmental conditions'.

According to A1, A2, A3 and A5, supportive elements of the set-up such as the beams and the fans had a positive influence during the embodied explorations. A greater amount of material would help to expand the spatial and formal possibilities of the embodied exploration, as suggested by A3. A5 suggested that a new embodied exploration in the local context would advance the ideation design process further. A1 emphasized how the embodied exploration made him realised the ability of the soft material to adapt to the complex environment and the issues that come into play when designing the courtyard.

The architects' feedback emphasises the importance of the context within the design process of ideating a soft space. Ideating in context not only helps to tackle the particularities of what is being designed, but also it can bring a certain newness to the embodied exploration (e.g. the use of the beams was not planned in the first place). Non-human agencies such as the beams and the floor become relevant as they

constrain and afford certain actions. Similarly, the dimensions of the fabric determined how much space can be occupied. The materiality of the chiffon fabric favoured the creation of a relaxed and elegant atmosphere seen in the lightweight body-space entity.

Questions related to the broad field of architectural design

6) How is this approach valuable for architectural design, as opposed to designing with the computer?

A1: 'As architects we always work to scale and very rarely do we have the opportunity to work one to one [...] it definitely expands your understanding of spatial configuration a lot. Especially when doing it with other people'

A2: 'It is much more fun, which is always influences the design process [...] if you are designing for the experience and through the experience, probably you are nearer the final result, you understand the feelings of the people that are going to be there, you are designing it'.

A3: 'As a design tool, I think it could be very interesting. Working on a project at the studio, we actually were using small samples of fabric, but obviously if you scale it up, they don't behave in the same way so actually to generate something that's really big, it's quite hard to scale it up, you have to use a larger work, I think it is quite important.

A5: 'The danger that I see in people jumping to digital software to create form without an understanding of the material quality or environmental factors [...] there is no understanding where there's a thickness or within architecture there's social layers that have to somehow meet'.

A1 and A2 agreed on the importance of the first-hand experience in terms of the interaction with the material and the others to gain spatial understanding. A3 pointed out that working at one-to-one is important to understand the material's behaviour. In a similar vein, A5 emphasised the importance of acknowledging the material's behaviour and the social context that come into play when designing a space.

The first-hand experience contributed to insights into both individual and collective spatial understanding. The workshop enabled the architects to bodily shape a soft space through the experience, thus acquiring an embodied understanding of its possible future uses. Working at one-to-one scale allowed architects to better

understand the materiality of the chiffon fabric and its possibilities in terms of interaction with others within a social environment.

7) How did this approach work for you?

A1: 'It works out in the sense that it breaks a very rigid methodology that we usually have and opens up different ways of looking at the problem. It is very aligned with the ethos of the experience, having a direct experience with the material not just as a finished thing but as a design process'.

A2: 'it opens your mind to new things and when you are exploring you are able to experience it, it changes completely the way you design with that'.

A3: 'I think this concept of what fabric generates, the kind of forms that you can produce [,,,] allow you to set up a system of rules that you could use to design, in a way that could be unique because it's not coming from your mind, it's coming from the actual fabric itself, the materiality which is something the studio is obviously interested in [...]. 'Everyone's using the same tools to design with, you are surrounded by the same history, the same education of what good design is and how to do it and you know we all appreciate similar forms and so you replicate them or absorb them in some way and it's actually very difficult to generate new forms, new ideas and new ways of designing, really'.

A5: 'It provided a different vocabulary, a different way of thinking about what fabric structures might be or might work, creating a different perception of what is possible'.

All the architects agreed on the potential of the embodied explorations as a way to open up new ways of ideating with soft materials. A3 saw potential in using the resulting forms to start a design process. A5 had a more conceptual take on it: according to him, it offers a different thinking, a new vocabulary. A1 and A2 highlighted the value of the experience as a source to inform the design process.

According to the architects, the embodied experience became a disruptive ideation tool that opened up new ways of ideating soft embodied architecture. The design process at Heatherwick Studio was based on a more diagrammatic and a smaller-scale material exploration approach. I maintain that the embodied experience led to an emergent design process that triggered a formal and conceptual shift in the way architects at Heatherwick Studio address a design project, expanding their design space.

Digital outputs analysis

A1 alone was interviewed to evaluate the digital output. The interview focused on evaluating the digital outputs of the hybrid EDI method and how these could be implemented within a soft embodied architectural design process. A1 led the digital design process of the high-end hotel, and furthermore, he is a professor with a PhD. Having both a professional and academic perspective made him a solid candidate to be interviewed for the purpose of the analysis.

A1 saw the potential in combining the embodied and the digital outputs to connect the experience with the geometry: 'most of the software pretty much describes geometry, but the design of geometry is very visual, it is not experiential, so if you put that as a problem within the design process – how can we re-think materiality within the digital design process? – then you link the digital design process with the experience and the material'. In this way, he proposed connecting participants' feedback to the form-giving process that was taking place: [...] 'when the radius (of the geometry) is this much and the tension is this much and the fabric has certain transparency and flexibility usually people feel like this, this and, this' [...].

A1 added: 'you would need a lot of feedback from other disciplines in order to complete that'. Here A1 referred to the need to discuss these specific insights with the rest of the team that usually involves an architectural process with engineers, environmental experts and constructors. He also highlighted the need for a more developed set-up in order to fully unpack its potential as a design methodology: 'Ideally this would be some sort of much more established design methodology. A room or a house to map the experience in a more rigid way, less loose, in which you have more control' [...] 'the relationship between materiality, experience and geometry needs to be more evident. He also pointed out that '[...] mapping the tension of the material and how the material is deformed during the embodied explorations becomes key and then the transparency which is very difficult to replicate within a software'.

Analysis report

Findings of the EDI Workshop

According to the architects, the main finding of the workshop was *the rapidity which with soft spaces could be ideated by means of the body* as well as the *unique formal*

expression of such soft spaces. Another important aspect for the architects was that the embodied explorations enabled them *to address the design values* that were important for the hotel project through interaction with others, the context of the explorations and the material.

The action of *layering up of the fabric on and around the bodies* was the main dynamic quality identified by the architects that led to specific embodied outputs. The action of overlapping several layers of the fabrics became a design principle for ideating a soft courtyard. This embodied process gave room to three soft body-space entities: *the lightweight body-space entity, the foldable body-space entity and the deformable body-space entity*.

According to the architects, the workshop offered *design insights* that could be used within an architectural design methodology at three levels: *formal, experiential and conceptual.* The three of them are intertwined as they are the consequence of each other. In this sense, the process was successful in producing distinct outputs that could inform the design of the soft courtyard but fell short of providing precise outputs that could be incorporated into a soft embodied architectural design methodology.

Findings in relation to the broad field of architectural design

The subtle and underlying understanding that emerged from the embodied explorations was the primary value identified by the architects. Working collaboratively at one-to-one scale contributed to a nuanced and situated understanding of the body-material relationships within a social environment. The embodied explorations enabled the architects to explore new ways of ideating a soft space and to verbalise specific findings that could be relevant both for the design of the soft courtyard and for the architectural design methodology. The embodied explorations offered an emergent design space, bringing novelty to the way architectural design can be addressed.

Despite the limitations of the experiment, A1 saw an opportunity in using the experience as a source to inform the early stages of a soft embodied architectural design. As A1 mentioned, there is a gap within the architectural design methodology that relates to experience. Traditionally, architecture has relied very much on form and materiality but less on designing through and for experience. I agree with A1 that

the use of a hybrid EDI process would help to add an experiential layer to the architectural design methodology. As suggested by A1, a more defined set-up in which the relationship between the experience, the material and the geometry is more evident would help to generate relevant insights to inform the design of a soft and embodied architecture.

5.6 Discussion of the results

The action of layering up textiles through body interaction offered a dynamic way of ideating a soft embodied space, manifested in three different soft body space-entities. By digitally capturing these entities, different geometries were obtained, enabling the exploration of spatial and formal aspects of such geometries. Architecture brings together people in the same space, and it is designed to be used by many. The action of ideating a soft space by collectively layering up a material could lead to a collaborative use of the resulting space, in which future users could creatively interact with space and others through the materiality of textiles.

Although the resulting embodied and digital outputs offered relevant insights to inform further design phases of the soft courtyard, the hybrid EDI process presented certain limitations. Such limitations include the need for a more controlled set-up, in terms of not only the interaction with the soft materials and the context but also the digital toolset. The new digital toolset should provide less fragmented data in order to fully explore and make use of the digital design possibilities in an architectural context. According to A1, such a hybrid EDI process shows the potential to be part of an architectural design methodology. However, the hybrid EDI process is not suitable yet to be implemented within an architectural design methodology, since it lacks precision.

Other hybrid EDI processes have proved to be useful for bringing innovative insights to the design methodology, as in the case of ‘embodied sketching’, an embodied activity that aims to support the design of novel play and social activities (Márquez Segura et al., 2016). However, according to the authors, the playful character of the project’s context was key to its success. In their paper, Marquez et al. (2016), encourage the exploration of the use of embodied activities in other design domains that do not operate within a playful context. In doing this, the potential of applying an EDI process could be explored within other design fields, helping to expand its use.

The hybrid EDI process developed in the third experiment of this thesis pursued the identification of the requirements needed to articulate a hybrid EDI process suitable for soft embodied architectural design. In doing so, the experiment helped to support the merging of the embodied design, dance, textile design and architectural design domains, supporting the use of EDI activities within a multi-disciplinary context.

5.9 Concluding remarks

In this chapter I have explored the design of a hybrid EDI process in collaboration with four architects and two dancers. The experiment consisted of several embodied explorations with three different textile materials: a chiffon fabric, a thick neoprene and a spandex Lycra fabric. As a result, the lightweight, foldable and stretchable body-space entities emerged and were digitally captured. The resulting embodied and digital outputs were examined with the architects through individual interviews. The limitations and the opportunities of the hybrid EDI process were outlined and discussed with the architects. The result of the analysis suggested that the hybrid EDI process has potential as an ideation process for soft embodied architectural design but that the lack of precision hinders the potential for it to be implemented into the broader architectural design methodology.

Chapter 6 aims to bring the precision needed for defining a hybrid EDI process that is suitable for soft embodied architectural design. To do this, a more precise set-up was designed that consisted of a Multi Kinect digital toolset and the creation of an elastic interface made out of soft and hard materials. In this way, a more controlled process would emerge in which the spatial transitions would be defined within a maximum given distance. The aim of Experiment 4 is to generate precise outputs that make explicit the connection between embodied and digital outputs.

Chapter Six

Soft Embodied Architectures: towards hybrid EDI method for soft embodied architectural design.[13]

The last chapter of this thesis aims to answer the following research question: How can a hybrid EDI process be designed that can be implemented into architectural design methodology? It focuses on the design of a Multi Kinect digital toolset and a soft and hard elastic interface to improve the hybrid EDI process developed through the two previous experiments. It presents the results of an improvised choreographic process that is mapped out into the digital realm, producing a collection of morphologies that are further explored to propose a future urban scenario. The results of the experiment show an incremental increase in the precision of the digital captures as three Kinect cameras were triangulated, producing less fragmented data. The results of the experiment help to define the phases of the hybrid EDI process, identify its strengths and outline its shortcomings.

6.1 The stage

As in Experiments 2 and 3, architect Daniel Suárez and I collaborated with dancers, in this case the Berlin-based Salvatore Siciliano company. The purpose of the collaboration was not only to make use of dancers' body movement skills but also to analyse the collaborative aspect of intersecting embodied design, textile design, architecture and dance disciplines. In the first meeting, I introduced the company's director to the previous experiments. The goal was to develop a more controlled set-up to get more precise outputs. The choreographer and director of the dance company suggested conducting an improvised choreography with the dancers in order to guide them to perform short sequences of more controlled movement. By performing shorter movements, less amount of data would be captured.

Daniel Suárez designed a Multi Kinect toolset that consisted of three Kinect cameras triangulated within a 4 x 4m perimeter. In order to produce shorter sequences of movements, we needed to design a more enclosed set-up of the material that limited the range of movement to a certain extent but that offered enough room for interaction. Thus we designed a bespoke interface consisting of a quasi-cube made

[13] Text partially adapted from Castán and Suárez (2018)

Figure 71. Aluminum frame.

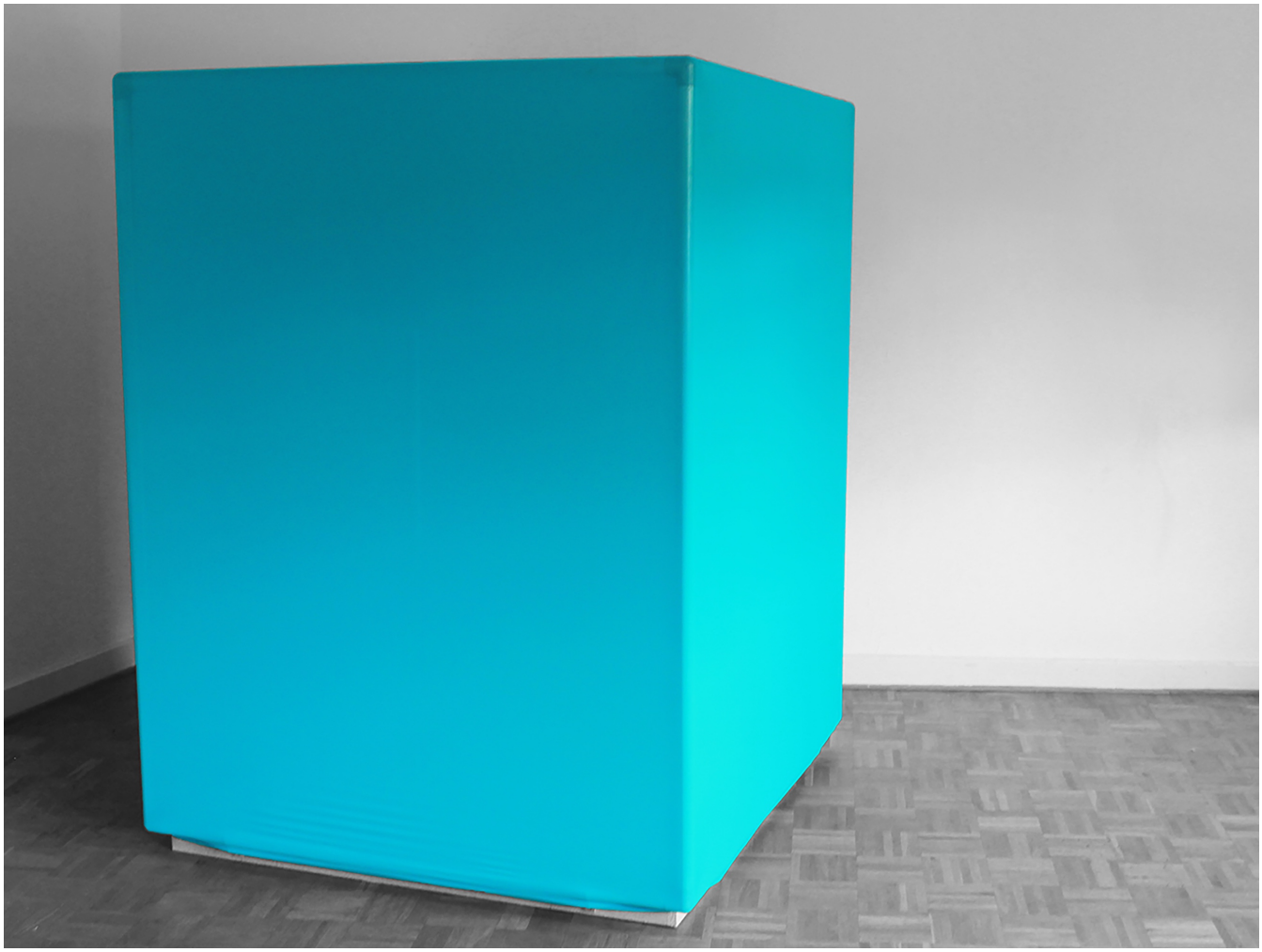


Figure 72. Elastic fabric pre-tensed onto the structure.

out of an aluminum frame (1.50 x 1.50 x 1.80m), that operated as a structural element. We chose to build a cube structure because of its stability and ease of construction. Dancers would be interacting inside the cube, and therefore we needed it to be stable. We sewed an elastic fabric of 5 x 2.20 metres into a tubular pattern and pre-tensed it onto the whole structure (Figures 71 and 72). The elastic fabric was chosen after trying out different material compositions, as we needed to test the stretchability of the material to find a balance of the right degree of elasticity. If the textile was too soft the body-material interactions became less defined, as the fabric did not keep the changes in its surface, and if the textile offered too much resistance there was no room for interacting with the material. As mentioned in the discussion in Chapter 5, combining hard and soft materials would provide a balance between freedom of interaction and structural support, and would contribute to the designing of a soft embodied architecture that enables dynamic interaction with textiles.

With the new Multi Kinect toolset and the elastic interface, I aimed to obtain more precise results. On one hand, the elastic interface would allow participants to produce more controlled movements and I could focus deeper on the relationships that emerge from the interaction between the elastic interface and the bodies. On the other hand, the Multi Kinect toolset would allow us to capture a complete geometry. These two outputs combined would enable us to make explicit the connection between the experience and the geometry and identify further design possibilities.

The collaboration took place at Berlin University of the Arts. Three Kinect cameras were triangulated to achieve a 360-degree capture of the embodied explorations. A GoPro camera was placed inside the cube, and a video-recording camera outside of it to capture the dancers' movements and document both the interior and exterior perspectives (Figures 73 and 74).

Brekel Multi Kinect software was used to record raw data retrieved from the Kinect cameras. The captured data was later imported into SideFX Houdini software to join the three meshes obtained by each of the Kinect cameras. The three meshes were joined into one single object. Following this, Suárez performed a reconstruction of this joined mesh. Once the mesh was cleaned, the geometry was exported as an *.obj file, imported into Rhino 3D and manipulated within Grasshopper to explore its formal characteristics.

Figure 73. Dancers interacting with the elastic interface (inside view)

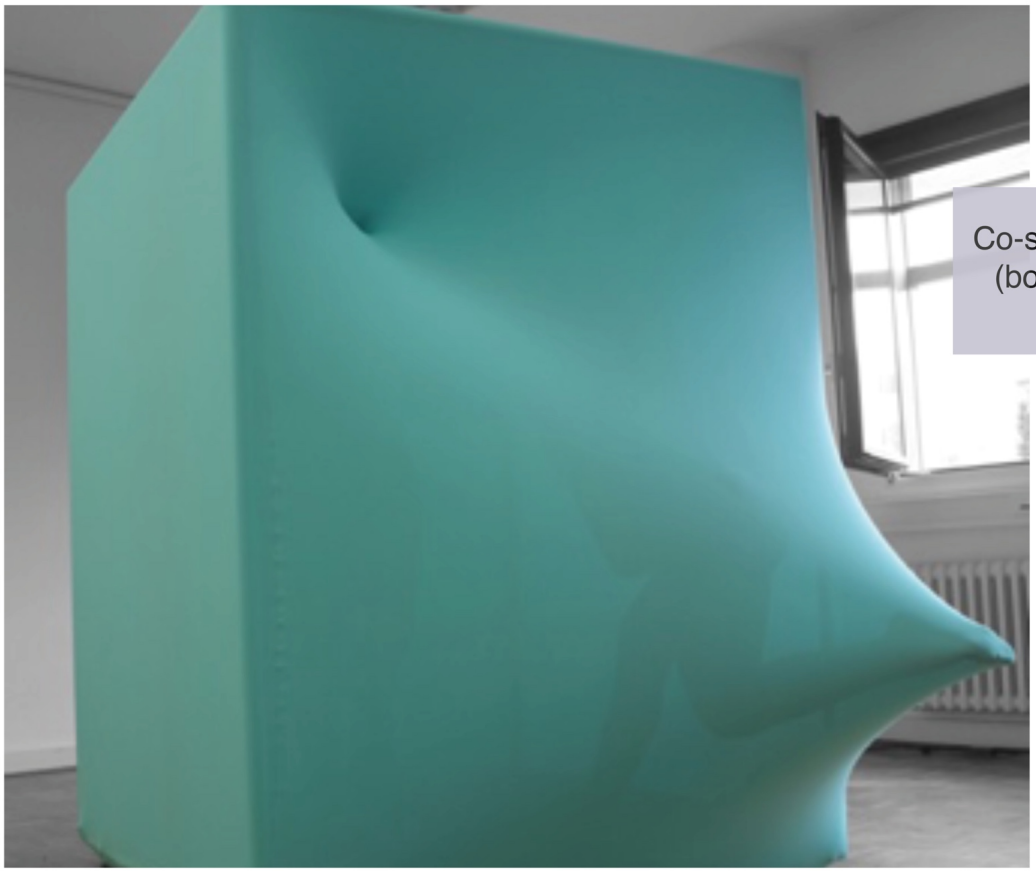


Figure 74. Dancers interacting with the elastic interface (outside view)

Figure 75. Annotations of the foldable body-space entity.

6.2 Exploring material elasticity through choreographed body-material interactions.

I explored the interaction with the elastic interface to acquire a first-hand experience and to run a test of the Multi Kinect digital toolset. Interacting with the elastic space felt very different to engaging with a hard space. The soft, elastic texture of the interface invited me to touch its walls and try out different bodily movements and positions. I identified differences between this exploration and the ones I had explored in Experiments 2 and 3. I could exert more pressure on the surface of the fabric and have more freedom to use my body in different ways, since I did not have to hold the material myself. I agreed on a two-day collaboration with the choreographer and three dancers. During Day 1, I introduced the dancers to my research topic. On Day 2, I asked the dancers to freely explore the elastic interface first so that they could become familiar with it. In a later exploration, the choreographer would guided the dancers through an improvised choreography.

Embodied Outputs

On day 2 the dancers explored the soft interface briefly while we observed the results in both the physical and the digital realm, as the digital captures happened in real-time. Following this, the dancers, guided by the choreographer, performed six different choreographic sequences using different parts of their bodies. Figure 76 shows the choreographic sequences performed by the dancers, as well as a brief description of their formal aspects: 1) Dot Patterns, 2) Spherical Volumes, 3) Convex and Surface Indentation, 4) Convex/Concave Forms, 5) Sharp Surfaces and 6) Smooth Contours. They started first by performing a more localised movement with their fingers, continuing by gradually integrating other parts of their bodies to have a higher impact on the walls of the elastic interface. Intuitively, they began to help each other to have more control of the deformation of the walls.

As Figure 73 shows, the dancers made use of the rigid frame to hold themselves when stretching the walls. A new spatial entity emerged when the bodies activated the elastic interface, in a co-shaping process between the dancers and the elastic interface. This elastic body-space entity created by the interaction between the body and the material revealed three dynamic qualities:

Form-giving process of the elastic body-space entity

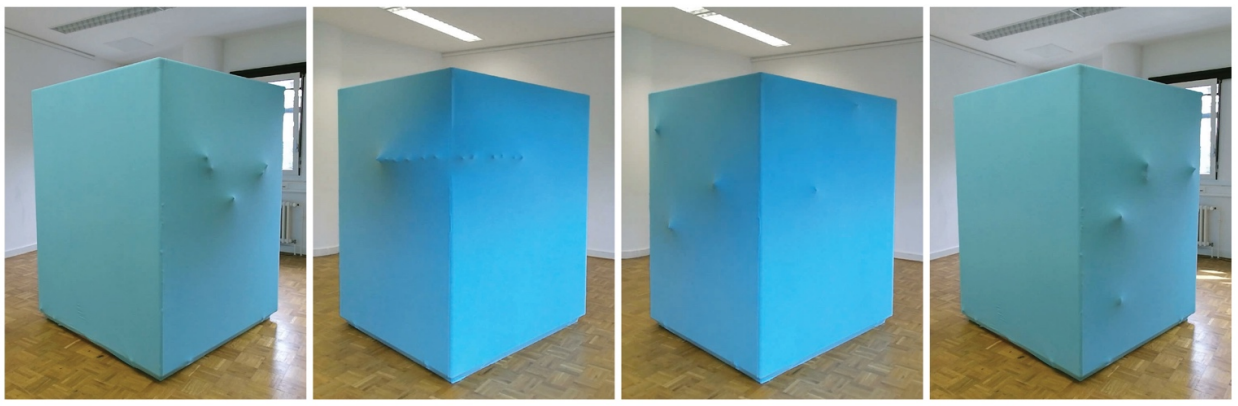
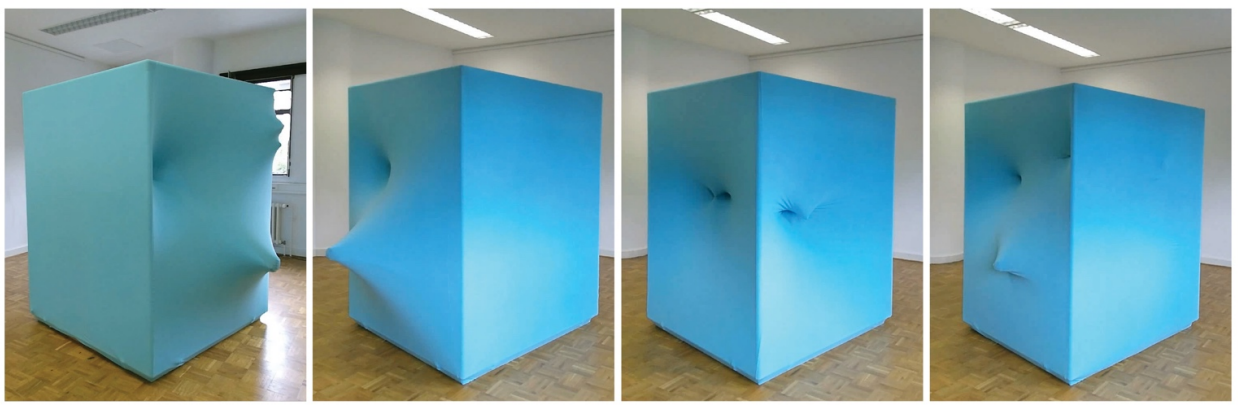
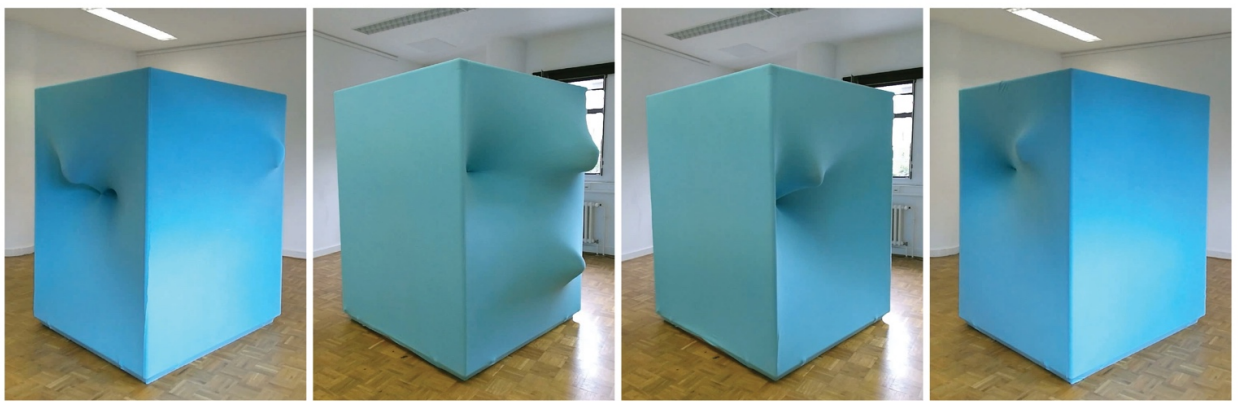
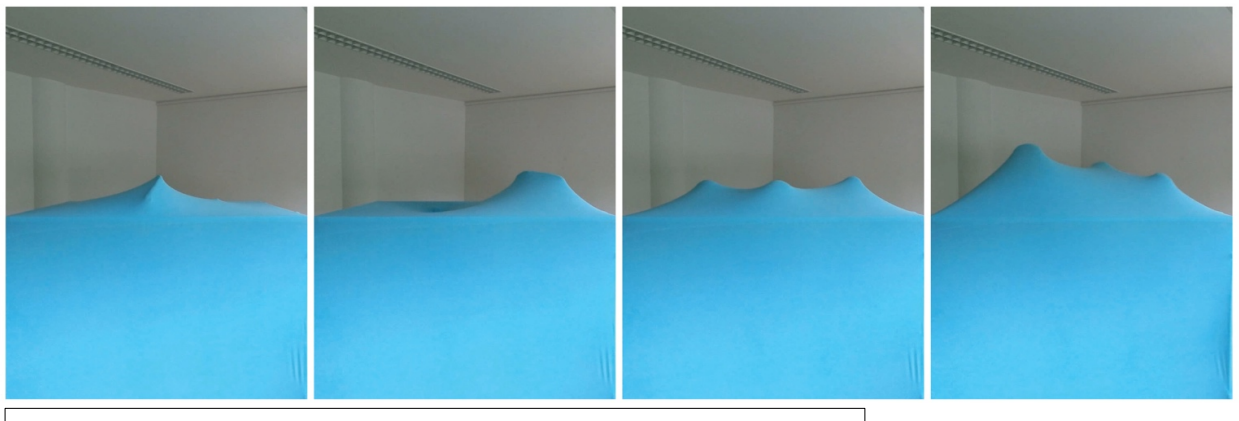
	Choreographic Sequences	Form Expressions
1. Dot Patterns		The dancers, as instructed by the choreographer, pushed the fabric with their fingers, first with one finger and later on with several of them. A sequence of relief dots moving up and down could be observed, creating abstract and subtle geometric patterns.
2. Spherical Volumes		Heads and knees were used to deform the textile by pushing it forward. As the head is less sharper than a finger, forms were more rounded and more predominant as they occupied more surface.
3. Convex and Surface Indentation		Hand movements deformed the textile inwards, creating convex volumes that made more evident the edges of the interface. By grabbing the textile and pulling it inwards, different degrees of indentation were created.
4. Convex / Concave Forms		Combining the movement of the heads and knees pushing the textile forward with hand movements to grab the textile inwards created a big tension that resulted in more prominent forms.
5. Sharp Surfaces		Interacting with arms and legs, offered the sharpest forms as the textile was under very high tension.
6. Smooth Contours		On the contrary, the top view offers softer shapes as that view allows to perceive the transition in height from the flat to the deformed surface of the textile. To be able to record data from the top view, the soft interface was turned around so it could stand in its shorter height.

Figure 76. Annotations of the choreographic sequences.

1) Transparency

The more the dancers pushed the walls of the interface, the more the exterior was revealed to them. Thus, the materiality of the elastic interface reveals a gradient of transparency that mediates the relationship between the interior and exterior, creating dynamic interactions between users and space.

2) Adaptability

The material's elasticity adapts to different volumes and forms, offering very defined shapes when the body activates the elastic interface. Its adaptability allows participants to modify the space according to their needs, taking up room when needed or using the minimum amount of space otherwise.

3) Thresholds of Elasticity

The elastic interface operates as a pre-tensed envelope, allowing participants to experience how it feels to be held by a soft, elastic wall, eventually performing counterbalanced movements through different thresholds of elasticity.

As a result of the co-shaping process, a collection of morphologies was created. The three dynamic qualities are interconnected, as they all happened within the same action, yet each of them relates to different spatial conditions. The transparency affects the experience between inside and outside through the visual. The adaptability relates to the use of the space, and how it becomes modified through the interaction between the users and the soft material. Finally, thresholds of elasticity connect to the tension of the elastic interface, which is a baseline condition that allowed dancers to explore different levels of elasticity while producing a series of formal expressions. The three dynamic qualities show that human and non-human agencies unfold a set of relationships.

Digital Outputs

The elastic body-space entity created different soft volumes, in a temporary event that modified one side of the interface from a plane to a three-dimensional surface. The Multi Kinect toolset allowed us to capture a complete raw geometry of the elastic body-space entity (Figure 77) and reconstruct the raw geometry into a mesh (Figures 78a and 78b). We could generate a precise visualisation that showed how the

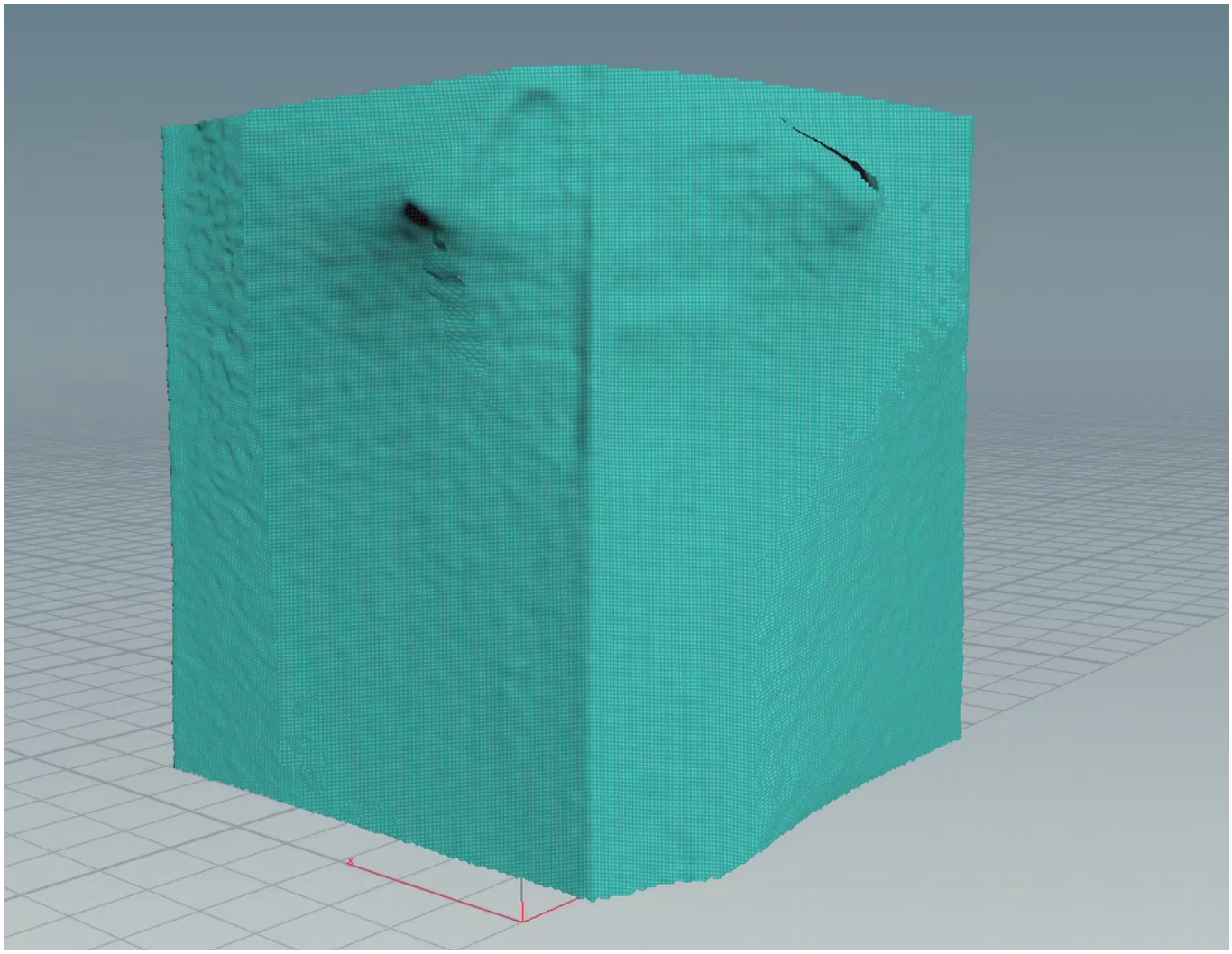
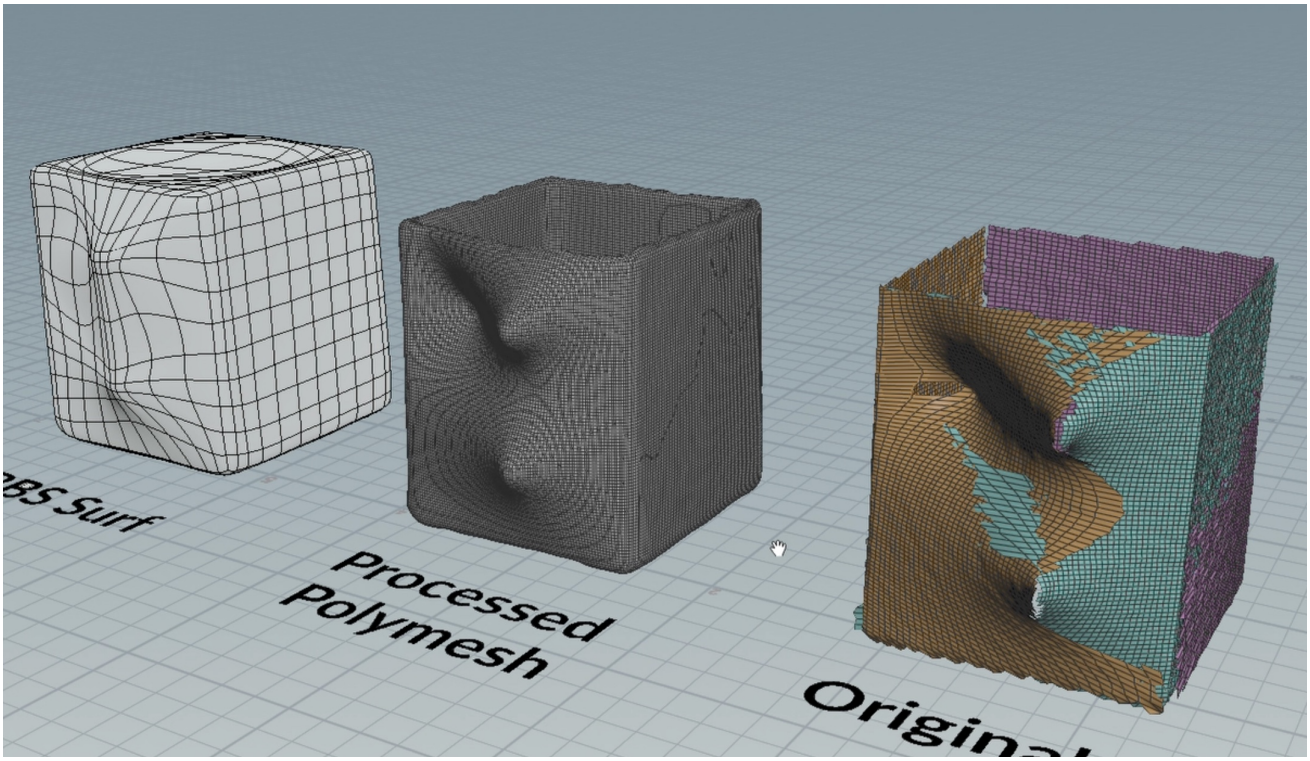


Figure 77. Raw mesh captured by the Kinect camera.



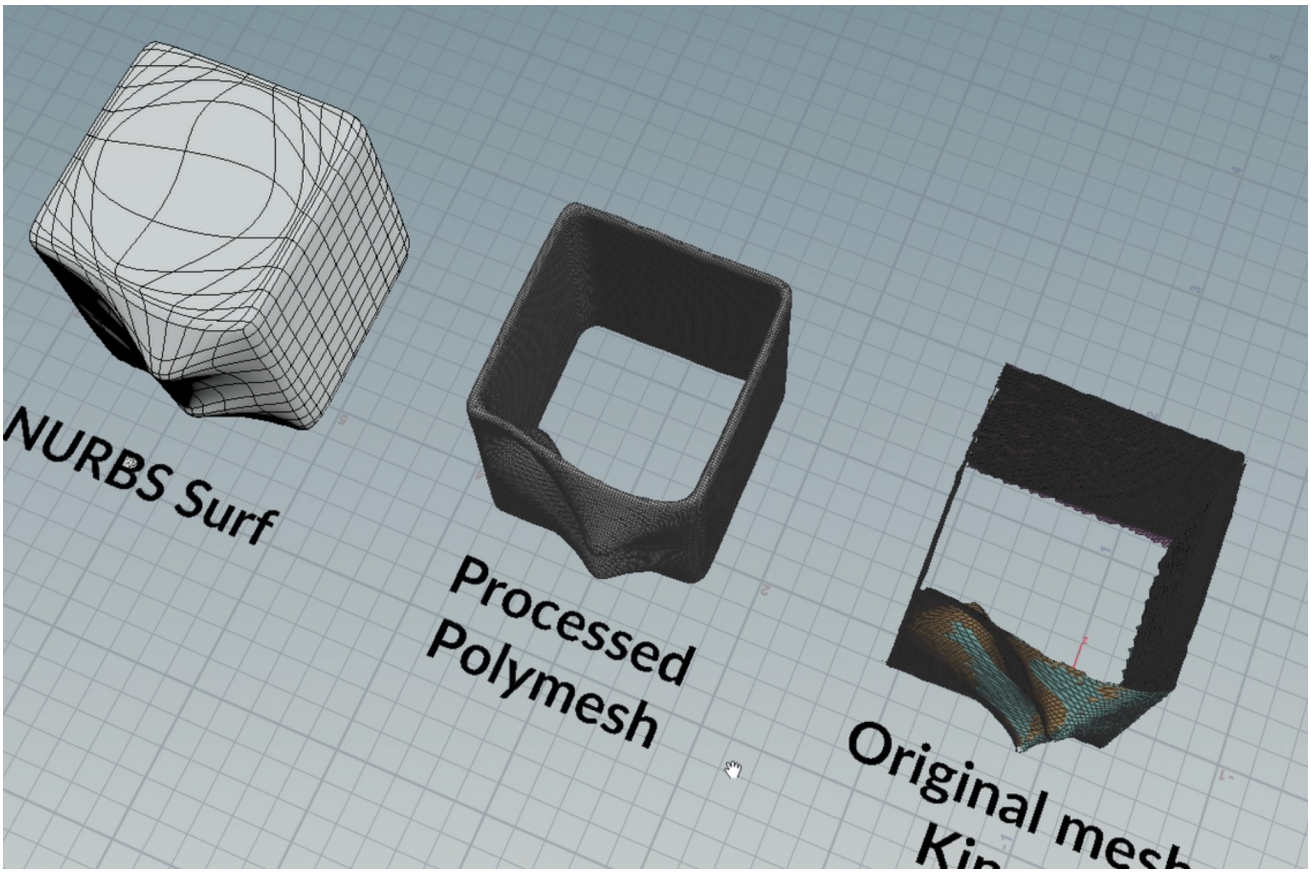


Figure 78a and 78b. Mesh reconstruction: top view and front view respectively.

deformation of the elastic interface provoked a change in the transparency of the fabric. We used Rhino software to interpret the gradients of transparency. We also interpreted the curvature of the surface in which the deformation was more evident. Figure 79 shows some of the captures that were reconstructed with Grasshopper tools and visualized in Rhino 3D, attending to the curvatures of the soft surface. The agency of the fabric and the body brings the dynamic quality of transparency through a transition that goes from almost opaque to almost transparent, depending on how much the bodies push the textile forward. Figure 80 shows how the dynamic quality of transparency was translated into a colour gradient map and applied to the reconstructed mesh. In this way, some distributed areas of gradient transparency were generated, enabling an assessment of the distances between the centres of an initial state of the mesh and the one that was deformed by the dancers.

Combining embodied and digital outputs

The collections of morphologies created by the elastic body-space entity hold certain qualities of plasticity and dynamism as design expressions, in both the physical and the digital realm. By re-connecting the experiential, *the body*, with the architecture, *the space*, a new formal language emerged, resulting in a new soft form vocabulary. Figure 81 shows a visualisation of how this soft form vocabulary could be further developed into a soft embodied architectural design. Through digital simulations, we explored a speculative urban scenario in which certain parts of the façade of a building could behave in an elastic way. Reflecting on the architectural design context, different ideas about potential applications emerged, such as, for example, the idea of an elastic wall or window as an interstitial space that mediates between the façade and the interior of a building. If the body pushes the elastic wall or window outward, the natural light conditions would be modified. This is a similar concept to that seen in the recently built Guelmim airport, in Morocco, by Groupe 3 Architectes.[14] They wrapped the building with a metal mesh skin, thus creating a light-filtering façade that mediated the relationship between the interior and the exterior.

As mentioned in the research context chapter, the use of the body as a choreographic tool to inform the design of space has been widely explored by architects in recent decades. Architects have collaborated with dancers and choreographers to map out

[14] Groupe3, 2017. Retrieved 3/03/2018 from http://www.groupe3architectes.com/

Figure 79. Curvature analysis in Rhino 3D.

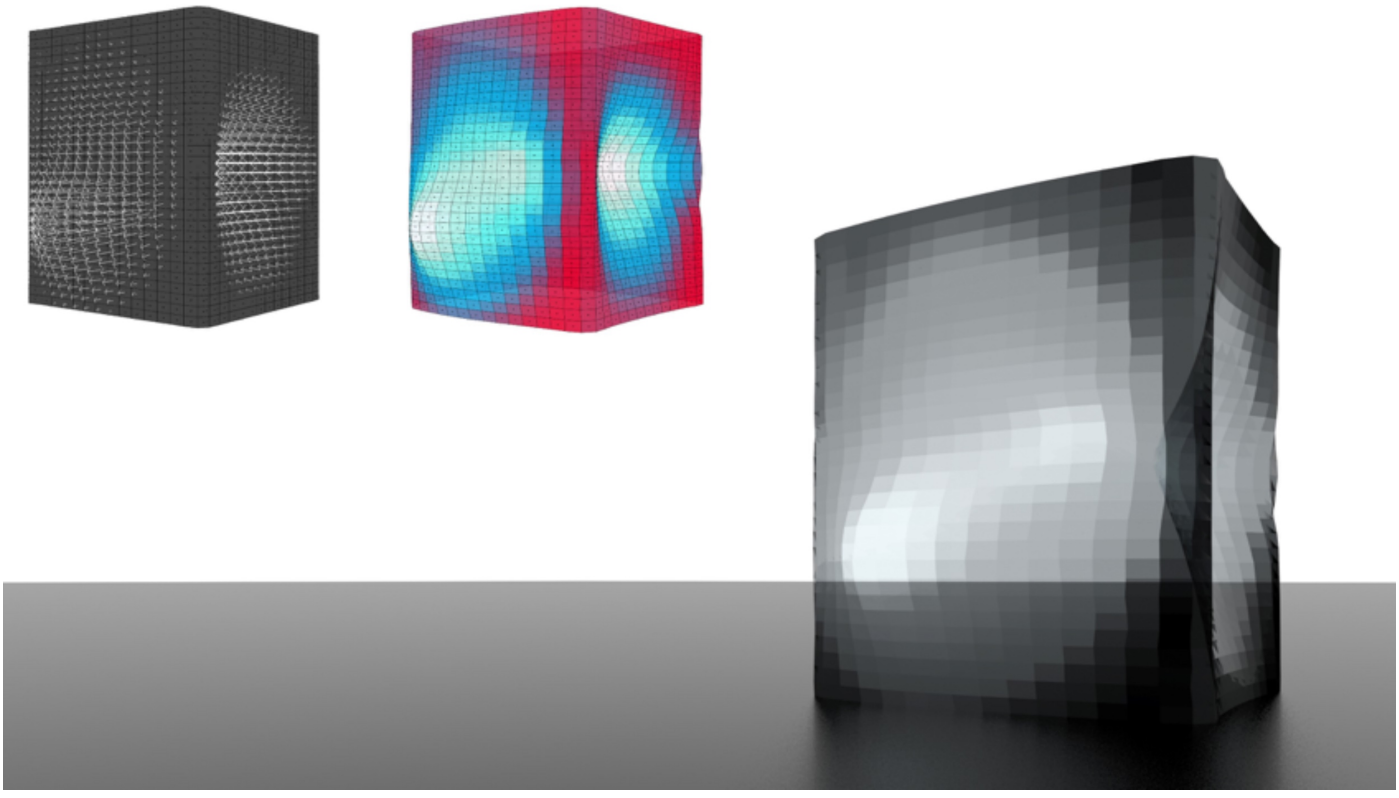
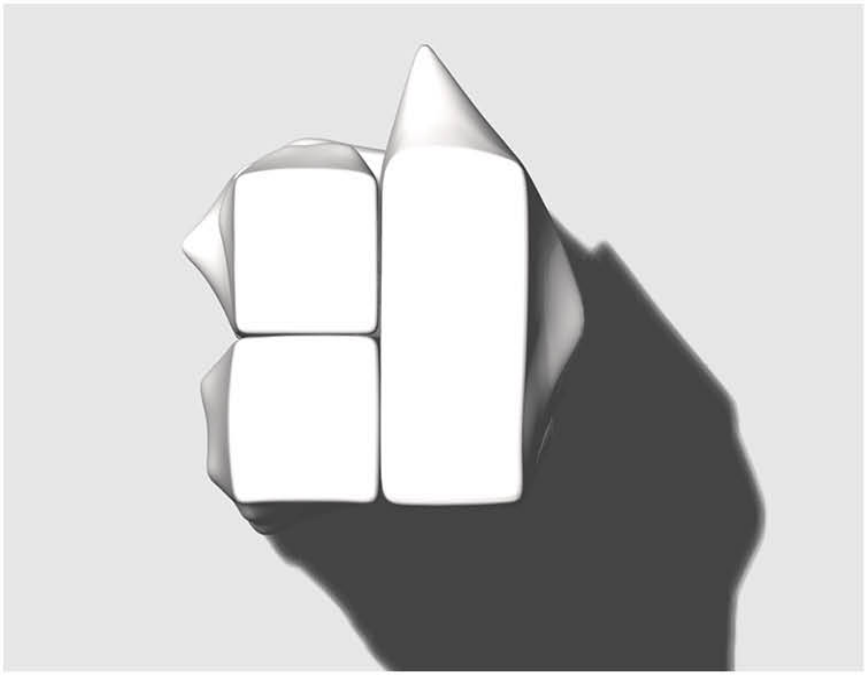


Figure 80. Interpreting transparency.



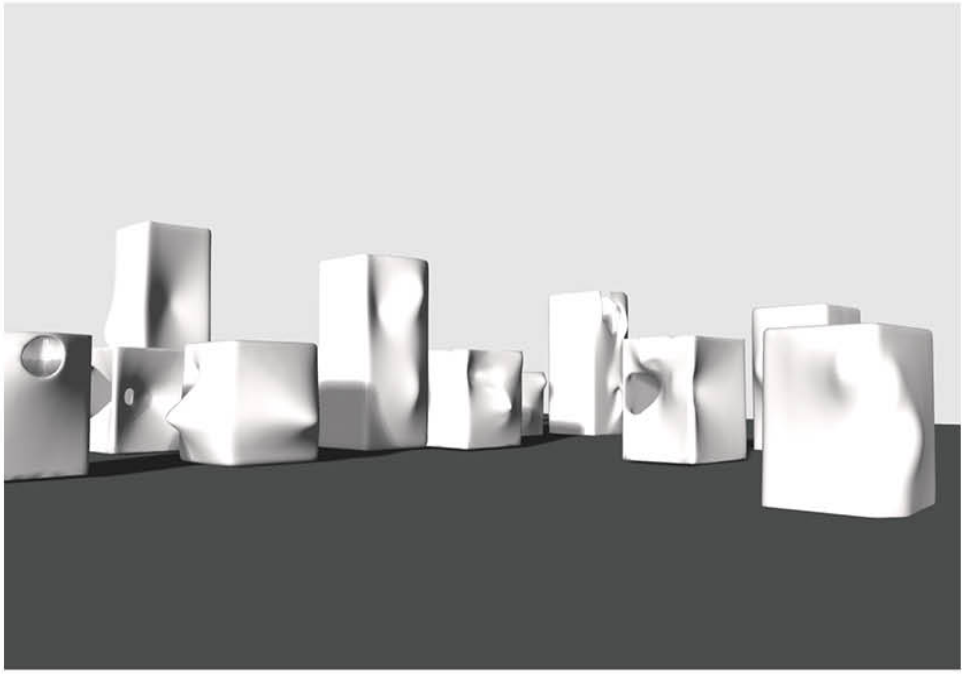


Figure 81. Soft Form Vocabulary.

movement into notation systems through analogue-digital workflows (Kato and Glynn, 2018; Stathopoulou, 2011; Manning, 2005). However, the use of a hybrid EDI process that maps out choreographic elastic body-spatial sequences and explores their potential as a design ideation tool has received little attention. The body in movement creates a 'invisible' space around it. This phenomenon was made tangible by choreographer William Forsythe in his 'Synchronous Objects' project (2009) in which the data from a choreography is processed and translated into physical objects, as a way to interrogate what else choreography could look like (Palazzi and Zuniga Shaw, 2009). In this fourth experiment, the elastic interface becomes an extension of the movement of the bodies, merging the act of choreographing with the creation of an architectural form in the same action.

6.3 Analysis of the experiment[15]

In order to analyse the process of the experiment, its outcomes and its collaborative aspect, I prepared a short questionnaire and sent it to all the participants – the architect, the choreographer, one of the dancers[16] and myself – to answer the following questions:

1) What do you think of the design of the set-up?
2) What did you find different from your usual way of working?
3) What did you find interesting/useful from your perspective?
4) What is your opinion regarding the outcomes of the exploration?
5) What do you think about the collaborative aspect of the project?

The data obtained from the questionnaire is qualitative, as it is based on first-hand experiences and personal perspectives from the participants of the experiment. The qualitative analysis acknowledges the aspect of subjectivity inherent in the data, and uses such data to turn it into findings. The qualitative analysis is thus inductive, since the findings are grounded on data rather than on previous theory (Lofland, 2006). Within this process of analysing the data, the design researcher is at the core of the process, acting both as an observer and participant. Participants' feedback[17] was analysed to identify the quotes that directly answered the questions. These were

[15] Text partially adapted from Castán and Suárez (2018)
[16] The other two dancers were approached but they did not answer the questionnaire.
[17] Participants' answers to the questionnaire can be consulted at the Appendix section of this thesis.

PARTICIPANTS / QUESTIONS	CHOREOGRAPHER SALVATORE SICILIANO	DANCER RACHEL TAK	TEXTILE AND EMBODIED DESIGNER MARINA CASTAN	ARCHITECT DANIEL SUAREZ
Q1. DESIGN OF THE SET UP	By keeping the body hidden, a new organism appears, It is a new entity.	Interesting setup in relation to material elasticity. Preference for close interactions as it allows to create more abstract shapes.	The size and constrains imposed by the soft interface and the use of a multi Kinect toolset contributed to reduce the amount of outputs and to focus deeper on formal and spatial aspects of the outcomes.	It has potential as a design tool. The augmented scale between user and material makes easier to explore form.
Q2. DIFFERENCES IN WAYS OF WORKING	Not seeing the body. Feeling like using a 3D software instead;	Not having a full picture of what was being created.	Combining textile material explorations with motion capture tools expands the design possibilities opening the door for new ideas and aesthetics.	A textile interface as a time-based modelling tool
Q3. INSIGHTS FOR EACH ONE'S PRACTICE	Body form-giving process instead of choreography	Having an extra element (soft interface) as a collaborator for shaping the body	The temporary and real-time aspect of the hybrid EDI process offer immediate results of what is being explored.	To design in a continuum space and its transition from one state to the other.
Q4. OUTCOMES EVALUATION	When the interface starts becoming irrecognizable. Dot pattern as the most interesting one.	Individual movements are less important, collaboration becomes essential in order to affect the space.	The new elastic entity blurs the boundary between body and space. It offers innovative formal, dynamic and spatial qualities that might be relevant for soft embodied architectural design.	Still incipient. Its main value relies on its potential as a form-giving tool based on analogue inputs.
Q5. COLLABORATIVE ASPECT	It is interesting as it invites to think in a different way.	As an observer, it is interesting the anonimity of the exploration, specially when all dancers sync up as it gaves the feeling of a whole unit instead of an interface and 3 separte humans inside.	An embodied approach to design through collaboration creates a shared experience that allows to reflect upon body-material / body-space / body-body relationships in an early stage of the design process across different disciplines.	I see value in collaborating with others as it brings new ways of working and new aesthetics.

Table 4. Participants' quotes.

organised in a table to facilitate the discussion of the results and the identification of the common themes. Table 4 offers a condensed view of the identified quotes from each participant.

The following themes were identified:

a) Both the choreographer and the dancer found the fact of not seeing the body (from outside the cube), challenging (Q2). The fact that they could not see each other while performing forced them to find other ways of communicating, through the elastic interface. I suggest that the agency of the elastic interface *shaped not only the way the dancers communicate with the choreographer but also the way the dancers interacted with each other, as stated by the dancer* (Q4).

b) The choreographer (Q1), the dancer (Q5) and I (Q4) coincide in our opinion that the interaction between the elastic interface and the bodies enables a *new entity* to emerge. Whilst the choreographer and the dancer identified this new entity by relating to it through body and movement, I observed that the elastic body-space entity creates a seamless, soft spatial expression, blurring the

boundaries between bodies and space. This shows that there is a common understanding of what *the elastic interface and the bodies are, perceived as an entirety rather than as separate entities.*

c) The choreographer (Q3) and the architect (Q1) agreed on the potential of the *hybrid EDI process as a form-giving process.* Both the choreographer (Q2) and the architect (Q2) saw the interactions between the elastic interface and the dancers as a 3D modelling tool. I argue that although the elastic body-space entity could be seen as a medium to generate an architectural form and reproduce it using hard materials, this would imply the ignoring of the dynamic qualities that emerge from the interaction between the material and the body, relegating the result to the formal aspect of the elastic body-space entity.

d) I (Q2) and the architect (Q2 and Q3) consider *the hybrid EDI process relevant as a way that opens up new design possibilities*. I would add that the hybrid EDI process *brings a new design space for exploring dynamic and interactional aspects from multiple perspectives (material, space and body) simultaneously.*

e) All the participants (Q5) perceived that there is value in working across different disciplines, as it offers a different way of thinking about one's own practice (choreographer), news ways of working and aesthetics (dancer, and architect) and a shared experience that allows for reflection at different levels within the design process: body-material, body-space, body-body (I). I suggest that collaboration becomes key when ideating soft embodied architecture from an embodied perspective to ensure *the generation of a diverse range of design opportunities and insights*.

Analysis Report

Findings on Q1. 'Design of the set-up'

The design of the set-up brought a degree of novelty to the way the dancer and the choreographer usually work. The dancer and the choreographer both had to rely only on what they said to each other during the improvised choreography. This is quite unusual, as dancers and choreographers do normally establish visual contact. In this regard, working through a textile interface might bring innovative choreographic processes to the dance domain.

To the architect, the set-up was useful to explore formal opportunities more easily. Following the same thinking, I said that the set-up allowed us to obtain fewer outputs in comparison to the ones obtained in Experiments 4 and 5 and to focus more deeply on interpreting the formal and spatial aspects. I suggest that the set-up allowed us to be more specific about the definition of the embodied and digital outputs and the connection between them.

The modifications on the design of the set-up introduced in this last experiment helped to bring the precision needed for designing a hybrid EDI process suitable for soft embodied architectural design. Architect A1 was contacted again to show him the results of the fourth experiment. He mentioned that the experiment worked out because both the elastic interface and the Multi Kinect toolset offered a controlled environment that produced more precise outputs, making explicit the connection between the experience and the geometry. He emphasised the importance of having a structure, in this case the frame of the elastic interface, to produce precise outputs.

Findings on Q2. 'Differences in ways of working'

All participants agreed that the experiment enabled them to work in a way that was different from their normal approach. To the dancer, the choreographer and the architect the difference resulted from the elastic interface, whilst to me, the difference resulted from combining a material exploration with motion capture tools. This shows that merging of different participants' backgrounds brings the discovery of new functionalities and aesthetics such as the formal and interactional aspects that emerged out of the elastic body-space entity.

Findings on Q3. 'Insights for each participant's practice'

The experiment enabled the expansion of each participant's practice, providing them with new insights such as a new way of choreographing, new ways of shaping the body movement and the creation of an emergent design ideation process resulting in the embodied outputs described in section 6.2.

Findings on Q4. 'Outcomes evaluation'

Both the choreographer and I highlighted the transformation of the elastic interface and the body into a new entity that blurs both the body and space. The dancer highlighted the importance of collective movements to create different patterns on the

elastic body-space entity. To me, the main value resides in the formal, dynamic and spatial qualities that emerged from the elastic-body space entity. To the architect, the outcome lies in the analogue-digital process afforded by the form-giving tool (the elastic interface and the digital toolset). This shows that the outcomes were perceived differently among the participants. Thus, the experiment was valuable in opening up different directions that could lead to other potential research activities.

Findings on Q5. 'Collaborative aspect'

The positive reaction from all participants regarding the collaborative aspect of the experiment shows that the way the disciplines of dance and choreography, textile and embodied design and architecture were combined in this experiment was relevant not only for the purpose of this investigation but also for each participant's practice. In this regard, I would highlight the importance of communicating and discussing ideas with all participants to ensure not only a common understanding of the research activity but also the participants' motivation. To sum up, the main findings of the analysis were as follows:

a) The agency of the elastic interface shaped not only the way the dancers communicate with the choreographer but also the way the dancers interacted with each other.

b) The elastic interface and the bodies were perceived as a new entity rather than as separate entities.

c) The experiment showed the potential of the hybrid EDI process as a form-giving process that connects the first-hand experience with a digital geometry.

d) The hybrid EDI process offers a new design space for exploring dynamic and interactional aspects from multiple perspectives (material, space, body and context) in the physical and digital realms.

6.4 Towards a hybrid EDI method for soft embodied architectural design

In contrast to the previous three experiments, in this fourth experiment, an elastic interface was designed to find a balance between the relative freedom of participants to interact and the generation of precise outputs. The hybrid EDI process in Experiment 4 evolved into a more structured set-up that abandoned the unpredictability manifested in Experiments 1, 2 and 3. This change in the set-up responded to the need to reduce the complexity of the experiment in favour of obtaining a precise hybrid EDI process that could be implemented within an

architectural design methodology. As A1 mentioned in Experiment 3, the hybrid EDI process lacked the precision required for its implementation within the architectural design process. In Experiment 4, what was tested was not the ideation of a soft space through the body from scratch but the formal and experiential relationships that could emerge from the interaction with a previously designed elastic interface. The hybrid EDI process implemented in Experiment 4 enabled the interpretation of precise and explicit connections between the embodied and digital outputs. This was demonstrated in the definition of three dynamic qualities: transparency, adaptability, and thresholds of elasticity of the new elastic spatial entity (embodied outputs) and the interpretation of these dynamic qualities into the digital realm (Figure 80).

Although the outcomes of this final experiment do not enable the definition and validation of a hybrid EDI method, as more experiments within other investigations should be carried out, they prove the potential of the hybrid EDI process as a way to generate relevant insights for soft embodied architectural design. In order to make the hybrid EDI process explicit and accessible to other researchers, a summary of its phases was defined and organised in a table (Table 5).

The iteration of the four phases within other architectural design research projects would help to redefine and improve the hybrid EDI process, and eventually lead to the definition and validation of a hybrid EDI method. By implementing the hybrid EDI process within the early phases of an architectural design methodology, architects could co-shape a soft space, and subsequently its architectural form. In doing this, architects could explore its implications and opportunities in both the physical and digital realm, acquiring novel design insights to inform their soft embodied architectural design projects.

6.5 Considerations for future research

To expand the use of the hybrid EDI process to other research projects I suggest few a number of considerations, with the aim of supporting its implementation:

1) Design of the set up

A previous selection of textile materials should be carried out to identify potential qualities (transparency, lightness, elasticity, etc.) that could fit into the given research topic. Likewise, the number of participants and the context should meet the research

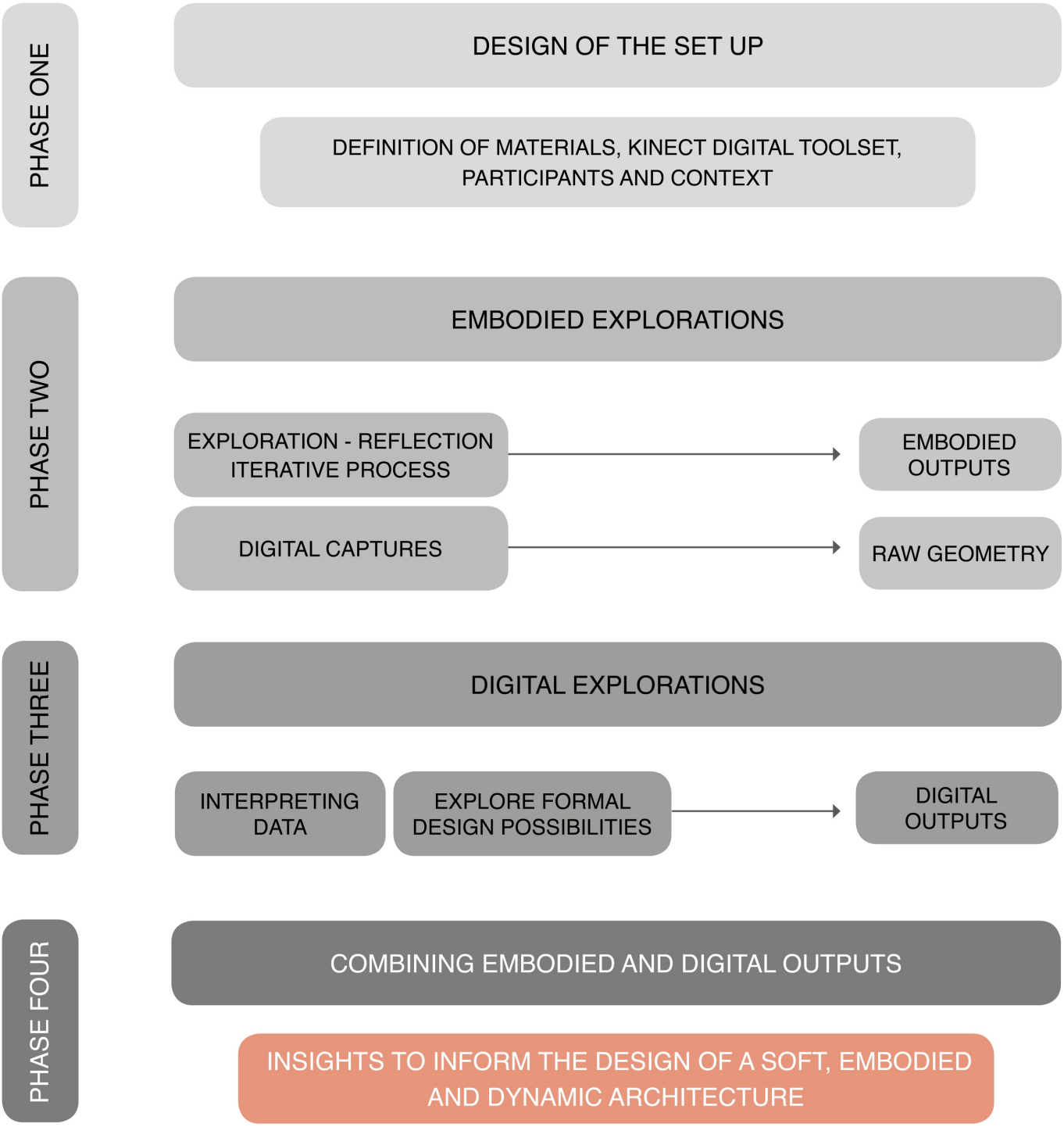


Table 5. Phases of the Hybrid EDI process.

topic requirements in terms of dimensions and location. The use of a controlled set-up that enables relative freedom for ideating a soft space but that also ensures the creation of precise embodied and digital outputs should be achieved to draw relevant insights to inform the research topic. This balance between freedom and precision should be explored through an iterative process that would guide the different changes in the set-up to eventually achieve a satisfactory outcome.

2) Embodied explorations

During the embodied explorations, a reflection-on-action process is key to ensure the capturing of the participants' feedback. Voice recording helps to capture the participants' first impressions after each of the explorations. This feedback, along with the videos of the embodied explorations, would help to analyse and identify the key concepts that would lead to the definition of the embodied outputs.

In terms of the digital captures, a Multi Kinect toolset is a minimum requirement for getting an almost complete geometry that enables the later digital explorative design process. Similarly, creating fixing points for the soft materials within a measured distance would facilitate the creation of precise embodied outputs, as the soft materials would be constrained within a given distance. In this way, the specific elements of the data captured by the digital toolset would be easier to interpret, as a range of distances within the context of the embodied explorations could be determined.

The use of elastic materials, in combination with a rigid structure, would produce defined embodied and digital outputs, as shown in Experiment 4. However, the use of non-elastic materials, such as the chiffon fabric used in Experiment 3, would entail a more complex set-up since the interaction between the material, the body and the context generates multiple overlapping of material layers that results in more complex formal and spatial arrangements.

When using material such as this, more unpredictable embodied outputs would emerge, as evidenced in Experiment 3 during the embodied explorations with the chiffon fabric. Therefore, for future experiments with lightweight and non-elastic materials I would suggest using a more sophisticated digital toolset such as the

OptiTrack system.[18] OptiTrack is a motion capture system that uses 3D tracking cameras and markers to map out environments precisely. By placing the markers on the fabric, more reference points and measurable information would be obtained, allowing the architects to further expand the digital design processes.

3) Digital explorative design process

The raw point cloud captured by the Multi Kinect toolset can be explored with most of the available procedural modelling software. To make use of the wide range of available software would help to enrich the explorative design process and identify digital strategies to inform future soft embodied architectural design scenarios. The raw digital captures present the opportunity to modify and explore different parameters such as the structural performance of the material, its rendered properties, and formal aspects of the raw geometry. In Experiment 4, the introduction of Rhino 3D and Grasshopper software helped to further interpret formal implications and develop new digital simulations of potential applications. The more precise the captured data is, the more details of the geometry would be captured, expanding the design possibilities of the explorative design process.

4) Combining embodied and digital outputs

The more explicit the connections that are established between the embodied and digital outputs, the richer the resultant design insights will be. By relating participants' feedback to key moments of the embodied explorations, a connection between the geometry and the experience can be traced. This was evident in Experiment 3, in which architects identified key moments that were later identified with their equivalent geometry. Such a co-relation between the geometry and the experience would provide architects with specific design insights that go beyond the creation of an architectural form by offering a first-hand experiential knowledge.

Concluding remarks

In this chapter, I have described the process and the outcomes of Experiment 4. This experiment explored the design of a hybrid EDI process suitable for implementation within architectural design in collaboration with dancers, a choreographer, an architect and, a textile / embodied designer. Participants' analysis of the process and

[18] https://optitrack.com/ [accessed 26/02/2019]

the outcomes of the experiment suggest that there is value in combining several disciplines for ideating soft embodied architecture since it brings different perspectives and offers an emergent design space. The hybrid EDI process described in this chapter helped to create precise embodied and digital outputs that led to a new soft form vocabulary and the simulation of future urban scenarios.

Experiment 4 led to the definition of the phases of a hybrid EDI process for soft embodied architectural design. The generation of design insights (embodied and digital outputs combination) proved the suitability of the hybrid EDI process to inform soft embodied architectural design processes. The results of Experiment 4 call for a more dynamic architecture in which future users could modify parts of a building, such as the walls, windows or façade elements, thus allowing users to discover new ways of interacting with others and the space. Finally, a few considerations were suggested for future research activities to support the implementation of the hybrid EDI process into other research projects of soft embodied architectural design.

Conclusions. Soft Embodied Architectures.

This thesis aims to explore new ways of ideating textile architecture by means of EDI methods. The embodied design perspective this thesis adopts emerged as a response to the lack of established EDI methods within the early stages of the design process of textile architecture. The majority of textile architecture projects do not take into consideration the potential of the dynamic and spatial qualities that emerge out of the interaction between the body and the textile material. The hybrid EDI process this thesis introduces situates the first-hand experience at the core of the design process, enabling the ideation of a temporary, soft, embodied and dynamic architecture. Such an experiential approach aims to offer architects a more direct interaction with textile materials while suggesting a closer connection between future users and architecture.

Acknowledging the importance that digital design has within the architectural design process, this investigation proposes the use of motion capture technology as a bridge between the experiential (embodied explorations) and the 3D modelling processes. In what follows, I will reiterate the research sub-questions and describe how I answered each of them and what the main contributions are in relation to each one.

The main research question of this thesis was: How can soft embodied architecture be ideated by means of EDI methods? This investigation addressed the use of EDI methods to open up new ways of ideating textile architecture. Through the literature review process, the fact that few examples exist that take an embodied approach to textile architecture was identified and highlighted in relation to the key concept this thesis proposes: soft embodied architectures. Building on Schillig's (2015) understanding of space as a continuous experience, and the concept of soft architecture proposed by Ramsgaard (2011), a soft, embodied approach to architectural design was developed through four experiments. Four research sub-questions addressed how this soft and embodied approach was redefined through the practice-based experiments, and a hybrid EDI process to ideate soft embodied architecture was formalised (Chapter 6).

The first research sub-question was: When does a textile become space? Experiment 1 (Figure 82) answered this sub-question by exploring the spatiality of lightweight nylon fabric, an elastic spandex fabric, and a transparent netting fabric. The findings

showed that human and non-human agencies came into play and produced three body-space entities. These soft body-space entities provide different ways of enacting soft spaces: the billowing soft-body space entity, the deformable body-space entity and the soft body-space foldable entity. An ANT perspective on the ideation process helped to underpin the connection between form, space and the interaction between participants.

The second research sub-question asked: How can the design possibilities of a soft embodied architecture be expanded into the digital realm? Experiment 2 (Figure 83) answered the second sub-question by presenting a digital toolset using motion capture technology. A soft billowing body-space entity and a soft deformable body-space entity were mapped out into the digital realm. The resulting digital captures enabled an explorative design process that resulted in a collection of volumetric digital morphologies and surface mesh visualisations. The findings showed that a hybrid EDI process emerged that enabled the connection of the two soft body-space entities with their digital equivalent.

The third research sub-question of this thesis was: How can a hybrid EDI process for soft embodied architectural be designed? Experiment 3 (Figure 84) responded to the third sub-question by exploring the design of the hybrid EDI process identified in Experiment 2 with a group of architects. Three soft body-space entities emerged from the embodied explorations, and raw geometries were obtained. Several meshes with different densities were processed out of one of the raw geometries to visualise its characteristics. Embodied and digital outputs were combined to identify the correlation between the geometry and the experience. The findings showed that the embodied explorations provided a positive and meaningful experience that adds a new layer of knowledge to architectural design methodology. On the other hand, the lack of a more controlled and precise set-up prevented the architects from considering the hybrid EDI process robust enough to be implemented within the architectural design methodology.

Lastly, the fourth sub-question was: How could the hybrid EDI process be implemented within an architectural design methodology? Experiment 4 (Figure 85) answered the sub-question with the designing of a Multi Kinect toolset and an elastic

Research Question
When does textile become space?

Aim
To explore the spatiality of textiles from an embodied perspective.

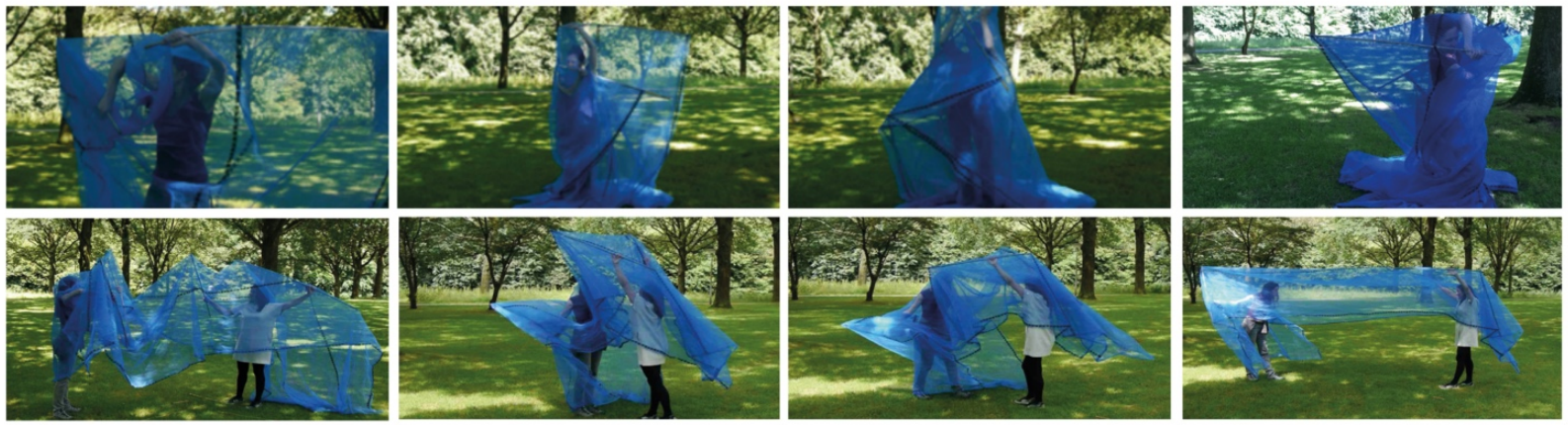
BODY-MATERIAL INTERACTIONS

NYLON FABRIC

THE BILLOWING BODY-SPACE ENTITY
It enables the experience of bodily enacting a soft volume in motion.

DYNAMIC QUALITIES	SPATIAL QUALITIES
Lightweight > Volumes	Soft space in motion

NETTING FABRIC



THE FOLDABLE BODY-SPACE ENTITY
It shows how the subtlety of a netting fabric allows the user to devise a space based on the context and its elements.

DYNAMIC QUALITIES	SPATIAL QUALITIES
Foldability and transparency > Inside-outside transitions	Extended space

SPANDEX LYCRA FABRIC

THE DEFORMABLE BODY-SPACE ENTITY
It allows the participant to shape the light and personalise the space by stretching out the textile.

DYNAMIC QUALITIES	SPATIAL QUALITIES
Stretchability > Gradient of transparency	Deformable space

Figure 82. Experiment 1: summary of the process and the results.

EXPERIMENT 2: SOFT EMBODIED GEOMETRIES

Research Question
How can the design possibilities of a soft embodied architecture be expanded into the digital realm?

Aim
To explore the potential of motion capture technology to support the ideation of soft embodied architecture.

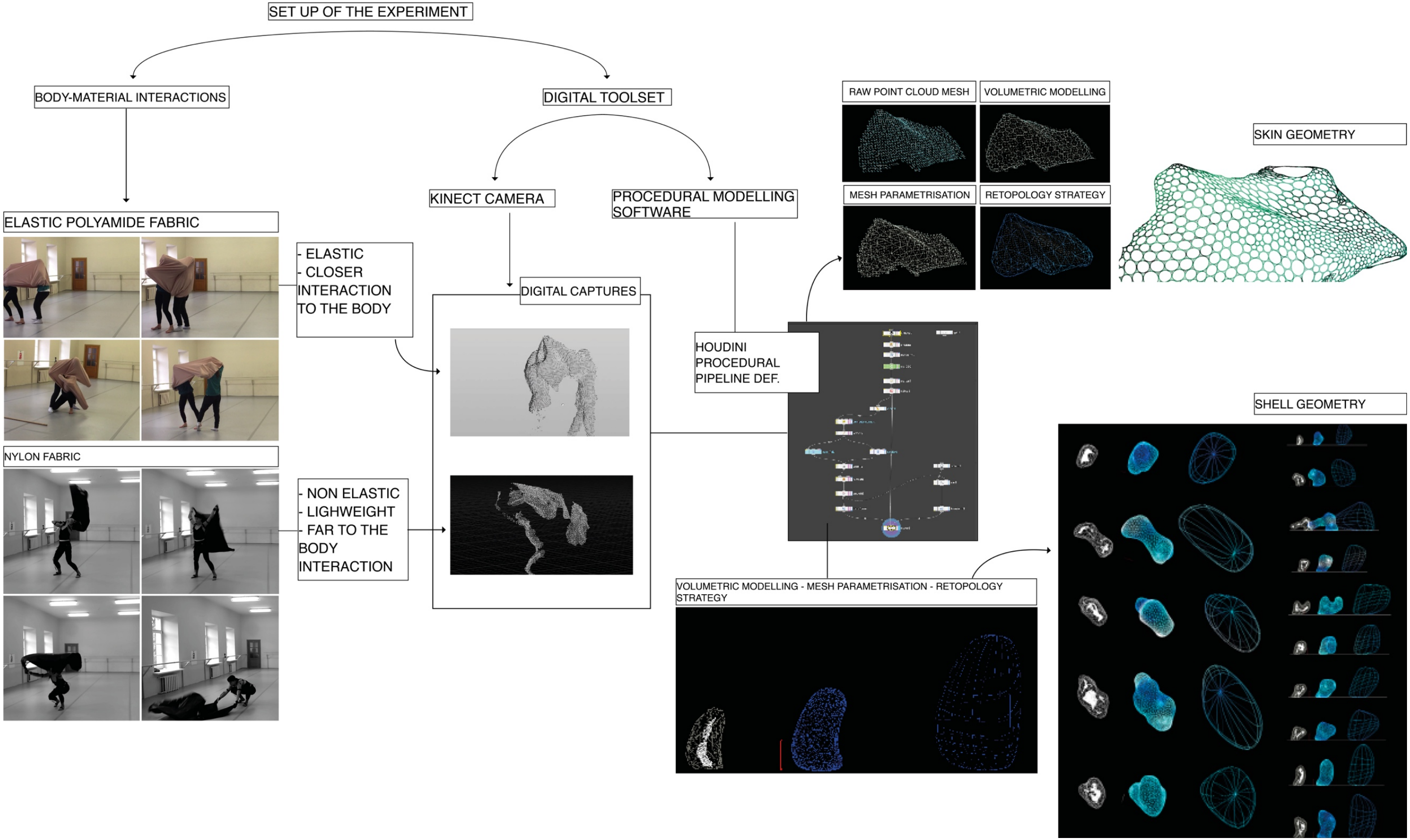


Figure 83. Experiment 2: summary of the process and the results.

interface to achieve the precision needed for the design of a hybrid EDI process suitable for soft embodied architectural design. Six choreographic sequences were carried out by a choreographer and a group of dancers to produce both embodied and digital outputs. A new elastic body-space entity emerged in a co-shaping process between the dancers and the elastic interface. The digital captures of the elastic body-space entity presented a complete raw geometry and enabled the interpretation of the deformation of the elastic interface in relation to the change in transparency of the fabric. The findings show that the hybrid EDI process enabled a precise connection between the transparency of the material, the dancer's spatial perception of inside and outside and the surface curvature of the elastic interface. The relationship between the first-hand experience, the material and geometry became explicit.

The four sub-questions revisited above built upon each other, helping to articulate a hybrid EDI process for soft embodied architectural design. Experiment 1 enabled the articulation of a preliminary soft embodied approach to architecture as evidenced by the creation of temporary soft body-space entities. Experiment 2 offered the possibility of exploring formal and spatial aspects of a temporary soft embodied architecture into the digital realm, as evidenced in the creation of a hybrid EDI process. Experiment 3 helped to identify the limitations and opportunities of the hybrid EDI process of Experiment 2, as evidenced in the identification of the need for a more precise hybrid EDI process. Finally, Experiment 4 proved the potential of the hybrid EDI process to produce insights that could inform the design of a soft, embodied and dynamic architecture as evidence in the articulation of a hybrid EDI process suitable for soft embodied architectural design.

The contributions above are grounded in empirical data, as in RtD tradition (Frayling, 1993), and through collaborative ideation design processes (Sanders and Stappers, 2008). Collaboration was a prominent aspect of this investigation. My role during the experiments alternated between observer and participant. This role allowed me to draw the design particulars (Stolterman, 2008) of each experiment and ground them in theory (Zimmerman and Forlizzi, 2014). The four experiments offer inspiration to other researchers willing to adopt an embodied approach in the early stages of the design process. Experiments 2, 3 and 4 suggest a supportive use of technology, rather than a technology-driven approach in which the material performance and the

Research Question
How can a hybrid EDI process for soft embodied architectural design be created?

Aim
To explore with architects the opportunities and limitations of a hybrid EDI process.

SET UP OF THE EXPERIMENT

EMBODIED EXPLORATIONS

DIGITAL TOOLSET

BODY-MATERIAL INTERACTIONS

EMBODIED OUTPUTS

KINECT CAMERA

PROCEDURAL MODELLING SOFTWARE

CHIFFON FABRIC

MATERIAL QUALITIES

- NON ELASTIC
- LIGHTWEIGHT

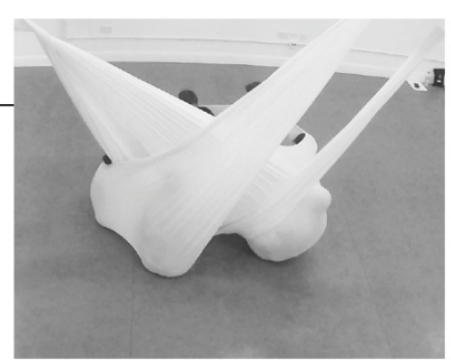
NEOPRENE FABRIC

- SEMI-ELASTIC
- THICK

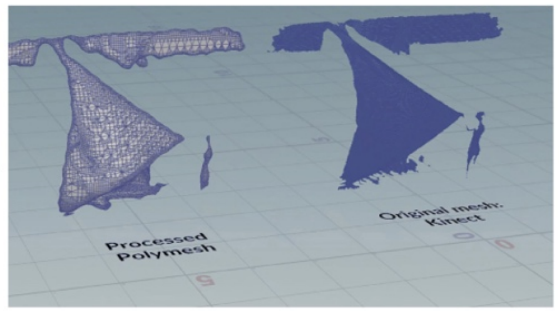
SPANDEX FABRIC

- ELASTIC
- SKIN STRUCTURE

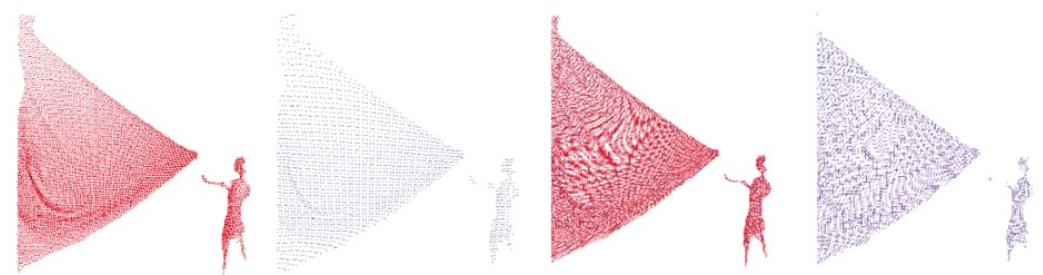
LAYERING UP SOFT MATERIALITY



RAW POINTCLOUD



DIGITAL OUTPUTS



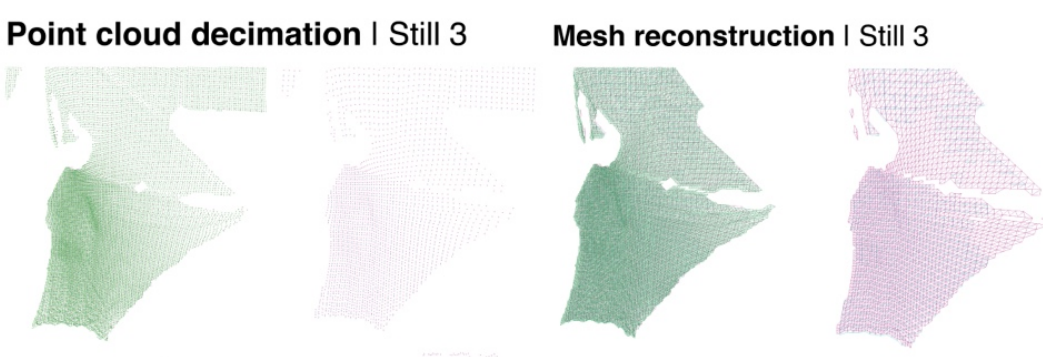


Figure 84. Experiment 3: summary of the process and the results.

Research Question
How could the hybrid EDI process be implemented within an architectural design methodology?

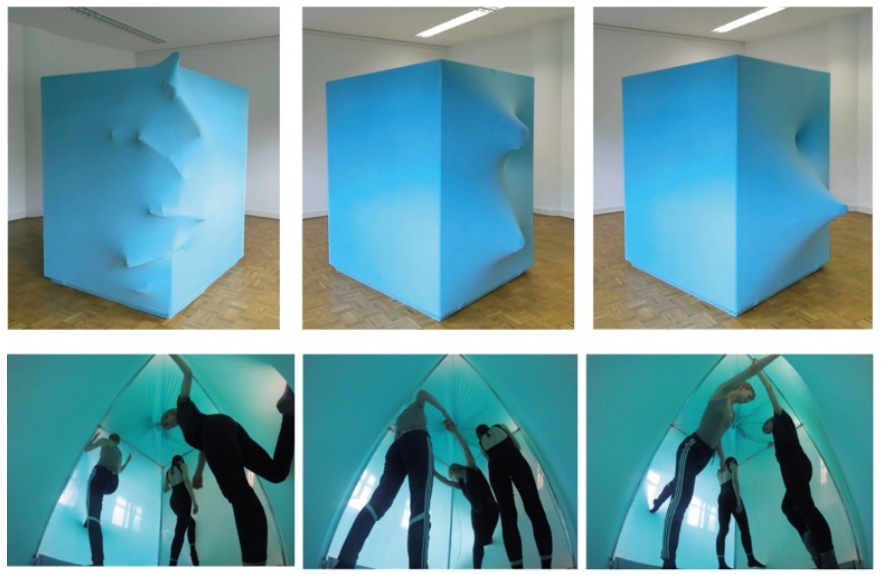
Aim
To design a hybrid EDI process suitable for soft embodied architectural design.

SET UP OF THE EXPERIMENT

CHOREOGRAPHED BODY-MATERIAL INTERACTIONS

ELASTIC INTERFACE

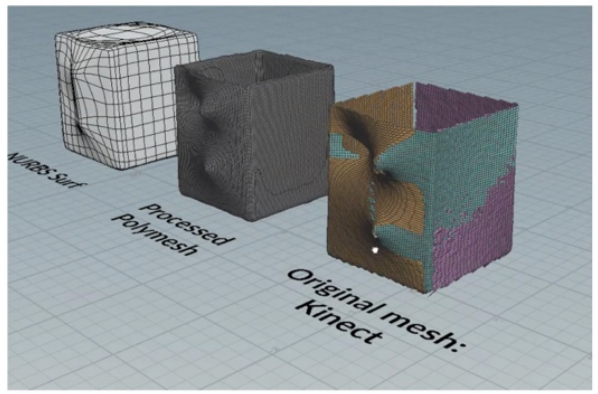
- ALUMINIUM FRAME
- SPANDEX LYCRA FABRIC



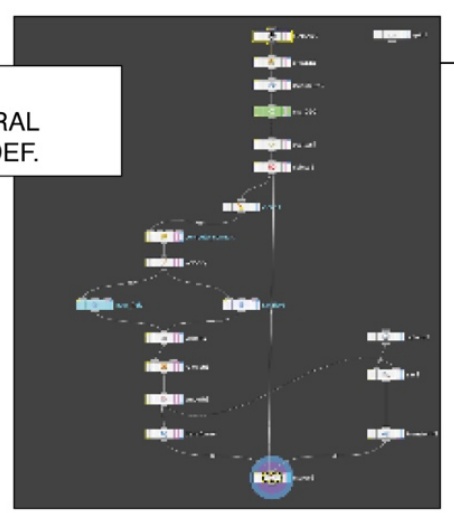
DIGITAL TOOLSET

MULTI KINECT SET-UP

POINT CLOUD MESH RECONSTRUCTED

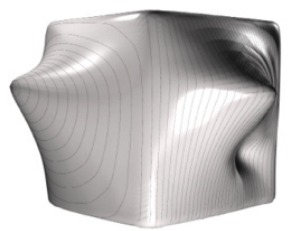


HOUDINI PROCEDURAL PIPELINE DEF.

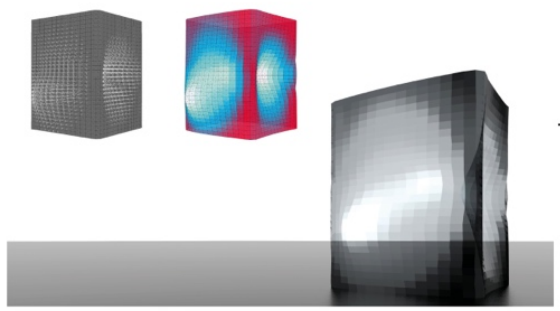


PROCEDURAL MODELLING SOFTWARE

SOFT MORPHOLOGIES



INTERPRETING TRANSPARENCY



SOFT FORM VOCABULARY

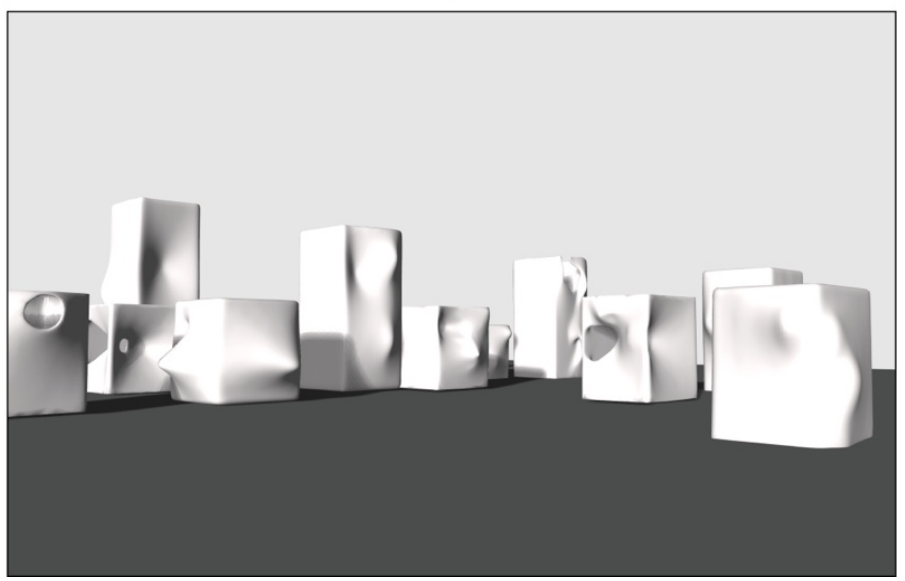


Figure 85. Experiment 4: summary of the process and the results.

architectural form predominate over the experiential aspect of the design as seen in the work of Spuybroek and Menges (Spuybroek, 2011; Prado et al., 2017).

Experiment 4 offers methodological suggestions as evidenced in the step-by-step definition of the hybrid EDI process. The four experiments outline an emergent design space that opens up a new way of ideating soft embodied architecture, which is materialised in the definition of a hybrid EDI process that combines the first-hand experience of embodied explorations with digital processes. The hybrid EDI process suggests dynamic ways of interacting within future architectural spaces and a nuanced understanding of soft embodied architecture based on human and non-human agencies.

Ultimately, the hybrid EDI process would allow architects to acquire a balance between the experiential and the structural. By engaging with soft materials in an embodied and situated way, architects would be able to shape the dynamic interaction that the final design should incorporate. For example, in the case of the explorations with the chiffon fabric (Experiment 3), architects would be able to decide which parts of the chiffon fabric should be fixed and which ones should drop down. Such an understanding of subtle contextual, material and human interaction would be difficult to acquire otherwise in such an immediate way.

Collaborative aspect

The outcomes of the experiments demonstrate that collaborating with dancers and choreographers as experts in body movement contributed to creating distinctive soft embodied spatial expressions. The collaborations with dancers and choreographers also helped architects to engage with the body-material interactions in a more active way. This was especially evident towards the final embodied explorations of Experiment 3, in which architects interacted actively with the dancers, forming cocoons with the spandex Lycra fabric.

The hybrid EDI process brings together the expertise of architects, textile designers, embodied interaction designers, dancers and choreographers in a collaborative process that provide a wealth of ideas and diverse feedback. This was evident in Experiments 1 and 4, in which participants' feedback helped to describe concrete formal, spatial and experiential aspects based on the interaction with the material, the

other participants and the context. To include users within the design process would enrich the insights into designing soft embodied architecture, and would enable a co-design process for soft embodied architectural design.

A nuanced understanding of soft embodied architecture based on human and non-human agency.

Drawing on the notions of human and non-human agency, a collection of soft body-space entities emerged across the four experiments. The four experiments addressed to the relationships that arise when the body interacted with the textile material, enabling a new entity that holds distinctive formal, dynamic and spatial qualities. The four experiments offer a nuanced understanding of soft embodied architecture that recognises human and non-human agency as drivers of the design process.

As the experiments in this investigation suggest, an awareness of human and non-human agencies helps to bring a relational perspective and supports the generation of knowledge. By understanding the act of ideating soft embodied architecture not only as an ideation process but as a theory of action – from an ANT perspective – I was able to further elaborate on the relationship between the material, the context and participants.

Future directions

This investigation opens up several opportunities to continue exploring the ideation of a soft embodied architecture. Firstly, from the perspective of the embodied explorations and the material I see value in exploring the use of other materials that behave similarly to textiles such as plastic, paper or even gaseous materials to investigate new soft embodied spatial expressions.

Secondly, based on the findings of Experiment 4 (Chapter 6), I would suggest to exploring other formats of the elastic interface such as façade modules and wall dividers to explore the implementation of elastic material behaviours and its relation to the light conditions between the inside and exterior of a building.

Thirdly, building on the findings of the embodied explorations with the chiffon fabric in Experiment 3 (Chapter 5), I would further investigate ways of finding the balance between participants' freedom of interaction with the chiffon fabric and a structural system that would hold it. For example, by identifying key areas of the fabric, these

could be held up by these fixed points while some layers of the fabric would remain free, enabling participants to interact through the layers of the chiffon fabric.

Lastly, it would be valuable to carry out further iterations of the hybrid EDI process and create a final design to gather users' reactions and opinions. This would help to assess the hybrid EDI process and eventually define a hybrid EDI method for soft embodied architectural design.

Bibliography

1. Agkathidis, A., Alexopoulou, A., Schillig, G., Lada, S., Lecatsa, R., Papakostas, G. and Vyzoviti, S., 2010. *Performative Geometries Transforming Textile Techniques*. Amsterdam: BIS Publishers.
2. Ahlquist, S., 2015. Integrating Differential Knit Logics and Pre-Stress in Textile Hybrid Structures. In: M.R. Thomsen, M. Tamke, C. Gengnagel, B. Faircloth and F. Scheurer, eds., *Modelling Behaviour*. *Design Modelling Symposium, 2015.* Cham:Springer
3. Ahlquist, S. and Menges, A., 2011. *Computational Design Thinking*. London: John Wiley and Sons.
4. Albright, T., Arbib, M., Eberhard, J.P., Farling, M., Gallese, V., Gattara, A., Johnson, M.L., Mallgrave, H.F., McGilchrist, I., Pallasmaa, J., Pérez-Gómez, A. and Robinson, S., 2015. *Mind in Architecture. Neuroscience, Embodiment, and the Future of Design*. Cambridge, MA: MIT Press.
5. Aldinger, I.L., 2016. Frei Otto: Heritage and Prospect. *International Journal of Space Structures*, 31(1), pp.3–8.
6. Allamoda, B., 2017. *Spandex Studies*. Berlin: Revolver Publishing.
7. *Ferrari Textiles*. 2018. [online] Available at: <https://www.sergeferrari.com/> [Accessed 5 May 2018].
8. *Kas Oosterhuis*. 2018 [online] Available at: <http://www.oosterhuis.nl/> [Accessed 10 Sep. 2018].
9. *Sefar*. 2018 [online] Available at: <https://www.sefar.com/en/> [Accessed 5 May 2018].
10. Arteaga, A., 2014. *The Architecture of Embodiment*. [online] Available at: <http://www.architecture-embodiment.org/> [Accessed 26 Mar. 2018].
11. Ban, S., 1995. *Curtain Wall House*. [online] Available at: <www.shigerubanarchitects.com> [Accessed 14 Jul. 2018].
12. Bardzell, S., Bardzell, J., Folizzi, J., Zimmerman, J. and Antanitis, J., 2012. Critical Design and Critical Theory: the Challenge of Designing for Provocation. In: *Proceedings of the Designing Interactive Systems Conference, DIS' 12*. ACM Press, New York, NY: ACM Press, pp.288–297.
13. Beesley, P., 2013. *Voltage Haute Couture*. [online] Available at: <http://philipbeesleyarchitect.com/projects/1222_Van-Herpen/> [Accessed 20 Apr. 2017].
14. Beim, A. and Thomsen, M.R., 2012. *The Role of Material Evidence in*

Architectural Research - Drawings, Models, Experiments. Copenhagen: Kunstakademiets Arkitektskole Forlag.

15. Blaisse, M., 2013. *The Emergence of Form*. Rotterdam: nai010.
16. Blaisse, P., 2009. The Instinctive Sense of Space and Boundary. *Architectural Design*, 79(3), pp.84–87.
17. Bloomer, K. and Moore, C., 1977. *Body, Memory and Architecture*. New Haven, CT: Yale University Press.
18. Bowen, S., Durrant, A., Nissen, B., Bowers, J. and Wright, P., 2016. The Value of Designers' Creative Practice in Complex Collaborations. *Design Studies,* 46, pp. 174-198.
19. Bravo, M., Chaltiel, S. and Carazas, W., 2018. Matter-Robotic Calibration for Bioshotcrete. *Temes de Disseny: Material Interactions in the Human-made Milieu* (34), pp.92–103.
20. Bugg, J., 2009. Fashion at the Interface: Designer—Wearer—Viewer. *Fashion Practice: the Journal of Design Creative Process & the Fashion Industry* 1(1), pp.9–32.
21. Burns, C., Dishman, E., Verplank, W. and Lassiter, B., 1994. Actors, Hairdos & Videotape---Informance Design. In: *Conference Companion on Human Factors in Computing Systems - CHI '94*. New York, NY: ACM. pp.119–120.
22. Candela, I., Ferreira, G., Martins, S.B. and Rajchman, J., 2017. *Lygia Pape: A Multitude of Forms.* New York, NY: Metropolitan Museum of Art.
23. Castán, M., Rubio, G. and Gonzalez, M., 2016. The Wearable Fashion Orchestra. In: S. Kettley, *Designing with Smart Textiles.* London: Bloomsbury Academic.
24. Castán, M. and Suárez, D., 2017. Textile Choreographies : Bridging Physical and Digital Domains in the Context of Architectural Design. In: S. Karana, Elvin; E. Giaccardi; E. Nimkulrat; K. Niedderer; S. Camere, eds., *International Conference 2017 of the Design Research Society Special Interest Group on Experiential Knowledge (EKSIG2017)*. Delft: TU Delft Open, pp.249–260.
25. Castán, M. and Suárez, D., 2018. Choreographed Morphologies: Exploring New Ways of Ideating Soft Architecture Through Material Elasticity. *Temes de Disseny: Material Interactions in the Human-made Milieu 34,* pp.58–71.
26. Castán, M. and Tomico, O., 2017. When Does Clothing Become Textile Architecture ? Creating Dynamic Qualities in Architecture Through the Power of Embodied Ideation Techniques. In: *Nordic Design Research Conference*

2017 Design + Power (NORDES2017), 15-17 June, AHO, Oslo.

27. Castan, M. and Tomico, O., 2018. Layering Up Soft Materiality: a Hybrid Embodied Design Ideation Method for Soft Architectural Design. In: *NordiCHI'18*, Oslo. New York, NY: ACM Press.
28. Choi, Y.W., Mcadams, H.P., Jeon, S.C., Park, C.K., Lee, S., Kim, B., Kim, J.H. and Hahm, C.K., 2002. Textile Logics in a Moving Architecture. *Structure*, 26(3), pp.335–341.
29. Cross, N., 2001. Designerly Ways of Knowing: Design Discipline Versus Design Science. *Design Issues*, 17(3), pp. 49-55.
30. DeLanda, M., 2015. The New Materiality. *Architectural Design*, 85(5), pp.16–21.
31. Deleuran, A.H., Schmeck, M., Quinn, G., Gengnagel, C., Tamke, M. and Thomsen, M.R., 2015. The Tower : Modelling , Analysis and Construction of Bending Active Tensile Membrane Hybrid Structures. In *Proceedings of the International Association for Shell and Spatial Structures Symposium,* Amsterdam (IASS), (August).
32. Deleuze, G., 1992. *The Fold: Leibniz and the Baroque*. Minneapolis, MN: University of Minessota Press.
33. Dumitrescu, D., Landin, H., Vallgårda, A., 2012. An Interactive Textile Hanging: Textile, Spaces, and Interaction. *Studies in Material Thinking*, vol.7., pp. 1-13.
34. Dykes, T., Bythe, M., Wallace, J., Thomas, J. and Regan, T., 2016. RtD Comics: A Medium for Representing Research Through Design. In: *Proceedings of the 2016 ACM Conference on Designing Interactive Systems DIS '16*., Brisbane. ACM Press, New York, NY: ACM Press, pp.971–982.
35. Faleh, O. Al, 2014. Responsive Architecture A Conceptual Framework for the Re-Examination of Space , Embodiment , and Perception. In *Fusion, Proceedings of the 32nd International Conference on Education and Research in Computer Aided Architectural Design in Europe*, Newcastle upon Tyne: Northumbria University, pp. 577–585. Vol. 2 eCCADe: Conferences 2.
36. Fallan, K., 2008. Architecture in Action: Traveling with Actor-Network Theory in the Land of Architectural Research. *Architectural Theory Review*, 13(1), pp.80–96.
37. Feldenkrais, M., 1972. *Awareness Through Movement*. New York: Harper & Row.

38. Filipovic, E. and Walther, E., 2014. *Franz Erhard Walther: The Body Decides*. Köln: Buchhandlung Walther König.
39. Findeli, A., 1998. A Quest for Credibility: Doctoral Education and Research in Design at the University of Montreal. In: *Doctoral Education in Design,* Ohio, 8-11 October 1998.
40. Frayling, C., 1993. Research in Art and Design. *Royal College of Art Research Papers*, 1(1) London: Royal College of Art.
41. Fuller, B., 1952. Buckminster Fuller. *Perspecta*, 1, pp.29–37.
42. Gannon, M., 2014. Reverberating Across the Divide Bridging Virtual and Physical Contexts in Digital Design and Fabrication. In *Proceedings of the 34rd Annual Conference of the Association for Computer Aided Design in Architecture*, ACADIA 2014. Los Angeles, USA: USC School of Architecture, 357–364.
43. Garcia, M., 2006. Architecture + Textiles = Architextiles. *Architectural Design*, 76(6), pp.1–134. [online] Available at: <http://dx.doi.org/10.1002/ad.345>.
44. Gaver, B. and Bowers, J., 2012. Annotated Portfolios. *Interactions*, July/August, pp.40–49. [online] Available at: <http://www.uio.no/studier/emner/matnat/ifi/INF5591/h16/pensumliste/gaver-and-bowers---2012---annotated-portfolios-copy.pdf>.
45. Gaver, W., 2012. What Should we Expect from Research Through Design? *Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems - CHI '12*, Austin, Texas, p.937. [online] p.937. Available at: <http://dl.acm.org/citation.cfm?doid=2207676.2208538>.
46. Gehry, F., 2015. *Dr Chau Chak Wing Building*. [online] Available at: <https://www.uts.edu.au/partners-and-community/initiatives/city-campus-master-plan/completed-projects/dr-chau-chak-wing> [Accessed 30 Nov. 2018].
47. Gorny, R.A. and van den Heuvel, D., 2017. Introduction: New Figurations in Architecture Theory: From Queer Performance to Becoming Trans. *Footprint*, 2017(21), pp.1–10.
48. Hirschberg, U., Sayegh, A., Frühwirth, M. and Zedlacher, S., 2006. 3D Motion Tracking in Architecture. Turning Movement into Form - Emerging Uses of a New Technology. In: V. Bourdakis and D. Charitos, eds., *Communicating Space(s): 24th eCAADe Conference Proceedings*. Volos, Greece: eCAADe: Conferences, pp.114–121.

49. Höök, K., Hummels, C., Isbister, K., Marti, P., Segura, E.M., Jonsson, M., Mueller, F., Sanches, P.A.N., Schiphorst, T., Ståhl, A., Svanaes, D., Trotto, A., Petersen, M.G. and Lim, Y.-K., 2017. Soma-based Design Theory. *Conference on Human Factors in Computing Systems - Proceedings*, *CHI-EA '17*, Part F1276, New York: ACM Press, pp.550–557.
50. Höök, K. and Löwgren, J., 2012. Strong concepts: Intermediate-Level Knowledge in Interaction Design Research. *ACM Transactions on Computer-Human Interaction*, 19(3), pp.1–18.
51. Hummels, C., Overbeeke, K.C. and Klooster, S., 2007. Move to Get Moved: A Search for Methods, Tools and Knowledge to Design for Expressive and Rich Movement-based Interaction. *Personal Ubiquitous Computing*, [online] 11(8), pp.677–690. Available at: <http://dx.doi.org/10.1007/s00779-006-0135-y>.
52. Iacucci, G. and Kuutti, K., 2002. Everyday Life as a Stage in Creating and Performing Scenarios for Wireless Devices. *Personal and Ubiquitous Computing*, 6(4), pp.299–306.
53. Isbister, K., Márquez Segura, E. and Melcer, E.F., 2018. Social Affordances at Play: Game Design Toward Socio-Technical Innovation. In: *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems CHI ´18*, Montreal. New York, NY: ACM Press.
54. Jarvis, N., Cameron, D. and Boucher, A., 2012. Attention To Detail : Annotations of a Design Process. In: *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design, NordiCHI '12*. Copenhagen: New York, NY: ACM Press, pp.11–20.
55. Jefferies, J., Conroy, D.W. and Clark, H., eds. 2016. *The Handbook of Textile Culture*. London: Bloomsbury Academic.
56. Jelić, A., Tieri, G., De Matteis, F., Babiloni, F. and Vecchiato, G., 2016. The Enactive Approach to Architectural Experience: A Neurophysiological Perspective on Embodiment, Motivation, and Affordances. *Frontiers in Psychology*, 7(Mar), pp.1–20.
57. Jonas, W., 2007a. Design Research and its Meaning to the Methodological Development of the Discipline. *Design Research Now* (January 2007), pp.187–206.
58. Jonas, W., 2007b. Research through DESIGN through Research: A Cybernetic Model of Designing Design Foundations. *Kybernetes*, 36(9–10),

pp.1362–1380.

59. Jones, J.C., 1992. *Design Methods.* New York: Wiley & Sons.
60. Kalantari, S., Poustinchi, E. and Ahmadi, N., 2016. Human-Based Design and Digital Fabrication: Behavioral Mapping Parametric Knitter (BMPK). *Journal of Engineering Technology (JET)*, 4(1), pp.13–17.
61. Karana, E., Barati, B., Rognoli, V. and Laan, A.Z. Van Der, 2015. Material Driven Design (MDD): A Method to Design for Material Experiences. *International Journal of Design*, 9(2), pp.35–54.
62. Kato, S. and Glynn, R., 2018. Fabricating Performance: Reciprocal Constructs of Dance Notation. *Nexus Network Journal*, 20(1), pp.75–94.
63. Kirsh, D., 2013. Embodied Cognition and the Magical Future of Interaction Design. *ACM Transactions on Computer-Human Interaction*, 20(1), p.30.
64. Klooster, S. and Overbeeke, K.C.J., 2005. Designing Products as an Integral Part of Choreography of Interaction: the Product's Form as an Integral Part of Movement. In: *Proceedings of the 1st European Workshop on Design and Semantics of Form and Movement (DeSForM)*. Northumbria University, Newcastle, pp.23–35.
65. Kuusisto, T.K., 2010. *Textile in Architecture*. [online] Available at: <https://dspace.cc.tut.fi/dpub/bitstream/handle/123456789/6619/kuusisto.pdf > [Accessed 23 May 2017].
66. Kyan, M., Sun, G., Li, H., Zhong, L., Muneesawang, P., Dong, N., Elder, B. and Guan, L., 2015. An Approach to Ballet Dance Training through MS Kinect and Visualization in a CAVE Virtual Reality Environment. *ACM Transactions on Intelligent Systems and Technology*, 6 (2), Article 23.
67. Latour, B., Yaneva, A., 2008. Give me a Gun and I will Make All Buildings Move: An ANT?s View of Architecture. In: R. Geiser, (eds). *Explorations in Architecture: Teaching, Design, Research.* Basel: Birkhauser, pp. 80-89.
68. Latour, B., 1992. Where are the Missing Masses? The Sociology of a Few Mundane Artifacts. In Bijker, W. , Law, J., eds., *Shaping Technology/Building Society: Studies in Sociotechnical Change*. Cambridge, MA: MIT Press, pp.225–258.
69. Latour, B., 2005. *Reassembling the Social. An Introduction to Actor-Network-Theory*. Oxford: Oxford University Press.
70. Laugier, M.-A., 1755. *An Essay on Architecture*. London: T. Osbourne and Shipton.

71. Lee, W., Lim, Y. and Shusterman, R., 2014. Practicing Somaesthetics: Exploring its Impact on Interactive Product Design Ideation. *Proceedings of the 2014 Conference on Designing Interactive Systems*, Vancouver, BC. pp.1055–1064.
72. Lindwell, W., Holden, K. and Butler, J., 2003. *Universal Principles of Design*. Beverley, MA: Rockport.
73. Lofland, J., Snow, D., Anderson L., & Lofland, L.H., 2005. *Analyzing Social Settings: A Guide to Qualitative Observation and Analysis* (4th Ed.), Belmont, CA: Wadsworth Thomson.
74. Loke, L. and Robertson, T., 2013. Moving and Making Strange: An Embodied Approach to Movement-based Interaction Design. *ACM Transactions on Computer Human Interaction*, 20(1), p.7:1–7:25.
75. Lorenz Schilling, M., Wakkary, R. and Odom, W., 2018. Focus Framework: Tracking Prototypes' Back-Talk. In: *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction*, Stockholm. New York, NY: ACM Press, pp.684–693.
76. Löwgren, J., 2013. Annotated Portfolios and Other Forms of Intermediate-Level Knowledge. *Interactions*. 20(1), pp. 30-34.
77. Manning, E., 2005. Choreography*as*Mobile*Architecture![1]! *Performance Paradigm*. [online] Available at: <http://www.performanceparadigm.net/index.php/journal/article/viewFile/134/133>.
78. Marble, S., 1988. *Architecture and Body*. New York: Rizzoli.
79. Márquez Segura, E., Turmo Vidal, L., Rostami, A. and Waern, A., 2016. Embodied Sketching. In: *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, San Jose, CA, pp.6014–6027.
80. Mossé, A., Gauthier, D. and Kofod, G., 2012. Towards Interconnectivity: Appropriation of Responsive Minimum Energy Structures in an Architectural Context. *Studies in Material Thinking*, 07 (January), paper 6.
81. Murray, S.C., 2009. *Contemporary Curtain Wall Architecture*. New York: Princeton Architectural Press.
82. Muslimin, R., 2010. Learning from Weaving for Digital Fabrication in Architecture. *Leonardo*, 43(4), pp.340–349.
83. Nerdinger, W., 2005. *Frei Otto: Complete Works: Lightweight Construction - Natural Design*. Basel: Birkhauser.

84. Neto, E., 2009. *Ernesto Neto: The Edges of the World*. London: Hayward Gallery Publishing.
85. Novak, M., 1991. Liquid Architectures In Cyberspace. In: M. Benedict, ed., *Cyberspace: First Steps.* Cambridge, MA: MIT Press.
86. Oulasvirta, A., Kurvinen, E. and Kankainen, T., 2003. Understanding Contexts by Being There: Case Studies in Bodystorming. *Personal and Ubiquitous Computing*, 7(2), pp.125–134.
87. Overbeeke, Kees C. J.; Hummels, C., 2011. Industrial Design, in: *Encyclopedia of Human-Computer Interaction* [online] Available at: <https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/industrial-design>.
88. Pacher, M., 2014. *Enacting Space*. Master's thesis, Bauhaus University, Weimar. [online] Available at: <https://www.uni-weimar.de/en/architecture-and-urbanism/chairs/dual-masters-degree/student-works/thesis-projects/enacting-space-l-matteo-pacher/> [Accessed 10 Oct. 2016].
89. Palazzi, M. and Zuniga Shaw, N., 2009. Synchronous Objects for One Flat Thing, Reproduced. In: *Proceedings of the 36th International Conference and Exhibition on Computer Graphics and Interactive Techniques, SIGGRAPH '09.* New Orleans: New York, NY: ACM Press.
90. Pallasmaa, J., 2012. *The Eyes of The Skin. Architecture and The Senses*. 3rd ed. John Wiley and Sons.
91. Peri Bader, A., 2015. A model for everyday experience of the built environment: the embodied perception of architecture. *The Journal of Architecture*, 20(2), pp.244–267. [online] Available at: <https://doi.org/10.1080/13602365.2015.1026835>.
92. Picon, A., 2004. Architecture and the Virtual: Towards a new Materiality? *Praxis,* 6, pp.114-121.
93. Pišteková, D., 2017. *Dress Codes: In-between Clothing and Architecture*. [online] Available at: <http://danicapistekova.com/> [Accessed 8 Apr. 2018].
94. Prado, M., Dörstelmann, M., Solly, J., Menges, A. and Knippers, J., 2017. Elytra Filament Pavilion: Robotic Filament Winding for Structural Composite Building Systems. In: *Fabricate 2017: Rethinking Design and Construction*, (May 2017), London: UCL Press, pp.224–231. Available at: http://discovery.ucl.ac.uk/1546589/1/Fabricate.pdf.
95. Prestinenza Puglisi, L., 1999. *Hyper Architecture: Spaces in the Electronic*

Age. Basel: Birkhauser.

96. Quinn, B., 2015. Textiles and Architecture. In: J. Jefferies, D.W. Conroy and H. Clark, eds., *The Handbook of Textile Culture*. London: Bloomsbury, pp.51-64.
97. Ramsgaard Thomsen, M. and Bech, K., 2011. *Textile Logic for a Soft Space*. Copenhagen: The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, Schoool of Architecture.
98. Rashid, H., 2018. *Hani Rashid*. [online] Available at: <http://www.studio-hani-rashid.at/> [Accessed 10 Sep. 2018].
99. Rasmussen, S.E., 2000. *Experiencing Architecture*. Cambridge, MA: MIT Press.
100. Rompay, T.J.L. van, and Ludden, G.D.S., 2015. Types of Embodiment in Design: The Embodied Foundations of Meaning and Affect in Product Design. *International Journal of Design*, 9(1), pp.1–11.
101. Ross, P.R. and Wensveen, S.A.G., 2010. Designing Behavior in Interaction: Using Aesthetic Experience as a Mechanism for Design. *International Journal of Design*, 4(2), pp.3–13.
102. Sabin, J., 2017. *Lumen*. [online] Available at: <http://www.jennysabin.com/lumen/> [Accessed 19 Apr. 2018].
103. Salazar Sutil, N., 2015. *Motion and Representation. The Language of Human Movement*. Cambridge, MA: MIT Press.
104. Salter, C., 2010. Entangled: Technology and the Transformation of Performance. Cambridge; London: MIT Press.
105. Sanders, E.B.-N. and Stappers, P.J., 2008. Co-creation and the New Landscapes of Design. *CoDesign*, [online] 4(1), pp.5–18. Available at: <http://www.tandfonline.com/doi/abs/10.1080/15710880701875068>.
106. Sauerwein, M., Bakker, C. and Balkenende, R., 2018. Annotated Portfolios as a Method to Analyse Interviews. In: *Design Research Society, DRS 2018*. London, UK: Design Research Society.
107. Schillig, G., 2009. *Mediating Space. Soft Geometries.Textile Structures. Body Architecture*. Stuttgart: Merz & Solitude.
108. Schillig, G., 2015. Intermediacies of Experience: Textile Spaces - Spaces of Communication. In: C. Perren and M. Mlecek, eds., *Perception in Architecture HERE and NOW*. s.l.: Cambridge Scholars Publishing, pp.58–69.
109. Schleicher, D., Jones, P. and Kachur, O., 2010. Bodystorming as

embodied designing. *Interactions*, 17(6), p.47. [online] Available at: <http://portal.acm.org/citation.cfm?doid=1865245.1865256>.

110. Schön, D., 1983. *The Reflective Practitioner: How professional think in action*. New York: Basic Books.

111. Segura, E.M., Vidal, L.T. and Rostami, A., 2016. Bodystorming for Movement-Based Interaction Design. *Human Technology*, 12(2), pp.193–251.

112. Semper, G., 1989. *The Four Elements of Architecture and Other Writings*. *RES Monographs in Anthropology and Aesthetics*. Cambridge: Cambridge University Press.

113. Serres, M. and Latour, B., 1995. *in Architextiles: Conversations on Science, Culture and Time*. Ann Arbor, MI: University of Michigan Press.

114. Sherwood, A. and Allison, M., 2012. *Firewall*. Available at: http://aaron-sherwood.com/works/firewall/

115. Shusterman, R., n.d. *Somaesthetics*. The Encyclopedia of Human-Computer Interaction, 2nd Ed. Lowman et al., eds. [online] Available at: https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/somaesthetics

116. Smeenk, W., Tomico, O. and Turnhout, K. Van, 2016. A Systematic Analysis of Mixed Perspectives in Empathic Design : Not One Perspective Encompasses All. *Journal of Design*, 10(2), pp.31–48.

117. Spuybroek, L., 2011. *Textile Tectonics: Research & Design*. Rotterdam: NAi Publishers.

118. Stappers, P.J., 2007. Doing Design as a Part of Doing Research. In: R Michael, ed., *Design Research Now: essays and selected projects*. Basel: Birkhauser, pp.81–91.

119. Stathopoulou, D., 2011. *From Dance Movement to Architectural Form.* Master's thesis, University of Bath.

120. Stolterman, E., 2008. The Nature of Design Practice and Implications for Interaction Design Research. *International Journal of Design*, 2(1), pp.55–65.

121. Storni, C., 2015. Notes on ANT for designers: ontological, methodological and epistemological turn in collaborative design. *CoDesign*, 11(3–4), pp.166–178. [online] Available at: <http://dx.doi.org/10.1080/15710882.2015.1081242>.

122. Storni, C., Binder, T., Linde, P. and Stuedahl, D., 2015. Designing things together: intersections of co-design and actor–network theory. *CoDesign*, 11(3–4), pp.149–151. [online] Available at: <http://dx.doi.org/10.1080/15710882.2015.1081442>.

123. Szalapaj, P., 2005. The Digital Design Process in Contemporary Architectural Practice. In: *Digital Design: The Quest for New Paradigms: 23rd eCAADe Conference*., pp.751–759.

124. Thompson, E., Rosch, E., Varela, F.J., Rosch, E. and Thompson, E., 1992. *The Embodied Mind: Cognitive Science and Human Experience*. Cambridge, MA: MIT Press.

125. Thomsen, M.R. and Karmon, A., 2011. Listener: A Probe Into Information Based Material Specification Mette. In: *Proceedings of Ambience'11*, University of Boras, Sweden.

126. Tomico, O. and Wilde, D., 2015. Soft, Embodied, Situated and Connected. In: *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct (MobileHCI '15)*, Copenhagen. New York, NY: ACM Press, pp.1179–1186.

127. Tomico, O., Winthagen, V. and Heist, M. van, 2012. Designing For, With or Within: 1st, 2nd and 3rd Person Points of View on Designing for Systems. In: *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design,* Copenhagen. New York, NY: ACM Press, pp. 180-188. [online] Available at: <http://dl.acm.org/citation.cfm?id=2399045>.

128. Turmo Vidal, L. and Márquez Segura, E., 2018. Documenting the Elusive and Ephemeral in Embodied Design Ideation Activities. *Multimodal Technologies and Interaction*, 2(3).

129. Underwood, J., Underwood, J., Underwood and J, 2009. *The Design of 3D Shape Knitted Preforms*. PhD thesis, RMIT University, Melbourne. [online] Available at: <http://researchbank.rmit.edu.au/view/rmit:6130>.

130. Urs, H., Sayegh, A., Frühwirth, M. and Zedlacher, S., n.d. 3D Motion Tracking in Architecture: Turning Movement into Form - Emerging Uses of a New Technology. *ecaade 24*. In Communicating Spaces: 24th eCAADe *Conference Proceedings.* Greece: University of Thessaly.

131. Varna, C., 2013. Improvisational Choreography as a Design Language for Spatial Interaction. In: *Proceedings of Fascinate: Thoughtful Technology*

and Beautiful Interfaces, Falmouth University, pp.1–18.

132. Wærsted, E.H., Lenau, T.A. and Brandt, E., 2014. *Textiles in the Material Practice of Architects – Opportunities , Challenges and Ways of Stimulating Use*. Technical University of Denmark; DTU Engineering.

133. Wilde, D., Cassinelli, A. and Zerroug, A., 2012. Light arrays. In: *CHI '12 Extended Abstracts on Human Factors in Computing Systems (CHI EA '12)*. Austin, Texas. New York, NY: ACM Press, pp.987–990.

134. Wilde, D., Schiphorst, T. and Klooster, S., 2011a. Move to Design/Design to Move: A Conversation About Designing for the Body. *Interactions*, 18(4), pp.22–27.

135. Wilde, D., Schiphorst, T. and Klooster, S., 2011b. Move to Design/Design to Move. *Interactions*, 18(4), p.22.

136. Wilde, D., Vallgårda, A. and Tomico, O., 2017. Embodied Design Ideation Methods : Analysing the Power of Estrangement. In: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17)*. Denver, Colorado, New York, NY: ACM Press, pp.5158–5170.

137. Yaneva, A., 2009. Making the Social Hold: Towards an Actor-Network Theory of Design. *Design and Culture*, 1(3), pp.273–288.

138. Zimmerman, J. and Forlizzi, J., 2014. Research Through Design in HCI. In: *Ways of Knowing in HCI*, J.A. Olson and W.A. Kellogg, eds. New York, NY: Springer Verlag.

139. Zimmerman, J., Forlizzi, J. and Evenson, S., 2007. Research through design as a method for interaction design research in HCI. In: *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '07*. New York, NY: ACM Press, pp.493–502.

Appendix

List of Figures

PhD and Supervisors Guide to

ArcInTexETN

Marie Skłodowska-Curie actions European Training Network (ETN)

Welcome to ArcInTexETN

This guide to the ArcInTexETN gives an overview of the research program of the training network, the impact promised in our application and also an overview of major network wide training activities as well as the work packages structure of the network.

For contact information, news and up-to-date information please check the ArcInTexETN web at www.arcintexetn.eu

We look forward to work with all of you to develop cross-disciplinary research and research education in the areas of architecture, textiles, fashion and interaction design.

Lars Hallnäs – Network Coordinator
Agneta Nordlund Andersson – Network Manager
Delia Dumitrescu – Director of Studies

Content

I. ArcInTexETN research program

This is the research context – with respect to programmatic and methodological directions – in which the PhD students of the network will be trained within the four (WP2-5) training work packages. As such it provides a research foundation for the ArcInTexETN.

The research program opens up for directions of exploring a main challenge. What this means is further open for interpretations from a range of different perspectives at the schools of the training network and maps out a research space for the PhD students built up by a rich variety of disciplines and methodological perspectives.

The research program thus opens up the initiative, opens up for interpretations, open up for building a research space, open up for mixing disciplines and methodological perspectives. Impact is then what defines the closure, the promises of the initiative.

Main challenge

A fundamental challenge in design research today is to define design programmes that suggest methods for turning current scientific knowledge and technical development into the design of new forms of living that will provide the foundations for a more sustainable way of life.

Design for sustainability is a vast subject covering a wide range of variables from almost all areas of design: materials, construction and production processes, use, waste, etc. Consequently, the range of different research perspectives on the issue of sustainable design is also very wide. The issue of sustainability is also a thematic foundation for research at universities in general. What makes the network (in this application) fairly unique is the combination of a very broad cross-disciplinary approach with a methodological focus on experimental design research, an area where Europe has a particularly strong position in comparison to other regions of the world.

Programmatic directions

The ArcInTex European Training Network (ETN) aims to strengthen the foundations of design for new forms of more sustainable ways of living by connecting architecture, textiles and interaction design in a training network for early-stage researchers (ESRs).

As natural science and engineering science introduce new materials and new technology, there is an increasing need to explore their possibilities and consequences for the design of our future living environments. Ways of living are intrinsic to both architecture and textiles as areas of design; from near-field clothing design, fashion design, and furnishing to far-field interior design and architectural design, from dressing us and our bodies to situating us in a living space: how to relate the near-field and far-field perspectives of design expression is a central issue as we try to use technological innovations to improve our ways of living.

Applying technical innovations in order to improve our ways of living is a matter of design. Explorations of possibilities and consequences with respect to the application of new technology require experimental design research. As this is not an area of research initially open for empirical studies, however, we will first need to explore possibilities and reflect on consequences by designing.

Applications of technology address the ways in which we design, both from a far-field perspective (architecture) and a near-field perspective (textile and wearables/fashion design), but also very much the ways in which we relate these perspectives; the interfaces we build and the communication systems and devices we construct (interaction design).

Deepening the connections between textile and fashion design, architectural design, and interaction design will open up for the establishment of a new, reflective foundation on which to base the design for living in an age of technological innovations.

Textile and fashion design is by tradition near-field design and can, in a broad sense, be seen as one of the links connecting ways of living with spaces of living; textile thinking provides the foundations for ways in which we dress ourselves and our living environment, from near-field perspectives to far-field perspectives. Architecture, on the other hand, can be seen as one of the links connecting spaces for living with ways of living; architectural thinking provides the foundations for ways in which we define our living environment, from far-field perspectives to near-field perspectives. In forming our ways of living, textile and fashion design and architectural design move in opposite directions, so to speak, which opens up for intrinsic interactions with respect to scales of designing.

Interaction design, as a mediating foundation, will put explicit focus on time (and timing) as a central variable. As John Chris Jones formulated this notion already in 1972: ”To design in time is, more so than when designing objects, to design life itself, the very form of existence, and surely calls for a gentler touch than can be felt in the insensitive forms of our production-systems, legal-systems, timetables, schedules, distribution-systems, etc.”

Methodological issues

The ArcInTex ETN propose training of early-stage researchers in an existing cross-disciplinary research network (ArcInTex, www.arcintex.se) with the main aim to develop new programmes, methods and techniques for the design of adaptive and responsive environments connecting the scales of the body, the interior and the building.

Through this cross-disciplinary and cross-national network, the consortium will build and train a new research community to take on challenges in innovative practice-based design research combining areas of design in which Europe by tradition has a very strong position Training within the ETN will focus on textile thinking as a programmatic and methodological foundation. By “textile thinking”, we refer to the ways in which textiles are understood within the field of textile design (which all along proceeds from textile material design, via textile product design, to fashion and textile interior design) as being adaptable and responsive. The ESRs in the network programme will after their initial training belong to a new generation of interdisciplinary trained and high-level educated architects, textile and fashion designers, and interaction designers, who build their work practice on new ideas of material thinking and design thinking with an emphasis on sensitive design expressions for reflective living:

- to explore modern technology through textiles – from body to space,
- to build with performative materials – from space to body.

The primary challenge for practice-based design research is to experimentally explore the nature of these changes. Such research includes everything from materials experimentation to forming scenarios in a sort of archaeology of the future. For the research training, we formulate the working axiom in a slightly more precise manner by saying that these changes go in the direction of more reflective ways of living. Turning scientific knowledge and technical development into design for new forms of living may focus on the functional solutions of given problems, but could also focus on expres- sional possibilities that open up for ways of living a reflective everyday life. It is this focus on expressional possibilities that is the main research theme.

Connecting architecture, textile and fashion design, and interaction design through explorations into the expressional possibilities of modern technology for dressing, furnishing, and building ways of leading more reflective every- day lives in the future the overall aim of the ETN is to:
- introduce new design programmes (DP)
- introduce and display new design techniques and methods (DT)
- introduce and display new perspectives on design aesthetics (DA)

Methodology and approach

Methodologically, the ArcInTexETN has its research foundation in prac- tice-based design/artistic research (research by design) concerned with design and artistic experimental work, and aims to develop and deepen practice by introducing new tools (techniques and methods) and new programmes for design and artistic work. ESRs will mainly be trained in the following central areas of practice-based design research methods:

Exploring materials and constructions: Material and constructional experiments are central to research by design. It is both a matter of putting questions to given materials and techniques and a matter of suggesting things that will challenge the invention of new materials and construction techniques. An example of this is the use of thermochromic colouring techniques to explore the idea of dynamic textile patterns, whereby new expressional means and new variables are introduced into textile design. What is important in practice-based textile design research are the questions we ask to an already existing technology: what does it mean to design a dynamic textile pattern, where do these typically slow changes in a textile pattern lead us with respect to expressive and reflective possibilities etc.? Another example is the development of architectural constructions using textile principles.

Further examples are experiments with shape changing structures using memory polymers and alloys to change the architecture of shape, the incorporation of electronics in order to facilitate interaction with a user and their space in a closed loop, and also materials explorations in textile technology as a foundation for design work.

Of particular interest is the exploration of materials and constructions connecting architecture, textiles and interaction design to find new ways in which to open up for expressions of future ways of reflective living (This relates to DT).

Critical design/art: Design work is also a methodological tool for critically reviewing and displaying the meanings, possible cultural and societal effects, and consequences of modern technology. The work by Dunne and Raby on the cultural effects of modern computation and communication technology is perhaps the canonical example of this, where critical design examples play a major methodological role.

Of particular interest are ways to connect architecture, textiles and interaction design in design experiments that critically demonstrates societal effects and consequences of the modern technologies used in dressing us and furnishing and building our living environments (This relates to DP and DA).

Deriving methods and defining programmes: Deriving methods and defining programmes on the basis of experimental work is another major example of design as research methodology.

In both cases we suggest things by design, ways of working and directions for future design work. This is methodology at the very heart of practice-based design research: from engineering science as design research to design research with a focus on issues of design aesthetics. The work on the development of methods for deriving computer programs that satisfy given specifications is a good example of design research in this sense. The work by Papanek on "design for the real world" in the 1970s and more recent work done within the DESIS Network on design programmes for social innovation and sustainability (www.desis-network.org/), as well as the design of innovative buildings to display new ways of dwelling, are all typical examples of programmatic work in design research.

Of particular interest are methodologies and programmatic work for new perspectives on the design of interactions for sustainable ways of living through the connection of architecture, textiles and interaction design. (This relates to DP, DT and DA).

From analysis to design and back again: The duality between analysis and design is fundamental in design work. The shift from one to the other involves shifting between methods for designing and methods for analysis. This is also a general characteristic of the relation between the design of an experiment and analysing the outcome of the experiment, which in turn suggests a design. The point here is the prominence of design as a research result in its own right and the emphasis on going from analysis to design, i.e. examples, methods, techniques and programmes as main

results. This is where design methodology becomes research methodology, i.e. experimental methodology for practice-based design research.

Of particular interest are methods that provide a foundation for experimental design research that systematically connects architecture, textiles and interaction design in experiments searching for the expressions of sustainable ways of living (This relates to DT and DA with respect to methods). From functionality to expressions and back again: The distinction between function and expression introduces another duality that is of fundamental importance to design work: what a design does as we use it and what it is that displays the design. Methodologically, this concerns the ways in which we relate abstractions and concrete expressions to each other in the design research process. This is where design aesthetics become research methodology; the systematic classification of design expressions that provide a solid foundation and frame of reference for future design work. Very typical, even classical, examples of this are the various systems of colour classifications,
e.g. the NCS system, and how these are used to relate function and expression in the process of designing.

Of particular interest are methods for describing and classifying expressions of living in the context of connecting architecture, textiles and interaction design (This relates to DT and DA with respect to methods).

Theory: From a methodological point of view, theory work in design research is no different from theoretical work in most other areas of research. It involves the introduction of foundational notions, systematic classifications, etc. What is characteristic here is of course that, in all essentials, this is also research work by design. This is w here we provide the concepts and basic tools for experimental work. Typical examples range from theories of form to foundational work in artistic research.

Of particular interest is theoretical work that provides new perspectives on issues of form, material and expression in the context of connecting architecture, textiles and interaction design (This relates to the theoretical foundations of DP, DT and DA).

The Nature and Status of Research Results

– Design examples: The design example is central to practice-based design/artistic research. It shows that something is possible and thereby establishes a matter of fact. As interesting as this

may be, however, what is of more interest to the development of the design practice is the way in which this is done. The nature of such a result is that of a generator for the derivation of methods, techniques and programmes. This is no different from the way in which we use e.g. examples in mathematics (which relates to DT, DA).

- Design methods and techniques: The status of design methods and techniques as results in design research is comparable to that of methods and techniques in engineering (which relates to DT).
- Design materials: We turn a given material into a "design material" by a characterisation in terms of expressional properties, where the result is an expressional classification (which relates to DT).
- Design programmes: A design programme is a programmatic declaration laying out the directions of design work and, as such, it has the status of a work plan. The world of science and research is full of such work plans, which receive their status as research results in their own right from the suggestive examples they build on (which relates to DP).

Originality

The main underlying research challenge of the ETN – how to turn the scientific knowledge and technical development of our day into design for the new forms of living that will provide the foundations for a more sustainable way of life – is of general interest in design research and is currently explored worldwide from a variety of perspectives and in many different ways. The originality of the (present proposal) research program concerns both programmatic directions and methodology:

Programmatic directions: A central working assumption is that design for future forms of sustainable living entails fundamental changes not only in ways of living, but also requires radical changes in design thinking. So, what could these changes be all about? The research consortium of the ArcInTex ETN meets this challenge by connecting architecture, textile and fashion design, and interaction design in explorations of the expressional possibilities of modern technology for dressing, furnishing and building for adaptive and responsive forms of future living. Through this programmatic direction of research, the ETN contributes to the "material turn" in design research by introducing an "expressional turn" in an area which has a strong focus on technical solutions and different forms of evidence-based design. The main rationale behind these "turns" is the axiom of design practice saying that analysis eventually must be turned into design through the creation of e.g. a prototype.

This is then considered an act of introducing expressions by shaping materials, one way or another. Experimental examples constitute fundamental sources of knowledge in this context.

Methodology: The research of the ETN is based on a very broad cross-disciplinary collaboration, which follows two majors, interlinked methodological tracks:

(i) Textile thinking as a methodological foundation for the connection between textiles and fashion, architecture, and interaction design, which links near-field and far-field perspectives when designing for body and space.

(ii) Design as a driving force for research that turns experimental research into expressional explorations.

On the basis of this methodological foundation for its research, the ETN introduces textile interaction design and textile architecture as two working methods for meeting the challenges presented by its main programmatic directions.

Innovative aspects

The innovation perspectives of the ETN concern meeting challenges, as well as identifying and making use of opportunities and possibilities to introduce new ways of doing things. Through examples and concrete actions, experimental design will work to turn opportunities into directions, and will in this way not only open up for innovation but proceed to guide it. In a sense, the academic research training of the ESRs will allow them to innovate at the level of design programmes, and as programmatic thinking meets development in the private sector, the ESRs will learn how innovative thinking, in this more general sense, directs the development of innovations for actual use. Thus, innovation is defined as the key methodological direction of the proposed ETN.

The practice-based foundation of research and research training ensures that training for innovation will play a central role in the ETN, in the sense that design is the key methodological dimension of the research training proposed here.

In addition, the environments at the participating schools, i.e. the architecture and design school, the technical university, and the art academy, provide links between innovative ideas in design research and their connections with, and the consequences for, development work in the private sector. Training in development work at partner companies strengthens and further

develops this through the addition of new perspectives on innovation and opens up for ideas that call for further research.

Consequently, the ETN constitutes a loop from research to innovation and back again, which is built on a close collaboration between academia and the private sector.

II. Impact of the ArcInTexETN

Impact is what defines the closure, the promises of the ArcInTexETN. This is what we promise in terms of impact, answering to the call of the Marie Sklodowska Curie Action.

Challenges and promises

Enhancing research- and innovation-related human resources, skills, and working conditions to realise the potential of individuals and to provide new career perspectives (WP2-5)

Potentials of individuals: *By forming a unique cross-disciplinary network of researchers, supervisors, research methods, and infrastructure for experimental design research ranging from fine art, fashion design, and textile design, via industrial design and architecture, to materials research and interaction design; the ETN will provide a unique innovation competence to young ESR that will be better trained for the future challenges given by the design of a more sustainable way of living.*

The broad foundation of the initiative provides all ESRs with a unique opportunity to take experimental research projects all the way from the initial idea to scaled-up models and prototypes ready to exhibit and try out, as well as a to relate fundamental research to development projects which covers all forms of living from a near-field to a far-field perspective.

New Career perspectives 1: The ArcInTexETN t raining network o pens up a new cross-disciplinary arena for research, education, and development projects by addressing a fundamental research challenge, i.e. experimentally exploring how new ways of more sustainable ways of living can be expressed, within a very broad cross-disciplinary context; linked together by a strong, common driving force, i.e. textile thinking for adaptation and responsiveness, the ESRs participating in the programme will receive training in the context of cross-disciplinary,

cutting-edge research and access to a broad network for the development of research within the areas of the ETN.

This provides the ESRs of the ETN with excellent opportunities to progress rapidly in newly opened areas of research, both with respect to experimental work and theoretical foundations.

Fellow's competence: All ESRs will be provided excellent conditions to make progress in their research training as they are supported by a strong research approach consisting of linked subjects and methods through the wide range of perspectives and skills offered by the members of the supervisory groups and through secondments and network-wide training events held both by academic institutions and members of the private sector.

Also, the studios for artistic experimental work and design experiments, the experimental workshops exploring a range of techniques, the laboratories for textile materials research, the studios for architectural experiments, and the industrial full-scale workshops for textile experimental work, will create excellent conditions for innovation and entrepreneurial research training.

Innovative and competitive: B*y forming the ESRs into cross-disciplinary teams, the flow of ideas between different disciplines is strengthened, and by establishing working environments in which the connections between architecture, fashion and textile design, and interaction design (body and space) are clearly in focus, the ETN lays down a very broad foundation for the realisation of the potential of individuals.*
Collaborations among the ESRs provide excellent conditions for the creation of lively cross-disciplinary environments, where individual projects are reflected over differently as other ways of relating to the central theme of the initiative and other forms of textile thinking present themselves. In this sense, the individual ESRs will work in an environment that opens up for new perspectives rather than refers to predefined demarcation lines.

New career perspectives 2: By linking academia and the private sector through a network, within a given context, the flow of ideas back and forth between experimental research and company-based development projects are strengthened, and the ETN opens up new channels for close communication between fundamental design research and innovative applied design practice.

Through this combination of in-depth specialisations, collaborative project work training, and private sector secondments, the ESRs of the ETN will form a highly trained avant-garde, ready to take on complex challenges both in academic design education and research and in design development work in the private sector with a focus on urgent issues, i.e. designing for new, sustainable ways of living.

With respect to new career prospects the ETN also emphases communication and innovation skills:

Communication skills: The context of research training within the ArcInTex Network and the cross-disciplinary environment at the networking institutions will provide a high level of implicit training in communication across disciplines. Secondments within development projects at private companies will provide in-depth training in communication between the public/academic and the private sector. Communication for research collaborations and team work in development projects is consequently a focal issue within the ETN.

Entrepreneurial and business skills: The training programme is a programme for training in practice-based design research and development work, which entails results in the form of design examples, prototypes, techniques, methods and design programmes in an academic setting as well as at private sector companies. This implies that training of creativity and entrepreneurial skills in relation to the development of design and more general design programmes is at the heart of the ETN.

Innovation and design skills: Secondments at partner companies within development projects will improve training in performing the process of going from the initial product and design ideas to actual product development. As design researchers and educated designers, ESRs will receive in-depth training in concept and prototype development, which will make them highly skilled in the early stages of company-based design development work in the areas of the ETN.

Contribution to structuring doctoral / early-stage research training at the European level and to strengthening European innovation capacity (WP1, WP5, WP6)

By defining a new arena for design research, one which builds on areas where Europe by tradition have a strong position, the initiative introduces a new type of cross-disciplinary doctoral and early-stage research training in which art, design and architecture co-operate on a background of broad thematic (design for new forms of living) and a focused methodological

approach (textile thinking), and where different European traditions within design, art and architecture are interwoven.

As a consequence, the ***(proposed)*** *ETN will contribute to further developing the European principles of Innovative Doctoral Training, and link together strong European traditions within the fields of art, design, and architecture on the level of practice-based research education. Through the structure, the ETN will define a form of European doctoral/early-stage research training which is characterised by:*

- *training in cross-disciplinary groups, in which the individual ESRs work with a specific perspective on a common theme.*
- *secondments which moves groups of ESRs between different academic institutions, between different environments with respect to subject matters and supervision, and between academic research training and company-based training in the application of research in development projects in which research innovations are linked together in a natural manner on a foundation of cross-disciplinary and practice-based design research.*
- *training in experimental design research with close links to the development of design practice.*

By this, the ETN contributes towards defining a new model for a European, nomadic form of doctoral/early-stage research training in artistic fields with a focus on urgent matters pertaining to the exploration of expressions of new forms of living.

Contribution of the non-academic sector to the doctoral / research training (as appropriate to the implementation mode and research) (WP2, WP3, WP4)

Through its strong focus on practice-based design research in the connected fields of architecture, textile and fashion design, and interaction design, *the ETN will contribute to further establishing design research at a level similar to that of engineering science,* which is of special importance for collaborations between academia and the private sector in the given areas of design research. *This will contribute to strengthening and establishing practice-based design research as a driving force in innovation.*

III. Work packages 2–4

The main objective of the ArcInTexETN, i.e. to develop programmes, methods and techniques

for the design of adaptive, responsive environments connecting the scales of the body, the interior and the building, is tackled in three work packages:

(WP2) Textile thinking for adaptive and responsive architecture – the scale of the building

This programme examines the largest-scale engagement of the research cluster. Using textiles as a material for adaptive and responsive architecture, the aim is to consider the structural, material and interactive complexities of the field and to further develop textile thinking in the field of architecture. The programme involves five ESRs, each with their own research project addressing one of the following three research topics:

21 *Textile structures for adaptive and responsive architecture (textile architecture – 2 ESRs) The Berlin University of the Arts*

22 *Designing adaptive and responsive textiles (textile and fashion design – 2 ESRs) Royal College of Art, The Swedish School of Textiles-University of Borås*

23 *Designing for adaptive and responsive far-field interactions (textile interaction design – 1 ESR) Royal College of Art*

(WP3) Textile thinking for adaptive and responsive interior design – the scale of the interior

The programme examines the middle scale of the research cluster, and, using textiles as spatial dividers, looks at the spatial functions, the decorative potentials, and the interactive relationships these textiles can embody. The programme involves five ESRs, each with their own project addressing one of the following research topics:

31 *Textile structures for adaptive and responsive interiors (textile design – 2 ESRs) Royal College of Art, Ludvig Svensson AB/The Swedish School of Textiles- University of Borås*

32 *Designing bespoke textiles for interior performance (textile and fashion design – 2 ESRs) Vilnius Academy of Arts*

33 *Designing for adaptive and responsive near-field interactions (textile interaction design – 1 ESR) The Berlin University of the Arts*

(WP4) Textile thinking for the design of adaptive and responsive wearables – the scale of the body

This programme examines the scale of the body through experimental explorations guided by the development of textile thinking in wearable design. The programme involves five ESRs, each with their own project addressing one of the following research topics:

4.1 *Textile structures for adaptive and responsive clothing (textile design – 2 ESRs) Heriot Watt University*

4.2 *Designing adaptive and responsive clothing (fashion design – 2 ESRs) Eindhoven University of Technology, The Swedish School of Textiles-University of Borås*

4.3 *Designing for adaptive and responsive wearable interactions (textile interaction design – 1 ESR) Philips Electronics Netherland B.V./Eindhoven University of Technology.*

IV. Summer schools, courses and workshops

In addition to the course programme at each home institution, which are open to visiting ESRs from the network, the training network will offer two joint courses (5 ECTS credits each) on the foundations of research within the network, and it will also organise three summer schools on transferable skills. The summer schools will focus on (1) practice-based research, (2) presenting and managing research, and (3) disseminating and exploiting research. Each school in the ArcInTex ETN will invite visiting researchers to the courses, summer schools, and joint workshops of the training network:

- Common course 1 – Textile architecture: This research course on textile architecture will discuss the role of textiles in architectural design, with a dual focus on spatial and structural implications. (January 2016)

Deliverables: papers on theoretical viewpoints within the field and mapping the research practice of the ESRs themselves into this field; an oral presentation in front of peers.

– **Common course 2 – Embodied textile interaction design:** This research course will explore the dynamic and interactive qualities of textiles and how these relate to ways of being and living. (December 2016)

Deliverables: conceptual models exemplified in prototype garments; an oral presentation in front of peers.

– **Summer school 1 – Practice-based research methods:** This first summer school will discuss the role of practice-based research in knowledge production (Universität der Künste, Berlin, September/October 2015).

Deliverables: a written paper reflecting on theoretical viewpoints in relation to the collaborative project selected by the ESR; an oral presentation in front of peers.

– **Summer school 2 – Research entrepreneurship in the academic and non- academic area:** The second summer school will focus on entrepreneurship both inside and outside of the academic area. (Royal College of Art, London, September 2016)

Deliverables: Innovative business ideas based on individual design.

– **Summer school 3 – Research, career development and business plans:** The third summer school will focus on the development of business plans based on exploitation of the results of design-led research. (Technische Universiteit Eindhoven, September 2017)

Deliverables: A business plan and a career development plan.

– **Secondments:** Each ESR will spend a total of four months at other schools in the network, covering all three main fields of the programme, and a total of four months at partner companies, working on development projects to exploit the maximum potential of **professional and complementary skills** and network-wide training.

Deliverables: This arrangement will provide ESRs training in complementary fields, thus offering ESR training by assistant supervisors while learning about different research methodologies and research topics. The secondment in the associate partner organisation will also provide ESRs knowledge about different research cultures, research management, and industrial applications. The table below gives an overview of secondment sequences, scheduled timing, and placement. It is, however, the SB who will decide on the exact schedule for secondments based on the development of the research and the partners' schedules.

– **Network-wide ESR training workshop 1 is a second innovation module which** will address the need for industry-academic training programmes focusing on applied research in the intersection between foundational research and industrial application. Thus, it will address both SMEs and financing and management during the start-up phase of a business. The workshop will be based on case presentations and seminars. (Technische Universiteit Eindhoven, March 2016)

Deliverables: Professional skills training.

– **Network-wide ESR training workshop 2 is a third innovation module which** answers to the requirements posed by national research councils, as well as those found in the European Charter for Researchers concerning the publication of research activities for the benefit of society at large. This workshop aims to improve the communication skills of the ESRs and prepare them to hold presentations aimed at non-specialists and laymen. Moreover, the workshop will explore the cultural and ethical dimension of the conducted research from a wider societal perspective. (Heriot-Watt University, Edinburgh, December 2017)

Deliverables: Professional skills training.

Seminars, videoconferences, web-based interaction: All partners will frequently hold local seminars and will be requested to present their research and the results thereof both internally and externally. As all partners are familiar with involving in international work via digital media, video, and the web, other forms of Internet-based communication will be used for the continuous communication within and the cross-disciplinary development of the ETN.

– **ETN start-up meeting:** At the ETN start-up meeting, the newly recruited ESRs will present their research proposals before the SB and their peers. This is a training event, integrated in the

first summer school, aimed at improving the ability of the ESRs to define and formulate research problems in practice- based design research.

Deliverables: Research proposals in relation to selected collaborative project.

– **Final ETN conference:** The final network conference will sum up and discuss three years of cross-disciplinary doctoral training in practice-based design research and highlight both doctoral training and research which cross the borders between the fields of architecture, textiles and interaction design. At the conference, there will be a special track for the discussion of pedagogical issues and evaluation of the learning outcomes of the ETN. The conference will have an international profile, inviting key researchers and practitioners from the network areas in order to advance and nourish the research community initiated by the ArcInTex ETN. As part of the conference, the network ESRs will present their thesis works to a broader public.

Deliverables: Conference proceedings/preliminary report of major learning outcomes of the ETN.

V. Secondments

Workpackage 2

Textile thinking for adaptive and responsive architecture – **the scale of the building**

WP Leader UDK	**Host and Main Supervisor**		**Objective**	**Expected result**	**Secondment 1** (project month 20-23)	**Purpose**	**Secondment 2** (project month 32-35)	**Purpose**	**Main Supervisor**	**Assistant Supervisor**	**Assistant Supervisor**
ESR1 Daniel Suarez	UDK	D2.1	Textile structures for adaptive and responsive architecture (textile architecture)	At the scale of the building, introduce and display design programmes, techniques and methods for the design of adaptive and responsive architecture and introduce and demonstrate expressive examples of textile thinking for adaptive and responsive architecture	VAA	Cross-disciplinary training in textile design	HWU	Cross-disciplinary training in interaction design	UDK Prof Norbert Palz*	RCA Prof. Jo-Anne Bichard*	RCA Prof Clare Johnston*
ESR 2 Iva Resetar	UDK	D2.1	Textile structures for adaptive and responsive architecture (textile architecture)	At the scale of the building, introduce and display design programmes, techniques and methods for the design of adaptive and responsive architecture and introduce and demonstrate expressive examples of textile thinking for adaptive and responsive architecture	VAA	Cross-disciplinary training in textile design	HB	Cross-disciplinary training in interaction design	UDK Prof Norbert Palz*	TUE Ass Prof Bart Hengeveld*	HB Dr. Delia Dumitrescu*
ESR 3 Marina Castan Cabrero	RCA	D2.2	Designing adaptive and responsive textiles (textile and fahion design)	At the scale of the building, introduce and display design programmes, techniques and methods for performance, detail and quality in the design of adaptive and responsive textiles and demonstrate expressive examples of textile thinking for adaptive and responsive architecture	VAA	Cross-disciplinary training in textile design	HWS	Architectural research for adaptable textiles structures, with uses in a variety of scenarios	RCA Prof Clare Johnston*	HB Dr. Delia Dumitrescu*	UDK Dr. Phil Katharina Bredies*
ESR 4 Jyoti Kapur	HB	D2.2	Designing adaptive and responsive textiles (textile and fahion design)	At the scale of the building, introduce and display design programmes, techniques and methods for performance, detail and quality in the design of adaptive and responsive textiles and demonstrate expressive examples of textile thinking for adaptive and responsive architecture	VAA	Cross-disciplinary training in textile design	LUS	Research and development work in functional interactive textiles for use in interior design for public spaces	HB Prof Clemens Thornquist*	UDK Prof Norbert Palz*	HB Dr. Delia Dumitrescu*
ESR 5 Bastian Beyer	RCA	D2.3	Designing for adaptive and responsive far-field interactions (textile interaction design)	At the scale of the building, introduce and display design programmes, techniques and methods for expressions of response in the design of far-field interactions and demonstrate expressive examples of textile thinking for adaptive and responsive architecture	VAA	Cross-disciplinary training in textile design	HWS	Architectural research for adaptable textile structures, with uses in a variety of scenarios	RCA Prof. Jo-Anne Bichard*	UDK Dr. Phil Katharina Bredies*	RCA Mr Ian Higgins*

*Or someone with similar expertise

Workpackage 3

Textile thinking for adaptive and responsive architecture – **the scale of the interior**

WP Leader RCA	**Host and Main Supervisor**		**Objective**	**Expected result**	**Secondment 1** (project month 20-23)	**Purpose**	**Secondment 2** (project month 32-35)	**Purpose**	**Main Supervisor**	**Assistant Supervisor**	**Assistant Supervisor**
ESR 6 Ana Piñeyro	RCA	D3.1	Textile structures for adaptive and responsive interiors (textile design)	At the scale of the interior, introduce and display design programmes, techniques and methods for the design of textile structures for adaptive and responsive iteriors and demonstrate expressive examples of textile thinking for adaptove and resposive interior design	HB	Cross-disciplinary training in interaction design	HWT	Cross-disciplinary training in textile art	RCA Prof Clare Johnston*	VAA Prof Egle Ganda Bogdaniene*	HB Dr. Delia Dumitrescu*
ESR 7 Svenja Keune	LUS	D3.1	Textile structures for adaptive and responsive interiors (textile design)	At the scale of the interior, introduce and display design programmes, techniques and methods for the design of textile structures for adaptive and responsive iteriors and demonstrate expressive examples of textile thinking for adaptove and resposive interior design	HB	Cross-disciplinary training in interaction design	RCA	Cross-disciplinary traning in architecture	HB (LUS) Dr. Delia Dumitrescu*	LUS Mrs Dorte Bo Bojesen*	VAA Prof Jolanta Vasalinskiene*
ESR 8 Sara Lundberg	VAA	D3.2	Designing bespoke textiles for interior performance (textile and fashion design)	At the scale of the interior, introduce and display design programmes, techniques and methods for the design of bespoke textiles for interior performance and demonstrate expressive examples of textile thinking for adaptive and responsive interior design	HB	Cross-disciplinary training in interaction design	AUD	Training in the development of interior fabrics, through focusing on the development in textile finishing	VAA Prof Jolanta Vasalinskiene*	RCA Prof Clare Johnston*	UDK Dr. Phil Katharina Bredies*
ESR 9 Juste Peciulyte	VAA	D3.2	Designing bespoke textiles for interior performance (textile and fashion design)	At the scale of the interior, introduce and display design programmes, techniques and methods for the design of bespoke textiles for interior performance and demonstrate expressive examples of textile thinking for adaptive and responsive interior design	HB	Cross-disciplinary training in interaction design	AUD	Training in the develpment of interior fabrics, through focusing on the developments in textile finishing	VAA Prof Egle Ganda Bogdaniene*	UB Hanna Landin*	HB Dr. Delia Dumitrescu*
ESR 10 Ramyah Gowrishankar	UDK	D3.3	Designing for adaptive and responsive near. field interactions (textile interaction design)	At the scale of the interior, introduce and display design programmes, techniques and methods for the design of adaptive and responsive near-field interactions and demonstrate expressive examples of textile thinking for adaptive and responsive interior design	HB	Cross-disciplinary training in textile design	TUE	Cross-disciplinary training in interaction design	UDK Dr. Phil Katharina Bredies*	VAA Prof Jolanta Vasalinskiene*	RCA Mr Ian Higgins*

*Or someone with similar expertise

Workpackage 4

Textile thinking for adaptive and responsive architecture – **the scale of the body**

WP Leader HB	Host and Main Supervisor		Objective	Expected result	Secondment 1 (project month 20-23)	Purpose	Secondment 2 (project month 32-35)	Purpose	Main Supervisor	Assistant Supervisor	Assistant Supervisor
ESR 11 Marion Bertin	HWU	D4.1	Textile structures for adaptive and responsive clothing (textile design)	At the scale of the body, introduce and display design programmes, techniques and methods for the design of textile structures for adaptive and responsive clothing and demonstrate expressive examples of textile thinking for the design of adaptive and responsive wearables	UDK	Cross-disciplinary training in interaction design	HB	Architectural research for adaptable textiles structures, with uses in a variety of scanarios	HWU Prof George Stylios*	TUE Ass Prof Oscar Tomico Plasencia*	HB Ass Prof. Sarah Keith*
ESR 12 Mila Svechtarova	HWU	D4.1	Textile structures for adaptive and responsive clothing (textile design)	At the scale of the body, introduce and display design programmes, techniques and methods for the design of textile structures for adaptive and responsive clothing and demonstrate expressive examples of textile thinking for the design of adaptive and responsive wearables	UDK	Cross-disciplinary training in interaction design	HB	Architectural research for adaptable textiles structures, with uses in a variety of scanarios	HWU Prof George Stylios*	TUE Ass Prof Bart Hengeveld*	TBA
ESR 13 Vidmina Stasiulyte	HB	D4.2	Designing adaptive and responsive clothing (fashion design)	At the scale of the body, introduce and display design programmes, techniques and methods for the design of adaptive and responsive clothing and demonstrate expressive examples of textile thinking for the design of adaptive and responsive wearables	UDK	Cross-disciplinary training in architecture	TUE	Cross-disciplinary training in interaction design	HB Prof Clemens Thornquist*	HWU Dr. Danmei Sun*	TUE Ass Prof Oscar Tomico Plasencia*
ESR 14 Troy Nachtigal	TUE	D4.2	Designing adaptive and responsive clothing (fashion design)	At the scale of the body, introduce and display design programmes, techniques and methods for the design of adaptive and responsive clothing and demonstrate expressive examples of textile thinking for the design of adaptive and responsive wearables	UDK	Cross-disciplinary training in textile and fashion design, architecture, and interaction design	PHI	Training in the field of designing wearable electronic systems that contribute to well-being of individuals; personal coaching	TUE Ass Prof Oscar Tomico Plasencia*	HB Dr. Delia Dumitrescu*	HB Ass Prof. Sarah Keith*
ESR 15 Angella Mackey	PHI	D4.3	Designing for adaptive and responsive wearable interactions (textile interaction design)	At the scale of the body, introduce and display design programmes, techniques and methods for the design of adaptive and responsive wearable interactions and demonstrate expressive examples of textile thinking for the design of adaptive and responsive wearables	UDK	Cross-disciplinary training in textile and fashion design, architecture, and interaction design	TUE	Cross-disciplinary training in textile and fashion design, architecture, and interaction design	TUE Ass Prof Stephan Wensveen*	PHI Mr Koen van Os*	UdK Dr. Phil. Katharina Bredies*

*Or someone with similar expertise

VI. Exploitation, dissemination and communication

Learning outcomes exploitation and dissemination during the course of the training programme:

(1) Supervisor seminars for pedagogical development of doctoral training, in cooperation with learning centres at the beneficiary partners, will be held in connection with the two-yearly joint meetings of the ESRs.

(2) Special workshop sessions will be organised at Summer schools 2 and 3. At Summer school 2, these sessions will focus on learning outcomes in relation to presenting and managing research, and at Summer school 3, they will focus on learning outcomes in relation to the exploitation and application of research results.

(3) A pedagogical track will be organised for the final network conference in order to sum up learning experiences.

(4) During the course of the training programme, the Supervisory Board (SB) will, in collaboration with the teams of supervisors, systematically keep track of the learning outcomes of the individual ESRs (individual study plans, etc.) in relation to the progress of research in their field, their capabilities to work and communicate across disciplines and between the public and pri- vate sectors, and their development toward an independent research career, and also in relation to issues of creativity and entrepreneurial skills. Special emphasis will be placed on learning outcomes and experiences of cross-dis- ciplinary doctoral training and also on the type of private sector secondment introduced by the ArcInTex ETN. Research results achieved by individual ESRs and project groups will be exploited and disseminated throughout the training programme.

Exploitation and dissemination after completion of the training programme

- *Seminars for pedagogical development of doctoral training will be organised within the ArcInTex Network, discussing the learning outcomes of the ETN.*
- *The Swedish School of Textiles will, after completion of the programme, publish the workbooks of the project groups.*

- *The central web of the training network will, after the completion of the programme, be used for dissemination of both research results and learning outcomes as part of the ArcInTex Network web.*

Communication and public engagement strategy of the project

The ETN will organise a series of public exhibitions, displaying the general research agenda of the ArcInTex doctoral training programme and the work of collaborative project groups under the title *"ArcInTex ETN exhibitions".*

Another central arena for communication is blogs reporting on the advance- ment of research and development. *Within the ETN, each ESR team will use selected social media as a workbook to report on the work performed within individual projects, as well as general team discussions.*

Concerning matters of communication, one of the big advantages of the ETN is that the fundamental research challenge, together with results in the form of concrete suggestions, are easy both to explain and display. This i s also why exhibitions and blog posts are very efficient means to open up for, and foster, a public discussion and thereby make a strong case for research training in the areas of the ArcInTex ETN.

Marie Skłodowska-Curie Ambassadors: All ESRs recruited by the ETN will be obliged to promote their research field as Marie Skłodowska-Curie Ambassadors by taking part in teaching at their home institutions, helping to organise workshops as visiting ESRs within the secondment programme of the ETN, and presenting the overall training network at partner companies during their secondments.

ETN Project Open Day: Each partner institution will, during the training programme period, organise one ETN Project Open Day with lectures and open labs, studios and workshops. ESRs will act as hosts at these events. Partner companies will be invited to take part in these events.

Publications: The Swedish School of Textiles, University of Borås will publish an overview of the training programme in the form of a book, which is aimed toward the general public in connection with the final ETN conference.

ETN web information: Public information about ETN activities will be published continuously as research carried out is reported in the project group blogs, at the central ArcInTex ETN website, and in the blogs of individual researchers. Information on the progress of the research work will also be available at the websites of the partner institutions.

VII. Overview ESR:s

Work Package 2 Lead UDK The Scale of the building						Work Package 3 Lead RCA The scale of the interior					Work Package 4 Lead HB The scale of the body Clemens Thornquist					Work Package 5 Lead HB Networkwide training activities Delia Dumitrescu							Work Package 6 Lead TUE Dissemination and Exploitation
ESR:s	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	All ESR:s							All ESR:s
																UDK	UDK/HB	TUE	RCA	VAA	TUE	HWU	
HB				D2.2 Jyoti Kapur									D4.2 Vidmina Stasiulyte										Journal publications
RCA			D2.2 Marina Castan Cabrero		D2.3 Bastian Beyer	D3.1 Ana Pineyro													Summer school 2				Commercial publications
HWU											D4.1 Marion Bertin	D4.1 Mila Svechtarova										Work shop 2	Webpage
VAA								D3.2 Sara Lundberg	D3.2 Juste Peciulyte											Common course 2			Results
UDK	D2.1 Daniel Suarez	D2.1 Iva Resetar								D3.3 Ramyah Gowrishankar						Summer school 1	Common course 1						Best Practice
TUE														D4.2 Troy Nachtigall				Work shop 1			Summer school 3		Outreach
PHI															D4.3 Angella Mackey								
LUS							D3.1 Svenja Keune																

D2.1 Textile structures for adaptive and responsive architecture (textile architecture)
D2.2 Designing adaptive and responsive textiles (textile and fashion design)
D2.3 Designing for adaptive and responsive far-field interactions (textile interaction design)
D3.1 Textile structures for adaptive and responsive interiors (textile architecture)
D3.2 Designing bespoke textiles for interior performance (textile and fashion design)
D3.3 Designing for adaptive and responsive near-field interactions (textile interaction design)
D4.1 Textile structures for adaptive and responsive clothing (textile architecture)
D4.2 Designing adaptive and responsive clothing (textile and fashion design)
D4.3 Designing for adaptive and responsive wearable interactions (textile interaction design)
WP 5 All ESR:s
WP 6 The ArcInTexETN will disseminate progress reports and research results through various channels.

VIII. Activities by year and month

Project month 1-12
Researcher month 1-6

2015	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Reporting							Researchers declaration Step 1 and Step 2			UdK to write a report on the Summerschool		
Supervisor / PhD activities	Kick Off meeting London Supervisory Board meeting			Recruitment			Employment contracts	Employment contracts	Employment contracts Summerschool, Berlin Supervisory Board meeting			

Project month 13-24
Researcher month 7-18

2016	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Reporting	Progess Report Deadline 31/1-2016 See Grant Agreement	UDK/UB to write a report on the Commn Course 1		TUE to write a report on Workshop 1					RCA to write a report on Summerschool 2		Mid Term review meeting, initiated by the comission See Grant Agreement	
Supervisor / PhD activities		Common Course 1 UDK/HB		Workshop 1, TUE			Summerschool 2, RCA		Secondment 1	Secondment 1	Secondment 1	Secondment 1

Project month 25-36
Researcher month 19-30

2017	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Reporting		RP 1 = Periodic report incl. Technical report Deadline 28/2-2017 See Grant Agreement	VAA to write a report on Common Course 2						TUE to write a report on Summerschool 3			
Supervisor / PhD activities		Common Course 2, VAA						Summerschool 3, TUE	Secondment 2	Secondment 2	Secondment 2	Secondment 2 Workshop 2, HWU

Project month 37-48
Researcher month 30-36

2018	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Reporting	HWU to write a report on Workshop 2											Reporting Period 2 (Periodic report incl. final technical report) See Grant Agreement
Supervisor / PhD activities												

4th year

2019	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Reporting		Deadline RP 2 incl final technical report										
Supervisor / PhD activities												

IX. Legal guide

This guide aims to give you some general pointers as to the issues, including intellectual property rights, confidentiality and dissemination of results, the recruited researchers and supervisors should be thinking about when participating in ArcInTex ETN.

- **Participating in ArcInTex**
- As research fellow, you will be expected to cooperate in the efficient implementation of the project, promptly and on time, in order to achieve the goals and objectives of ArcInTex.

Intellectual property rights

Definitions

- **Access rights:** means rights to use results or background under the terms and conditions laid down in the Grant Agreement.[1]
- **Background:** means any data, know-how or information – whatever its form or nature (tangible or intangible), including any rights such as intellectual property rights – that:

(a) is held by the beneficiaries before they acceded to the Agreement, and

(b) is needed to implement the action or exploit the results.[2]

- **Results**: means any (tangible or intangible) output of the action such as data, knowledge or information – whatever its form or nature, whether it can be protected or not – that is generated in the action, as well as any rights attached to it, including intellectual property rights.[3]
- **Confidential information:** All information in whatever form or mode of communication, which is disclosed by a Party (the "Disclosing Party") to any other Party (the "Recipient") in connection with the Project during its implementation and which has been explicitly marked as "confidential" at the time of disclosure, or when disclosed orally has been identified as confidential at the time of disclosure and has been confirmed and designated in writing within

[1] Article 25 of the Grant Agreement
[2] Article 24 (GA)
[3] Article 26 (GA)

15 calendar days from oral disclosure at the latest as confidential information by the Disclosing Party[4].

Results

- The grant agreement and consortium agreement set out the intellectual property rules for the project, so each beneficiary is responsible to have appropriate contracts in place with its recruited researchers to ensure that the beneficiary controls the intellectual property generated by them in the course of the project implementation.
- Results are owned by the Party (beneficiary) who carried out the work generating the Results or on whose behalf such work was carried out by subcontractors[5].
- ArcInTex ETN strives for a broad and efficient exploitation of results. To achieve this purpose, the protection of research results is essential. Research results potentially eligible for commercial or industrial exploitation must be protected during an appropriate period.

Access Rights

- The recruited researchers are entitled to access rights, on a royalty free basis, to the beneficiaries' background and project results necessary for their research training under the action[6].
  - The request should be done in writing and do not include the right to sub-license.
  - Any such access rights will be governed by confidentiality provisions.

Confidentiality

- The beneficiaries are bound by confidentiality obligations imposed by the grant agreement and the consortium agreement during the term and for a period of 4 years[7] after the end of the Project.
- The beneficiaries have undertaken the following contractual obligations in regards to confidential information:
  - not to use Confidential Information otherwise than for the purpose for which it was disclosed;
  - not to disclose Confidential Information to any third party without the prior written consent by the Disclosing Party;
  - to ensure that internal distribution of Confidential Information by a Recipient shall take place on a strict nee to-know basis; and
  - to return to the Disclosing Party on demand all Confidential Information which has been supplied to or acquired by the Recipients including all copies thereof and to delete all information stored in a machine readable form[8].
- Since we count with the involvement of an industrial partner, there are some specific measures to keep in mind when working with confidential information:
  - All confidential information should be stored in locked file cabinets or rooms accessible only to those who have a "need-to- know."
  - Use strong passwords to protect confidential information on electronic devices.
  - Staff should clear their desks of any confidential information before going home at the end of the day.

4 Article 10.1 of the consortium agreement
5 Article 8 (CA)
6 Articles 25.5 and 31.6 (GA)
7 Article 10.2 (CA)
8 ditto

- Staff should refrain from leaving confidential information visible on their computer monitors when they leave their work stations.
- All confidential information, whether contained on written documents or electronically, should be marked as "confidential."
- Balance the interests involved in your publication – Confidentiality is a common publication issue, in particular for PhD students.

Exploitation and Dissemination of results

- The cornerstone of the Marie Curie Training program is the knowledge-sharing activities and ArcInTexETN will focus on promoting a wide transfer of knowledge and dissemination of results.
- According to the Grant Agreement, beneficiaries are obliged to disseminate the results swiftly by any appropriate means (e.g. scientific publications, general information on web sites, participation in conferences and workshop) unless it goes against the legitimate interests of the other beneficiaries or it is subject to restrictions (e.g. confidentiality or the publication of research results can block the registrability of certain IP that require novelty: patents and designs)
- In order to monitor the dissemination process, the beneficiary that intends to disseminate its results must give advance notice to the other beneficiaries of at least 45 days, together with sufficient information on the results it will disseminate[9]. If no objection is made within the time limit stated above, the publication is permitted[10].
- In case of publication in a scientific journal which the publisher wants you to enter into a contract with them, please contact the legal counsel at your institution to verify that this contract does not contravene the grant agreement or the consortium agreement.
- The researchers should collaborate in ensuring open access to all peer reviewed scientific publications relating to the beneficiary's results.
- Any dissemination of results must display the EU emblem and the following text: "This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 642328"[11].
- All related matters must be discussed with the supervisor at your host institution.

9 Article 29 (GA)
10 Article 8.3 (CA)
11 Article 29.4 (GA)

Transcriptions of the interviews with the architects (Chapter five)

AR (A1)

1) What was the main finding of the workshop?

For me personally, I was quite impressed by the aesthetic and the spatial power of textiles. I've never thought we could do this. The main finding was the spatial expressivity of the fabric, its versatility, the number of things you can do with a piece of fabric just relying on the material properties of a specific textile.

2) Which material was more appropriate in terms of the design of the soft courtyard?

The black chiffon.

How transparency and layering kind of related to the material properties was very successful. It was quite tight to the local culture we are working in, which has a lot of veils, it is a very different social landscape and human relations have a lot of transitions and that has to be reflected in the space and the fabric mediated and managed to express this.

3) What was the main quality that you identified while interacting with the chiffon fabric?

It's a combination of things: the transparency, the layering, the drape of the fabric was quite beautiful and really expressive in a very strange way because it is a very subtle thing. The fact that it was black and in contrast you have a white background. I think within the context of the project, the video we are looking at it is very beautiful. I think its flexibility as well and the fact these properties produce layers of transparency. It felt very airy, very easy going, inviting you to transform it and move it around and stretch it. The pink one was stiffer.

The dimension was a very important fact.

4) How could this quality be used for the design of the soft courtyard?

The iterations we did, of course, you will never interact in the same exact way in the courtyard. What makes you think about is:

1. The possibility of making a very flexible space
2. It has formal and geometrical complexity to accommodate different things
3. A flat piece of fabric, it is a very simple principle but it can get really complex: spatial experience, material richness, programmatic and actual use of the space.
4. It pushes you to re-think in a one to one scale the possibilities of space, also the limits of the fabric and of the space.

5) What aspects of the set-up and material selection worked and what did not?
In order for this to be directly translatable into an architectural project, there are few conditions that have to be taken into account:

The fabric was held by a structure. The beams played a quite important role. I think also, acknowledging that architecture is made out of parts, not just one single think it is very important. In other words, in the hotel in the Middle East, we will have a structure that holds the fabric and fabric that holds the structure, many layers that are interacting with each other, mechanical issues, air conditioning, humidity sensors, that will eventually inform the fabric and vice versa. Acknowledging these layers of complexity will benefit the project. Although I have to say the fabric is the most flexible device to cope with all these differences. In that sense, the exercise is quite rich.

6) How is this approach valuable for architectural design, as opposed to designing with the computer?
There is a massive difference, not just with the material but by doing it one to one scale. We as architects we always work on scale and very rarely we have the opportunity to work one to one. I am very bad at that so I think, in general as a discipline, working one to one from the beginning, it is very challenging but it definitely expands your understanding of spatial configuration a lot. Especially when doing it with other people.

For the specific context of the project, it might be at least, what you are adding is not too much to the specific context of the Middle East, which can be applied of course. It is more a methodological thing, you are actually expanding the possibilities of architectural design, this is the potential I see. For this to be effective and very specific, we will have to set it up in very specific constraints, maybe will have to do the experiment in the local context, to cope with the light, climate conditions, sand storms and so on.

I think is not as important within the context of the project, it is more important to expand the spatial design methodologies. The hotel is in a very under stages, it is difficult to judge, it has a lot of potentials.

We have a long way to go, in that sense but once the programmatic agenda of the courtyards is set then I am absolutely sure that the courtyard will have fabric, probably more than one, because it is a very flexible way of dealing with differences and different flows, different privacy issues, services issues, in the middle east this is one and main condition that also has to be dealt with. These all variations that will happen within a tight space, that we have to be helpful. The courtyards have to be flexible in nature, to the point that I can't see any other way out than using fabrics. Now, the traditional way of using fabrics is using curtains, which is what we don't want to do. Making a 360 spatial experience, it is a 4D, it has time as factor well, I think it will be quite rich.

7) How did this approach work for you?

It works out in the sense that it breaks a very rigid methodology that we usually have and opens different ways of looking at the problem. It is very aligned with the ethos of the experience, having a direct experience with the material not just as a finished thing but as a design process. Taking this to the one to one scale I think it is a brilliant initiative and I am sure the studio will do it if we could in every project. Sometimes spatial limitations, you need the facilities.

LS (A2)

1) What was the main finding of the workshop?

I think the workshop was quite interesting in terms of dealing with the material, I think it was, at least for me as an architect, touching the material and creating shapes was quite a very interesting way of form finding. We are used to working with the computer, so obviously when you want to create those space at a real time is quite an amazing feeling. The textile allows you for those kinds of very fast changes and different iterations. Sometimes even too fast, it is difficult to freeze a moment. It is definitely a method for testing really fast in a very cheap way and timewise also. Very different formal configurations can be tested. I think the main finding was understanding a little bit more about the different materials we were dealing with and exploring the experience of that material while creating different spaces.

2) Which material was more appropriate in terms of the design of the soft courtyard?

I would say it depends on the user of the courtyard. I think the black chiffon was more theatrical in a more serious way. So, for a courtyard that is going to express luxury and elegance and sophistication, probably the black chiffon is the most suitable.

3) What was the main quality that you identified while interacting with the chiffon fabric?

I think the material was very permeable, this permeability allowed us to start making all these different configurations and see what was behind and interact with other people. I think this was putting everyone together in a shared way. Not so playful as in the white fabric but in a more relaxed way. I think the texture and the light created a very relaxed atmosphere, unconsciously we were kind of dancing with this fabric and diving into it as if the fabric was part of our bodies nearly. I would say the space that is created inside it is not completely enclosed because of the permeability of the material.

I think at the beginning we just explored in a very individual way, each of us touching the material like in a new way. The more we were more familiar with the material, we were probably freer, interacting with other people and creating effects that we probably knew that they would happen if we move the fabric in this way or another.

So, I think it was a very gradual exploration from something very new and I think at the end we were quite familiar with it and this would allow us to do things like the one Arturo is doing right now, just covering your head and making these tunnels (9:32 final exploration day 2). And interacting with the others that would probably be doing the same thing, you could learn from you'd seen in others or what you had heard.

I think the moment for example that we all were to the centre and there was this compression of the textile, like for example there, we were all inside and we created this kind of niche, that was something we kind of did intuitively, we did that because we had this first exploration at the beginning and then we started to create this kind of niches and figures and spaces. I think that was quite relevant, working with this permeability, putting more layers or less around people.

I think that the layering up quality was the most significant of all of them.

The tension is another quality that is different between them (black and white). The white is all the time in tension and the black one is floating, more draping than being expanded or compressed.

4) How could this quality be used for the design of the soft courtyard?

I guess that is what we have to discover, that's a great question. I guess it depends on how literal is the translation so you can extract values and qualities of the textiles and then apply them to architecture in an abstract way. You can talk about elasticity or layering or tensile structure. Or you can take it literally and take the textile itself and create a courtyard with that textile. So probably those would be 2 different approaches. In the end, it is definitely very architectural, all the qualities of the textiles. So, probably the boundaries are not so defined.

5) What aspects of the set-up and material selection worked and what did not?

I think the 3 setups were quite relevant. They were very different from each other, that allowed us to test different experiences. Probably the black one was the one that I would find the more suitable for the case, there are some connotations, it is the one that is more open and relevant to the context. The other two were also interesting, although it is not something that we could use, it is a bit more limited than the black chiffon. If we are speaking of a high-end hotel, probably those two are not so relevant, as the aesthetics of the other two setups are more informal.

6) How is this approach valuable for architectural design, as opposed to designing with the computer?

It is probably very relevant for small scale projects of soft architecture. It could be relevant for furniture as well, obviously, you cannot make a whole building out of it because there are different complexities that the scale allows and you always need a structure. There are things that are very challenging the bigger you go so obviously I think for soft architecture or small-scale architecture is quite valuable and appropriate using this approach.

It is much more fun which is always influencing the design process. You interact, you share, I think there is a direct exploration with the material and when you are designing in the computer, probably you are more precise, you can save the screen and go back with crl z but it is very far from the material itself because it is just a simulation, right? So, you lose the whole experience. So, if you are designing for the experience and through the experience, probably you are nearer the final result, you understand the feelings of the people that are going to be there, you are designing it. So, you use the experience as a design tool which I think it is quite important, at least in soft architecture, where people are going to be touching the material. So, probably

it is a good way to go, to start as a triggering of ideas. I am not sure about how that would evolve, to make it more precise, iterations, plans of it…

7) How did this approach work for you?

I think it is extremely important to touch the materials that you are going to be working with because it opens your mind to new things and when you are exploring you and when you are able to experience it, it changes completely the way you design with that. If not just designing from behind the barrier without not touching it. So, yes, I think it is relevant.

I would love to continue exploring it, it is a good way also of understanding a little bit more the whole design process, when you dive, when you cover yourself with this material and also it is a really good way of establishing good communication with the material. Because ultimately, when you are designing with a computer, you just have a screen and you are simulating and you make all this optical illusion, your eye captures like a virtual material but it is not actually a material, just an illusion. So, yeah, and also, I think it is very difficult to simulate what we were doing, I don't think computers can do that, to translate what we felt while we were doing it. I think technology would evolve and it will become very sophisticated but we haven't really achieved a moment where you can feel everything that we felt when we were inside moving because that is a completely different experience.

I think it was quite an interesting experiment. We are used to do things and we always try to do things that are innovative and try to thing out of the box I guess. So, probably, diving into this kind of design processes which are not the traditional ones, are quite inspiring and suggestive and I think they really bring ideas into the table, I am up for continuing exploring it.

HP (A3)

1) What was the main finding of the workshop?

I think having seen a little bit of your work before, I was really interested in how amazingly manipulated the fabric was and how quickly the spaces were generated. I guess being part of it was actually quite interesting, the first-hand experience. I was wondering if you can do something different with the fabric that people won't do it because I think you instinctively do things that you know fabric does. Just trying things and see what happens is quite nice. I've never really thought about it necessarily in a small scale, I've always thinking about it in a larger scale and where my fabric was

coming to and where I was taking it to until that one moment perhaps that we were gathering or looking directly through the fabric. Most of the time I was thinking of where I can take the fabric.

2) Which material was more appropriate in terms of the design of the soft courtyard?

The black chiffon. I think the fact the fabric is semi-transparent is crucial because without that you don't see the forms. I think it is absolutely necessary, it is something that lacked in the pink fabric.

3) What was the main quality that you identified while interacting with the chiffon fabric?

I think when we were all working together, you suddenly saw layered up the fabric. During the whole process, you noticed when the fabric clusters massively in the middle, you don't necessarily appreciate it, I think it is when we move, when it's really close together it doesn't feel like much but then suddenly we moved apart again and I think is those moments when you appreciate it (6:15). Space evolves and grows out of that moment. I guess the twist is something we would never appreciate when you are inside because you are constantly reading your surroundings and reading what the fabric is doing around you and so with the transparency, you actually read it very clearly and obviously you are judging distance when you are inside so it's much easier. I guess any other fabric that isn't transparent you wouldn't get that experience. You would see as a wall, it is quite suffocating, actually and claustrophobic, compared to the other one.

4) How could this quality be used for the design of the soft courtyard?

I think it could be in many different ways. If you are looking for patterns, purely for facade details, just pattern generation. You could think of something 2D mould 3D stepping back if you take it as a literal image but also you can see the volumes coming out of it. You can use it in many different ways. It is not about 3D generating it is about the details that you could take as a flat static image and used that to then inform a design process o the beginnings of a design.

You could see a how pattern-generation, it's like hair. There is also something quite nice about the panelisations, because you get very linear lines, that are giving you much like, sort of direction of space and how you read the fabric better but it's also you know like when you pick a nice curve from a 3D model it's the same kind of thing,

you are able to read it much more visually, it's easier because it gives you a point of reference.

Also, the concept of the ceiling is quite interesting, sort of changing, like having low ceilings and high ceilings, that's something that doesn't really happen in real life for architecture but the concept that that could happen, it makes a cosier space, then they could move to open up when needed to assembly a volume, that's quite an interesting idea, again it's about the ceiling but I guess it's because most of the time you don't look at them, so that's provocative. You could imagine that potentially if you had two different types of fabric interacting simultaneously o perhaps different sections of the same fabric then you get gaps in the fabric which is something that you are not getting as much, even less if you are crossing them or whatever. It's always like a strange moment when it comes down, you are sort of happy and not happy all of the same time, but it's lost its structure because you can't get it back on the process. Everything's flatter.

5) What aspects of the set-up and material selection worked and what did not?

I think the beams they were ideal, having the ability to support it a structure. It would be nice to have an abundance of fabric as in the black chiffon setup because I would be interested to see what happens if you have even more, because there is something about creating a space like that where you are limited, obviously we were trying to create space, we were thinking at human scale, 1:1, so once you start creating that space of 1:1 we run out of fabric if you are trying to do too much whereas if you have even more fabric you can imagine that gathering something will then not take fabric away from another area to do something else. You'll be creating something here, something there, it will afford you to tight something up and leave it and go away and do something different in a different area. It's sort of perpetuating this concept of luxury, that's something that I think I sort of thought about in the tea room experience, it's a luxury experience, it's a relaxing moment, and when you think about it you think of excess and abundance. So, more fabric would be a way to take it further.

6) How is this approach valuable for architectural design, as opposed to designing with the computer?

As a design tool, I think it could be very interesting. There have been several projects where I think it'd have been very valuable to have actually experimented with real fabric. I think there was one particular point on a project where we were looking at curtains and also on Shanghai Bund, where there was actually going to be a curtain

but they were looking at chain mall but you could have tested a lot of things in a very similar way in fabric, quicker and potentially to get vouwling, the teams are modeling fabric and it is quite difficult without actually having the fabric, it would have been interesting. In the end we actually were using small samples of fabric, but obviously if you scale it up, they don't behave in the same way so actually to generate something that's really big, it's quite hard to scale it up, you have to use a larger work to 1:1, I think it is quite important.

7) How did this approach work for you?

I think it will be quite specific to the project. Obviously immediately if you are using fabric it makes sense but I think this concept of what fabric generates the kind of forms that you can produce using certain types of fabric, I mean, the straight lines if you tether, the curves if you allow it to fall, allow you to set up a system of rules that you could use to design, in a way that could be unique because it's not coming from your mind, it's coming from the actual fabric itself, the materiality which is something the studio is obviously interested in.

The hours it would take to generate that forms digitally...you can't. It's probably a million of forms in there...it's really interesting. Everyone's using the same tools to design with, you are surrounded by the same history, the same education of what good design is and how to do it and you know we all appreciate similar forms and so you replicate them or absorb them in some way and it's actually very difficult to generate new forms, new ideas and new ways of designing, really. So, I think it's got the lot of potentials to be used in a variety of different ways and I don't know if whether it's just the fabric you choose, you know, it's not necessarily just architecture. If you draw scribbles and then you make a picture from the scribble, you can imagine that in a 3D world, you are scribbling, you are sketching in 3D and you then tidied up and generate the from out of it. But in 3D form, at this scale, it is very unique.

PHP (A4)

1) What was the main finding of the workshop?

It's definitely a sense like we were working more in terms of the wider landscape that becomes from the fabric. Say once we understood the smaller scale possibilities of them.

It feels like that's kind of another of the third level step back kind of directorship curating role. So, any person that's running around the whole installation to see if.

That moment in we were creating spaces within spaces was quite an enjoyable moment.

Well for me these observations of the movement as the engagement continued, that kind of change in granularity of understanding perception the kind of small scale of the fabric worked to the individual enable to start to make these big movements begin to engage with others but not at the size of the whole group. And then we had to step back again.

There's a difference in distances from the material interesting as it is. You can only ever really produce, it's a little bit of a perfect believe, that design is so particular to what you are working with. Just produce something abstractly without understanding material properties is not as strong and not as rich as it should be. That's' exactly is happening here when material can start to inform the design process, different fabrics require different responses. I had a very clear sense of the dialogue that was taking place.

2) Which material was more appropriate in terms of the design of the soft courtyard?

For me the black one. And that was to do with scale, so in a room of that size, we were able to do a lot more because we could hold it more easily, twisted more easily. With the pink one, you could get much more effective, it was relatively little. The size of it. You need to understand what is going on...

3) What was the main quality that you identified while interacting with the chiffon fabric?

Flexibility. I was able to stretch legs and arms and there was enough material to expand it. It has to do with thickness as well whereas with the pink one was more difficult. The video in when I was in the middle, it´s not to do with the fabric but with the size of the fabric as I was able to kind of draw things and stretch things while being inside. It was more about, dragging, pulling things and gathering. I am thinking of spring qualities, you can pull it out, the material allows you for a particular formation (minute 6).

4) How could this quality be used for the design of the soft courtyard?

I guess for me I am thinking more of a series of actions that become drivers. Traditional textile architecture, the form it's also very known, the double curvature, intention, proportion. That's a difference, I am thinking of building a particular

vocabulary for a particular design task. Not knowing what the results would be again you have to engage with the verbs to see what come out of the other way around rather than doing abstract spatial explorations. Development of vocabulary, a vocabulary of verbs.

5) What aspects of the set-up and material selection worked and what did not?

I was really intrigued about the fan effect, wind generation, coming from the fan, flow air of a particular. The next step would be to go to the Middle East to the hotel rooftop having a natural flow air of a particular location, wind changing direction, increasing and decreasing as it creates different vocabulary as there's a different environmental condition. Transparency of the fabric, the thickness or working with the one same fabric at different sizes to look for all variables as a physical sense of it. There was the possibility of being able to start to fix points so in the context of the hotel if there's going to be an architectural context working with them, they are all then be a proposal for space with fixed points which suggests moments of the connecting type of fabric. The more constraints that are imposed the more opportunities to be creative. How would it be, how many different levels would be possible to start to fix the fabrics and what happens if you fix them at the same level or diagonally.

6. How is this approach valuable for architectural design, as opposed to designing with the computer?

The danger that I see in people jumping to digital software to create form without an understanding of the material quality or environmental factors we often get that what people are designing is extraordinary shapes in Rhino but there were surfaces, there is no understanding where there's a thickness or within architecture or there are social layers that have to somehow meet. Similarly, with fabric, that would be the best knot you can, the kind of software that we use to start questions of tension and compression and how to write some kind of script in a digital world the fabric would behave. Even then there is no substitute for this particular piece of fabric that you are working with which may or may not have, for example, where people working doing a lot of digital fabrication, I'd say timber, program with the qualities and properties of timber, what about the timber taken from the top of the tree versus the bottom of the tree and what happens with this knot that starts to grow here, what happens if there's a split of a piece of timber that you are putting into the machine once to get a particular direction and that is a particularity of the material that you could never replicate. Every tree is different, every piece of wood is different so that would be a kind of way of making sense of the physical-digital relationship.

I was touching on earlier about, if you look at the history of tensile fabrics in architecture there's a very particular form vocabulary that comes from structural principles. I like this approach as a kind of disturbance, as a way of questioning other possibilities, other ways. Maybe it's easier if it's not structural element providing a roof protection it's more of a way of exploring architectural space within a courtyard, maybe those constrains, I'd like a sense of there's so much that can be done.

I haven't got a good way of describing it theoretically but I can give an example of song writing. I used to write songs years ago and my way into it was to change all the tunings on the guitar strings so the cord of G has this particular finger shape, if I change all the tunings suddenly I don't know what a cord looks like and I have to listen to the sounds randomly putting my fingers in different places to try to find a cord that sounded good and then I didn't know what a standard cord professional would be. So, then it's just start again, what is the next sound that is good, so it becomes a very explorative way of developing. It has a little bit of that quality for me, if you change the vocabulary if you change the context, if you change the frame of it you can start creating surprising outcomes.

7) How did this approach work for you?

It provided a different vocabulary, different way of thinking about what fabric structures might be or might work, creating a different perception of what is possible.

Transcriptions of participants' questionnaire responses (Chapter six)

Choreographer (SS)

1) What do you think of the design of the set-up?

The soft interface connects with my idea of architectural dance, as it is a very architectural way of composing with the body. By keeping the bodies hidden, a complete organism appears, it is a new entity.

2) What did you find different from your usual way of working?

It was difficult for me to compose with the fabric because usually I have a very visual way of working and I need to see the body, it is very fundamental. It was really challenging.

You can't think about dance anymore. I felt more as if I were using 3D software.

3) What did you find interesting/useful from your perspective?

When I create with the body I imagine it first and then I tell the dancers to do it. This time I had something in mind but when asked the dancers to do it something very different came out. It was very unpredictable. When I understood that I started to think differently, to ask them to do very minimal movements and that result in more interesting shapes. Body form-giving process rather than choreography.

4) What is your opinion regarding the outcomes of the exploration?

It is especially interesting when the form of the soft interface becomes unrecognisable as the dancers deform the corners of it. By adding more dancers, the whole cube could be blurred. I find the dots pattern the most interesting and elegant one.

5) What do you think about the collaborative aspect of the project?

I think it is very interesting because it invites to imagine a wall based on body instructions which bring a very interesting aesthetic. You can arrive at the conclusion of having a wall with the dots.

Dancer (RT)

1) What do you think of the design of the set-up?

I thought the setup was interesting and enjoyed experimenting with the elasticity of the material. Personally, I enjoyed the more closed in spaces we worked with at the end because it became more confined and we could create more shapes. Also, the shapes we were creating were more abstract. We could only minimally affect the shape of the cube since its frame was already defined and much larger than us.

2) What did you find different from your usual way of working?

We heavily relied on the feedback of those outside the cube to tell us what movements we were doing were visually more interesting. I also didn't have a complete picture of what we were creating because the 3 dancers inside were all contributing the shape, not just myself. It felt more the material/cube was the performer and we were the puppeteer or manipulator.

3) What did you find interesting/useful from your perspective?

Dance has a lot to do with the shape of the body, so I find it interesting to add an extra element that manipulates the shape of the body. It also gave more importance to space because the cube was a defined space around us. Space because of a collaborative element.

4) What is your opinion regarding the outcomes of the exploration?

The cube acts as a sort of shield. I am not longer directly visible to the public and so the individual shapes I make or the way I look is less important. We also started to use one other as counterbalances so we could stretch further in the cube wall.

5) What do you think about the collaborative aspect of the project?

As an observer, I find the anonymity of the exploration very interesting - seeing shaped appear and disappear and not knowing who/what they are. For example, the heads coming in and out of the material. I also enjoyed watching the fingers against the fabric, particularly when we sync up with one another because it gives a feeling that the cube is one object and not 3 separate humans inside.

Architect (DS)

1) What do you think of the design of the set-up?

I like the potential of this elastic interface as a design tool. In this augmented relational scale between user and material is easier to explore and sculpt form while one experiences in the first person how the material behaves.

2) What did you find different from your usual way of working?

What is interesting for me is to use the textile as a 3d modelling tool like ones used in the computer software and see the difference between them. Also, that is a time-based modelling tool as such it captures many potential solutions within the same model. In contrast with regular models which only holds particular states of for**m.**

3) What did you find interesting/useful from your perspective?

The most interesting part is to design in a continuum space and to have the opportunity to explore in the computer not only interesting forms but also transitions from one state to another.

4) What is your opinion regarding the outcomes of the exploration?

For me is still incipient. It presents many potentials for more concrete design tasks and it has many parameters to tweak according to what one, as a designer, wants to explore and focus on. Might be the structural performance of a particular material, its qualities or other rendered properties and those objectives define different design scenarios and demand different computational design paths.

The principal value of this toolset is a form generation or giving process similar to a sort of explicit tool but in this case, mediated by analog inputs. Once the form is digitalised it can be used and analyse in many different ways.

5) What do you think about the collaborative aspect of the project?

It was very interesting for me to see how others experienced an elastic interface and explored form making by means of interaction with the material and their bodies. It brings new ways of working and new aesthetics.

Royal College of Art
RESEARCH & INNOVATION

Project Information Sheet

Soft Embodied Geometries

For further information
Supervisor: *Professor Clare Johnston*
clare.johnston@rca.ac.uk

19/10/2016

Dear Potential Participant,

I am Marina Castán a Research Associate in the Textiles programme at the Royal College of Art. As part of my studies, *I am* conducting a research project entitled Soft Embodied Geometries and the project is externally sponsored by ArcInTex European training network. You are invited to take part in this research project which explores *how improvised choreography and soft materials could be translated into a digital workflow*.

If you consent to participate, this will involve:

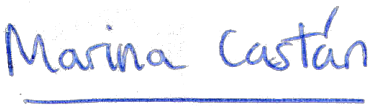
- Taking part in a 3 hours workshop at the Lithuanian Academy of Music and Theatre – Dance

(Participants were contacted through professor Eglė Ganda Bogdanienė from Vilnius Academy of Arts).

Participation is entirely voluntary. You can withdraw at any time and there will be no disadvantage if you decide not to take part in the workshop. All information collected will be used as data to inform my research, including visual material for its later publication in conference papers.

If you have any concerns or would like to know the outcome of this project, please contact my supervisor (Clare Johnston) at the below address.

Thank you for your interest,
Marina Castán



Complaints Clause:
This project follows the guidelines laid out by the Royal College of Art Research Ethics Policy.

If you have any questions, please speak with the researcher. If you have any concerns or a complaint about the manner in which this research is conducted, please the address the RCA Research Ethics Committee by emailing ethics@rca.ac.uk or by sending a letter addressed to:
The Research Ethics Committee
Royal College of Art
Kensington Gore
London
SW7 2EU

Royal College of Art
RESEARCH & INNOVATION

Consent Form

Soft Embodied Geometries

For further information
Supervisor: *Professor Clare Johnston*
clare.johnston@rca.ac.uk

19-10-2016

I Julija Mintaute have read the information on the research project Soft Embodied Geometries which is to be conducted by Marina Castán from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

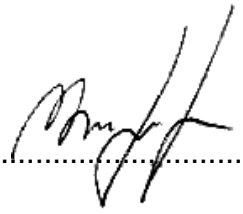
I understand that I can withdraw my participation from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:

- *Taking part in a 3 hours workshop at the Lithuanian Academy of Music and Theatre – Dance*

I understand that all information gathered will be stored securely, and my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name: *Julija Mintaute*

Signature.....  .....

Date: 19-10-2016

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Royal College of Art
RESEARCH & INNOVATION

Consent Form

Soft Embodied Geometries

For further information
Supervisor: *Professor Clare Johnston*
clare.johnston@rca.ac.uk

19-10-2016

I Petras Lisauskas have read the information on the research project Soft Embodied Geometries which is to be conducted by Marina Castán from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

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I consent to:

- *Taking part in a 3 hours workshop at the Lithuanian Academy of Music and Theatre – Dance*

I understand that all information gathered will be stored securely, and my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name: Petras Lisauskas

Signature.....

Date: 19-10-2016

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London
SW7 2EU

Royal College of Art
RESEARCH & INNOVATION

Project Information Sheet
Layering Up Soft Materiality

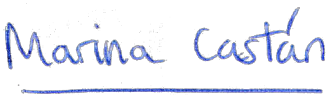
For further information
Supervisor: *Professor Clare Johnston*
clare.johnston@rca.ac.uk

20 /11/2017
Dear Potential Participant,

I am Marina Castán *a Research Associate* in the Textiles programme at the Royal College of Art. As part of my studies, I am conducting a research project entitled Layering Up Soft Materiality and the project is externally sponsored by ArcInTex European training network. You are invited to take part in this research project which explores *the value of applying an embodied collaborative approach to soft architecture.*
If you consent to participate, this will involve:
• Taking part in a 6 hours workshop at the Depot Point community space at 15-27 Britannia St, London, WC1X 9AH, UK the 28-29/11/2017.
(Participants were contacted during my secondment at Heatherwick Studio).
Participation is entirely voluntary. You can withdraw at any time and there will be no disadvantage if you decide not to take part in the workshop. All information collected will be used as data to inform my research, including visual material for its later publication in conference papers.

If you have any concerns or would like to know the outcome of this project, please contact my supervisor (Clare Johnston) at the below address.

Thank you for your interest,
Marina Castán



Complaints Clause:
This project follows the guidelines laid out by the Royal College of Art Research Ethics Policy.

If you have any questions, please speak with the researcher. If you have any concerns or a complaint about the manner in which this research is conducted, please the address the RCA Research Ethics Committee by emailing ethics@rca.ac.uk or by sending a letter addressed to:
The Research Ethics Committee
Royal College of Art
Kensington Gore
London
SW7 2EU

Royal College of Art
RESEARCH & INNOVATION

Consent Form

Layering Up Soft Materiality

For further information
Supervisor: *Professor Clare Johnston*
clare.johnston@rca.ac.uk

20/11/2017

I Darragh Casey have read the information on the research project Layering Up Soft Materiality which is to be conducted by Marina Castán from the Royal College of Art, and all queries have been answered to my satisfaction.

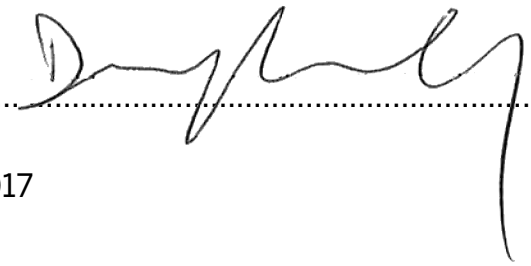
I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw my participation from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:
Taking part in a 6 hours workshop at the Depot Point community space at 15-27 Britannia St, London, WC1X 9AH, UK the 28-29/11/2017.

I understand that all information gathered will be stored securely, and my opinions will be accurately represented. All information collected during the workshop will be used as data to inform the present research, including visual material for its later publication in conference papers.

Print Name: Darragh Casey

Signature.....  .....

Date: 20/11/2017

Complaints Clause:
This project follows the guidelines laid out by the Royal College of Art Research Ethics Policy.

If you have any questions, please speak with the researcher. If you have any concerns or a complaint about the manner in which this research is conducted, please the address the RCA Research Ethics Committee by emailing ethics@rca.ac.uk or by sending a letter addressed to:
The Research Ethics Committee
Royal College of Art
Kensington Gore
London
SW7 2EU

Royal College of Art
RESEARCH & INNOVATION

Consent Form

Layering Up Soft Materiality

For further information
Supervisor: *Professor Clare Johnston*
clare.johnston@rca.ac.uk

20/11/2017

I Hae Yeon Lim have read the information on the research project Layering Up Soft Materiality which is to be conducted by Marina Castán from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw my participation from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:
Taking part in a 8 hours workshop at the Depot Point community space at 15-27 Britannia St, London, WC1X 9AH, UK the 28-29/11/2017.

I understand that all information gathered will be stored securely, and my opinions will be accurately represented. All information collected during the workshop will be used as data to inform the present research, including visual material for its later publication in conference papers.

Print Name: Hae Yeon Lim

Signature.....Hae Yeon Lim.....

Date: 20/11/2017

Complaints Clause:
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Royal College of Art
RESEARCH & INNOVATION

Consent Form

Layering Up Soft Materiality

For further information
Supervisor: *Professor Clare Johnston*
clare.johnston@rca.ac.uk

20/11/2017

I Hannah Parker have read the information on the research project Layering Up Soft Materiality which is to be conducted by Marina Castán from the Royal College of Art, and all queries have been answered to my satisfaction.

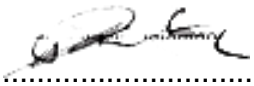
I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw my participation from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:
Taking part in an 3 hours workshop at the Depot Point community space at 15-27 Britannia St, London, WC1X 9AH, UK the 28/11/2017.

I understand that all information gathered will be stored securely, and my opinions will be accurately represented. All information collected during the workshop will be used as
data to inform the present research, including visual material for its later publication in conference papers.

Print Name: Hanna Parker

Signature  .....

Date: 20/11/2017

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Royal College of Art
RESEARCH & INNOVATION

Consent Form

Layering Up Soft Materiality

For further information
Supervisor: *Professor Clare Johnston*
clare.johnston@rca.ac.uk

20/11/2017

I Katerina Chaida have read the information on the research project Layering Up Soft Materiality which is to be conducted by Marina Castán from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw my participation from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:
Taking part in a 4 hours workshop at the Depot Point community space at 15-27 Britannia St, London, WC1X 9AH, UK the 28/11/2017.

I understand that all information gathered will be stored securely, and my opinions will be accurately represented. All information collected during the workshop will be used as data to inform the present research, including visual material for its later publication in conference papers.

Print Name: Katerina Chaida

Signature  .....

Date: 20/11/2017

Complaints Clause:
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Royal College of Art
RESEARCH & INNOVATION

Consent Form

Layering Up Soft Materiality

For further information
Supervisor: *Professor Clare Johnston*
clare.johnston@rca.ac.uk

20/11/2017

I Luis Sacristán have read the information on the research project Layering Up Soft Materiality which is to be conducted by Marina Castán from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw my participation from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:
Taking part in a 6 hours workshop at the Depot Point community space at 15-27 Britannia St, London, WC1X 9AH, UK the 28-29/11/2017.

I understand that all information gathered will be stored securely, and my opinions will be accurately represented. All information collected during the workshop will be used as data to inform the present research, including visual material for its later publication in conference papers.

Print Name: Luis Sacristán

Signature 

Date: 20/11/2017

Complaints Clause:
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Royal College of Art
RESEARCH & INNOVATION

Consent Form

Layering Up Soft Materiality

For further information
Supervisor: *Professor Clare Johnston*
clare.johnston@rca.ac.uk

20/11/2017

I Phillip Hall-Patch have read the information on the research project Layering Up Soft Materiality which is to be conducted by Marina Castán from the Royal College of Art, and all queries have been answered to my satisfaction.

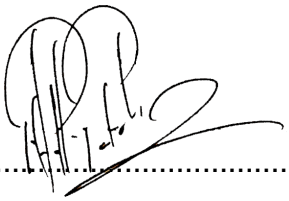
I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw my participation from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:
Taking part in a 3 hours workshop at the Depot Point community space at 15-27 Britannia St, London, WC1X 9AH, UK the 28/11/2017.

I understand that all information gathered will be stored securely, and my opinions will be accurately represented. All information collected during the workshop will be used as data to inform the present research, including visual material for its later publication in conference papers.

Print Name: Phillip Hall-Patch

Signature.....  .....

Date: 20/11/2017

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Royal College of Art
RESEARCH & INNOVATION

Project Information Sheet

Soft Embodied Architectures

For further information
Supervisor: *Professor Clare Johnston*
clare.johnston@rca.ac.uk

20/06/2017

Dear Potential Participant,

I am Marina Castán, a Research Associate in the Textiles programme at the Royal College of Art. As part of my studies, I am conducting a research project entitled Soft Embodied Architectures and the project is externally sponsored by ArcInTex European training network. You are invited to take part in this research project which explores How can a hybrid EDI process be designed that can be implemented into architectural design methodology?

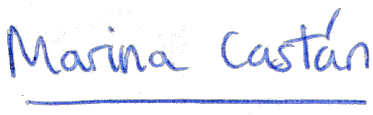
If you consent to participate, this will involve:

- Taking part in an 8 hours workshop at the Berlin University of the Arts (UDK) (Participants were contacted through a common colleague).

Participation is entirely voluntary. You can withdraw at any time and there will be no disadvantage if you decide not to take part in the workshop. All information collected will be used as data to inform my research, including visual material for its later publication in conference papers.

If you have any concerns or would like to know the outcome of this project, please contact my supervisor (Clare Johnston) at the below address.

Thank you for your interest,
Marina Castán



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Royal College of Art
RESEARCH & INNOVATION

Consent Form

Soft Embodied Architectures

For further information
Supervisor: *Professor Clare Johnston*
clare.johnston@rca.ac.uk

20/06/2018

I Salvatore Siciliano have read the information on the research project Soft Embodied Architectures which is to be conducted by Marina Castán from the Royal College of Art, and all queries have been answered to my satisfaction.

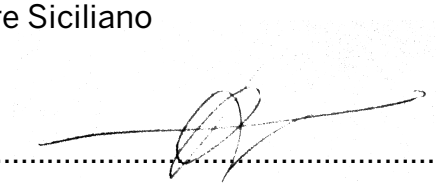
I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw my participation from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:
Taking part in an 8 hours workshop at the Berlin University of the Arts (UDK) the 23/06/2017

I understand that all information gathered will be stored securely, and my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name: Salvatore Siciliano

Signature.....  .....

Date: 20/06/2017

Complaints Clause:
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If you have any questions, please speak with the researcher. If you have any concerns or a complaint about the manner in which this research is conducted, please the address the RCA Research Ethics Committee by emailing ethics@rca.ac.uk or by sending a letter addressed to:
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Royal College of Art
RESEARCH & INNOVATION

Consent Form
Soft Embodied Architectures

For further information
Supervisor: *Professor Clare Johnston*
clare.johnston@rca.ac.uk

20/06/2018

I Berit Einemo Frøysland have read the information on the research project Soft Embodied Architectures which is to be conducted by Marina Castán from the Royal College of Art, and all queries have been answered to my satisfaction.

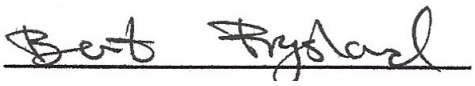
I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw my participation from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:
Taking part in an 8 hours workshop at the Berlin University of the Arts (UDK) the 23/06/2017

I understand that all information gathered will be stored securely, and my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name: Berit Einemo Frøysland

Signature 

Date: 20/06/2017

Complaints Clause:
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Royal College of Art
RESEARCH & INNOVATION

Consent Form

Soft Embodied Architectures

For further information
Supervisor: *Professor Clare Johnston*
clare.johnston@rca.ac.uk

20/06/2018

I Marika Giannoccari have read the information on the research project Soft Embodied Architectures which is to be conducted by *Marina Castán* from the Royal College of Art, and all queries have been answered to my satisfaction.

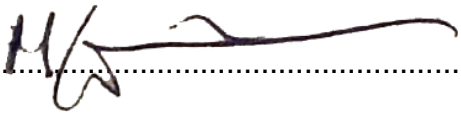
I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw my participation from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:
Taking part in an 8 hours workshop at the Berlin University of the Arts (UDK) the 23/06/2017

I understand that all information gathered will be stored securely, and my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name: Marika Giannoccari

Signature..... 

Date: 20/06/2017

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SW7 2EU

Royal College of Art
RESEARCH & INNOVATION

Consent Form
Soft Embodied Architectures

For further information
Supervisor: Professor Clare Johnston
clare.johnston@rca.ac.uk

20/06/2018

I Rachel Tack have read the information on the research project Soft Embodied Architectures which is to be conducted by Marina Castán from the Royal College of Art, and all queries have been answered to my satisfaction.

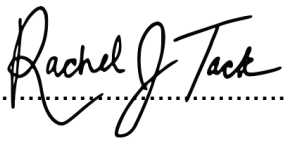
I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw my participation from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:
Taking part in an 8 hours workshop at the Berlin University of the Arts (UDK) the 23/06/2017

I understand that all information gathered will be stored securely, and my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name: Rachel Tack

Signature.....  .....

Date: 20/06/2017

Complaints Clause:
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