# Wall Curtain. On the Idea of the Soft within the Digital and Fabrication Realms

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Fig. 1. Wall Curtain. Photograph by Anders Ingvartsen.

Architectural space is filled with soft proximities which build a different space and invites us to visit and experience its inner cavities, providing depth to accommodate multiple bodies, which imprint their traces and co-shape its performance.

Additional Key Words and Phrases: digital sewing, soft enclosure, in-between

## 1 INTRODUCTION

The project questions the architectural space, arguing that it is not an empty void but rather the environment full of envelopes around the body, creating gradients from soft to hard, individual to social, private to shared. It describes the interspaces and searches for processes and transformations of an interior textile layer or cutting patterns tailored to a body into architectural space that measures and transcribes other types of dimensions.

The new envelope is not a dress anymore, although it dresses a body, and it is not yet architectural in the classical sense, although it gathers. It is seen as an autonomous space, a space of its own. It shifts the attention to the problems of inside and outside, of surface and cover, of the curtain, wall and partition. It fills the room, dresses it, while the human occupation and interaction are still allowed. The project introduces a world where there is no difference between putting on clothes and entering a space. What would it be like to live in a soft space?

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Wall Curtain creates a spatial curtain to be inhabited by the body. Like a cocoon, it invites inhabitation of a threshold space between inside and outside, where light seeps through its translucent layers. Like a room in a room, Wall Curtain creates soft proximities, dressing the space as an internal membrane and creating a new programme within the existing architectural frame. Wall curtain examines the concept of a soft architecture.

The soft spaces are investigated in the current context of computational design and simulation-based design. These questions are explored through textile probes and prototypes in the range from intuitive and formal sketches to highly complex models and full-scale installations. The project uses virtual simulation of the textile properties not simply to analyze or evaluate their final behaviour, but to include simulation as an equal tool at the very beginning of the design process.

The project operates within the concept of the soft in both physical and digital worlds, that meet each other on different semantic, analytical or technological levels. Computation is here seen as a material address, transferring techniques from physical crafts to digital design environments through developing concepts of digital sewing and digital stitch. Here, the geometric description of the mesh, as a collection of polygons and vertices, acts as an interface between the physical and the digital. Thus, Wall Curtain examines how the digital modelling of a mesh surface can be translated into a textile membrane. By the digital stitching its shape is formed, then disassembled to 2D unfolded representation in the form of sewing patterns, and afterward connected together to the structure of an aggregate, where every piece is a unique element. The crucial part of the research contains prototype making in textile materials, where the deviation between the computational prediction and the fabricated model provides valuable feedback and a new layer of performance.

Further, the project poses the question: how can the textile logic influence the architectural practice and what are the consequences for integrating double curved surfaces, pliability, highly personalized and defined spaces, specific tectonic principles or sensual and haptic aspects [1]. These topics are, at the same time, linked to the means of notations. Architecture uses plans and sections on an orthogonal basis, while the fashion design industry employs garment patterns, which traditionally emerge from the flat surface and represent unfolded envelopes of the body, subsequently shaped by darts and seams. Thus, the research shows an opportunity to rethink or hybridize both the perspectives (unfolding and orthogonal cutting) and to establish a new complex system, flexible enough to react to different requirements and ideas (moveable, curved, ephemeral, sensual).

Wall Curtain examines a new type of a soft space or enclosure, which stands outside the standard design or architectural practices. This particular project focuses on the relationship between a garment and a room, both of which form an envelope around the body, in order to explore the wrapping in between them. In consequence, it defines a new category of proxemics. Proxemics, defined by anthropologist E. Hall, is the study of personal space and interpersonal non-verbal communication, measuring the distance between people. The new proxemics is not dependent on the amount of space between individuals but on the space between a body (human or architectural) and the layers around.

The Wall Curtain project demonstrates how a constant correlation between design, simulation and fabrication leads to nontrivial spatial solutions and a rethinking of our material practices. At present, architects are not just creators of buildings, but also design materials, tools and processes, an effort closely related to interdisciplinary overlappings and revealing their hidden interdependencies. In consequence, the construction and investigation of different collaborative concepts broaden the traditional limits of our discipline.

## 2 WHEN TEXTILE MEETS ARCHITECTURE

We are surrounded by textile layers every day. We cover our bodies, we use blankets and duvets when we sleep, tablecloths while eating, carpets while walking, tents and umbrellas to protect ourselves against the external conditions. Similarly to how we cannot escape architecture, it is impossible to avoid textile surfaces.

## 2.1 Historical links between architecture and textiles

*2.1.1 Textile in interiors.* Textile layers have had a long history in our interiors. In ancient times, curtains were used to divide sacral spaces from the secular: Byzantine temples used to be decorated with embroidered textiles placed under icons, especially during special occasions. During the medieval times in Europe, new arrangements of the textile layer appeared in forms of tapestries on walls. During the summer period, a silk layer provided cooling, while woolen tapestries protected against the cold walls during the winter. Hence, they were used as a heat insulation, but they also absorbed smoke and odors and were places for representation and narration of stories. Bed curtains were also popular in medieval times, creating the textile spaces enclosing the bed from all sides like a room inside a room to protect its inhabitant from cold, dust, insects or draft. Curtains became more refined in the Baroque era, when luxurious fabrics as silk, brocade or damask were widely used. In the 19th century palaces, the textile layers created an exotic atmosphere towards the theatrical curtaining of ceilings and corners. This fashion vanished at the end of the century due to hygienic restrictions and introduction of heating, when the warm textile walls were no longer needed [2].

*2.1.2 Textile as the origin of architecture.* The significance of the interior textile layer disappeared when people started to inhabit more stable and firm dwellings, much as the transformation of nomads to settlers can indicate a transition from the dominance of textiles to the importance of architecture [3]. Still, according to certain remarkable architects, the origin of architecture lies precisely in textiles, in form of a blanket on the lying body as kind of a second skin, as Adolf Loos claimed [4], or a mat, woven or leather, as the primary layer superior to its construction, demonstrating Gottfried Semper's dressing principle [5]. Furthermore, Semper viewed the genesis of architecture itself as grounded in textile techniques. The methods of weaving and knotting do not have to result in a woven fabric, but by using different materials, a wall or a cladding can emerge. Since the technique itself is abstract, it is thus able to pass through several materials and scales.

So in the beginning there was a weaving or a carpet, which became a protowall providing heat, protection and defining space. Here, the wall dresses for the first time.

In Semper's theory, the cultural importance of the textile wall exceeds the significance of the structural, as the construction was used merely to support it and stabilise its position. Here the textile art and architecture meet and split at the same time to evolve into more complex disciplines. Moreover, Semper defined the foundations of protoarchitecture by describing craft operations through the logic of physical activities.

Adolf Loos did not recognize clothing as fashion. Until World War II, architects sturdily refused confrontations with the volatility of fashion, which they associated with ornament and flimsiness. Especially ladies' fashion was considered dysfunctional and unnecessary and was only an antithesis to rationality and simplicity of the men's fashion.

Textile covers our nudity, protects us against the weather and unauthorised looks and still acts as a mask or decoration. It becomes ambiguous, it shows and reveals at the same time.

*2.1.3 Curtain wall.* At this point, we can see analogy with the curtain wall. Since the rise of Modernism, the outer covering of a building is not structural any more: not needing to bear any structural load, it can use lightweight materials and thus open its space to its surroundings. The inner organization, as a result of material development, is stable enough, being mainly steel.

The title of the project, "Wall Curtain", plays with the term and refers to a new role it can assume. If the curtain wall points out the thickness of the outer layer while comparing it to a thin, almost invisible curtain which can be removed without any significant influence, the Wall Curtain wants to win back its relevance and value in an interior space. It is able to act as a wall, divide a space and still protect from the sunlight or unauthorized views, and even control it. The Wall Curtain will not remain unnoticed or subordinate to architecture. It will not follow its curves to serve and obey, but instead to live its own independent life, though based on the forces surrounding it. With its own rules, it builds another space and invites us to visit and experience its inner organism, providing depth and cavities to accommodate different bodies, which imprint their traces and thereby co-shape its performance.

### 2.2 Contemporary challenges

The situation of contemporary architecture seeks to find new textile purposes, leading to a more autonomous position. Textiles can fulfill many needs that architecture is not able to satisfy immediately. The medium creates various spatial situations, escapes the logic of rigid construction, changes the acoustics or reflects the trajectories of our bodies [6].

At the same time, the material of textiles has come a long way. New technological components can be implemented into textile structures directly during the process knitting, where even the smallest thread can be highly controlled. Textiles are entering new areas of fabrication and application that connect traditional technologies with those only recently developed – hence resulting in highly customized and specified materials which challenge the standard purposes and start to belong to the world of computational discourse with a focus on performance and response.

## 3 ON THE IDEA OF THE SOFT

Soft matter physics explains the soft as easily deformed by thermal fluctuations and external forces. Its mesoscopic scale structures may determine the macroscopic behaviour of the material much more than the atomic scale. Many aspects of its behaviour derive not directly from the chemical details, but, for example, from the topological implications [7].

Related to computer systems, soft architecture defines the generation of transformable spaces with multiple uses, where it is possible to respond to particular and constantly changing data in order not to only react but also revaluate [8]. The concept of soft architecture describes the architecture which both responds to our actions but also inscribe our behaviour. Negroponte argues: "Every state of a manipulative environment is in a very real sense non flexible. To achieve a multiplicity of uses, the environment must undergo a physical transformation." [9] To be soft then means to feedback, to give responses to users like a machine does, here in both physical and digital interfaces.

### 3.1 Regulating textiles

*3.1.1 Sewing.* Sewing is one of the oldest technique of attaching objects using stitches made with a needle and thread. During the Paleolithic Era, sewing was used to connect animal hides and skins together to create clothing or shelter. It means that this technique stood at the crossroad of developing both textile and building crafts. All sewing was done by hand for centuries. Till rather a recent invention of the sewing machine in 19 century changed the industry, led to mass production and opened access to this craft for everyone.

The machine sewing technique has not changed much since the first machine was introduced. But the current possibilities of the digital interface allow us to transform the perception of the sewing from merely functional and useful craft to the complex (architectural) method. With all its consequences in folds, bulges or constrictions, it creates amazing possibilities flexible in scale, not only in the size of a garment.

*3.1.2 Digital sewing.* The computational part of the project is closely tied to material, using the assistance of a live physics engine (Kangaroo), which helps to simulate, optimize and form-find in a graphic algorithm editor (Grasshopper), tightly integrated with 3D modeling tools (Rhinoceros). Accordingly, the simulation of the textile behaviour and explorations with the digital sewing were carried out, this being the process where a virtual needle penetrates a mesh surface and connects different points, i.e. vertices of the grid. The investigated surface behaves in accordance with the setting of various possible levels of creasing the membrane and strength of the strings. The two vertices then meet in one point tightly, connecting two surfaces or two points of the same cloth (zero string). In the case of different settings, the effectiveness of the string can be weaker, where it is not pulled fully to the touch of the points, so the "thread" marks the distance between them. (Fig. 2)

The virtual stitch emerges by this process and the mesh surface is creased by the set level. The stiffness of the textile is simulated in forms of various folds or wrinkles. The process is very playful and one can try to work with multiple layers, holes or a stitch force. While exploring the tool, several techniques of working with membranes have been found. Smocking is an embroidery gathering technique using stitching to create areas of tension and release which allow a garment to fit and to be flexible at the same time. It has strong decorative visuality while its arrangement can be highly controlled. Both the computational and physical representations use grid or dots as the starting layout. Following the defined rhythm and using simple rules, by connecting the dots or corners the smocking pattern can be made in many sophisticated ways according to the selected path. Stitches can follow the edge of the grid plane or run diagonally. In prototypes, the thread uses knots to stabilize the fold, or runs throughout the cloth allowing different densities of gaps and creases. (Fig. 3 and 4)

Another possibility of shaping a membrane through digital sewing is to use darts in the form of folds or cutouts. Darts tailor the garment to a body with its concave and convex curves (shoulder darts, waist darts, bust darts), and transform a flat, 2D textile material into a 3D object. It is usually created by 3 points or 2 sets of information. The vertex of the triangle shows its length, while the edge points represent the amount of folded or removed material [10]. Here again, the virtual needle connects the opposite points, the vertices of a dart, and generates a surface which is no longer flat. Symmetrical multiplying of a dart creates different modules which can be integrated into more extensive clusters. The darts have to be activated by another force therefore the simulation of inflation is applied here, to explore the extreme conditions. The material properties are changed and the results show various behaviours of the module according to the strength of air, material stiffness and its elasticity. (Fig. 5)

It is obvious that the mesh, as a collection of polygons and vertices, acts as an interface between the physical and the digital. As a result, it not only describes geometry, but turns the mesh into a changing infrastructure. Hence it becomes a complex, unstable entity full of intensities and possible transformations.

Although each technique has its own unique way of specification for the description of the manufacturing, it is mainly seen as a design tool for, integrated into the early design phases. In consequence, additional digital instruments were created and self-coded to shift the virtual configuration to the next stage of unpacking and preparing the fabrication.

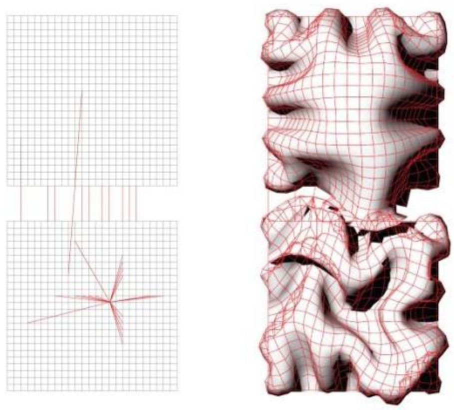

Fig. 2. Digital sewing.

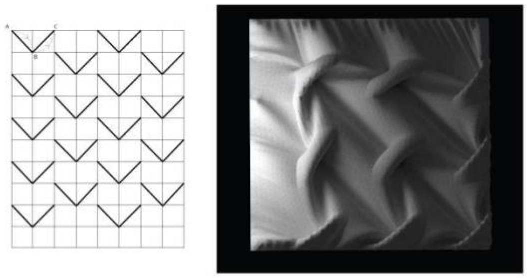

Fig. 3. Smocking technique made by digital sewing.

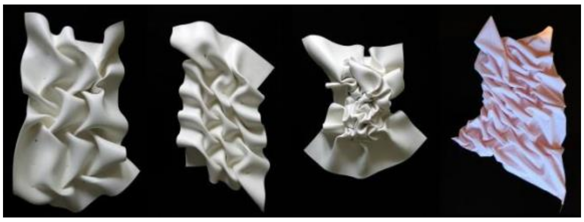

Fig. 4. Analog samples of smocking technique.

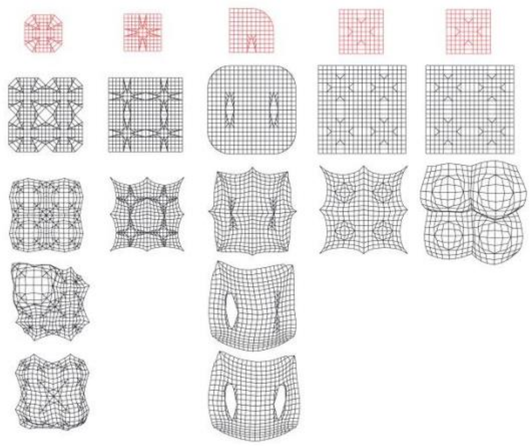

Fig. 5. Digital sewing, simulation of using darts and inflation.

## 4 THE DIALOG OF THE REAL AND THE VIRTUAL

The Wall Curtain is formed to the exact measure of a given room, including a window on the shorter side. The choice of an exact site ensures the direct application of the computational rules and provides a relatively objective environment for reviewing and comparing the digital behaviour to its physical representations. The object covers the entire back wall with the window and blurs the corner to divide the space to several subspaces: the entrance space of the room, the in-between space inside the two textile layers, the gap between the window and the installation itself, and finally the area underneath the outer bump of the curtain. As a result, the project influences the space and stimulates a new choreography.

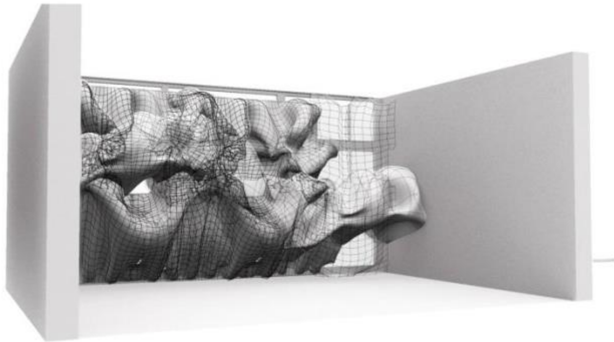

Fig. 6. Simulation as a design tool.

### 4.1 Unfolding and pattern development

After forming the object by digital sewing, the question arises of unfolding the shape. While the fashion industry uses several methods of creating the right cuts for the body, Wall Curtain has to dress the room and still have it remain habitable. Thus it must take into consideration several different elements: the site, location of the windows or height of the ceiling and other forces like inflation and human interaction. Consequently, various ways of pattern making were investigated in direct relation to physical prototypes in different scales and materials. These processes feed each other and optimize themselves. Since it is a 2D unfolded representation, the unfolded pattern is seen as a new way of marking and fabricating architecture.

*4.1.1 Striping method.* The striping method was chosen to impose the visible order onto the naturally arbitrary performance of the fabric. It gives a system to the willful activity, yet on the other hand it recalls some features related to textiles, such as a striped motif or density of seams. As such, an aggregate is created, formed by plenty of separate elements, all of them unique and exclusive.

The patterns were always tested in reality, so most of the problems were indicated during the analog sewing. The process provided valuable information for the reverse calibration. Excessively sharp edges, or too many corners meeting at a single point, cause bulges or holes, while pieces that are too narrow or too small are hard to cut and handle with such a large amount of segments (Fig. 7, 8, 9, 10). While the first explorations were scaled down to evaluate the overall response of the material, it soon turned out that the outcomes cannot be judged completely without being undertaken in 1:1 scale and in the appropriate material. Bearing in mind that textiles cannot be scaled, the real-scale tests are crucial and the types of the final textile materials need to be chosen during the early stages of the manual investigations. (Fig. 11, 12)

All these limitations are important inputs for the digital pattern development. The striping method without in-between embedded pieces and sharp edges and with more gentle, continuous lines solved the issues. Every step of the process is very complex and contains a certain number of sub-tasks. Once the shape is unfolded into the appropriate pattern pieces, it becomes crucial to create a suitable system of marking. The outlines need to be added to offset the distances from the edges to mark out the sewing path. Back and front sides need to be labeled so as not to confuse the seam side and the outer side of the cloth. And finally, the left and the right edges are tagged to secure the correct order.

The segments of the aggregate are further explored and divided horizontally into several zones of different transparency. As the object still partly fulfills the role of a curtain, its remains to control the sunlight and create areas of direct or dimmed illumination. (Fig. 13, 14, 15, 16)

As a material, 3D spacer fabric is mainly used. The spacer fabric is the result of industrial experiments with textile warp knitting technology and its quality lies in its distribution of air, recovery, soft cushioning and very low weight and recyclability at the same time. If the smart usage of a material is the key issue in contemporary architectural research, textiles are but one material among many. Foldability, low weight, easiness to transport and the ability to create a space without applying enormous quantities tend to have less impact on environment and cost.

The Wall Curtain is created from surfaces with different thicknesses, while the material properties ensure the form, together with the in-between layer of inflatable cushions. As a result, the object not only is able to accommodate a human body, but also involve a body in a more abstract way, i.e. the dynamic, pneumatic layer, which is impressed to the surface.

Fig. 7, 8, 9. First tests of unfolding a shape (from left to right: unfolding by Ivy plug-in for mesh analysis, self-coded unrolling, sewn prototype of the unrolling.

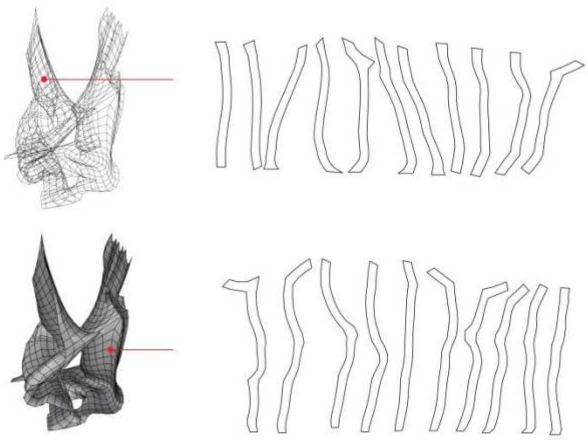

Fig. 10. First tests of unfolding a shape.

Fig. 11. Sewn prototype in 1:1 scale. Photograph by Michaela Jakobsen.

Fig. 12. Sewn prototype in 1:1 scale.

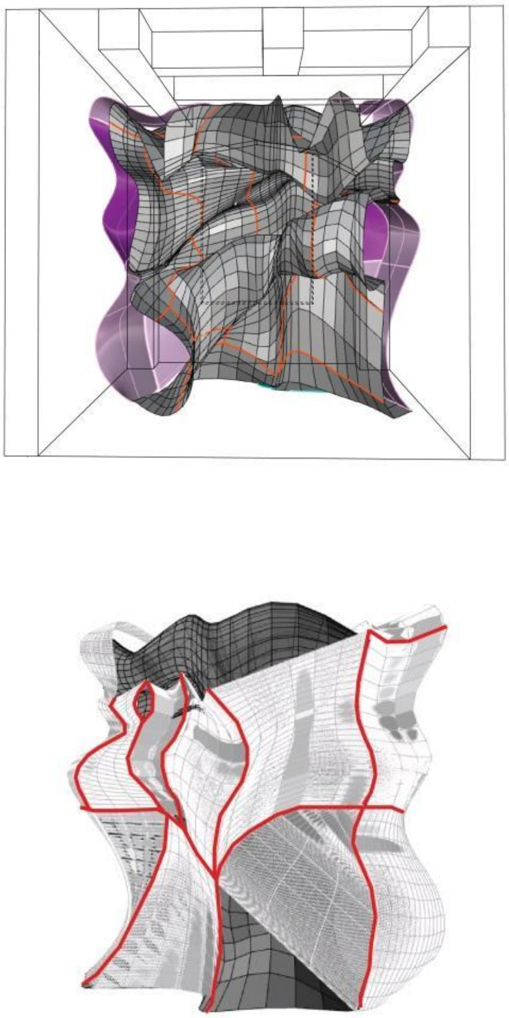

Fig. 13, 14. Wall Curtain shaped by digital sewing (front and back explorations).

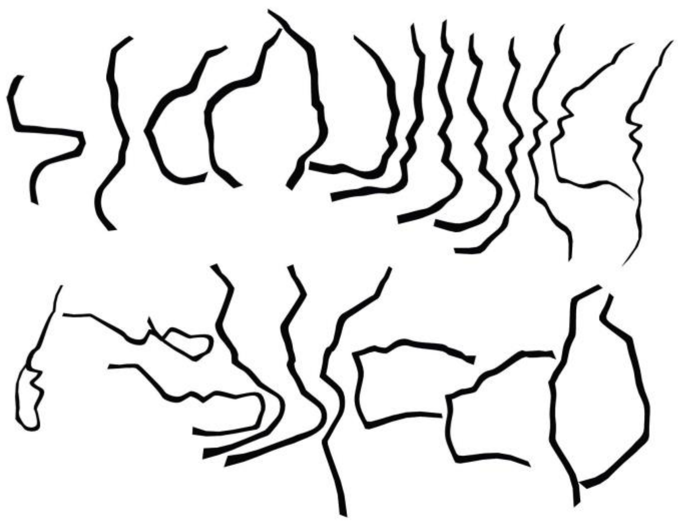

Fig. 15. Final unfolding to stripes.

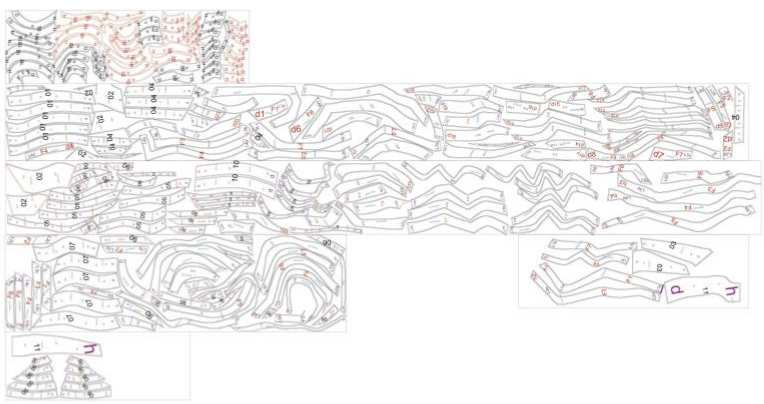

Fig. 16. Layout of the stripes.

## 5 CONCLUSION

The Wall Curtain is an inhabitable textile space within the space of a room, consisting of two layers with various interspace pockets. It is a drapery communicating with a window, as well as a tight tunnel for a living human body. This spatial curtain offers a completely different type of experience from the hard, orthogonal and squared forms of our most common houses, while remaining ephemerally atmospheric through the use of textile features such as stitches, translucency and play of the light, colour and softness. The project works with textiles using not only human hands and a real needle, but moreover the extracted rules of a technique to show that it is possible to control its instability and softness in both the physical and digital realms. As demonstrated, the textile space has the potential to become a proper part of our buildings rather than an inferior decoration, as it is perceived today. The new textile layer creates a lively interface between the facade and the room, the flat surface and the inner space, and includes the traces of the body accommodated in it, as well as the architecture in which it hangs.

Although highly speculative, the project presents a new reflection of design, one now seen as something very complex and dynamic. The digital territory allows the discovery of various scales and achieves a surprisingly high level of precision. A seam follows a stitch; the computational simulation reflects the textile properties by producing folds (micro scale) and through the tested patterns (meso scale) the segments for an overall shape are prepared, to construct an installation in real scale (macro scale). Consequently, the design process is not straightforward with a specific order, but instead contains inter-scale operations which provide constant feedback between each other.

Further, the Wall Curtain's contribution lies in the constructing of the series of actual prototypes. It shows that they are not built as a full representation of the digital outcomes, but instead become equal, well-informed parts of the research. The deviation between the computational prediction and the fabricated prototype provides valuable feedback for simulation calibration. Moreover, the failures or errors are integrated parts of the project with crucial importance. Some are repaired during the new iterations, but some are subject to external conditions that are so temporary or contextual that is hard to incorporate them to the digital setup. Fabrication, like measuring, cutting, sewing and installation itself, brings even more inaccuracies, but all of them enrich the project and provide a new layer of information and performances in order to gain more spatial significance.

In this project, architecture contains different soft layers, and shows how spaces could be dressed, too. In the digital age, architecture strives for complexity, and it is completely understandable that it continually reaches for a textile material as a medium for its experiments. The micro scale of the textile structure determines the macro scale of the large objects and vice versa, making it almost ideal for investigation its possibilities in full complexity. Whilst the material and its properties are still more accepted than perfectly programmed here, the object becomes an independent piece of design taking all the previous expertise to the field of computation, where the stubborn material meets systems, codes, restrictions and rules.

As a result, the new interior, soft enclosure is created. Architectural space is filled with soft proximities which build a different space and invites us to visit and experience its inner cavities, providing depth to accommodate multiple bodies, which imprint their traces and co-shape its performance. (Fig. 17, 18, 19, 20, 21)

Fig. 17. Wall Curtain. Photograph by Anders Ingvartsen.

Fig. 18. Wall Curtain. Photograph by Anders Ingvartsen.

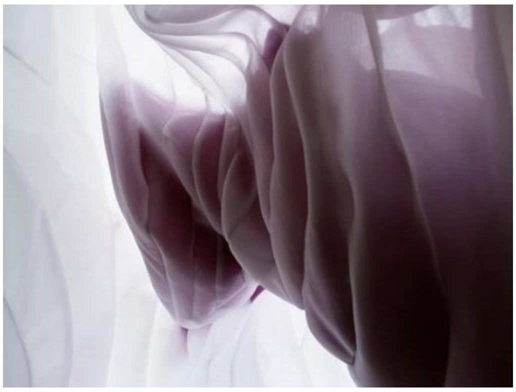

Fig. 19. Wall Curtain. Photograph by Anders Ingvartsen.

Fig. 20. Wall Curtain. Photograph by Anders Ingvartsen.

Fig. 21. Wall Curtain. Photograph by Anders Ingvartsen.

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