Exploring static electricity as design material for woven and hand-tufted textiles

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Stella Katsarou
Thesis

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“Electrostatic textile surfaces” is a design example of surfaces which have the ability to interact to human action by movement. The design exploration was directed by the intention of achieving movement through static electricity. During this project textile techniques such as weaving and hand-tufting have been explored in combination with unconventional materials and functions and used as methods to design the surfaces. The findings from the design process regard the categorization of the yarns through the material exploration, the development of a design method through the experimentation of the technique and the surface appearance through the materialization of the method. The two final surfaces are exhibited horizontally and vertically in relation to the ground. The scale of the final structures is related to the body scale. One can electrify the surfaces by walking around or through them letting an open dialog to take place depended on personal interpretations.

Keywords: textile design, spatial surfaces, weaving and hand-tufting, static electricity.
Approaching Energy from a design perspective: Introduction

Modern living is defined by electrical power. Dynamic electricity\(^1\) is the most common type of power that has been used for many years in different applications and devices within the design area, especially as a power mediator between energy sources and final energy forms, as for example the production of electricity (mediator) by solar energy (source) and its use by an electrical device which converts it to the final energy form. In order to produce dynamic electricity the consumption of energy occurs. With the introduction of dynamic electricity to the design field computation became part of our life and of our living environments. However one question rises; do spatial elements react to human presence in an active way?

Contrary to dynamic electricity, when it comes to static electricity most people think of it as a phenomenon that creates sudden shocks to them when touching something metallic, or as an annoying situation of flying hair when brushed with a plastic comb or taking off a blouse. Mostly because of these two demonstrations of static electricity in everyday life, it has turned out to be perceived as a negative experience. In this design research it will be attempted to alter this conception around electrostatic phenomena.

In this work energy is provided by body movement, a source theoretically inexhaustible, used to build-up static electricity. In contrast to the common use of dynamic electricity, in this project “Electrostatic textile surfaces” energy transformations are intended to happen directly from one type to another, without transitional stages that may need the use of supplementary devices such as electrical support or embedded computation.

When designing an interactive environment it is common that the designer has a clear intention for a specific design thus directs his/her process towards achieving a final result. In the present work movement as design material is essential, but the use of static electricity makes the surface behaviour not totally predictable or controlled. Consequently, movement becomes an intriguing material to be explored in the design process. From this perspective, which design variables can be controlled by the designer when movement by the use of static electricity is part of the desired expression? How do unpredictable factors affect the desired designed expression?

1. Exploring static electricity as design element: Design Program

Aiming to explore the expressiveness of static electricity by locating it in the design area, changeability and interaction with human presence are the elements which will contribute to communicate specific properties and

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1. There are two types of electricity, dynamic and static. Static electricity is created when electrical charges build up on the surface of a material. Usually, substances that do not conduct dynamic electricity (insulators) are good at holding a charge. Dynamic is the rate of flow of electrons, thus an electric current. Unlike static electricity, dynamic electricity flows through a conductor (e.g. copper wire). By using just the word “electricity” we refer to dynamic electricity as it is the most frequently used type and it can also be found also in the term “current electricity”.

3
expressions materialized by the textile constructions. Accordingly, this work explores the expression of changes within textile structures in relation to human interaction. The focus is on movement by static electricity; created by friction between body and textile parts. Thus, static electricity is used here as a design element which comes from the field of physics.

1.1. Previous design examples

The subject of research is framed by the contexts of interactive spaces and textile design. Intending to establish a link between them, systems consisting of physical phenomena and designed elements have been explored in my previous design work. During the project “Exploring static electricity through textiles”, an installation of several hand-made textile structures has been arranged in a room (Fig.1). Each of these structures could change its shape from a “close” to an “expanded” form making visible its construction details. The use of static electricity made them interact to the human body by moving towards it and at the same time moving to opposite directions between them.
The idea of interaction between human body and textile structures by movement was the main intention regarding the functionality and expression of an artwork. A sequence of reactions between body and the textile artwork occurred starting from body movement which provoked the effect of animated objects. Movement, which has been explored through textile structures in relation to human presence, implies the material and the type of construction of the textile design, defines the changeable character of the structure of the interactive design and constitutes the result of repulsion due to static electricity between electrified objects. In other words movement is the expressive element which outlines the design process.

Designing systems between textile surfaces and human body movement with creating an expression of changeability is the subject of this design program. Figure 2 represents the context diagram in the centre of which human interaction is placed, focusing on the body and object movement.

In order to achieve movement, excluding the use of dynamic electricity, static electricity has been selected to be the energy source. This choice has its roots in the idea of exploiting “free” (in the sense of renewable) energy sources in designing, a theme that has been introduced in my previous work. Static electricity generated by friction with the help of the body is the power that provokes movement by means of attraction or repulsion forces (Fig.3).
The findings from the research course used as a continuation for the design process, concern the properties of the materials, forms and construction details suitable for expression of the movement. The “Electrostatic textile surfaces” are partially made of PTFE² (Teflon) material, whose exploration started during the research course. Weaving, hand-tufting and crafting are the techniques which have been used. Weaving is used for the surface on which the tufted areas are located and allows the functionality of the structure towards the movement of the tufted piles. Weaving is suitable because of its strength to tensile forces, necessary element for a backing tufting fabric. Tufting is used because of the possibility to create piles; free edges of yarn which stick out of a flat surface. Crafting, manipulations on the tufted surfaces, describes the technique used to create piles much longer than the ones the tufting machine can provide.

The combination of these three techniques is appropriate for the exploration of the design variables and for the intentions regarding the scale of the structures in relation to the body. Movement is explored in two levels of expression; body movement which provokes static electricity on the textile surfaces and as a consequence, movement which is created on the textile surfaces.

2. PTFE (Polytetrafluoroethylene) widely known with the brand name Teflon®, has a very low coefficient of friction therefore it has the tendency to get electrified almost with minimal friction with other materials and can retain the charge for quite a long period. It is also used to produce “electrets”, materials are made to be permanently electrified, as respective equivalent to magnets that use static electricity instead of magnetism.
1.2. Electrostatic textile surfaces: Aim

The aim of the project and main challenge is to investigate conventional textile construction techniques in combination with unconventional materials and functions; to work together with these different elements in order to develop methods and materials for textile design using static electricity as the medium to achieve movement on textile surfaces, at various scales related to the body.

There are however more objectives to explore which are lying in more than one direction. Some of them, which will be used at the same time as guidelines for the actions that will be taken to reach the main goal, are: a) to invite people be part and influence a designed system in real time by playing with its changeable patterns, b) to inspire other designers to work with the use of forms of energy other than dynamic electricity and to include in their design languages others than just the visual which, in a sense, transforms the person that relates to it into a spectator, c) to raise awareness of invisible static electricity by altering the rather negative impression around its experience in everyday life, into an incident of moving fibers from a distance through a system of reactions, d) to sum up the findings from the research project and dig deeper into the investigation of material expression, techniques and constructions (Fig.4), e) to create a sort of an artificial “living organism” that will be able to react to stimuli and parts of it to resist to gravity forces, f) to suggest a shift of the target of architectural design from solid and visually interesting structures to more flexible and inviting for interaction areas.

- Intentions for the structures regarding the expression and the aesthetical qualities.

The main intension for the structures is to achieve movement by combining materials that are able to attract to the human skin when electrified. Movement is used to express the changeability. Describing the intentions of my work with verbs referring to modes of action, words can be used such as: move, repel/attract, change, involve, block/allow.

The intentions about the aesthetical qualities, lying under the expression of the movement, can be described by the adjectives: invisible /transparent/ transitive /contrasting. These qualities are intended to be materialized as transitions between opaque and transparent areas, as almost invisible fine threads characterized by lightness contrasting to the solidity of other areas on the same structure. A subtle tactile expression is enforcing the invisible/weightless element. Strengthening the contrasting impression, opposing feelings can be provoked when the fine, subtle fibers are touching the human skin, when the body is surrounded by them and they are all moving towards the body.
Fig. 4. Combination of elements from previous design projects, variables to work with.
2. Context

2.1. Correlated characteristics of Living, Interactive and Architectural environments.

There are different ways in which a living organism\(^3\) can be described: changeability, impermanence, unconventionality, mobility. Living organisms are described as: "highly organized, from the smallest part to the largest (...) able to acquire and use energy, (...) able to react, able to stay in balance with its outside and inside environments" (Cruz, 2011). Another definition of living organisms states that: "the resistance to gravity is the only dynamic criterion which unambiguously elucidates the context of the term 'living'" (HubPages, 2013). These two statements have been used as inspiration for my work; most of all the reaction to stimuli and resistance to gravity. Spatial interactive environments have the ability to react to stimuli. According to the criteria that define interactive environments, in particular kinetic environments, it is asserted that: "a kinetic environment without the computation is like a body without a brain: incapable of moving. (...) The computation is, in a sense, the brain that can control the behaviour of the motion."(Fox and Kemp, 2009, p.58). Complementary to the first statement, and as it is illustrated through this design work, movement is explored as design material even without the assistance of embedded computation. Nevertheless, for a high control of motion computation is necessary.

Artistic installations cover another important task in comparison to architectural spaces. Fox and Kemp mention that “Installations and other artistic endeavours free the designer from many of the constraints associated with constructing architecture, such as building codes or life safety considerations.”(Fox and Kemp, 2009, p.169). Artistic explorations create the ground where new possibilities are exposed and start to develop, assisting the expansion of architecture in other directions. Especially artistic installations enforce this track because they create spatial experiences, since architecture strongly relates to space.

The notions of living organism and organized systems which react to stimuli without the use of dynamic electricity are introduced in Tomas Saraceno’s work. Tomas Saraceno has been working with installations which involve people into unconventional spatial experiences. Defining his work using adjectives, the words – ambiental, transparent, suspended, floating, living – can be used in order to describe repetitive qualities in his projects. Some remarks from others on his work state that: “Saraceno’s work floats. (...)These works propose new social organization while redefining the architect’s relationship to the gallery, in which the exhibition is invoked as a site of proposal for future worlds and redefine our

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3. Organism: From the greek word ὄργανον, organon, i.e. “instrument, implement, tool, organ of sense or apprehension”. In biology, an organism is any contiguous living system. In at least some form, all types of organisms are capable of responding to stimuli, reproduction, growth and development, and maintenance of homeostasis as a stable whole. Here is used to define a structure that is capable of responding to stimuli.
behaviours in this one.” (Di Carlo, 2010). Reflecting on this statement the proposal expressed through his work for a shift on the way in which the artwork relates to the visitor and to the gallery, is useful for the detachment of the visitor from the role of the observer, converting him/her into an active participant of a happening between body, materials and space. Relating it to my work this proposal is also suggested with my structures by inviting people touch or walk through them, contributing in this way to the instant or temporal patterns of the installation. “Much of Saraceno’s work demonstrates the physical properties of his materials” (Thomas, 2007). “This artist-architect has frequently compared his creations to living organisms. Changes in the environment trigger thought processes; Saraceno is interested in the way in which “spaces and people generate new ideas.” (Kunstsammlung, 2013). The notions of a living organism, artificial changeable environments, floating structures, the use of devices that do not use electricity, and the expose of the physical properties of materials associative to his work are elements which are introduced in my work as well. Through his work he is modelling possible utopias suggesting new worlds.

I see my work relevant to Saraceno’s on a conceptual level; on the level of suggesting possibilities for creating dialogs between people and designed environments and not on the scale of the structures or the actual techniques used. Movement is an example of this dialogs. The movement of the body generates movement on the designed structures which subsequently creates changes on the structures giving response back to the body.

In his work “In Orbit” Saraceno has constructed a layered installation consisting of three nets suspended horizontally in a way of three parallel levels holding apart from each other by a series of air-filled PVC “spheres”. The visitors can walk on nets and at the same time influence the movement of the whole structure. They can be seen from below, or they can see others walking above them. As mentioned in the press information about this project:

The various materials underscore Saraceno’s basic ideas of flow and lightness: When I look at the multilayered levels of diaphanous lines and spheres, I am reminded of models of the universe that depict the forces of gravity and planetary bodies. For me, the work visualizes the space-time continuum, the three-dimensional web of a spider, the ramifications of tissue in the brain, dark matter, or the structure of the universe. (Kunstsammlung, 2013)

Creating installations which float, which challenge the force of gravity, give the impression of something which is not static or explicit, and trigger the imagination to travel in notions such as life which always flows, creating feelings of both easiness and discomfort. His installations create dialogs between human body and artificial structures which are open for personal interpretation. Transparency which characterizes his work, allows the visual connection with the environment which occupies the installation. The visual connection with the surroundings is an element used in my project too. In my research project “Exploring static electricity through textiles” the associations of the forms (Fig.1,3) to spider webs or tissues of nature was obvious. In the final design work, the arrangement of the forms follows the lines of the rectangular coordinate system which associates to the artificial representation system. However, the expression of the long piles of yarn, through which someone can walk and experience their
contact to the skin, creates associations to the experience of spider webs touching the skin. Due to the interest in the ever-changing view of what architecture is for me and for people around me – to what does an architectural environment refers to – the idea of introducing unconventional structures such as flexible, lightweight structures in creating space is tempting. Organizing structural elements in a designed system can be considered as an expanded definition of architecture but also links to the characteristics of living organisms. As Saraceno suggests:

Architecture doesn’t necessarily define people; it defines the structure and organization. We speak about the architecture of a mission, of a system, software, or the architecture of a habitat. (...) So it seems to me that architecture is understood more as a kind of coherent logical system that allows for the creation of environments and for the running of secure, productive and, one hopes, enjoyable activities. Therefore, “architecture” is to organize logic. (Saraceno, 2004)

“FIBER WAVE” is a landscape artwork, an environmental sculpture, made by the Japanese architect Makoto Sei Watanabe in 1995. It consists of many thin carbon fiber rods of 4.5 meters height. They are organized in rows which sway naturally with the wind like a field of grass and they stand still when the air is calm. On top of each rod there is a blue light which lights up during the night using the stored during the daytime sunlight. Neither mechanical nor electrical power is used.

There are more than one interesting points in this work related to the intentions of my work. The element of the living form is distinctive. The movement of the artwork is harmonic and organic almost in the way that trees move. The observer can detect the beauty of the living organism. The association between the organizations of designed structures with the notion of a living organism is already defined as element of my design program. Watanabe uses free energy sources such as the wind and the sunlight, with the intention to make visible something that is not by the means of movement. Watanabe points out:

One can feel the wind, but cannot see it. It is when we see the movement of something that we become aware of the wind. To see the wind we need something supple that sways. "FIBER WAVE" is just such a device for making the wind visible. (Watanabe, 1995).

Consequently the designed part treats the arrangement of the rods, the material, its flexibility and dimensions but not the “form” of motion. The rhythm and the patterns are articulated through the medium, the wind. However even if the form and movement are free, they are not random, they follow the regularities of nature. The wind here is a designer itself on a continuous design process. The idea behind his design, the intention to render visible something that it is not such as the wind, relates to my intention, of rendering static electricity visible, pretty much in the way “FIBER WAVE” does; through arrangements of vertical elements which use movement as device of expressing the invisible.

From an architectural point of view Watanabe states that: “The underlying goal of this project is a reformation of the activity we call design. (...) Architectural structures are built to resist the wind and stand firm. "FIBER WAVE" does not fight against the wind. It bends low when the wind is strong and waves gently when
the wind is weak, submitting naturally to the force of the wind.” (Watanabe, 1995). I consider this work as a materialized proposal towards a shift of architecture closer to the natural forms and at the same time divergent from the ordinary design practices. It is an attitude related to mine on how to relocate the target of architectural design, which is the creation of solid structures and visual aesthetics, to a richer sensory experience.

2.2. Use of static electricity as design material

A description of static electricity clarifies that:

“Static” electricity (more correctly called "net electric charge") appears whenever the normal quantities of positive and negative electricity in a substance are not perfectly equal. Remember that everything is made of atoms, and atoms in turn are made of positive and negative electric charges. In other words, your body is just a collection of positive and negative electrical particles. Normally the positives cancel out the negatives, and everything behaves electrically "neutral." (Electricity central, 2010)

Regarding this quote static electricity is a regenerative energy which can be created without any additional effort than the simple touch of two surfaces which exchange particles. Our skin is a surface and thus can generate static electricity when comes in contact to other surfaces that have not an equal electrical charge. These charges can be cancelled out instantly or in longer periods allowing different possibilities of use.

Zane Berzina and Jackson Tan within the project “E-static shadows” have explored the poetic potential of static electricity found in everyday life. “It studies the possible translations of electrostatic energy into other types of energy such as light, sound and motion using specially engineered intelligent textile systems as mediators and displays for these processes.” (Berzina, 2009). They have built a full-scale interactive installation which invited visitors to act as players in an interactive scenario and it was intended to “provoke a higher awareness of invisible static electricity and its hidden potential leading to a better understanding of interactions between people; people and objects/materials; people and space” (Berzina, 2009). As they mention:

Electrostatic energy is an essentially regenerative energy. Therefore, to some extent, this project also explores the potential of the electrostatic energy as a certain type of renewable energy that, under circumstances, can easily be generated virtually when and where desired. Eventually this interrogation could lead to interesting uses of this energy not only in an interactive art and design context but also in other fields such as architecture or in the development of new technologies and processes.” (Berzina, 2009)

This last statement relates to my point of view of how to re-approach the construction of our living environments and architectural spaces using as starting points artistic initiatives.
E-static shadows: “addresses the positive and playful potential of static
electricity” (Berzina, 2009). The associations between my project and “E-Static
shadows” can be found in the context of interactive design through the use of
static electricity and to the creating new perspectives for static electricity by
altering the negative picture around it.

2.3. Creating spatial qualities using the tufting technique

Anna Gravelle’s “Tufted wall” is part of the final design project in MA Textile
Design at the Bath School of Art. Gravelle used tufting technique which creates
an inviting environment with tactile properties. Regarding the material used it is
mentioned that: “The choice of wool was not only for technical reasons but also
because of its earthy and grounding qualities and for its sound proofing
capabilities.” (Gravelle, 2013). The fabric has been attached to an “S” shape wall
and finally elaborated in order to get a more interesting perspective by pulling
rows of threads out of the tufted surface. The aim of the architectural piece was
to create an attractive wall of soft threads. The final object has been presented
as being part of a reception area, giving her the possibility to explore what
happens when textiles are produced in large scale and installed in a public
space.

Her work partially illustrates the type of form and technique that are used for my
final project, since the term “tufted wall” is already defining my intentions
regarding the technique and the relation of the design to the space. The general
expression however is different as in my work the woven background fabric and
its transparency have a great level of importance, the length range of the tufted
piles is wider and the arrangement of the final installation lays in more than one
directions in relation to the ground level. The use of the tufting technique to
create space is the central associative element referring to my work.
3. Design process and Results

The diagram of figure 5 explains the structure of the design process followed to materialize the intentions of the “Electrostatic textile surfaces”.

The design process is divided in two stages. The subject of the first stage is the material exploration and the textile structure regarding the technique and methods. Since the main intention of the final design example was to achieve movement by combining materials that attract to the human skin, the design process started from the exploration of the features of the yarn materials. The weaving and tufting techniques followed regarding the use of the yarns and the bindings of the woven structures.

The results from that stage, together with the intentions for the final design example have been used on the second part of the design process which regards the appearance of the surfaces in order to create a method to design them. During this process the repeat of the woven-base layer, the pattern of the tufted layer and the human scale in relation to the final structures have been combined and defined the appearance of the final structures.

"Electrostatic Textile Surfaces" Aim: Investigate methods and materials using static electricity as design material in order to achieve movement on textile surfaces, at various scales related to the body.

Main Intention: To achieve "better" movement by combining materials that attract to human skin

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Fig.5. The structure of the design process and results
Design Process Part 1: Material & Textile Structure

3.1. Material exploration

The material exploration in this design programme was based on the idea of repel-attract system and the material library was filled in following existing material tables such as the triboelectric series (Fig. 7) but also by testing most of the materials existing at the laboratories of the Swedish School of Textiles. The fact that the positively charged materials attract to the negatively charged ones has been used as principal idea. The testing of the materials has been done with the help of two gloves (Fig.8) which I used to rub the yarns, one woollen and one of polyester fabric, contrasting materials regarding their electrostatic properties. The woollen glove helped to detect the negatively charged yarns because they attract to it and the polyester glove on the other hand helped to pick up the positively charged ones. With the help of the triboelectric series, the yarns have been classified into negatively and positively charged. The fact that dry-human-skin is one of the materials that has a great tendency in loosing electrons, so to become positively charged, facilitated the decision to focus on the materials that can get negatively charged and consequently attract to human skin. Ptfe (Teflon) membranes of different types occupied a big part of the material exploration (Fig.6). The Ptfe can be electrified by friction with dry skin even without the help of the woolen glove, but since the human skin is not always dry or clean thus not easy to control its state, the safest way to electrify the Ptfe is with the use of the glove.

Fig.6. Exploration of PTFE membrane.
Most Positive (+)

Air
Human Hands, Skin
Asbestos

+++ Rabbit Fur
Glass
Human Hair
Mica

---

Nylon
Wool

Choice of positive material
Positive material for assisting gloves

Most Negative (-)

---

Teflon (PTFE)
Silicone Rubber

Choice of negative material

Fig. 7. The triboelectric series, table based on SiliconFarEast, 2001
Due to the lack of Ptfe yarn a separated research on Ptfe was realized during the research course where the Ptfe membrane was manually spun in different ways (Fig.10) and in combination with other materials (Fig.9). Results from that research have been used during the experimentation on tufting.

Fig.8. Gloves made from different knitted fabrics of different materials used to rub yarns and surfaces during the investigation of static electricity.

Fig.9. Spinning the PTFE membrane. Combination with other materials.

Fig.10. Twisting the PTFE membrane. 100% PTFE alterations.
3.1.1. Results: Categorization of the yarns.

The negative-charge materials proved to be more suitable to take the exploration further with because they react to human skin by attraction and as a result movement is created. For the facilitation on the terminology in the text these materials can be named “active”* materials (Fig.11) and “inactive” the ones that do not perform movement. Since then the electrification tests were done with a piece of Ptfe thread. The same test was done on knitted samples of different monofilament types. Only one of the samples repel to Ptfe or other materials which gain the same charge (Fig.12).

![Fig.11. “Active” materials. They gain the same type of charge, negative in this case.](image)

1. Monofilament Polyamide “Colorific”  
2. Non-woven ribbon  
3. Polyester band transparent  
4. Brown Ptfe multifilament not spun  
5. White Ptfe narrow membrane

![Fig.12. Knitted samples of monofilaments made to try out their electrostatic behavior in relation to Ptfe](image)

The manually twisting process of the Ptfe membrane was time-consuming for the amount of material that is needed for the tufting and this was the first reason for not using in the final design example. The second reason was the thickness of the yarn which made the piles heavy and therefore difficult to move from vertical to horizontal position, thus not “active” in a sufficient level.

3.2. Technique and methods

After having a clear idea on materials and their electrostatic behaviour I started exploring the construction of the background fabric which would be used for the tufting.

The most common type of backing fabric used on the tufting frame is a heavy, opaque polyester woven fabric. The first tufting experiments have been done using this fabric and the way of how to create long piles by using the tufting gun in slow motion was found. Concerning the intensions for the structures as

4. The term “active” and “inactive” is used in this text to describe the electrostatic behavior of materials always in relation to movement and it is only used for facilitation reasons. Active materials are the ones that move towards the human skin when electrified, inactive the ones that do not react to the skin with movement.
described before, soon I realized that neither the expression (colour, density etc.)
or its electrostatic properties ("inactive" material) of this background fabric
were suitable for the project (Fig.13).

I needed to make a textile strong, suitable for
the tufting frame where it gets a lot of tensile
forces, and at the same time not too dense so
that the point of the tufting gun can pass
through it.

The weaving machine used to make the try-
outs has a 16-shafts transparent monofilament
warp. I found its transparency interesting
because, in relation to the weft material, the
textile can have a transitional appearance
from opaque to fully transparent. The warp of
the machine is polyethylene which repels to
the electrified yarns so it is not restricting their
movement. In order to try out the movement I
made a few tests with different bindings and
materials in weft and tried their electrostatic
behaviour with a piece of electrified Ptfe
thread. I cut a piece of fabric, I cut off the
same shape in the middle of a piece of paper and I glued the fabric on the
paper so it was surrounded by it. (Fig.14). The “active” fabrics are the ones which
repel the Ptfe threads (brown material), thus sample 3 and sample 4 (the Ptfe
sticks on the paper and not on the fabric’s surface). The ones chosen to try on
the tufting frame was those of sample 1 and sample 4, the first one because of its
semi-transparency and its strength in tension due to the binding used (plain
weave), the other one because of its transparency and “active” electrostatic
behavior.

In the beginning the fabric was tested mainly regarding its strength. The aesthetic
qualities such as the expression of the transparency in relation to the tufted areas
and the feeling that creates when touched were lower in the priority list at that time.

The tufted areas followed simple lines and no special drawing was made in order to get faster results. However different lengths of loops and piles have been tried in three types of yarns. Different materials have been tested in order to find the ones that correspond to the demands of movement. The first attempt to tuft on the semi-transparent fabric (sample 1) has been realized with encouraging results. Yet the whole idea needed improvements so that the tufting gun does not break the fabric and the piles stay firmly into the woven structure. Furthermore the tactile feeling was not satisfying as the fabric had a rough surface. The fabric has been stitched together with other fabrics so that it could be put up on the tufting frame which was bigger than the available dimensions of the fabric. The rectangular in the centre was the area for the try out (Fig.15). The tufted areas follow diagonal, vertical and curved lines in order to find out which directions correspond better to the construction and the technique. The tufting material is 100% transparent polyester band which gets a white colour because of the density of the tufted piles.

![Tufting on transparent polyester fabric, back side](image)

Wanting to highlight the expression of the movement, I covered optical fibers with Ptfe membrane in order to use light as an element which emphasizes the motion. The optical fibers manually “coated” with PTFE have the ability to move when static electricity builds up by friction. The whole structure is placed in a room so that one side of the fabric is better lit than the other. The light source is the existing lighting system in the room and it is transmitted from one side of the fabric (brighter) to the other (darker). Thus light is a supplement element which follows and describes the movement. The optical fibers have been inserted in the tufted area to examine the combination with the other materials and their movement (Fig.16).
The attachment of the optical fibers on the fabric was done by using the tufting loops in as functional element which keeps the optical fibers in place as shown in Figure 17. By pulling one of the edges the loops shorten until they create “stitches” securing the edges of the fibers. However the optical fibers were excluded from the final design example because light was an extra design variable which was not sufficiently explored and the existing variables were already enough.

The next step to take was the drawing of the areas which would be tufted. For this try-out, the transparent woven background fabric of sample 4 (Fig. 14) has been used which proved to be better for the tufting process since it was strong enough and yet not too dense. In the first attempts the drawing was not much elaborated (Fig. 18). The fabric was chosen to be transparent because it allows the viewer to move and see the electrified yarns from both front and rear side (Fig. 19). It is also possible to tuft on both sides (Fig. 20). Depending on the viewer’s side, the materials gain different visual expressions and shades (Fig. 21). On the v-shaped surfaces of the white tufted areas the light diffuses so to create bright areas contrasting to the darker lines which outline the shapes seen from the back side.
In order to describe the hand tufting process better figure 22 illustrates how the yarn is inserted in the tufting gun. The tufting gun has the possibility to have a knife which cuts the yarn creating piles or not, which means that it creates loops.
The length of the piles (cut-loops) is defined by the cylinder and point gear used in the tufting gun (Fig.23). The biggest cylinder in combination with the longest point gear creates the longest piles in even shape (U shape). A shorter point gear combined with a bigger cylinder creates uneven piles in length (J shape) (Fig.24). The length of the loops on the other hand is only defined by the cylinder and by the speed of the hand-tufting process (Fig.25).

3.2.1. The woven structure in relation to the tufting technique: Towards development of the method

On the next try, the process was more controlled and a sketch was made using as background image the representation of the woven fabric’s binding (Fig.26). The idea behind the sketch was to follow the lines of the background fabric and the filled/tufted areas to be gradually reduced functioning as a transitive element for the design variables.

The diamond shapes of the graphical pattern follow the direction of the lines of the background. On the bottom they are close to each other so to cover most of the area and gradually in higher points, they become smaller or parts are cut out in order to create a more sparse arrangement. The result is not an actual design sample, it was made to try out and develop a method to design with the design variables. Movement is the most important variable. Since the tufting technique was new for me I had to experiment in different levels such as the use of the tufting machine, the variables connected to the tufting technique and the variables of the drawing.
The empty black areas are the areas which would have been tufted and the grey the empty ones. Through this arrangement of shapes I intended to examine and evaluate the level of precision for creating clear forms by tufting, and the behaviour of the active materials in relation to the empty or tufted with inactive yarns, areas.

For a better precision of the distances between the shapes, in order to get the right scale, I transferred this image in Autocad (Fig.27)
Having noticed that a single tufted line spreads on both sides a few centimetres, always in relation to the length of the piles or loops (a single line of the longest piles occupies an area of 6 cm in width), I created the lines which I should follow with the tufting gun in order to get as closer as possible to the drawing. The black lines are the guidelines for the long piles of 4.5 cm, and the red lines are for shorter piles of 1-2 cm).

The drawing was then projected on the fabric which has been put up on the tufting frame (Fig. 28). Projection proved to be useful for saving time in transferring the pattern on the fabric, furthermore it does not leave any stains and it also gives a special lighting on the surface which creates interesting colour variations on the transparent, shiny yarns. It was possible due to the transparency of the fabric, to project the drawing on one side and tuft on the other.

Fig. 27. The drawing of Fig. 26 in better precision.

Fig. 28. The drawing projected on the transparent fabric.
In this try out materials (Fig.30) like cotton, wool, linen and other yarns have been tested which do not belong to the category of the “active” yarns. These yarns cannot move with static electricity. However, when they are used as a first layer where the “active” yarns are tufted over in longer piles, then they don’t restrict the movement (Fig.29). The words active and inactive describe only properties of in terms of movement.

The reason why I used the inactive materials was to create areas which will be attractive to the touch but mainly to test their relation to the active ones regarding the movement. The design concept was to create a surface of active, from the perspective of movement areas, not active tactile areas and areas where these two properties will be blended. The brown material which stands out in the middle of figure 32 is multifilament, not spun Ptfe which was used only to try its ability in movement and not its visual result. Later I got hold of the same material in white colour which matches better with rest materials. It is very easy to get electrified and due to the very fine filaments it moves efficiently.

The final result of Figure 32 has been analyzed to understand the different areas better (Fig.33). The variables for the tufting which were chosen to be tested are divided in two layers. The first layer is divided in two main categories and it is strongly related to the technique. The first category is the material of the yarns and the second the length of the piles/loops. The second layer, which consists of design variables such the tactile and visual expression and the movement, (Fig.31) derive from the design intentions of invisible, transparent, transitive and
contrasting. Things got more complicated when the yarns were combined together making the evaluation too difficult to be precise.

<table>
<thead>
<tr>
<th>Variables</th>
<th>1st Layer</th>
<th>2nd Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Tactile expression</td>
<td>Visual expression</td>
</tr>
<tr>
<td>Length</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 31. Table with the design variables used for the tufting

On the left side of the drawing, there are four rectangular areas where I wanted to try the same shapes with different materials (Fig. 32). The analysis of these four areas has been done regarding the variables of the table in figure 31. The analysis is presented on pages 30-32 (Fig. 34).

Even if the initial plan was to use only these four areas as exploration areas, in the end the whole surface was used as an exploration board for the selected variables since the materials I wanted to try were too many and the range of the length of the piles too big to be able to evaluate them in such small regions. In some cases some of the variables were excluded from the later evaluation such as in case of the brown Ptfe material, the visual and tactile expression since it was used only to try its movement.

Since movement is the main variable the analysis of this sample focuses on it. The materials of the background fabric belong to the category of the active ones. There are cases such as in Area 1/Zone 3 where the movement of the active piles is restricted because of their short length. In other cases (Area 1/Zone 3) there is no movement at all because of the use of only inactive materials. The movement is also restricted in Area 2/Zones 1&2 and Area3/Zone 2 because of the blend of active and inactive materials and the inefficient height of the loops. In other cases where the active materials are in highest proportions as in Area 3/Zone 1 no movement is performing due to the heaviness of the material used in combination to its length. The long white Ptfe threads, manually twisted, proved to be inappropriate for this technique regarding the aim of their use which was the movement. In Area 4/Zone 2&3 the inactive dense area beneath the active long piles is not restricting their movement. Figure 29 is illustrating this fact.
Fig. 3.2. Front side of the tufted textile
Fig. 3. Map of the materials and length of piles/loops of the different tufted areas of the sample.
Fig. 34. Analysis of the four areas

**Area 1**

**Variables Zone 1**

<table>
<thead>
<tr>
<th>Variables Zone 1</th>
<th>Tactile expression</th>
<th>Visual expression</th>
<th>Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wool / pes ribbon Medium loops/ 8cm piles</td>
<td>Scratchy</td>
<td>Dull, clumsy</td>
<td>Restricted movement of the piles</td>
</tr>
</tbody>
</table>

**Variables Zone 2**

| Wool / pes ribbon Medium loops | Scratchy | Spotted dense area | Inactive |

**Variables Zone 3**

| Wool / linen Big loops | Rough | Dark dense area | Inactive |

**Area 2**

**Variables Zone 1**

| Wool / pes ribbon Medium loops/ 8cm piles | Shiny yarn/ linen/ plast. Medium loops |

**Variables Zone 2**

| Wool / pes ribbon Medium loops | Shiny yarn/ wool/ plast. Medium loops |

**Variables Zone 3**

<p>| Wool / linen Big loops | Shiny yarn/ linen/ plast. Medium loops |</p>
<table>
<thead>
<tr>
<th>Variables Zone 1</th>
<th>Tactile expression</th>
<th>Visual expression</th>
<th>Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linen/ shiny yarn/ Pes ribbon</td>
<td>Slick</td>
<td>Glittery, spotted</td>
<td>Inactive, attracts active fibers</td>
</tr>
<tr>
<td>Medium loops</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables Zone 2</th>
<th>Tactile expression</th>
<th>Visual expression</th>
<th>Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wool / shiny yarn/ Pes ribbon</td>
<td>Slick</td>
<td>Dense, glittery, spotted</td>
<td>Inactive, attracts active fibers</td>
</tr>
<tr>
<td>Medium loops</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables Zone 3</th>
<th>Tactile expression</th>
<th>Visual expression</th>
<th>Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linen/ wool/ shiny yarn/ Pes ribbon</td>
<td>Rough</td>
<td>Dense, spotted area</td>
<td>Active piles on inactive base</td>
</tr>
<tr>
<td>Medium loops with 8cm piles</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Area 3

#### Zone 1

- Shinny yarn/ Pes ribbon/filling yarn/white Teflon spun
- Medium loops/long piles

**Tactile expression:** Soft, slick

**Visual expression:** Dense, bright, glittery

**Movement:** The piles are too heavy to move

#### Zone 2

- Shinny yarn/ Pes ribbon/filling yarn
- Medium loops

**Tactile expression:** Soft, slick

**Visual expression:** Bright, glittery, even

**Movement:** Inactive
<table>
<thead>
<tr>
<th>Variables Zone 1</th>
<th>Tactile expression</th>
<th>Visual expression</th>
<th>Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shinny yarn/ linen/ Pes ribbon/filling yarn</td>
<td>Soft</td>
<td>Spotted</td>
<td>Inactive</td>
</tr>
<tr>
<td>Medium loops</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Variables Zone 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pes ribbon</td>
<td>Slick, scratchy</td>
<td>Bright, Semi-transparent layer on top of opaque base</td>
<td>Active</td>
</tr>
<tr>
<td>Long piles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Variables Zone 3</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shinny yarn/ linen/ Pes ribbon/filling yarn</td>
<td>Slick, soft</td>
<td>Dense, spotted area</td>
<td>Inactive, does not restrict the movement of other fibers</td>
</tr>
<tr>
<td>Big loops</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2.2. Analysis of the experiments

Regarding the movement and material

From the observations on the tufted surfaces I tried to systematize the movement of materials and collect the elements which I found. The movement always depends on the stiffness and the weight of the material. Figure 35 shows schematically the movement of a tufted polyester band pile on a repelling and an attracting surface respectively, seen from the side (related figure 29). The sketch with the circle shows the possibility of a tufted pile to move around its axis, seen from front. The longer the pile is, the bigger area its covers. It is important to understand the movement of each material in order to decide its position on the surface.

![Figure 35](image)

**Fig.35. Movement of piles. Repelling / attracting, resisting or not the gravity.**

From that first observation regarding the relation between the length of the piles and movement, or more precisely the ability to resist gravity, I assumed that the maximum length of the active tufted piles on a vertical to the ground surface cannot exceed 30 cm for being able to move. For longer piles, horizontal arrangement would be more effective, in the way that the structures of Figure 1 (p.4) are hanging and moving and as illustrated on sketches on Figure 36. This arrangement can give another experience, inviting the person to walk through them, get surrounded by the piles which will attract to the skin and the clothes.

![Figure 36](image)

**Fig.36. Long active piles tufted on horizontal surface.**
The second interesting element is the combination of active and inactive materials depending their relative position, size and length which create contrasting effects and temporary patterns when the active materials are electrified. The active long piles when combined with piles of inactive materials they attract to each other and they create link points between them. (Fig.37).

![Horizontal arrangement of the backing fabric.](image)

Fig.37. Relation between active (red) and inactive (blue) long piles.

Each of the active yarns has its own way of movement, level of charge, ease of movement and its own time of losing the charge. For example the non-spun Ptfe, gets electrified easily and loses its charge immediately when a sharp edge approaches, as for example a finger, but follows the movement of a hand much easier than the other yarns. The polyester band needs to be rubbed more times to get electrified but loses the charge slower. Consequently temporal patterns of different duration can be achieved by the use of more materials in relation to others. However none of them two is going to be used for the final sample since they do not meet the visual, for the Ptfe, and tactile, for the polyester, desired expressions.

Regarding the visual and tactile expression in relation to pattern, time and material

The gradation of the tufted area from more opaque and denser surfaces to more transparent and light regions, allows the exploration of many different properties regarding the tactility, and temporal patterns created on the tufted surface. Denser tufted surfaces give a more tactile feeling. The transparent – not tufted areas can allow the visual contact on both sides and define the sites for interaction.

The tactile expression of the polyester band is rough and scratchy, the same stands for the woollen yarn. In addition the polyester band separates in too many thin fibers, fibrillates, in an uneven way due to the air pressure through the tufting gun which creates a clumsy expression both visual and tactile. The filling and shiny yarns have a softer, smoother texture. These are the ones to continue with (Fig.38).

![Shiny and filling yarn](image)

Fig. 38. Shiny and filling yarn

Before the activation, all the long fibers have a vertical direction. This verticality stars to disappear when the active fibers are electrified. The shorter active piles when electrified, either change from vertical to horizontal position, or they stick on their base if they are on an inactive one. The longer ones that resist the gravity attract to regions of inactive materials which are in close proximity or if there are no such areas close by, they hover until they lose their electrification. If someone
places his/her hand behind this area, they stick on the background. Instant patterns are created until the hand moves away. Then they return to the floating state, which if seen from the side, creates curved shapes in relation to the background, as if there is something invisible underneath supporting them in this position. After a few hours or minutes, depending on the environmental conditions (humidity, temperature) they lose their charge and return the first state.

Pattern and colour

Regarding the shapes of the drawing, they follow the lines of the background fabric intending to give coherence to the transition from the woven to the tufting technique. Yet, the woven fabric of sample 1, seen from a distance has a linear appearance than zik-zak because of the small size of the repeat of the pattern (Fig.39).

As for the tufting materials, the colour distracts the focus on the movement so the use of yarns closer to grey or white colours seems to be more appropriate. Reducing the design variables empowers the ones more important which in this case is the movement.

Design method: Tufting

Since there is no specific design program or method for patterning on tufting, the need of creating a design method for tufting was essential. The use of digital programs such as Adobe Photoshop which allows image layering, and Autocad which gives precision in dimensions and scale, was satisfying.
3.2.3. Results: A method to design the surface

Since the tufting technique was intended to be used in a different context than in the ones usually met (carpet or tapestry making), a new method for designing the surface had to be invented which would be appropriate for the purpose of this design programme (use of static electricity as a medium to achieve movement on textile surfaces). The scale of the final structure intended to be able to involve and create dialogs with different parts of the body starting from relations at the scale of a finger, up to relations at the scale of a whole body. The body-scale implied the adjustment of the tufting technique to it and has led to the idea of the large variation of the length of the piles.

As a continuation, I decided to weave a new background material using the same warp (polyethylene which belongs to the “active” materials) which itself would have threads that can be electrified and move, thus long floatings in order to interrelate the expression of the two techniques on the surface (Fig.40), which was not satisfying on the woven sample of figure 39. The binding consists of a layer with a diagonal warp dominated pattern, and on top of it long warp floatings which go over a surface of 20 cm. The diagonal binding is suitable for the tufting technique since the tufting gun does not break the threads of the fabric. The long floatings can be used in two ways, either as they are, or cut, as supplementary active threads on the tufted surface. By having these long floatings on the woven fabric a transition between the two techniques is possible to be made regarding their visual expression and movement; long piles coming from the hand-tufting and long floatings from the weaving.

Fig.40. Fabric made of transparent monofilament warp Part of the binding pattern

In order to give to the surface spatial characteristics able to “incorporate” the human body, the final structure has been decided to consist of a horizontal and a vertical surface located so to create a corner. This setting creates a space both open and surrounding at the same time in relation to the body. The two surfaces are integrated in the same drawing for the tufting part and the shift between them is indicated by a dashed line. The general principals to follow for the last tufting design are shown diagrammatically on figure 41. The images of this figure are used as diagrams related to the variables and they are not
translated as graphical elements. The surface is divided by the dashed folding line which shows the shift from the vertical to the horizontal surface in relation to the ground. Having as guideline the intensions for the aesthetical qualities (invisible / transparent / transitive / contrasting), the darker areas are the ones where the described parameter is more evident and gradually fades to the direction of the arrow. These parameters are connected to the design variables which are the length of the piles (length), the visual expression (opacity to transparency) and the movement (relations between the positions of the active materials, their length and the size of the shapes.)

By combining all these elements in one organization emerges a dialog between the different variables, allowing a variety of temporal patterns appear on the electrostatic textile surfaces and relations with the body in different scales.
Design Variables

Active materials

Starting from active (right upper corner) to inactive (left lower corner). Follows the same direction as the length.

Length

Starting from long (right upper corner) to short (left lower corner). Follows the same direction as the active materials.

Opacity to Transparency

Starting from opaque (left lower corner) to transparent (right upper corner). Follows the same direction as the size of shapes.

Size of shapes

Starting from big tufted lines (left lower corner) to small tufted lines (right upper corner). Follows the same direction as the opacity.

Fig. 41. Diagrams of the gradient of each parameter for the final surfaces.
Intentions for the Final Structures: An illustration of the invisible

The intention of the structures is to render static electricity visible through movement and create an environment, open for interpretation, suggesting dialogs between parts of the body in various scales.

The sketch of Figure 42 was made to visualize the final structure and illustrate how it behaves including the human-interaction scenario. The position of people in relation to the electrified structures will affect the movement of the piles. The electrification is done by friction with bare, dry skin or with the help of fabrics (clothes, gloves). In the final structure though, the two textile surfaces, one vertical and one horizontal, are detached one from the other, as two arrangements which follow the same design method but create however different spatial relations and relations to the body.

The vertical surface is accessible from both front and rear side. The structure is placed on a frame so that it is stretched, which is important for the friction areas. The organisation of the structures follows the rectangular coordinate system (x,y,z). The surfaces can be met in two states/modes: the active, switch on mode and the inactive-switch off mode. During the inactive, switch off mode the tufted areas, on the vertical surface follow horizontal lines, the long fibers on the horizontal surface drape straight towards the floor. In contrast to this inactive state, the organisation changes when someone interacts with the surfaces by walking through the fibers or by electrifying them by friction. They instantly respond with movement. The straight lines expand and move to different than the (x,y,z) directions. The sharp white lines of the vertical surface become blurry and the flat vertical surface becomes uneven by the fibers that stick out. This is when the idea of “living” is expressed.

The woven textile of the vertical surface is opaque on the bottom, less opaque in the middle and transparent in higher levels. Its level of transparency lets people watch what is happening on the other side such as others touching the vertical surface, moving the piles from distance or simply watch the fibers swinging. One can move the electrified fibers even from the back side letting others watch their movement from the front. Walking under the horizontal surface with the long fibers, creates a fused feeling, since it is unusual to walk through fibers which stick on the skin and all over the body but still being soft in the touch and blended with light iridescent colour tones. Looking upwards under this area, the transparency of the woven fabric will render the rest environment visible, but seen through linear arrangements of fibers. Lights and shades of the surroundings are distorting when focusing on the smooth movement of the shiny transparent floats. Some of the fibers on the vertical surface stick on the tufted lines or on the inactive areas of the woven fabric. Others simply hang straight or sway slightly trying to balance the forces. In this way, every time that the surface is electrified there is a new pattern created which, after some time disappears, when the fibers return to their neutral charge. Everything returns to the inactive, switch off state until the next touch.
Fig. 4.2. Sketch of the structure in relation to space and interaction scenarios
Design process part 2. Surface appearance

3.3. Surface appearance: Materialization of the method.

The first attempt to materialize the method was focused on the appearance of the surface. The design variables for the tufting were the material and the length of the piles. In this sample only tufted piles have been used and not loops because their visual expression creates a logical correlation between the variety of their length, starting from short piles of 1.5 cm up to 1.2 meters long. Moreover the piles are moving in a more free way than the loops whose movement is restricted because of their closed shape.

The materials used were active and inactive both for the weaving (for the weft) and the tufting. The pattern of the woven background textile was the one of figure 40.

The new tufting design was made with linear arrangements. This decision was taken in order to remove most of the graphical information and visual associations which are not related to my project. Furthermore, through the arrangement of lines in an equal spacing system emerge spatial properties, by creating perspective. The linear design of figure 44 was the base for this sample. As basic unit, has been used the height of the repeat of the woven fabric. This unit has been divided into 4 defining the guides of the horizontal lines. However the length of this lines was still random. The piles on the lower levels are shorter however the fabric was tufted upside down for technical reasons because it was easier to tuft the long piles (the ones longer than 50cm) starting from bottom.

The tufting was made in 3 steps. Fist the drawing was projected and the all the lines where tufted with the smaller size of inactive piles using two yarns of each of the materials of figure 43. The smaller size of piles is labelled with number 1 on the drawing and stands for the smallest of the 8 cylinders of the tufting gun (Fig.45). Then with the same yarns, the lines were tufted one more time on top of the fists layer, creating gradually an increscent of the length of the piles using all the cylinders from 2 to 8. In the end, the active piles were tufted using at the same time 12 cones of Ptfel and one of colour-effect polyester. The pictures (Fig.46, Fig. 47, Fig.48)are during the tufting process and the textile is on the tufting frame, inverted 180 degrees in relation to the drawing. The lines in the bottom are longer and on the top smaller and with bigger empty spaces between them.
The height of this sample has not the size of the full-scale structure because the materials, both the woven textile and the Ptfe white yarn, were not enough. Thus, it was a first-cut to materialize the method developed and a compact version of the final design example. The textile surface was tested in horizontal position, parallel to the ground (Fig.49, 50).

**Fig.44.** The linear drawing for tufting. Direction of the increase of the length of the piles and the length of the inactive piles numbered in relation to the tufting gun’s cylinders.

**Fig.45.** Numbering the cylinders of the tufting gun from 1 to 8

Height of the repeat of the woven fabric.
Fig. 46. Front side during the second stage

Back side during the second stage
Fig. 47. Side view during the second stage

Fig. 48. Front view during the third stage

Fig. 49. The textile in horizontal arrangement
Fig. 50. The textile in horizontal arrangement. Electrified fibers.
3.3.1. Decisions for the final design example: Arrangement of the Surfaces in relation to space

The final design sample is going to be exhibited at three different occasions as part of bigger exhibition events. It consists of one vertical and one horizontal surface in dimensions able to create spatial relations with the body scale. The vertical textile surface is stretched on a metallic frame (Fig. 51). The width of the surface is 2,3 meters and has the double size of the previous sample. The height is 2,3 meters too. The horizontal surface is 2,3 meters in width and expands approximately 2 meters lengthwise.

The dimensions of the sketch for the tufting and for the whole structure are defined by the repeat of the pattern of the woven fabric, as illustrated in figures 52, 54 and 55. The latest version of the woven material (Fig. 53) has even longer floatings (35 cm) and the total repeat is 37 cm in height. The first repeat on the bottom is more opaque because of the proportions of the dark grey yarn in weft in relation to the transparent monofilament (3/1). The second section consists of two repeats with weft proportions of 1 grey to 3 transparent yarns (1/3), thus it is more transparent. All the other repeats are woven only with the transparent yarn in the weft so it has the maximum transparency.

Fig. 51. Draft for the vertical stretching frame.

Fig. 52. Dimensions of the woven fabric. Vertical and horizontal arrangement of the surfaces.

Fig. 53. The woven textile and its repeats. It will be divided in two to form the vertical and horizontal surfaces.
The sketch for both the surfaces was made by a sequence of filled and empty lines, one after the other, starting from the longest filled line, continuing with the shortest empty one and so on (Fig. 56). The filled lines represent the areas that will be tufted (coloured lines of figure 54 and 55) and the empty ones are shown as dashed lines. The empty areas in the final arrangement emerged to follow a diagonal path which grows in width on the higher regions of the surfaces (Fig. 57).

The rest tufting process was based on the same method as in the sample presented on the chapter “Materialization of the method”. The length of the piles as well as and the other design variables, increase or decrease to the direction of the arrows, as shown in the diagrams of figure 41.
3.3.2. Results: Final design example

The two surfaces are placed in close distance in order to be able to affect each other with the movement of the fibers. Because of the transparency and the very fine yarns the details of the movement was difficult to be documented. However some moments have been captured. Figures 58 and 59 show the two main states of the horizontal structure (switch onswitch off). Figure 60 show how the electrified fibers react in relation to the position of the body, accumulating around it. The gradation of the length of the fibers (Fig.61) let different parts of the body to come in contact to them. Moreover associations are created between the fibers which remain linked until the next activation (Fig. 62). Links are also created between the inactive fibers of the vertical surface (Fig. 63) or other objects and surfaces of the room (Fig. 64). The horizontal surface relates more to the scale of the entire body and the vertical surface relates to the scale of the hands and fingers due to the shorter length of the fibers (Fig. 65). The fibers are able to attract to the skin even from the back side of the surface.
Fig. 58. Arrangement of the surfaces inside the space of a gallery. Inactive, switch off state.

Fig. 59. The surfaces electrified. Active, switch on state.

Fig. 60. Alterations of the structure. Reaction of the fibers in relation to body.

Fig. 61. Side view of the structures.

Fig. 62. Associations created between the fibers.
Fig. 63. Links with the vertical surface.

Fig. 64. Attraction to other surfaces.

Fig. 65. Active fibers attracting to the skin, from front or back side of the vertical surface.
4. Discussion

“Electrostatic textile surfaces” is a suggestion of how to create a dialog in space between human body and textiles using static electricity as design material. The results regard 1) a method to design the electrostatic textile surfaces and 2) a spatial illustration showing the application of the method. The work is focused on the technique of hand-tufting and weaving through an ongoing exploration of materials directed by the objectives of movement created by static electricity. The research part has started from the fiber level in order to define which categories of yarn materials are suitable to be combined together to create a stronger movement in relation to the human skin. The relation to human body scale has affected the appearance of the structures and the development of the possibilities of the tufting technique. Therefore, the technique was adapted to the scale, starting from smaller body parts as a finger up to the entire body scale. Through the experimentation with the variables of the tufting technique (material and length of piles), ways have been suggested on how to use yarns which are not commonly met in tufting applications, such as plastic membranes or very fine fibers, on how to achieve excess length of piles through a process which is not controlled by the machine but controlled manually.

Since the surfaces are designed to create dialogs with people in a physical level, an important input for the technique is the determination of the use of the background fabric as a component which is not hidden but accessible from the viewer. The way of construction becomes transparent by exhibiting and involving in the function of the surface its rear side, which normally is concealed in other uses of tufting. The background is not anymore a blank base, invisible or insignificant for the expression and the function of the textile but on the contrary is a component of a single unity.

Regarding the patterning and the methods used for designing the tufting areas, I tried to develop my own ways to work since there are no specific tools for that. The projection of the drawings is a helpful tool for big and complicated patterns. The analysis of the experiments on tufting led to the decisions for the final woven structure in relation to the tufting technique. The shapes for the tufting used in the chapter “Towards development of the method” had too much graphical information and the background fabric was less visible and present in terms of movement. The decision for the final woven textile was the result of this observation and of the intention to create a visual and functional correlation between the two techniques. In the final design example both the tufting and weaving patterns have a linear visual expression with dominant vertical and horizontal lines and “active” threads that stick out from the flat surface.

By exhibiting the final design example in two different locations I noticed that the environmental conditions, especially the humidity of the space is essential for the expression of the movement. Answering to the question which design variables can be controlled by the designer when static electricity is used as design
material, the choice of the material and its physical properties (length, composition) can be controlled but not the environmental conditions which affect the phenomenon and thus the movement, since the movement depends on the presence of static electricity. Even if the movement is in this work the most important design variable, yet is not completely controlled, due to the nature of the medium that produces it. Movement therefore is itself a matrix of expressions, different in every time or space, and cannot be predefined. The expression of the movement is then a result and not an intention. The associations of this work to “Fiber wave” are therefore obvious: the pattern of the movement is not completely controlled by the designer and is defined every time by the conditions of the environment (presence of people, environmental conditions, interaction or not etc).

The surfaces are functioning as structures open for objective interpretations, depending on the dialog that the person which relates to them creates. During the exhibitions at the gallery Ålgården in Borås and at the Swedish School of Textiles, I had the chance to observe the reaction of people and the dialogs that they create with the “Electrostatic textile surfaces”. The structures were observed by close distance and the exterior areas were the ones mostly touched and electrified. Only a few people attempted to walk through the arrangement of the long fibers. The children were more open for placing their entire body among the electrified threads and older people where more curious about the material used and the medium which produces the effect of movement. Most of the visitors extended their arms or fingers and tried to move the fibers without touching them in different directions and some of them extended their heads to feel the attraction of the fibers with their face. Someone said that these surfaces have a playful character. Reflecting on this opinion and connecting it to the background references and the “E-shadow” installation, the intention to alter the negative experience of static electricity by suggesting a positive and playful potential was realized for some of the visitors which acted as players in the same way as Berzina and Jackson intended.

Reflecting on my work in relation to Saraceno’s installations I detect that the linear arrangements create aesthetics more linked to the artificial world than the natural but yet the feeling of walking through webs can be provoked when walking under the horizontal surface. The scale of the installation is significantly smaller than the installations of Saraceno or Watanabe but still allow the involvement of the whole body and of more people with it. As a further development, it would be intriguing to magnify the horizontal surface up to the scale of a whole room where new relations with the body and between the visitors would be created. If the fibers covered the area of an entire room and even touched the ground, walking through them is a necessary condition to relate to the structure. The idea of exposing the body into the experience of the space is more tangible, and the designed object has not anymore the usual relation of a sculpture in a gallery. Additionally, the structure would interact even more with the elements of the room (walls, objects ect.).
5. Reference list


Figure 1-6. Katsarou, S. 2013. Personal files, Personal collection

Figure 7. The Triboelectric Series, 2001. [image online] Available at: http://www.siliconfareast.com/tribo_series.htm [Accessed 20 November 2013]

Figure 8-65. Katsarou, S. 2014. Photographs, Personal files, Personal collection